Water content at pF 2 as a characteristic in soil-cultivation research in the Netherlands

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Summary

Water content at pF 2 is a valuable measure for the interpretation of soil bulk density on medium textured and heavy soils in the Netherlands. It decreases at very high densities when aeration under wet conditions is too poor for plant growth. It increases if the soil contains a considerable amount of aggregates smaller than 1 mm. This can be dangerous for soil stability. It can be determined on aggregates coarser than 2 or 3 mm in many cases.

1. Introduction

In physical terms the result of soil cultivation can be described as a rearrangement of soil particles. This rearrangement will be reflected in changes of soil homogenity and bulk density.

Characterisation of bulk density is rather simple. For its interpretation with respect to plant-growth however, more data are required. In the Netherlands water content at pF 2 is likely to be a valuable measure for that purpose as, at least in wet years and on inorganic soils containing more than about 20 % clay, aeration under wet conditions seems to be a limiting factor for plant growth in many cases (BOEKEL, 1959; KUIPERS, 1959 *a* and *b*).

In section 2 a brief account is given of the relation between bulk density and moisture content at pF 2 found in practice.

Soil homogenity can be characterised in many ways, e.g. by determining the coarseness of the aggregates or clods.

In a homogeneous soil a small sample of a few cm³ will be a good representative of the geometric arrangement of the soil particles. The bigger the clods that are found, the bigger the minimum volume that can be regarded as a good representative and the less soil homogenity will be.

About the relation between soil homogenity and plant-growth still less is known than about the one between bulk density and plant growth. Perhaps the most important relation of soil homogenity with agricultural practice will be found in the mechanisation. However sometimes there will be a relation with water content at pF 2 as is shown in section 3, where the influence of aggregate size on this content is demonstrated.

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2. Bulk density and moisture content at pF 2

As is generally accepted, the direct effect of a change in bulk density by soil cultivation is a change in the air content of the soil. Yet in theory it would be possible to increase water content at pF 2 as well by compaction as by loosening the soil. In the first case pores that are too wide to hold water at pF 2 should be narrowed, in the second one, the narrowest pores should be brought as near as possible to their critical value, perhaps a much more difficult job.

The relation between pore space and water content at a certain pF value is well known at extreme moisture tensions: at high ones there is no relation at all, at very low ones there will be a mathematically determined positive relation as water content can be calculated from pore space as soon as all the pores are filled with water. So, if water is withdrawn from a saturated soil by suction forces, this positive relation will diminish gradually. This is demonstrated in FIG. 1 for a medium textured marine soil.

For pF 1,5 the data are omitted. At pF 0,4 the relation is very strong and approaches line S, indicating water content at saturation. At pF 1,9 there will be hardly any relation left. A negative relation as could be expected from increasing the water content by narrowing too wide pores seems to be a rather complicated case. Actually up to now, no examples of it are found. It stands to reason that on a volumetric base water content will be increased when soil is compacted without loss of water; but if pore space is regarded as a variable as is done here, water content expressed as a percentage of dry weight is a much better characteristic.

Further it appears that increasing the water holding capacity of the soil by loosening it, will only be successful if the water is stored at suctions smaller than about 1 m water.

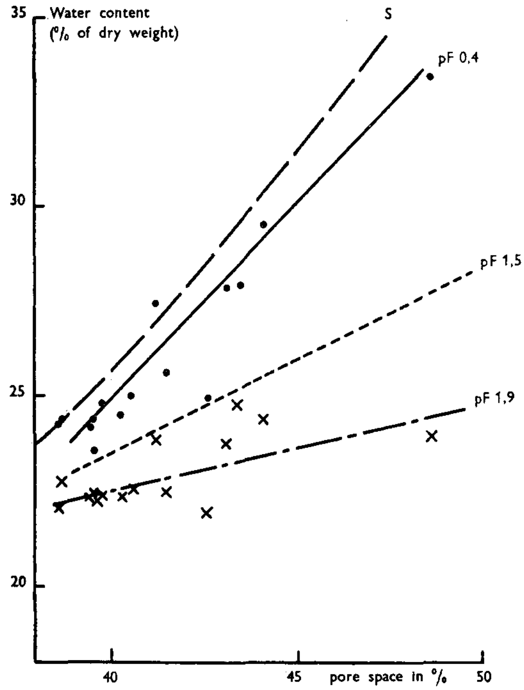
FIG. 2 shows some practical examples of the relation between pore space and water content, expressed as a percentage of the dry weight as found from determinations on core samples. Here, and in all the other examples in this paper, moisture content at pF 1,9 was determined for technical reasons. It is regarded as a sufficiently close approximation of the moisture content at pF 2, the more convenient number to be used as a general characteristic. FIGS 2a and b refer to medium textured marine soils. Attention should be given to the wide variation in pore space that is normally found and that requires a large number of replicates for most investigations.

Moisture content at pF 2 rises very slowly with increasing pore space. In FIG. 2c the saturation line seems to have a small influence at low pore spaces, but also on this sea bottom soil the total influence of pore space is restricted. In FIG. 2d the results for a sandy soil are shown. The saturation line is outside the figure and the relation is neglectable.

In FIG. 3 however some examples are given, where a clear correlation can be seen at very low pore spaces. The points group along the saturation line in a downward direction, indicating that pore space is too low to contain the same quantities of water as are found at high pore spaces. One may assume, that in this region air content at pF 2,0 is practically zero and that the distance between the dots and the saturation line is a measure for the amount of air, that is entrapped in the samples. So the lowering of moisture content at pF 2 can be an indication of severe soil compaction.

FIG. 3a refers to a heavy soil, as can be seen from the high values for pore space. Even at a pore space of 50 % compaction is serious. The medium textured soils

FIG. 1. Relation between pore space and water content of a medium textured soil at different suctions.



of FIGS 3b and 3c are levelled with a bulldozer. Samples before and after the following cultivation are put together in this graph. In FIG. 3b there is more evidence for severe compaction than in FIG. 3c. FIG. 3d at last refers to a very dense and heavy river soil. Here and in FIG. 3a samples from differently cultivated plots are put together. In both cases the crop was worse on the compacted plots in springtime, but only in the case of 3a also at harvest.

The graphs of FIG. 3 are practically the same as those used by VON NITZSCH (1937) to characterise soil density. The only difference is, that the samples used by VON NITZSCH were brought at a much lower pF-value, so he found a strong correlation between water content and pore space over practically the whole range of pore spaces and only a minor indication of the horizontal part.

FIG. 4 at last shows a clear relation between moisture content at pF 2 and pore space over the entire range. This is probably due to differences in clay content between the different samples. The samples of FIG. 4a are taken from the virgin subsoil of a sea bottom soil, which is built up of alternating small layers of sand and clay varying in thickness. Samples containing much clay will have a high moisture content and a high pore space and the reverse will be true for the sandy samples.

In FIG. 4b the results are shown of a set of samples taken at depths of 10, 20 and 30 cm on a heavy soil of the oldest Zuiderzee polder. From the enormous variety in pore space (45—75 %) and moisture content at pF 2 (35—100 %) it is clear that texture differences have much more influence than was expected. This is demonstrated by the separate indication of the samples from a depth of 30 cm, which all lie at the right hand side of the graph.

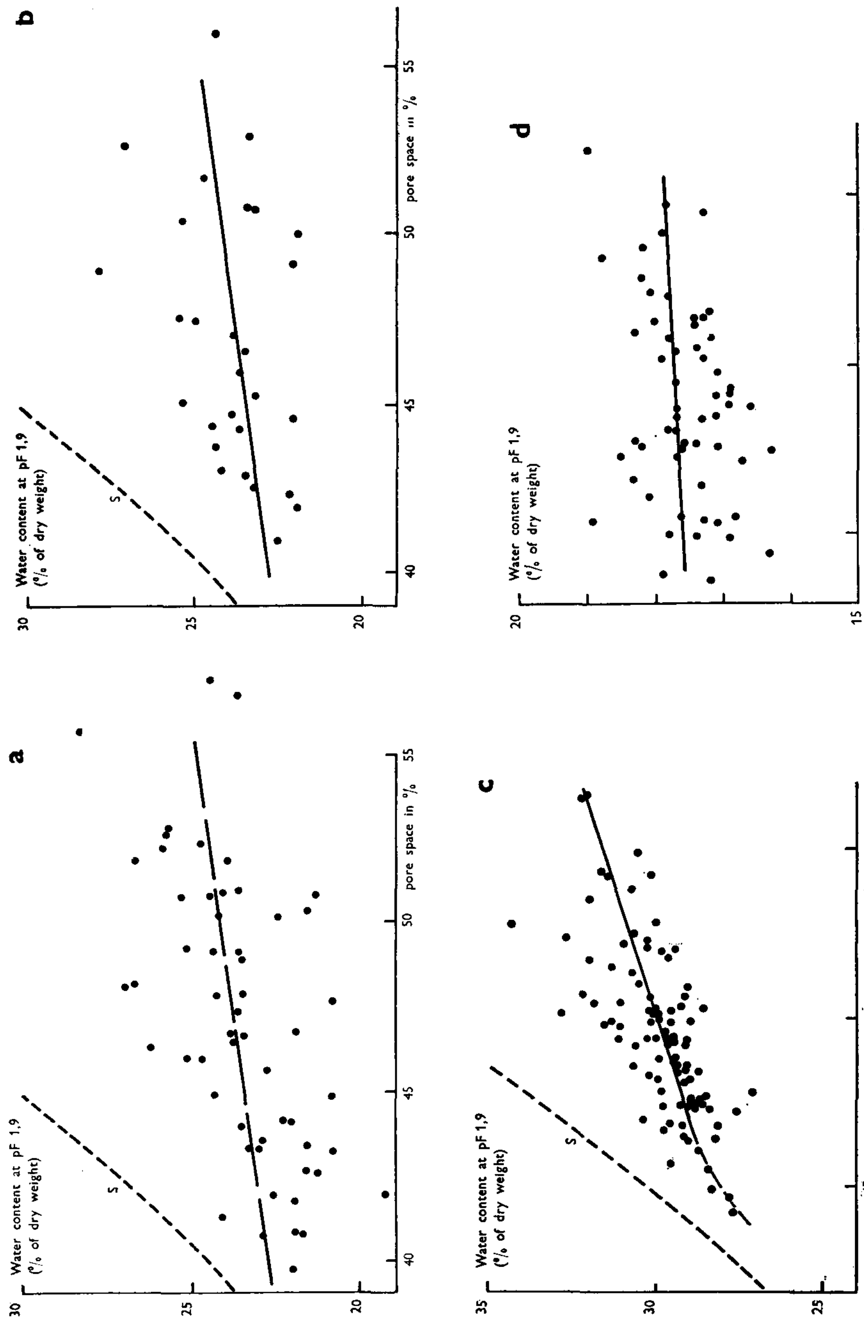


FIG. 2. Relation between water content at pF 1,9 of core samples and pore space.
a. and b. medium textured marine soils; c. light sea bottom soil (Northeast Polder); d. sandy soil (4,5 % organic matter); S = line of full saturation.

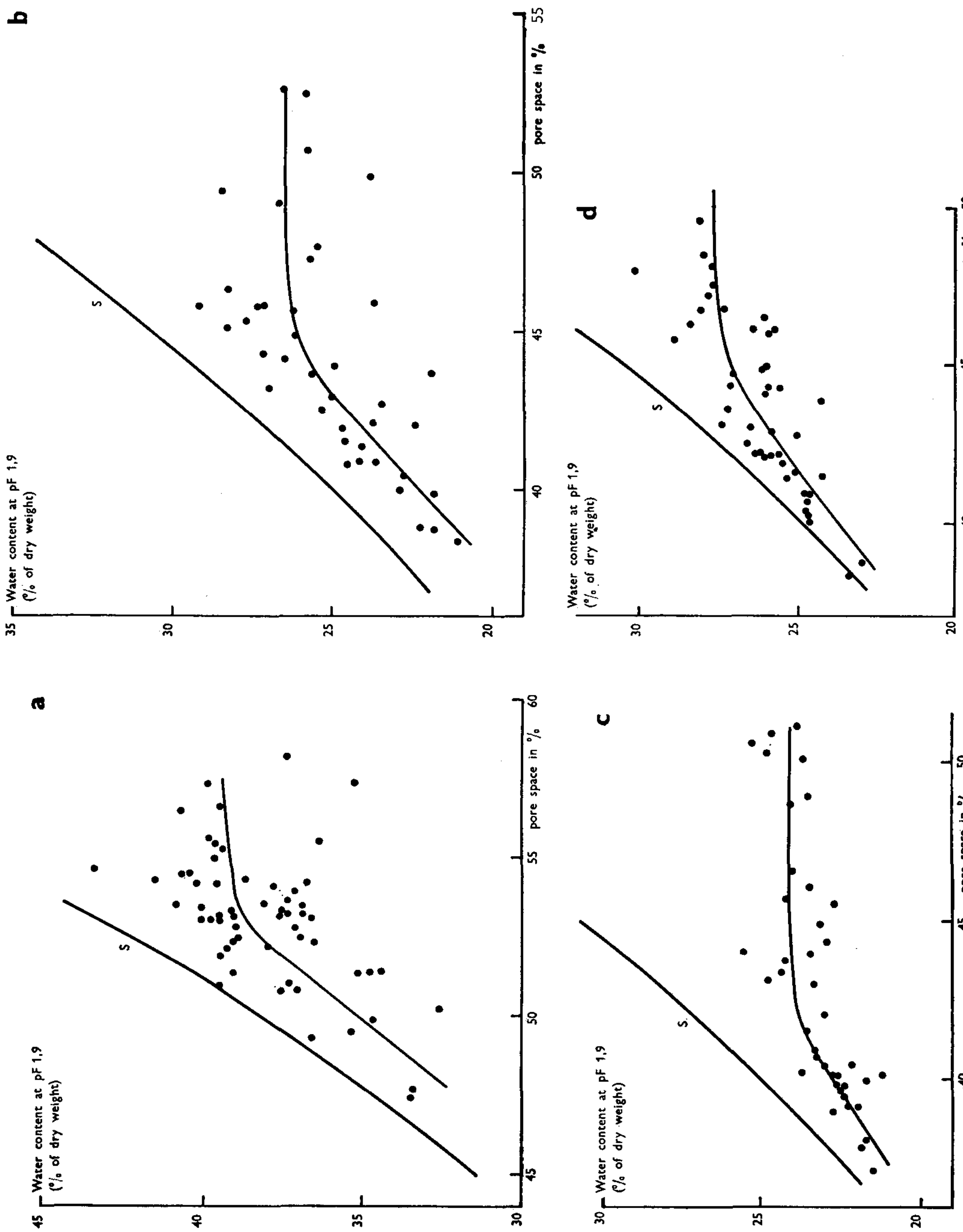


FIG. 3. Relation between water content at pF 1,9 and pore space on compacted fields.
a. heavy marine soil; b. and c. medium textured marine soils compacted by a bulldozer; d. heavy river soil.

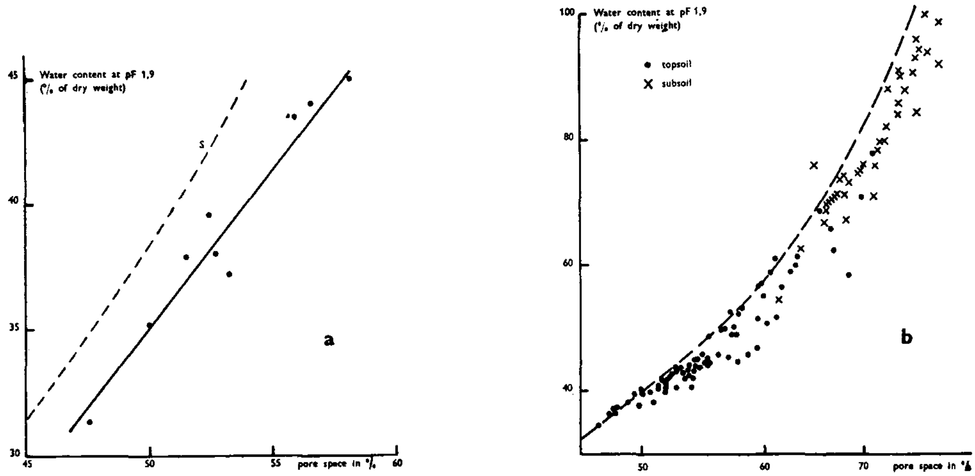


FIG. 4. Close relation between water content at pF 1,9 and pore space caused by differences in texture.
a. alternating layers of sand and clay; b. topsoil and subsoil samples of a heavy, dense soil.

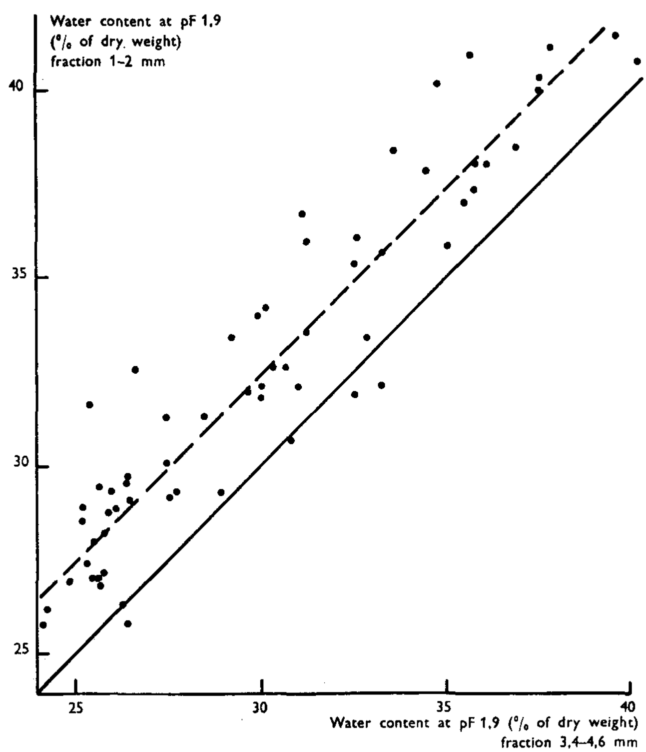


FIG. 5. Relation between the water content at pF 1,9 of two aggregate fractions of 63 soils.

This type of curves can be seen as a combination of the left hand parts of graphs like those in 3a and 3b, so as the result of compaction on a soil varying in texture. Without compaction the correlation should have been far less. So generally a relation between pore space and moisture content should be regarded as a warning, that either the soil is seriously compacted or there is an important difference in texture in the field examined.

3. Aggregate size and water content at pF 2

If a big soil lump is broken into pieces, there is no reason to expect the water content at pF 2 to be changed. If this process is continued, there may be some change at a certain fineness of the aggregates. This will be of special interest for the soils in which severe compaction lowered moisture content at pF 2.
FIG. 5 shows the relation between water content at pF 1,9 of the fractions 1—2 mm and 3,4—4,6 mm of a set of 63 soils. The fractions were made by breaking air dry soil lumps, so there will be no difference between the texture of the two fractions.

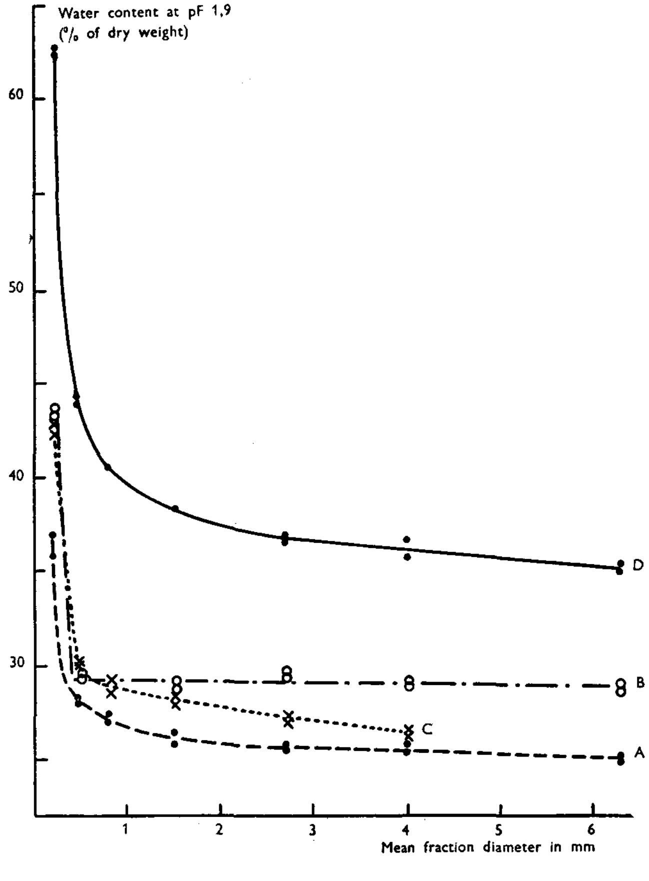


FIG. 6. Examples of the increasing water content at pF 1,9 at finer fractions. A. light soil; B. light soil with somewhat higher humus content; C. medium textured soil; D. heavy soil.

Moisture content at pF 2 is determined after wetting in vacuum. The finer fraction appears to have a higher moisture content.
FIG. 6 shows the relation more in detail for four soils. The very fine fractions show an enormous increase in water content. The lighter soils generally show no or a very slow increase down to aggregates of 1 mm, whereas the heavy soils generally show a more gradual increase in the fractions coarser than 1 mm.
In FIG. 7 finally an example from agricultural practice is given. It refers to a heavy soil, which after the dry summer of 1959 was cultivated many times with a disk harrow, till the soil became rather dusty. The surface material was divided into fractions and water content at pF 2 was determined after wetting in vacuum as is normally done. The dots show the results. So water content at pF 2 may be expected at a level of about 25 %, under normal conditions.
Five cores were filled with a mixture of the fractions in their original composition. The moisture content at pF 2 of these fractions is indicated by the five crosses. So moisture content at pF 2 was increased from 25 to 30 % by a too intensive soil cultivation. This will be unfavourable for the further development of soil structure (BOEKEL & PEERLKAMP, 1956). Generally aggregates smaller than 1 mm should not be produced by soil cultivation.

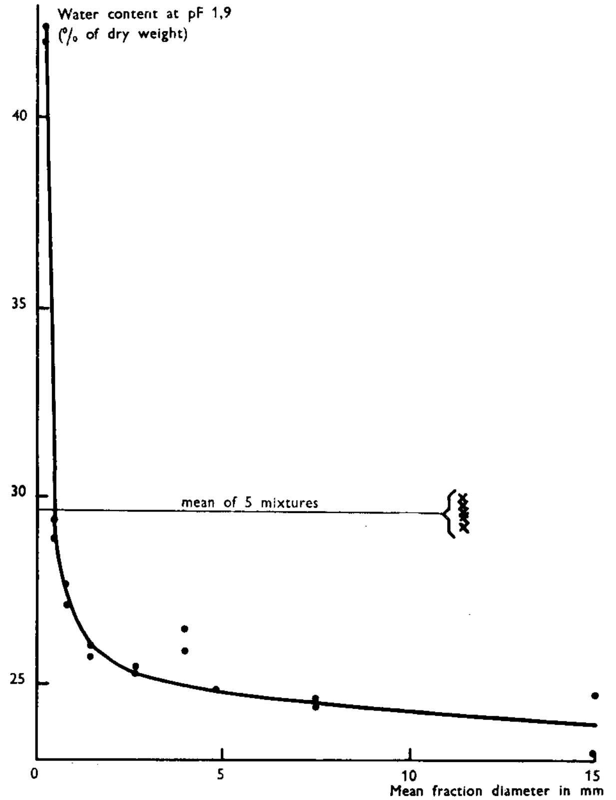


FIG. 7. Fractions of a heavy soil collected after heavy disk harrowing demonstrate the increase in moisture content at pF 1,9 with very small aggregates.

From these experiments we can also learn that it will not be necessary to determine moisture content at pF 2 always on undisturbed core samples, as above certain numerical values neither pore space nor aggregate size has an important influence. If no aggregates smaller than 2 or 3 mm are formed on preparing the subsample and if the soil is not too strongly compacted, there is no reason to expect deviations using aggregate samples.

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