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Structure formation and faunal activity in two well drained soils in Kenya.

Hans Nobbe, 1987

Vakgroe⁻ ⁾demkunde en Geologie
voor in⁾ gebruik

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Abstract

Nobbe, J.M. 1987. Structure formation and faunal activity in two well drained soil in Kenya. Department of Soil Science and Geology, Agricultural University Wageningen.

An attempt is made to show the influences of biological activity on the physical properties of two Nitosols in the Chuka area, Kenya.
Three different kind of techniques were used to get an insight in the role of faunal activity in the physical structure development in well drained soils.

- pF measurement at different depth and water-presures
- accurate profile description of 10 x 10 cm square sections throughout the profile
- analysis of thin sections

The landuse, soil animal-activity and soil-structure were studied in detail.

This report does not stand alone. In the Embu district some other studies on effects of soil animals are done as well. Those studies are concentrated on many different parameters dealing with the effect of soil animals (eg. climatological-, vegetational-, soil-differences). One of the common aims of those researches was to studie the possibilities of the use of soil-animals to improve agriculture, especially the soil properties.

The research made clear that soil animals do have influence on structure formation in soils. It is not clear how time influences the process of structure formation. The latter is important when processes of soil-animals are used to get better soil-structure for agricultural activities.

On base of the research can be said that in the coffee-zone the positive influence of soil-animals is doubted. Probably the influence is even negative because of the damage some soil animals cause on living crops.

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1. Introduction

For many years it is known that soil fauna can play a role of importance in structure development of soils.
Soil fauna influences the chemical and physical properties of a soil. Research so far showed a high activity of termites in Nitosols (Wielemaker, 1984).
The aim of this research is to obtain a better insight in the role of soil fauna (particularly termites) on the chemical and physical properties of well drained soils Kenya.
This report covers the physical aspects of the research. For the chemical aspect of the same area is referred to the report of Aalders, 1987.

2. Environment

2.1 Location

The research took place on two soil profiles, P18 and P 24, near Kigumo and Kathageri, Embu-district, Kenya, (see figure 2.1.). These profiles are located on the footslope of Mount Kenya on a height of about 1600 m (Aalders and Nobbe, 1985).

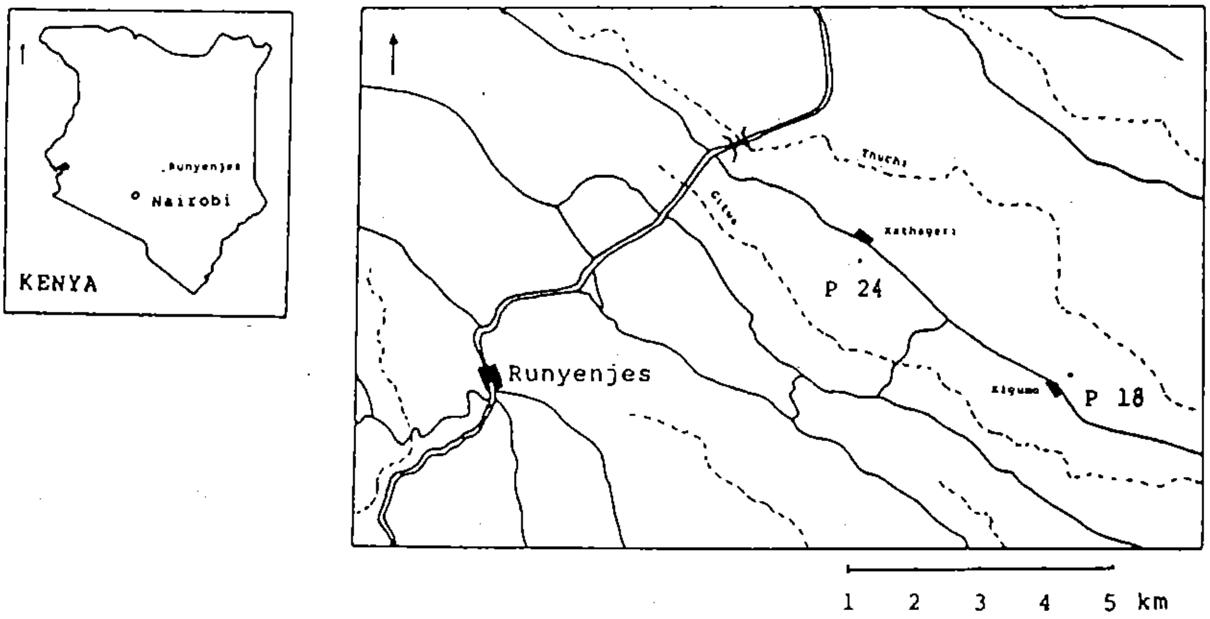


Fig. 2.1 Location of the research area

2.2 Geology

The profiles are a part of the volcanic footridge of Mount Kenya and are developed in deeply weathered lava- and lahar flows (pyroclastic material and phonolite), (Baker, 1967).

2.3 Climate

According to the Agro-climatic zone map of Kenya, the climate of the research area can be classified as subhumid to semihumid. The average rainfall varies from 1050-1400 mm (Jaetzhold, 1983). Most of the rain falls in two rainy periods in April-May and October-November. The mean annual temperature is 20-22oC.
A more detailed presentation of the distribution of the rainfall is given in figure 2.2.

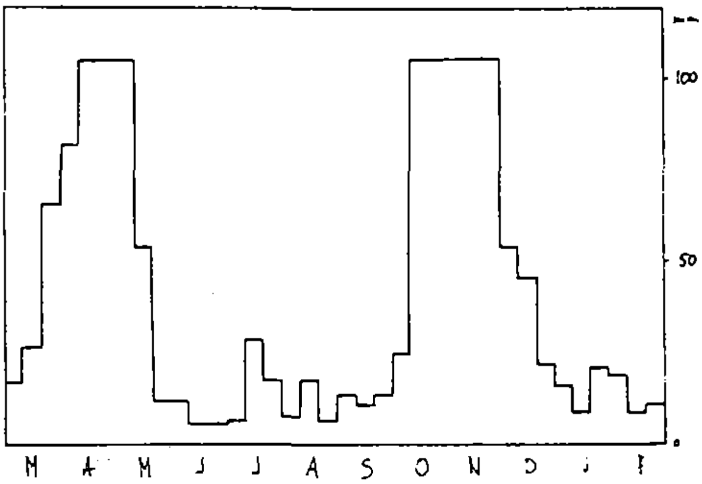


Fig 2.2 Distribution of the average annual rainfall.

2.4 Vegetation and land-use

Originally the whole area was covered with forest of which only remnants in the form of old trees can be found on the very steep slopes. At present the majority of the area is being cultivated. According to Jaetzhold (1983) the area belongs to the main and marginal coffee zones.
Both foodcrops and cashcrops are grown. The main foodcrops are beans, maize and bananas. The main cashcrop is coffee.
Profile 18 is situated in a corner of a shamba on which, during a period of approximately 20 years, maize and beans have been grown.
Profile 24 is situated in a coffee field in which soil management has been restricted to the top ten to fifteen cm. for the purpose of weed control.

3. Profile description and classification

Introduction

For the classification of soils, the FAO/Unesco legend (1974) is used. This classification, originally designed for the soil map of the world 1:5,000,000. is adapted by the Kenya Soil Survey and adjusted to the Kenyan situation. This resulted in the "Kenya Concept" as described by Siderius and Pouw, 1980.

Originally for the profile description both profiles were classified as mollic Nitosols* (see appendix 1). Only recently additional lab-results, both physical and chemical, became available. On base of those results the classification needed to be rectified to humic Nitosols.

3.1 Soil properties of P 18 and P 24

Topsoil

For the profiles P 18 and P 24 the organic matter content of the A-horizon is respectively 2.0 and 3.5 percent (according to the method of Kjeldahl). The base saturation of both profiles is low (less then 30%). This means the presence of an Umbric A-horizon (according to FAO-guidelines).

Subsoil

In table 3.1 and 3.2 the grain-size distribution of both profiles is given.

grain size depth	> 50 u	2-50 u	< 2 u
0 - 35 cm	3	53	44
35 -100 cm	3	49	48
100-160 cm	4	53	42

Table 3.1 Grain size distribution P 18 in %

grain size depth	> 50 u	2-50 u	< 2 u
0 - 5 cm	7	58	35
15 - 30 cm	6	56	38
30 - 60 cm	3	54	43
60 -120 cm	2	53	45
120-200 cm	2	55	43

Table 3.2 Grain size distribution P 24 in %

To distinguish an argillic B-horizon the following properties are required:

a. if the eluvial horizon has more than 40 percent and less than 15 percent total clay in the fine earth fraction, the ratio of the clay in the argillic B-horizon to that in the E-horizon must be 1.2 or more;

b. if the eluvial horizon has more than 40 percent total clay in the fine earth fraction, the argillic B-horizon must contain at least 8 percent more clay.

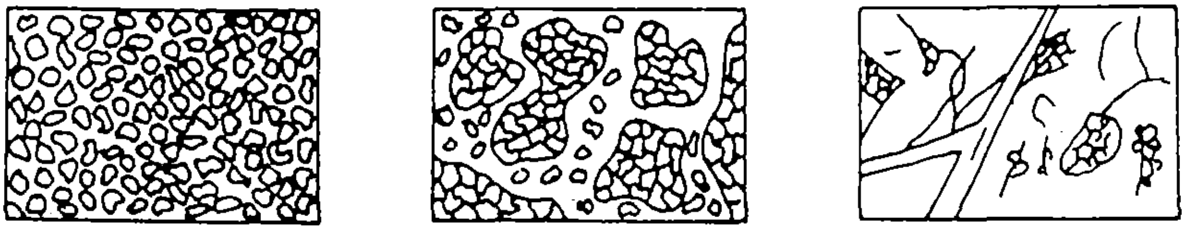
Profile P 24 contains less than 40 percent clay in the eluvial horizon. This means that this profile has to meet the conditions of a.) and that the ratio of clay in the illuvial horizon to that in the eluvial horizon must be at least 1.2. The ratio is exactly 1.2.
This means that profile P 24 meets the requirements for an argillic B-horizon. It therefore is classified as a humic Nitosol (Nh).
Profile P 18 does have more than 40 percent clay in the eluvial horizon. This means that this profile has to meet the properties of b.). However, the clay content in the B-horizon is only 4% higher than in the A-horizon.

So when strictly applied, profile P 18 has no argillic horizon
However, both the Kenya Concept as well the latest version on FAO-soil classification (Sombroek, personal communication) gives a less strictly applied interpretation of the data. That means that both profiles have an argillic horizon that can be called diagnostic. In that case P 18 can also be classified as humic Nitosol (Nh).
Besides grain-size distribution, other physical properties are recognized throughout the profile. In the field the fecal pellets can be recognized as granular structure elements and the plasm as subangular-blocky structure elements.
Those structure elements also influence the properties of soils.

* According to the "Kenya Concept" as described by Siderius and van der Pouw, 1980.

4. Soil fauna activity

Soil fauna influences the structure of soils by changing the pore distribution. As a result the hydrological properties and aeration of the soil changes.
By their digging activities or by letting soil material pass through their intestinal canal soil fauna also can produce granular structure elements.
Finally soil fauna redistributes organic material. As a result homogenization of soil material throughout the profile takes place.
The hypothesis for this research was, that granular elements, with packing voids, are mainly formed by the activity of soil fauna (fig. 4.1.a). In a process of ageing granular structure elements get welded (fig. 4.1.b), resulting in subangularblocky structure elements with planes and channels (fig 4.1.c).



4.1.a Granular structure   4.1.b Transition   4.1.c Subangular structure

Fig. 4.1 Structure development in time

By the ageing processes, the soil becomes more compact with a lower pore density.
The development of structure (and especially in time) can be of importance for the properties of a soil. For instance: permeability and rootability.
Because the relative short period over which the research took place, the research had to be restricted to the observation of the different structure elements.

5. Methods

5.1 Drawings of structure

Of each profile drawings were made of 10 x 10 cm sections at intervals of 10 cm. In the drawings the location of granular and subangular blocky structure elements was made. Beside the structure elements, other features as roots and large pores were observed. On base of those drawings the distribution of granular and subangular blocky structure elements was studied.

5.2 Micromorphological analysis

Of each soil-horizon a sample was collected of which a thin section was prepared. The latter was described according to the micromorphological description method of Brewer, 1976.

5.3 pF Measurements

Of each soil-horizon 5 pF-rings were collected. pF Measurements were done at water pressures of 0, 5, 10, 25, 50, 100, 200, and 500 cm water.

5.4 Pore density

As mentioned before, pore density is an important soil property. For the definition of the pore density, different methods are possible.

1. Visual, on base of the pore distribution of thin sections.
2. Mathematical, on base of the water content of pF-rings.
   A pF-ring has a standardized volume of 100 ml. When fully saturated, all pores are filled with water. The difference in water content between saturated and pF 2.7 gives the volume of macro-pores in the sample (Koorevaar et al, 1983).

5.4.1 Equivalent pore-diameter

The pF-value represents a water-pressure on which a certain amount of water will be released by the soil-sample. The different pF-values also represent a certain pore-diameter. This can give an impression of the distribution of different pore-diameters throughout the soil.
Equivalent pore-diameter can be calculated with following formula:

$$2\sigma\cos\alpha = rh\Gamma g$$

$\sigma = 0.075$ N/m
$\alpha = 0$ $\cos\alpha = 1$
$\Gamma = 1000$ kg/m3
$g = 10$ m/s2

pF	Equivalent pore diameter
sat	3 mm
0.7	0.6 mm
1.0	0.3 mm
1.4	0.12 mm
1.7	0.06 mm
2.0	0.03 mm
2.3	0.015 mm
2.7	0.006 mm

Table 5.1 Equivalent pore-diameter

5.5 Infiltration ratios

The infiltration rate gives an indication of the amount of continuous macro pores and channels.
For the measurement of the infiltration rate a cylinder, with a diameter of 20.6 cm was filled with undisturbed soil material (like a pF ring). Next a constant head of water was applied and the time needed to let 100 ml of water infiltrate was measured.

6 Results

6.1 Drawings of structure

Of the drawings, the coverage, in percentages, of the granular structure elements was measured. These results are presented in table 6.1. This reveals an increase of subangular-blocky structure elements with depth. From the drawings themselves a change in channelform can be observed. In the topsoil a large amount of continuous, vertical channels are present. In the subsoil the vertical channels are less numerous, mostly not continuous and more horizontal.
In figure 6.1 the reduced simplifications of the original drawings are given.

P 18	granular structure elements	subangular blocky structure elements
0-10 cm	35%	65%
10-20 cm	25%	75%
20-30 cm	30%	70%
30-40 cm	25%	75%
40-50 cm	10%	90%
60-70 cm	15%	85%
P 24		
0-10 cm	30%	70%
10-20 cm	30%	70%
20-30 cm	50%	50%
30-40 cm	20%	80%
40-50 cm	15%	85%
60-70 cm	15%	85%

Table 6.1 Distribution of structure elements

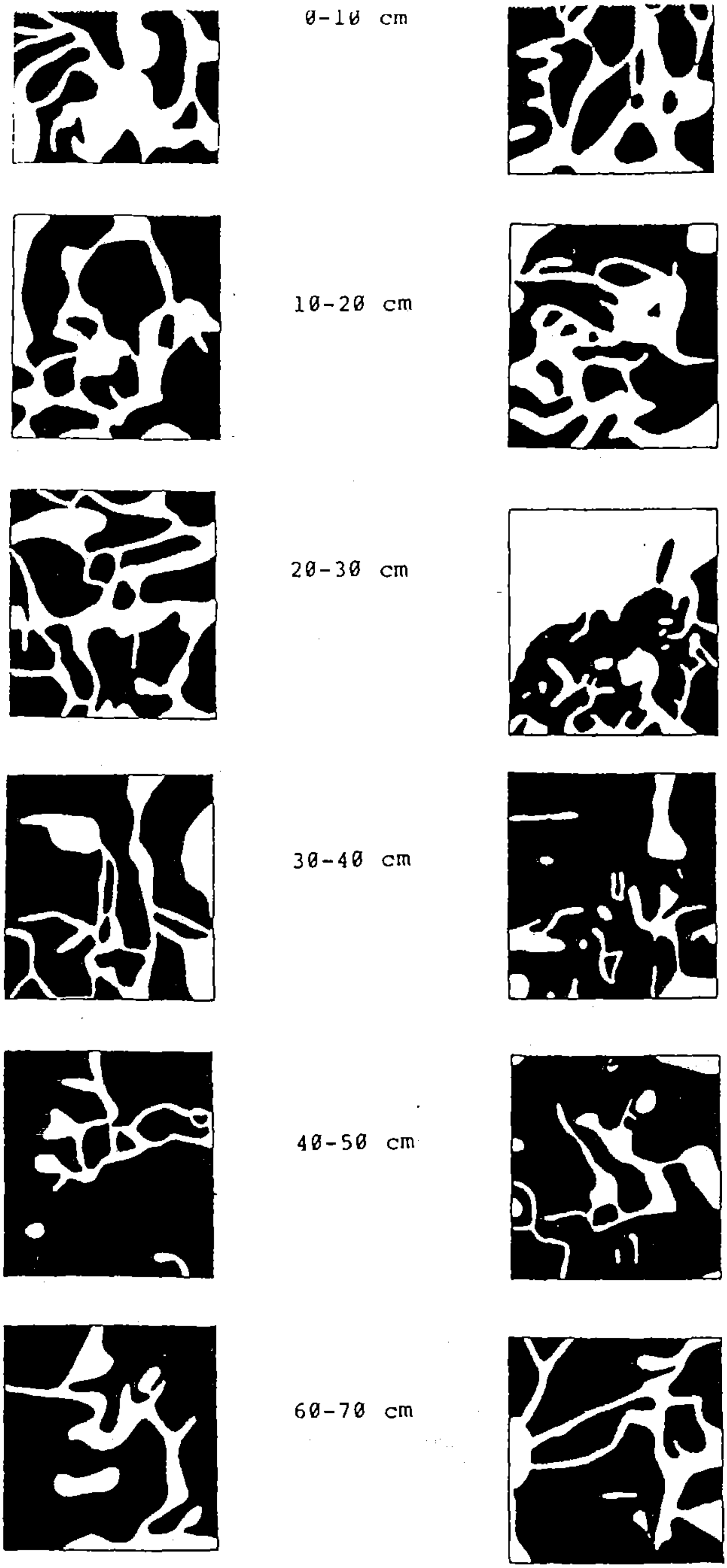


Fig 6.1 Reduced drawings of structure

☐ granular

■ subangular-blocky

6.2 Micromorphological analysis

In thin slides, biological activity in the soil can be recognized.

- The occurrence and abundance of so called 'fecal pellets'. Those fecal pellets are rounded to subrounded excrements, of small insects. They can be found in most deserted channels and voids.
- Features caused by the digging activity of soil animals i.e. channels and voids.

In general it can be said that the topsoil is characterized by an open structure and a large amount of fecal pellets. The different features are very homogeneously spread over the thin sections.
The subsoil shows a more compact structure. Fecal pellets can be found in filled-up channels and voids, mostly in clusters. Besides that, by getting "welded", the fecal pellets transform into the plasm.

6.3 pF Measurements

The moisture content, at a certain pF value, show a little change with depth. The differences between the soil-horizons become smaller with higher water pressure level.
This is normal for homogeneous soil material. The water content at low water pressures is concentrated in large pores and channels. This water will quickly disappear with higher water pressures. On higher water pressures the water content of the soil is concentrated in small pores. The equivalent pore diameters (the pores which are emptied by a certain water pressure) are given in table 5.1. In general can be said that the changes in pF-values are very smooth with varying water-pressures. Also the changes with depth are very slight. As a result the distribution of macro-pores throughout the profile is very regular. Only a slight transition towards more fine pores with depth can be recognized. As a result the topsoil contains relatively more wide pores. Likely as a result of a higher activity of soil-animals and roots of plants and trees.
Results are given in table. 6.2 and 6.3.

pF	sat.	0.7	1.0	1.4	1.7	2.0	2.3	2.7
depth								
0 - 5	42.2	39.6	39.5	37.9	33.4	30.5	27.9	26.0
35 - 40	44.3	39.7	39.1	35.0	31.3	29.1	26.1	25.3
70 - 75	38.8	36.1	35.6	33.7	31.8	30.0	27.8	26.0
160-165	39.8	37.1	37.0	35.6	33.5	31.7	26.2	24.8
200-205	39.8	36.2	36.2	35.1	33.7	32.3	30.4	29.0

table 6.2 pF values profile P 18 in cm3.cm-3

pF	sat.	0.7	1.0	1.4	1.7	2.0	2.3	2.7
depth								
0 - 5	43.1	39.3	39.1	35.4	31.5	29.5	27.4	26.5
15-20	47.0	39.7	38.3	33.3	30.2	29.8	26.2	24.7
40-45	40.4	35.4	34.7	31.7	29.5	28.1	27.7	25.9
65-70	37.4	34.6	33.8	33.5	32.2	31.0	28.7	27.9

table 6.3 pF values profile P 24 in cm3.cm-3cm

6.4 Pore density

The results of the two methods used for the determination of pore density are given in able 6.4 and 6.5.

	Visual	Mathematical (equivalent pore diam. in mm.)							
		Total	3.0	0.6	0.3	0.12	0.06	0.03	0.015
	%	%							
0-5 cm	20	17	2.6	0.1	1.6	4.5	2.9	2.6	1.9
35-40 cm	25	19	4.6	0.6	4.1	3.7	2.2	3.0	0.8
70-75 cm	10	13	2.7	0.5	1.9	1.9	1.8	2.2	1.8
160-165 cm	5	15	2.7	0.1	1.4	2.1	1.8	3.5	1.4

table 6.4 pore density profile P18

	Visual	Mathematical (equivalent pore diam. in mm.)							
		Total	3.0	0.6	0.3	0.12	0.06	0.03	0.015
	%	%							
0- 5 cm	20	17	3.8	0.2	3.7	3.9	2.0	2.1	0.9
10- 15 cm	20	22	7.3	1.4	5.0	3.1	0.4	1.6	1.5
40- 45 cm	25	15	5.0	0.7	3.0	2.2	1.4	0.6	1.6
200-205 cm	5	-	-	-	-	-	-	-	-

table 6.5 pore density profile P24

Visually both profiles show a maximum pore density between 35-45 cm below the surface. Mathematically the maximum pore density of P18 is also from 35-45 cm as P24 is from 10-15 cm but the trend for both profiles is the same.
This trend is a surface horizon with a pore density between 15 and 20%, a subsurface horizon at 20-40 cm with a pore density of 20-25% and a decreasing pore density in the lower horizons of the profile.

6.5 Infiltration rates

The infiltration rates are given in table 6.6 and 6.7.

depth	time
30 - 50 cm	18 sec/100 ml
120-140 cm	184 sec/100 ml

table 6.6 infiltration rates of P 18

depth	time
0 - 20 cm	22 sec/100 ml
15 - 35 cm	9.5 sec/100 ml
30 - 50 cm	10 sec/100 ml
50 - 70 cm	65 sec/100 ml

table 6.7 infiltration rates of P 24

Unfortunately the rates of P18 are incomplete.
P24 shows a maximum infiltration rate on a depth of 15-50 cm below the surface.
The more compacted, deeper horizons, (of both P18 and P24) have a obvious lower infiltration rate.

7. Discussion and conclusions

From the results of the different tests used in this research, it can be concluded that:

1. maximum pore density occurs at 30-40 cm depth,
2. looser structure in topsoil, more compact structure in subsoil,
3. granular structures get welded and a clear transition to subangular blocky structure elements can be observed,
4. some very large, filled channels can be distinguished. Those channels are filled with very fine granular elements,
5. compared with the topsoil, a large amount of pores in the subsoil exists of planes and channels instead of packing voids.

One of the aims of this research was to investigate the development of structure in time. However during the research the factor time in the development of granular structures towards subangular blocky structures became more important. The problem was formed by the large amount of granular structure elements. With the present number of termites it would take many years to form the amount of granular structure elements. But with the present amount of granular structure elements it must also take several years before those elements transform into subangular blocky structure elements.

On base of those observations one of the following explanation might be possible.

1. The process of ageing indeed takes a large period of time or,
2. The forming of a large amount of granular structure elements is not only on account of the termites but as well other soil fauna, or even other sources, can produce a significant amount of granular structure elements.
3. A combination of the two above mentioned possibilities.

Which of the above mentioned possibilities is true cannot be said, but further research on this subject could provide more and useful information about this subject.

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Appendix 1a: Soil description P24 Kathageri

Observation no	: 122/3-24
Agro-Ecological zone	: Main coffee zone
Mapping unit	: FV 1
Soil Classification	: humic Nitosol (Vermic Argiudoll)
Parent material	: Pyroclastica/phonolit flow
Physiography	: Volcanic Footridge
Relief	: Flat
Vegetation/landuse	: Coffee
Erosion	: non to very slight splash erosion
Rockiness	: nil
Surface stoniness	: nil
Overwash/overblow	: nil
Slope gradient	: 0 %
Surface sealing/crusting	: cracks, width 5 mm, spacing 15 cm
Effective soil depth	: 120 cm
Drainage class	: well drained

Horizons:

Ap 0-15 cm	Dark reddish brown (5YR 3/2, moist); silty clay to clay; moderate very fine to fine granular structure; very friable when moist, slightly sticky and slightly plastic when wet; many biopores; very frequent very fine roots; abrupt and wavy transition to:
A 15-30/35 cm	Dusky red (2.5YR 3/2, moist); silty clay to clay; moderate very fine to subangular blocky structure; very friable when moist, slightly sticky and slightly plastic when wet; many biopores; very frequent very fine and very frequent fine roots; clear and wavy transition to:
Bt1 30/35-65 cm	Dusky red (2.5YR 3/2, moist); silty clay to clay; moderate very fine angular and subangular blocky structure; broken thin clay skins; very friable when moist, slightly sticky and slightly plastic when wet; many biopores;common very fine and common fine roots; gradual and smooth transition to:
B 65-90 cm	Dark reddish brown (2.5YR 3/4, moist) and dark red (2.5YR 3/6, moist); silty clay to clay; moderate very fine angular and subangular blocky structure; broken thin clay skins; friable when moist, slightly sticky and slightly plastic when wet; many biopores; common very fine and fine roots; gradual and smooth transition to:
B2 90-130 cm	Dark red (2.5YR 3/6, moist); silty clay to clay; moderate very fine angular and subangular blocky structure; broken thin clay skins; friable when moist, slightly sticky and slightly plastic when wet; many biopores; common very fine and fine roots; gradual and smooth transition to:
B2 130-200+ cm	Dark red (2.5YR 3/6, moist) silty clay to clay; moderate very fine angular blocky stucture; patchy thin clay skins; very friable when moist, slightly sticky and slightly plastic when wet; many biopores; common very fine and fine roots.

Appendix 1b : Soil description P18 Kigumo

Observation no	: 122/3-18
Agro ecological zone	: Main coffee zone
Mapping unit	: RV2
Soil Classification	: humic Nitosol (vermic Argiudoll)
Parent material	: Pyroclastic material/Phonolite
Physiography	: Top of Volcanic Footridge
Relief	: Flat to very gently undulating
Vegetation/landuse	: Annual crop cultivation
Erosion	: very slight sheet and splash erosion
Rockiness	: nil
Surface stoniness	: nil
Overwash/overblow	: nil
Slope gradient	: 1 %
Surface stoniness	: nil
Effective soil depth	: 160 cm
Drainage class	: well drained

Horizons:

A 0-35 cm	Dark reddish brown (5YR 3/2, moist); silty loam; moderate, very fine, granular structure; friable when moist, sticky and slightly plastic when wet; many biopores; very frequent, very fine and common fine roots; gradual and wavy transition to:
Bu1 35-100 cm	Dark reddish brown (5YR 3/3, moist); silty clay; moderate very fine to fine subangular blocky structure; patchy, thin clay skins; friable when moist, slightly sticky and slightly plastic when wet; many biopores; few fine and common very fine roots; diffuse and smooth transition to:
Bu2 100-160 cm	Dark reddish brown (2.5YR 3/4, moist); silty clay; moderate very fine subangular blocky structure; friable when moist, slightly sticky and slightly plastic when wet; many biopores; few fine and common very fine roots.