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Farm mechanization and soil structure

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Summary

When farms using horse traction only are compared with farms using exclusively tractor-drawn implements, it is found that farm mechanization has a negative effect on total pore space and air content of the soil. This effect was usually small, but it was more pronounced in the years where the general level of soil structure was low.

Introduction

It is often believed that farm mechanization is the main cause of the unfavourable soil structure that seems to be common nowadays (Kuipers, 1959). The simplest and most direct test seemed to compare soil structure on farms using horse traction only and farms with tractor traction only.
However, in 1958, when H. Kuipers [1] initiated this study, farms with only horse traction were rapidly disappearing and only a few of the remaining ones were suited to our purposes. In fact, already in 1962, this study had to be terminated for lack of comparable farms.

Procedure

The arable farms with horse traction only which were selected, were situated in different parts of The Netherlands on fine-textured soils. They were well-run farms where using horses was a personal preference or a hobby (horse breeding). In view of the influence of soil composition on soil structure care was taken to select nearby mechanized farms on similar soils (Table 1).
It is known that soil structure is influenced by tillage treatments and cropping system, and that it fluctuates with weather conditions (Boekel, 1963; Kuipers et al., 1966). From 1958 to 1960 inclusive, therefore, only fields with cereal crops were sampled, shortly after harvest. To get a more complete picture, in 1961 all fields of the two types of farms were investigated. This was done by visual rating of soil structure (Peerlkamp, 1959), the results of which could be interpreted in terms of pore space and air content by comparing them with core-sampling data from three selected fields per farm.
The number of farms and of fields per farm varied from year to year (Table 1).

[1] Since 1960 : Soil Tillage Laboratory, Agricultural University, Wageningen, The Netherlands.

Table 1 Total number of farms investigated with total number of fields (in parentheses) used for comparison

District	*1958*	*1959*	*1960*	*1961*
Northern Groningen	2 (10)	2 (10)	2 (6)	—
Northeast Groningen	—	—	2 (12)	2 (16)
Northern Friesland	—	—	—	3 (36) *
Northern North-Holland	—	—	2 (10)	2 (21)
Northwest Brabant	3 (14) **	3 (15) **	2 (8)	2 (24)
Northeast Polder	2 (10)	2 (10)	2 (14)	2 (28)

* One farm with horse traction supplemented by much contractor's work included
** Two farms with tractor traction and one farm with horse traction

When farms closed down or changed from horse to tractor traction, they had to be replaced by others. So the farms compared were not always the same. However, the range of soils investigated was large enough to enable comparison of results obtained in different years.
In spite of careful selection clay [2] and organic-matter content of the fields to be compared varied so much that direct comparison of soil structure on horse farms and tractor farms was impossible. Within the same district, however, there is a fairly strong positive correlation between organic-matter and clay content of the soil so that generally only differences in the latter had to be considered.

Results

The results for 1958 are shown in Table 2. Between districts there are marked differences in soil composition. The high values for pore space and moisture content in the Northeast Polder are characteristic for a young soil.
Accidentally, in all three districts, tractor farms had a higher clay and organic-matter content than horse farms. Therefore, larger pore spaces and higher moisture contents

Table 2 Soil composition and soil structure in 1958

District	*Farm*	*Traction*	*Clay (% < 16 μ)*	*Org. matter (%)*	*$CaCO_3$ (%)*	*Pore space (vol. %)*	*Moisture content * (% dry weight)*	*Air content * (vol. %)*
Northern Groningen	A	horse	38.3	2.1	5.0	44.7	24.8	8.3
	B	tractor	45.4	2.4	3.3	45.0	27.6	4.6
Northeast Polder	C	horse	38.5	2.9	8.5	51.0	30.4	11.3
	D	tractor	41.8	3.1	8.8	50.7	31.7	9.6
Northwest Brabant	E	horse	38.9	3.0	4.3	46.8	25.6	10.3
	F	tractor	41.8	3.8	5.2	46.9	27.6	8.1
	G	tractor	57.9	3.5	3.0	47.4	30.9	4.5

* At sampling

[2] For marine clay soil the relation percentage $< 16\,\mu$ = 1.5 percentage $< 2\,\mu$ holds.

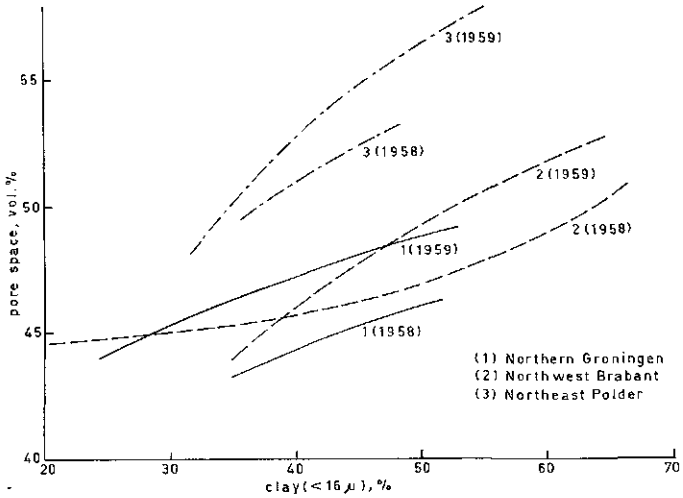

Fig. 1 Relationship between clay content and pore space

were to be expected. It is true that moisture content was significantly higher on tractor farms but pore space was not. This may be considered an indirect proof that in 1958 soil structure on tractor farms was worse than on horse farms. Air contents seem to confirm this conclusion.

According to Fig. 1 a 1 % increase in clay content corresponded on an average with a 0.25 and 0.4 vol. % increase in pore space for Northern Groningen and the Northeast Polder, respectively. After correction for the differences in clay content, pore space was found to be 1.5 vol. % higher on horse farms than on tractor farms in these districts. In Northwest Brabant the range of clay and organic-matter contents for horse and tractor farms did not coincide sufficiently to enable a reliable comparison.

The results for 1959 are shown in Table 3 in which fields with organic-matter contents differing too much from the general relationship with clay content were not considered. Again, differences in moisture content could be explained by differences in soil composition. On horse farms A, C, and E pore space was found to be 1.5, 0.6 or 0.3 vol. % higher (correction as in 1958) than on tractor forms B, D, and G, respectively. The corresponding differences in air content at pF 1.9 were 1.9, 0.5 and 0.5, respectively.

So, generally, the differences were much smaller than in 1958. This may be caused by the favourable effect of the extremely dry weather conditions from which the worst structure will have benefited most. At harvest no compaction had taken place so pore space did stay at a higher level than in 1958. Although the relationship between clay content and pore space in most cases was not very close, Fig. 1 shows marked differences in the mean level of pore space between the two years.

In 1960, for most plots on farms with horse traction a plot on the nearby farm with tractor traction of practically the same clay content (max. deviation 2.0 % $< 16\ \mu$) could be found. These comparable plots generally differed, however, in organic-matter content. Increasing organic-matter content by 1 % caused pore space to in-

Table 3 Soil composition and soil structure in 1959

District	*Farm*	*Traction*	*Clay (% < 16 μ)*	*Org. matter (%)*	*$CaCO_3$ (%)*	*Pore space (vol.%)*	*Moisture content * (% dry weight)*	*Air content * (vol.%)*
Northern	A	horse	36.4	2.3	4.4	47.2	24.6	12.7
Groningen	B	tractor	45.5	2.6	4.4	48.0	27.0	11.5
Northeast	C	horse	38.8	3.0	8.5	52.6	29.2	16.1
Polder	D	tractor	44.6	3.1	8.0	54.0	32.5	15.7
Northwest	E	horse	42.0	2.4	3.7	46.4	25.6	9.6
Brabant	G	tractor	53.0	2.9	3.3	48.9	29.4	8.7

* At pF 1.9

crease by 2.3 vol.% (up to 4% organic matter; at higher contents the effect was smaller). Therefore, a correction could be made to eliminate the influence of organic-matter content. On an average, corrected pore space in the ploughed layer appeared to be 1 vol.% higher on farms with horse traction than on those with tractor traction (Fig. 2).

Moisture contents at pF 2.0 were corrected in the same way and from the corrected pore space and moisture contents corrected air contents at pF 2.0 were calculated. Between pore space (x) and air content at pF 2.0 (y) a positive relationship was found: $y = 1.607\ x - 71.1$; $r = 0.75$. The total effect of mechanization on soil structure in 1960 can, therefore, be estimated at a decrease of 1 vol.% of pore space or 1.6 vol.% of air at pF 2.0.

In order to eliminate the influence of harvesting operations, in 1961 soil-structure research was carried out in early summer, about a month after emergence of the crop. Disregarding plots which differed too much in soil composition or crop, the visual rating was generally better on farms with horse traction (Table 4). On an average,

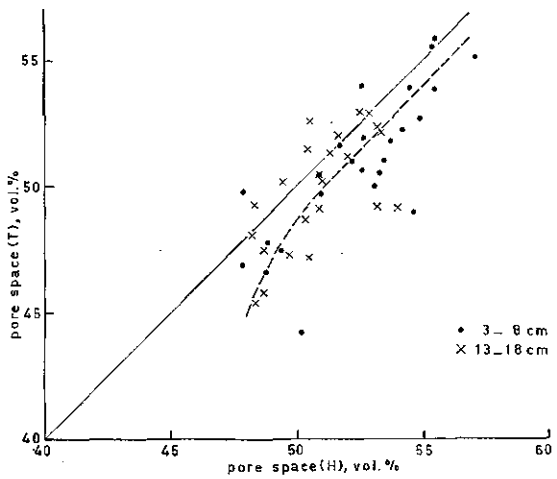

Fig. 2 Pore space (corrected) on farms with horse traction (H) and farms with tractor traction (T) (1960)

Table 4 Visual rating of soil structure (points) in spring (1961)

District	*Traction*			*Average soil composition*		
	horse	*horse + tractor*	*tractor*	*clay (% < 16 μ)*	*org. matter (%)*	*$CaCO_3$ (%)*
Northeast Groningen	5	—	4½	28.6	1.7	0.9
Northern Friesland	5	5	5	27.7	1.8	3.4
Northern North-Holland	5	—	4+	60.6	4.8	2.4
Northwest Brabant	5	—	4+	37.2	2.7	5.0
Northeast Polder	5+	—	5—	38.9	3.0	8.7

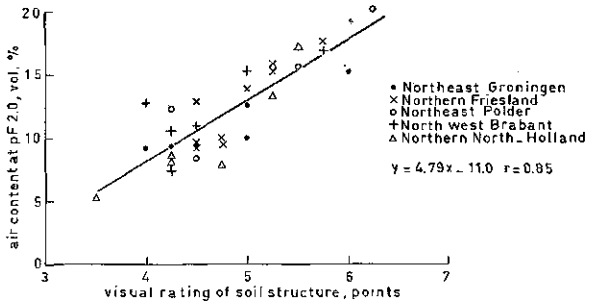

Fig. 3 Relationship between visual rating of soil structure and air content at pF 2.0 (1961)

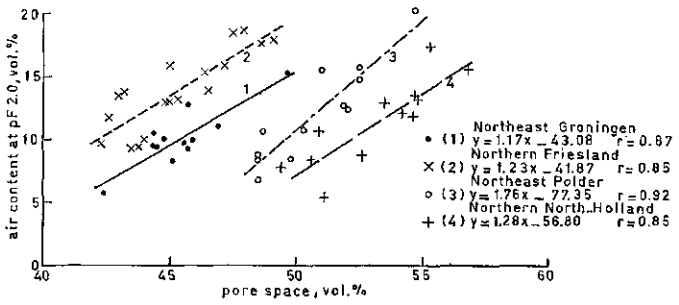

Fig. 4 Relationship between pore space and air content at pF 2.0 (1961)

the difference varied from ½ point on the lighter soils to ¾ point on the heavier soils. In Northern Friesland no differences were observed, probably because in this district on farms with horse traction so much contractor's work is done that there is practically no difference in degree of mechanization with farms using horse traction only.

It was found (Fig. 3) that an increase of 1 point in visual rating corresponds with a 4.8 vol. % increase in air content at pF 2.0. So the observed difference of ½ to ¾ point in visual rating represents 2.4 to 3.6 vol. % of air at pF 2.0.

The relationship between pore space and air content at pF 2.0 varied somewhat

between districts (Fig. 4); for Northwest Brabant no distinct relation was found. A 1-vol. % increase of pore space corresponded in the old polders with about 1.25 and in the relatively young Northeast Polder with 1.75 vol. % of air at pF 2.0.

Discussion

There seems to be a certain variation in the differences found in different years (Table 5). In 1959 the difference was small, in 1961 it seemed to be large. Fluctuations in soil-structural level as illustrated in Table 6 (P. Boekel, personal communication, 1968), are in accordance with this result.

Table 5 Differences in soil structure (in favour of horse traction)

Year	*Visual rating (points)*	*Pore space (vol. %)*	*Air content (vol. %)*
1958	—	1.5	—
1959	—	0.3–1.5	0.5–1.9 (at pF 1.9)
1960	—	1.0	1.6 (at pF 2.0)
1961	½–¾	1.5–2.5	2.4–3.6 (at pF 2.0)

Table 6 Visual rating (points) of the structure of fine-textured soils

Year	*Limed*	*Unlimed*
1958	4½	3½
1959	5½	4+
1960	6+	6—
1961	5—	3+

As discussed above, soil structure in 1959 was better than in 1958 due to the extremely dry 1959 summer. The 1959 autumn was still dry, so harvesting hardly deteriorated soil structure while afterwards soil tillage could be intensive. Moreover, weather conditions in winter and spring were dry too. Consequently, soil structure in 1960 was good. Due to the extremely wet autumn and to unfavourable weather conditions in winter and spring, soil structure in 1961 was bad on most plots.
The difference in soil-structural level between farms with horse and tractor traction is smaller than between limed and unlimed plots. There is, however, no reason to expect a different trend in the yearly variation in soil structure. In both cases the differences in soil structure seem to be largest in unfavourable years, where the air content of fine-textured soils in The Netherlands is critical. The seemingly small differences in soil structure found here may then become determinant for plant growth (Boekel, 1963).

Conclusion

The results of this investigation indicate that the structure of fine-textured soils is generally worse on farms with tractor traction than on farms with horse traction.

This negative effect of mechanization seems to be most pronounced in years with a bad soil structure.

Ten years ago, when this study was initiated, the discussion of the effects of mechanical traction on soil structure was up to date, but today the tractor is in and the horse is obsolete. The findings of this paper will not reverse this trend, but it is hoped that they may underline once again the basic fact that farm mechanization has something to do with the Trojan horse, and may inspire further research pointed at minimizing its deleterious effects.

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