A RELIEFMETER FOR SOIL CULTIVATION STUDIES [1]

H. KUIPERS

Institute for Soil Fertility, Groningen, Netherlands

SUMMARY

A simple apparatus is described to measure soil surface-roughness after cultivation and before seed-bed preparation. The roughness is defined as 100 times the ten logarithm of the standard-deviation of the heights in cm's relative to a certain level, which heights show a normal distribution. Some results with respect to levelling of the soil surface during winter, plowing depth and clay content of the soil are demonstrated briefly.

1 INTRODUCTION

Many experimental fields were laid out to correlate soil cultivation and crop yield. The results of these experiments were quite different in different years as might be understood from the complexity of the relation.

Splitting up the problem into two phases: 1) the relation between cultivation and soil physical conditions; 2) the relation between soil physical conditions and plant growth, will be of great help.

Although a more fundamental understanding of the processes concerned in soil cultivation is of great importance, a simple testing of the effects of various methods of soil cultivation in practice will be not only a source of inspiration to the research-worker but also a valuable method for obtaining a base for practical advices.

For this type of investigations it is necessary to evaluate the results of a cultivation operation in a reproducible scale. Immediately after plowing or when the soil is frozen most usual methods give great difficulties. In this paper a method is described which can be applied under these circumstances.

It is a method of determining soil surface roughness, as one of the most readily obtained impressions of the result of the principal cultivation operations. As appeared after the preparation of this paper, a similar idea of determining soil surface roughness was developed in Italy at the Centre for Agricultural Engineering in Torino (1).

2 APPARATUS

Fig. 1 shows the entire apparatus [2] and fig. 2 a detail of it. It consists of a board with a scale in cm's in front of which at distances of 10 cm 20 needles are placed, each divided in 4 parts by different colours. All the needles are kept in place by a spring mounted brass bar at the back of the board on which 20 small pins covered with pieces of rubber tube are placed. These pins emerge on the frontside of the board and are visible in fig. 2.

By means of a waterlevel the board is placed horizontally above the soil surface, fixed by pins at the ends of the board, which are pressed into the

---

1) Received for publication August 25, 1957.

2) Drawing of the construction available on request at: Instituut voor Bodemvruchtbaarheid, van Hallstraat 3, Groningen, Netherlands.

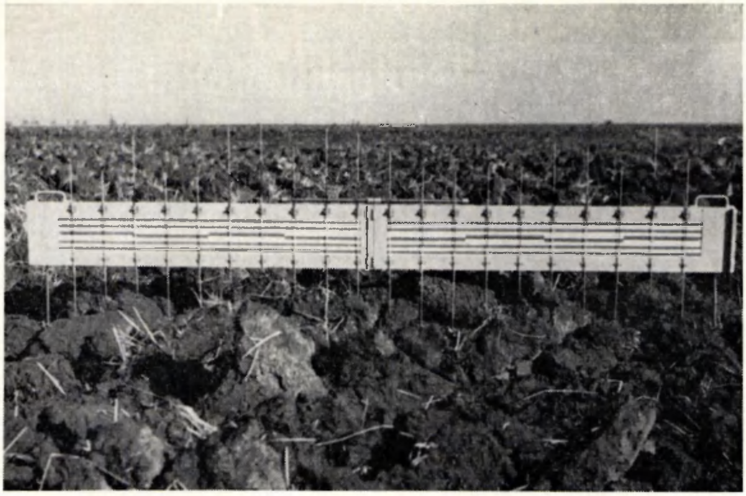

Fig. 1 Reliefmeter on cultivated field.

soil. When the bar holding the needles is pushed in, all the needles slide down till they touch the soil surface. On a slope the board should be placed parallel to the soil surface.

The height of the needles is read in cm's from the scale and the 20 figures are noted as a column in a note book. This is repeated 20 times at fixed distances which depend from the area to be investigated. To bring the needles back in their original place the board is simply turned over. If the surface is frozen, the two pins which are pushed into the soil to keep the board in place, are replaced by T-shaped supports.

The foot of each needle is formed by 2 small rings at a distance of 2 cm. The lower ring prevents penetration into the soil and the upper one hurts the lower eye when the needle slides back and prevents dirt sticking to the foot of the needle to get into this eye.

For transport the needles can be bolted and the apparatus fold double or the needles can be removed.

Time required for one set of 400 observations is about 20–30 minutes for two persons.

3 Evaluation of figures

Each measurement results into 20 columns of 20 figures, each column corresponding with one position of the board. If all the columns are corrected for their mean values, a set of 400 heights relative to a certain level is obtained. The distribution of these figures will be a measure for the roughness of the surface. This distribution will be composed from three components, one raising from the clods and soil aggregates, a second from the furrows and the third one from differences in height present before plowing or from an inclination of the soil surface to the board.

If the needles are so far apart that the clods are relatively small to the distance between two needles and the volumes of the clods show a random-

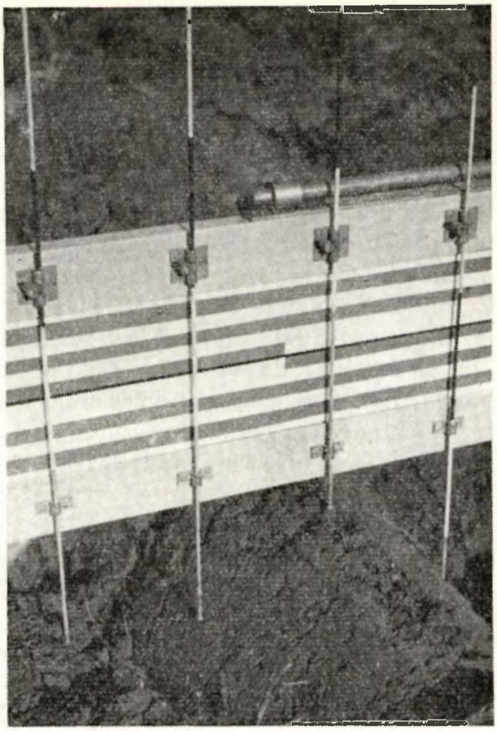

FIG. 2 DETAIL OF RELIEFMETER.

distribution, we may expect a more or less normal distribution of the height-figures as far as they are due to this component. If the furrows are idealized by some periodic function, the contribution to the height-figures of this component is not at all expected to give a normal distribution. The third component is not essential for the process studied and should be evited. Generally it will flatten off the distribution-curve.

In all cases examined it appeared that the distribution found did not significantly differ from a normal one. So characterization is easiest by means of the standard-deviation. However applying this as a measure for the roughness of the soil surface has a disadvantage, as its accuracy is not the same for high and low values. The standard-error of a standard-deviation only depends on sample size, or degrees of freedom available. It equals $\frac{s}{\sqrt{2n}}$ (n = degrees of freedom available, s = standard deviation). In our case $n = 380$, so the standard-error of the standard-deviation is 3,63 %.

For reliability calculations this is troublesome. These difficulties can be evited by introducing the logarithm of the standard-deviation as a measure for the roughness. If the standard-deviation was expressed in cm's, the logarithm was found between 0,01 and 1,00. To evite the decimals the roughness R is defined as 100 times the 10 logarithm of the standard-deviation of the heights in cm's. So the figures obtained on fields between plowing and seedbed preparation will lie between 0 and 100. The standard-error of these figures will be *100 × log. 1,0363 = about 1,5.* So the roughness should be rounded off in units and a difference between two determinations should be about 5 units to be regarded as reliable, if 400 figures are concerned and their distribution is a normal one.

The calculation of the standard-deviation can be done on several ways. So the deviations within each column from the mean value of the column can be squared and summed over all columns. This is rather time-consuming. Time is saved by correcting each column for its mean value, rounded off in cm's and determining the distribution by tally marks. So it can be checked, whether the distribution is normal or not. Much quicker we arrive at our aim if the standard-deviation is calculated from the differences in height. Then a certain sample size is chosen (say 5) and the figures are devided in groups of this size (so 80 groups of 5 figures). In each sample, the difference between the highest and the lowest value, the range, is determined and from the mean range the standard-deviation is found simply by deviding the mean range by a factor only depending on sample size (2). This grouping of the figures can be done in many ways and this offers a possibility for a closer examination of the figures.

If the standard-deviation is calculated from groups of two successive figures in the columns, the roughnesses found (R_2) are consistently lower than those calculated from the heights immediately (R_h). As a mean of 34 determinations was found: $R_h - R_2 = 9{,}7 \pm 0{,}81$. This learns that between two successive pins the differences in height are smaller than generally between two pins at random chosen. If the standard-deviation is calculated from the range of two pins that are 20 cm apart a higher result is obtained. If the standard-deviation is calculated from the 40 groups of 10 successive figures (R_{10}), we find for the same set of 34 observations $R_h - R_{10} = 3{,}2 \pm 0{,}32$. If we start from the range of 10 figures of pins 20 cm apart, so from the readings 1, 3, 5 ...... 19 and 2, 4, 6 ...... 20 in each column we find the same roughness as from the heights directly, as the difference then becomes 0,3 ± 0,23. So, if the range is only taken from figures within the same column, we have two things to choose: the number of figures forming one group and the distance between the successive items in this group. From combinations as mentioned above is learned that generally two aspects play a part. 1) The differences in height at a distance of 10 cm are relatively small. 2) The influence of higher and lower places in the field existing before the cultivation operation and the influence of erroneous inclinations of the board to the soil surface become greater when the group is taken from a greater part of the board. Calculating the standard-deviation from the range of 10 successive figures is accepted as a good compromis. With 10 figures there are 45 combinations of 2 figures possible to find the range. Of these 45 combinations only 9 depend on needles lying only 10 cm apart. Yet, this sample of 10 figures only covers half the board.

One more observation will be mentioned. On 20 fields, plowed with mouldboard plows measurements were made perpendicular to the furrows, starting each measurement exactly between two furrows. The 20 columns of each measurement were corrected for their mean values and then the roughness was calculated from the ranges of 10 successive figures in the rows instead of the columns. So only differences in height are taken into account that are found in the direction of plowing at distances of some meters. The difference between the roughness found in this way and the one found in the normal

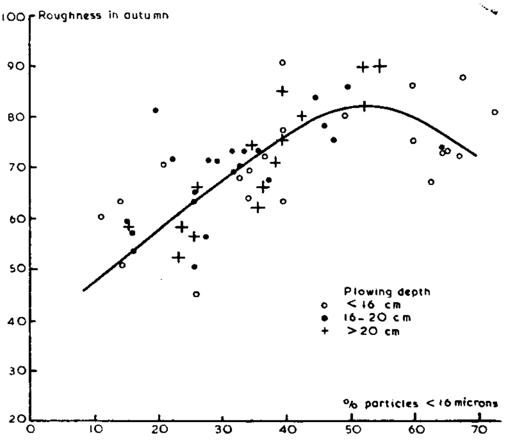

FIG. 3 RELATION BETWEEN CLAY CONTENT OF SOIL AND ROUGHNESS AFTER PLOWING IN AUTUMN WITH DIFFERENT PLOWING-DEPTHS IN 1955 AND 1956.

way, so from the range of 10 successive figures in the columns, was for this set of 20 fields *0,4* ± *0,31*. This makes it more acceptable, that the influence of the furrows on the distribution of the height figures is not so strong that it disturbs the normal distribution. This can be understood by the fact, that the ridges formed by the plow are generally not continuous, but interrupted on many places.

4 SOME RESULTS

In autumn 1955 and 1956 a set of observations werd made on practice fields immediately after plowing with moldboard plows and again in spring. All fields lay on marine soils with a great variation in clay content. Content of organic matter was generally normal for old arable land, so it is correlated to clay-content. Only part of the soils were calcareous.

Winter 1955–1956 had a severe freezing period in february 1956, with rather much snow. In springtime the soil became extremely wet. Winter 1956–1957 was very mild with hardly any frost, and a dry spring.

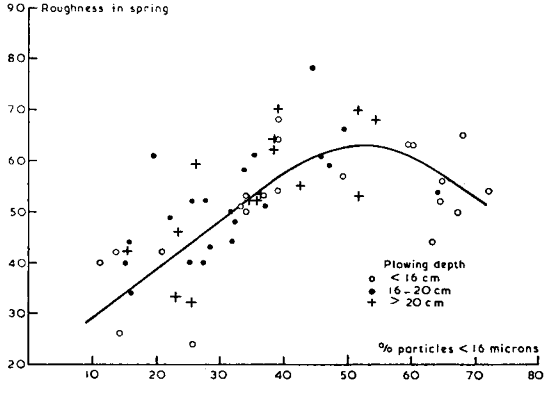

FIG. 4 RELATION BETWEEN CLAY CONTENT OF SOIL AND ROUGHNESS IN SPRING 1956 AND 1957 AFTER PLOWING TO DIFFERENT DEPTHS.

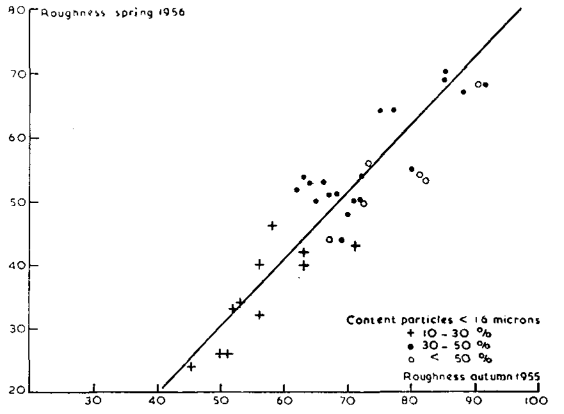

FIG. 5 RELATION BETWEEN ROUGHNESS IN SPRING 1956 AND AUTUMN 1955 WITH RESPECT TO CLAY CONTENT OF SOIL.

Fig.'s 3 and 4 show the relation between the roughness of the soil-surface in autumn and spring for both sets together and the content of particles < 16 microns. The points are distinguished in plowing depth < 16 cm, from 16 to 20 cm and > 20 cm.

Both figures give the same relation. Spring observations are only lower than the autumn observations. The heavy soils show a lower roughness than the medium textured ones and all the heavy soils except one are plowed shallow. So here could be thought of an influence of plowing depth, but on the other soils this influence is not visible.

Fig.'s 5 and 6 show the relation between roughness in autumn and spring for the two years separated. The line in both figures is the same. The points are distinguished in three classes of clay content. It appears, that within each class there is a clear relation between the roughness in autumn and in spring. This means, that the roughness in spring is primarily determined by the roughness after plowing. So differences made in autumn did not disappear during the two quite different winters.

Unexpected is that in fig.'s 5 and 6 the points lie around the same line.

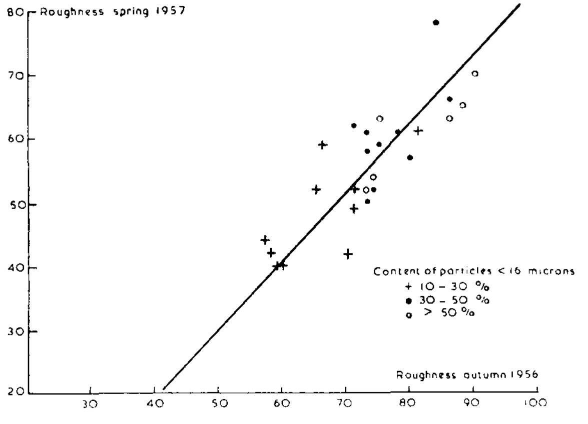

FIG. 6 RELATION BETWEEN ROUGHNESS IN SPRING 1957 AND AUTUMN 1956 WITH RESPECT TO CLAY CONTENT OF SOIL.

This line has a slope of 45 degrees. The tangent of this line was calculated for both sets together and found as 1,07 with a standard-deviation of 0,07. The mean values for roughness in autumn and spring were 70,7 and 52,1. So this line could be represented by roughness in spring = roughness in autumn − 19. This means that the relation between the standard-deviations used for the calculation of the roughness is a straight line through the origin. The slope of this line is given by $log\ tg\ \alpha = 0{,}81 - 1$, so the tangent is about 0,65.

Roughness in autumn should be examined more in detail. As is shown in fig. 3 it is largely dependent on clay-content of the soil. About the influence of other factors there are not yet dates enough.

On two experimental fields with different depths of plowing observations were made and here some aspects could be observed, which were not visible in the material mentioned above.

Both experimental fields lie on young calcareous marine soils. Westmaas ZZH 691 in South-West-Holland has a content of particles $<$ 16 microns of about 40%; PrLov 7 in one of the Zuiderzeepolders is lighter (content of particles $<$ 16 microns is about 25) and contains much more silt.

Table 1 shows results from 1954 to 1957.

Table 1 Roughness and plowing depth on two experimental fields at different times.

Ex. field	Plowing depth in cm's	Date					
		1-12 1954	4-3 1955	11-11 1955	17-3 1956	13-12 1956	14-3 1957
Pr Lov 7	12	42	34	42	24	45	44
	20	–	–	50	26	48	46
	28	57	42	56	32	59	56
		Date					
		4-2 1955	17-3 1955	9-11 1955	21-3 1956		
Westmaas ZZH 691	5	72	71	63	54		
	15	76	69	76	64		
	25	76	70	85	70		
	35	67	67	75	64		

On Pr Lov 7 the difficulty is, that the surface is too quickly clogged by the rains. Autumn 1954 was extremely wet, observations were made about 10 days after plowing. In spring 1955 the soil remained wet for a long time by a slow thawing of the soil in a period with heavy night frosts. In autumn 1955 observations were made immediately after plowing, under favourable conditions. In spring 1956 the soil became extremely wet by the melting of large quantities of snow and the roughness of the soil surface became lower than in 1955. In autumn 1956 observations were again made about a fortnight after plowing. The winter was very mild with practically no frost or snow and low rainfall. In spring the soil appeared to have a much rougher surface than normally, which was highly appreciated by the farmer.

Westmaas ZZH 691 has a heavier soil, without any particular difficulties.

In the wet autumn 1954 the soil was plowed about Christmas, so the first observations are no real autumn-observations.

In autumn 1955 observations were made immediately after plowing. It appears that the soil surface becomes much rougher here than on Pr Lov 7 and it stays so during winter. Here too in spring 1956 the soil has generally spoken a lower roughness than in 1955.

On Pr Lov 7 it is clear that a greater plowing depth results in a rougher surface. On Westmaas ZZH 691 we get the impression that the relation between plowing depth and roughness is a curvilinear one. So the effects of plowing depth and year, which were not visible in the large material can be recognized here. Generally speaking here too can be said, that the differences in roughness do not disappear during winter.

It is clear, that there are great differences in roughness which cannot be explained by clay content or plowing depth. Other factors however can be investigated in a similar way.

So on a plowing demonstration differences due to the type of plow used up to 15 units were found. The results mentioned above are meant only to demonstrate that the method described can be used under practical conditions. It will help to describe the results of autumn cultivation objectively. For spring cultivation to prepare a seedbed this method will not be suitable, as the height differences than become too small.

References

1 Candura, G., A. Casella, S. Sarcinelli: Prove di lavorazione meccanica del terreno a profondità variabile. *Atti del Centro Nazionale Meccanico Agricolo,* Torino 1957, Vol. 1. Parte Seconda Annata 1955–1956, pg. 107–131.

2 See e.g.: Moroney, Facts from figures. Penguin Books London 1954, pg. 155.