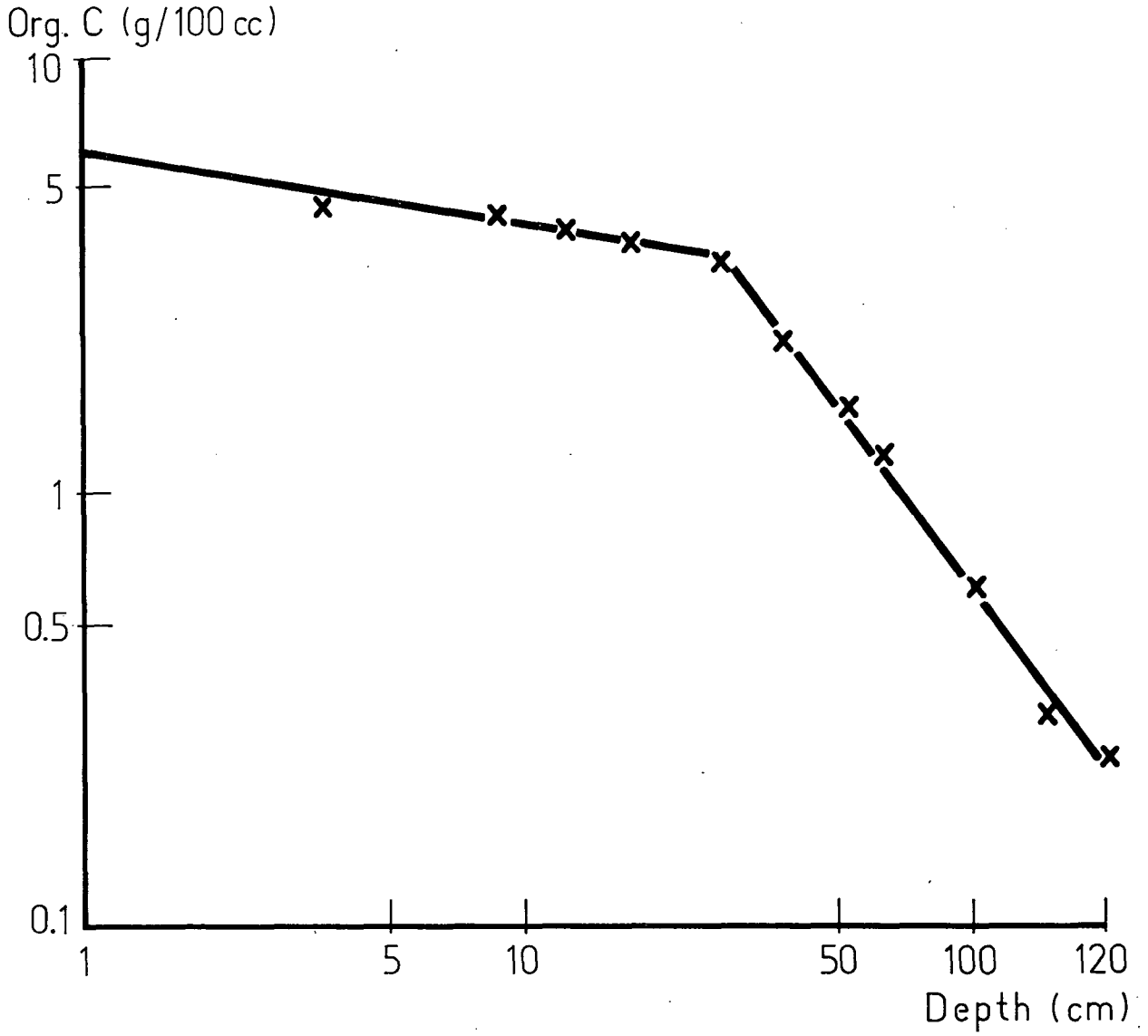
TRAINING PROJECT IN PEDOLOGY

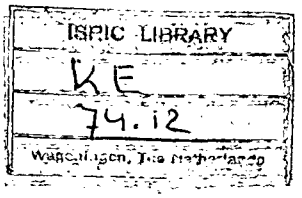
KISII KENYA



The Influence of Cultivation Practices on the Organic Carbon Content of some Deep Soils

PRELIMINARY REPORT NO 4

RICULTURAL UNIVERSITY
GENINGEN - THE NETHERLANDS



THE INFLUENCE OF CULTIVATION PRACTICES ON THE ORGANIC CARBON CONTENT OF SOME DEEP SOILS IN KISII DISTRICT

A study

by H.L.M.van Wissen

Preliminary Report no. 4

December 1974

TRAINING PROJECT IN PEDOLOGY, KISII KENYA.

Agricultural University, Wageningen - The Netherlands.

Contents page no:

Preface

This report of the Training Project in Pedology at Kisii, Kenya, of the section on Tropical Soil Science of the Agricultural University at Wageningen, the Netherlands, is the fourth one of a series to be presented to Kenyan officials.

The project started in November 1973 after assen had been granted by the Office of the President of Kenya. It is meant for training of postgraduate students of the Agricultural University at Wageningen and for furnishing research opportunities to the staff. The activities of students and staff are directed to obtaining a better knowledge of the soils and the agricultural conditions of the project area to provide a basis for the further agricultural development of the area.

The project in Kisii is conducted by:
Ir.W.G.Wielemaker, teaching and research
Ing.H.W.Boxen, management.
Visiting specialists from the Agricultural University at Wageningen help to resolve special problems.

This report is the result of a special survey on carbon content of the soil carried out by Mr.H.L.M.van Wissen, who also wrote the report. The fieldwork and attached laboratory work was carried out under guidance of Mr.H.W.Boxem who also edited the text.

We hope to pay back with these reports a small part of the great debt we owe to Kenya in general and to many Kenyans in particular for their valuable contributions to the good functioning of the project.

The supervisor of the project

J.Bennema, Professor of Tropical Soil Science

1. Introduction

The study of the influence of cultivation practices on soil formation and on productivity of soils is of great theoretical and practical importance. The productivity of soils depends for a great part on the level of organic content. Especially in the tropics, where the growing season extends through the major part of the year, the removal of plant nutrients by crops, by leaching and external and internal erosion processes is much more important than in temperate region and the rate of degredation of the organic matter is therefore much higher than in temperate soils.

A decrease in organic matter causes a decrease in soil fertility, structure and water holding capacity and increases the possibility of surface erosion.

Based on samples taken from selected profiles in the Kisii district during the start of the soil survey for the preparation of the soil map (sheet 130 of the survey of Kenya, scale 1:100,000), the influence of cultivation practices on the carbon content of the soils was studied and the results are given in this report. The results can be used for assesment of the soil fertility, which is a major landquality which will be used for the final landevaluation of the soils in the formentioned district. Moreover this study gives some ideas about the decrease of organic matter content in general which counts for a much larger area and therefore can be regarded as basic information for further study.

2. Material and methods

According to Jenny (1941) the following groups are responsible for the amount and kind humus enrichment: climate, microorganism, relief, parent material, age of the profile and human influence.
In this report mainly the human influence on the carbon content of the profile will be discussed.
In order to keep the main groups more or less constant the profiles had to be taken preferably a short distance apart. On the other hand it was necessary to find a broad range of profiles of different duration under cultivation. In the border area between Narok District and Kisii District such a situation exists. On one side of the sharp "man made" boundary we find the intensive farming system of the Kisii tribe while on the other side we find the grazing lands of the Masai tribe. Until recently every now and then this boundary was replaced illegaly this made it possible to find a broad range in ages of cultivated fields on a short distance apart.
The following samples were taken in March 1974 near the border village Nyabitunwa:

Profile no.	Years under cultivation	crop
154	0	(grass cover)
157	2	maize
158	10	maize
159	18	sw.pot./sorg/maize
155	25	wimbi/maize
156	30	maize/wimbi

In the north-western part of the Kisii District (Wanjare Division), samples were taken of profiles under different crops.

Profile no.	crop
151	bananas/coffee
150	maize
152	bananas
153	maize/wimbi

Determination of organic matter was done according to Walkley and Black.

Principle:

Concentrated H_2SO_4 is added to a mixture of soil and aqueous $K_2Cr_2O_7$. The heat of dilution raises the temperature sufficiently to induce a very substancial oxidation within a minute or so. After a certain waiting time the residual $K_2Cr_2O_7$ is titrated against ferrous ammonium sulphate. The values obtained by this method are in most instances considerably lower than those obtained by dry combustion, and a multiplication factor, however, may vary from soil to soil and must first be determinated by comparing the method with elementary analysis (Schouwenburg). The multiplication factor is estimated on 100/75 because no data on elementary analysis were available in September 1974.

In this report the carbon content is expressed as weight per volumes, e.g. gr. carbon per 100 cc soil. This expression represents quantities in relation to volume (these quantities can in calculations be added up or substracted).

3. Rate of increase in humus

The rate of increase will depend primarly on the balance between the rates of addition of organic matter to the soil and losses of organic matter from the soil (Nye and Greenland 1960).
The additions come from (i) litter and root material; the losses by (ii) oxidation and to a lesser extent, leaching.
Arable soils receive organic matter from the residues of the crops growing on them. The crop always leaves behind much of its root system in the soil, but except for some grasses the actual weight of the roots is usually very small (Hardy, 1944).

ad i) Litter and root production.

In this zone the annual production of aerial parts of grasses depends greatly on the rainfall. The production of organic material in forest regions is ± 15,000 kg/ha per annum (Nye and Greenland). In the sample area, however, we have a grass cover and addition of organic material to the soil is therefore probably only $\frac{1}{4}$ of the production in forest regions.

ad ii) Losses of organic material.

Of the fresh organic material produced by the vegetation, only a fraction becomes incorperated within the soil humus, the remainder being lost through oxidation, and possibly also through leaching and erosion. The soil humus, itself will also be subject to oxidation through its rates of destruction is very much less than that of organic material.

A) Birch and Friend (1956) suggested that in general as temperature rose, the rate of decomposition of organic matter by microbial activity did rise, but that the addition of organic matter to the soil also increased to about the same degree.

B) Nye and Greenland (1960) suggest that about one fifth to one tenth of the carbon content of fresh organic material is converted to humus, but they say that there is very little evidence on this point.
The vegetation of the area is not the climax vegetation.
The grass cover is probably created by burning and grazing,
Under this assumption we can estimate the increase of soil carbon ac-

cording to Nye and Greenland (long fallowed soil).

Rate of increase = rate of addition - rate of loss.

$I = A - kf\ C.$

Where I : is the annual increase of humus carbon in the soil;

A : is the annual addition of humus carbon;

C : is the present amount of humus carbon;

kf : is a decomposition constant.

The humus decomposition constant could be caculated from a knowledge of the equilibrium level of humus in very long fallowed soils in which the humus level has ceased to build up. Here $A = kf\ C_E$, where C_E is the equilibrium level of humus carbon in the long fallowed soil.

4. Effect of cultivation of the carbon profile of the soil

4.1 Relation between duration of cultivation and carbon content demonstrated in

Profile no. 154, 0 year under cultivation

The profile is situated in an area with an annual rainfall of ± 1500 mm. The vegetation can be described as: "Montane Acacia vegetation of probable forest origin: undifferentiated secondary and valley types".
This vegetation type produces an unusual and striking pattern on air photographs. The pattern is one of uniformly distributed rounded bush clumps in grassland.
Land use: grazing lands of the Massai tribe. However, at the moment the area is more used as grazing lands for cows belonging to Kisii farmers.
The complete profile description is given in Appendix I.

Table 1

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon (total)
3.5 cm	35.5%	0.85	88%	4.66
8.5 cm	35.5%	0.89	90%	4.44
12.5 cm	33.5%	0.94	94%	4.15
17.5 cm	33.5%	0.98	94%	3.86
27.5 cm	32.5%	1.06	91%	3.48
37.5 cm	29.5%	1.08	89%	2.35
52.5 cm	29.0%	1.08	92%	1.60
62.5 cm	31.0%	1.11	92%	1.25
82.5 cm	28.5%	1.14	90%	0.75
102.5 cm	30.0%	1.13	91%	0.63
145.0 cm	30.0%	1.09	90%	0.31
185.0 cm	29.5%	1.21	89%	0.25

Fig.1 (page 15) shows that the organic carbon content is a function of depth. The carbon profile of thisundisturbed soil gives on logaritmic paper a straight line with a breaking point at ± 30 cm.

The equation for the profile to 30 cm can be written as $c = 6.1\ p^{-0.25}$, in which c is the carbon content, p the depth, and a and b constants (a = 6.1; b = -0.25) (Bennema, unpublished doc.).
As can be seen in Appendix I, most of the roots (± 90 %) of the grass can be found in the 0 - 28 cm layer!

Profile no.157, 2 years under cultivation

The distance between profile 154 and 157 is about 400 m. The climatic conditoons are therefore more or less identical. Also other properties, like slope gradient, position on the slope, evaluation, geol.formation, parent material, and length, shape and pattern of the slope are corres - ponding to each other (Appendix I).
Land use: Two years maize, with one harvest per year.
Table 2

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon(total)
3.5 cm	36.0%	0.78	83%	3.98
7.4 cm	35.3%	0.87	82%	4.02
12.5 cm	34.0%	0.97	80%	3.07
17.5 cm	33.0%	1.02	86%	3.44
27.5 cm	31.5%	1.12	93%	3.17
37.5 cm	30.5%	0.98	88%	2.00
47.5 cm	29.5%	1.02	87%	1.74
62.5 cm	30.0%	1.05	87%	1.30
82.5 cm	28.5%	1.11	88%	0.96
102.5 cm	28.5%	1.21	81%	0.61
145.0 cm	27.0%	1.16	80%	0.27
185.0 cm	28.0%	1.19	80%	0.23

In the top 30 cm, the organic carbon is distributed irregularly (ploughing!).
Both the bulkdensity and the "percentage smaller than 0.6 mm" are, espe- cially at 27.5 cm, unusual high.

Profile no. 158, 10 years under cultivation

The profile is situated in the Narok District. Officially the Masai tribe is owner of this area, but the greater part of this border area is every now and then ploughed by Kisii farmers.
This illegal tillage is difficult to compare with the normal cultivation practices.
The crop is not given so much attention as in normal circumstances, and this profile is therefore not a good representative in the range.

Table 3

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon (total)
3.5cm	37.5%	0.75	90%	4.26
7.5cm	34.0%	0.89	85%	3.52
12.5cm	35.5%	0.87	88%	3.78
17.5cm	34.0%	0.83	87%	2.15
27.5cm	30.5%	0.97	85%	2.23
37.5cm	30.5%	0.93	85%	1.52
47.5cm	30.0%	1.02	82%	1.66
62.5cm	30.5%	1.01	88%	1.34
82.5cm	30.0%	1.08	87%	0.98
102.5cm	30.0%	1.12	88%	0.69
145.0cm	30.0%	1.15	90%	0.45
185.0cm	29.0%	1.17	91%	0.31

Table 4

	Estimated carbon content	Relative carbon content	
Depth (cm)	tons/hectare	0 year cult.	10 years cult.
0 - 27.5	85	100%	75%
27.5- 37.5	19	100%	66%
37.5- 52.5	23	100%	77%
52.5- 62.5	14	100%	100%
62.5- 82.5	23	100%	115%
82.5- 102.5	18	100%	136%
102.5- 145.0	23	100%	115%
145.0- 185.0	15	100%	136%
total	220	100%	87%

Profile no. 159, 18 years under cultivation

This profile is situated in Kisii District not far from profile 158.
The farmer applies every year a little cow dung.
The main crop is maize, sometimes in rotation with sorghum or sweet potatoes, but without a fallow period.

Table 5

Depth	moisture content	bulkdensity	% sm .th.0.6 mm	% carbon(tot.)
3.5cm	29.5%	0.89	87%	3.21
7.5cm	27.5%	0.85	88%	3.53
12.5cm	26.5%	0.89	88%	3.05
17.5cm	33.5%	0.82	89%	2.63
27.5cm	29.5%	1.01	88%	2.37
37.5cm	30.0%	1.02	88%	2.17
47.5cm	29.5%	1.08	88%	1.92
62.5cm	28.5%	1.11	90%	1.50
82.5cm	29.5%	1.07	90%	0.77
102.5cm	30.0%	1.09	90%	0.67
145.0cm	29.5%	1.11	91%	0.36
185.0cm	29.5%	1.16	87%	0.29

The graph of the moisture content with depth of this profile is irregular in comparison with the other profiles.

Profile no.155, 25 years under cultivation

This profile is like profile no.158 not a good representative in the range of different duration of cultivation. Mainly due to the fact that the rotation maize/fingermillet is alternated with a fallow period (4.2).

Table 6

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon(tot.)
3.5cm	34.0%	0.88	87%	3.91
8.5cm	33.0%	0.84	79%	3.11
12.5cm	33.0%	0.98	81%	3.59

Depth	moisture content	bulkdensity	% sm.th.0.6 mm %	carbon (tot.)
22.5cm	33.5%	1.03	80%	2.42
32.5cm	30.5%	1.00	82%	2.14
47.5cm	31.0%	0.97	79%	1.70
52.5cm	31.0%	1.03	82%	1.58
67.5cm	31.0%	1.03	81%	0.86
75.5cm	31.5%	1.03	80%	0.88
102.5cm	29.0%	1.17	82%	0.43
138.0cm	30.5%	1.08	78%	0.27
190.0cm	27.5%	1.23	81%	0.21

Table 7

	Estimated carbon content	Relative carbon content	
Depth (cm)	tons/hectare	0 year cult.	25 years cult.
0- 27.5	85	100%	75%
27.5- 37.5	21	100%	72%
37.5- 52.5	27	100%	90%
52.5- 62.5	13	100%	94%
62.5- 82.5	18	100%	90%
82.5-102.5	12	100%	86%
102.5-145.0	14	100%	70%
145.0-185.0	10	100%	92%
total	200	100%	79%

Profile no.156, 30 years under cultivation

The farmer applies cow dung every year.

Maize is alternated with finger millet (Eleusine coracana).

Table 8

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon (total)
3.5cm	34.5%	0.95	81%	3.50
7.5cm	35.0%	0.87	84%	3.14
12.5cm	33.5%	0.99	79%	2.71
22.5cm	32.0%	0.95	80%	1.94
32.5cm	31.0%	0.98	84%	2.94

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon(tot.)
42.5cm	30.5%	1.01	83%	1.26
52.5cm	31.0%	1.03	89%	1.26
67.5cm	29.5%	1.13	86%	0.73
82.5cm	30.5%	1.06	88%	0.51
102.5cm	31.0%	1.07	84%	0.57
145.0cm	30.5%	1.07	84%	0.27
185.0cm	29.5%	1.17	85%	0.20

4.2 Discussion and conclusions about duration of cultivation and carbon content.

There is not only a great uniformity in profile characteristics of the different profiles (Appendix I), but also moisture content and percentage smaller than 0.16 mm, are more or less similar.

In general the moisture content is decreasing with greater depth (from ± 35% in the 0 - 10 cm layer, to ± 28% at 180 cm).

The percentage smaller than 0.6 mm varies between 80% and 90%.

Because of thisuniformity in characteristics it is possible to compare the different profiles in this range of different duration of cultivation.

Fig.1 shows the following organic carbon profiles on logaritmic paper:

1) 0 year cultivation (profile no.154);
2) 2 years cultivation (profile no.157);
3)18 years cultivation (profile no.159);
4)30 years cultivation (profile no.156).

The carbon profile of 0 years cultivation is a straight line with a breaking point at ± 30 cm. This corresponds to graphs of profiles under natural grasslands in other parts of the world. And it is therefore possible to use this "line" as a reference.

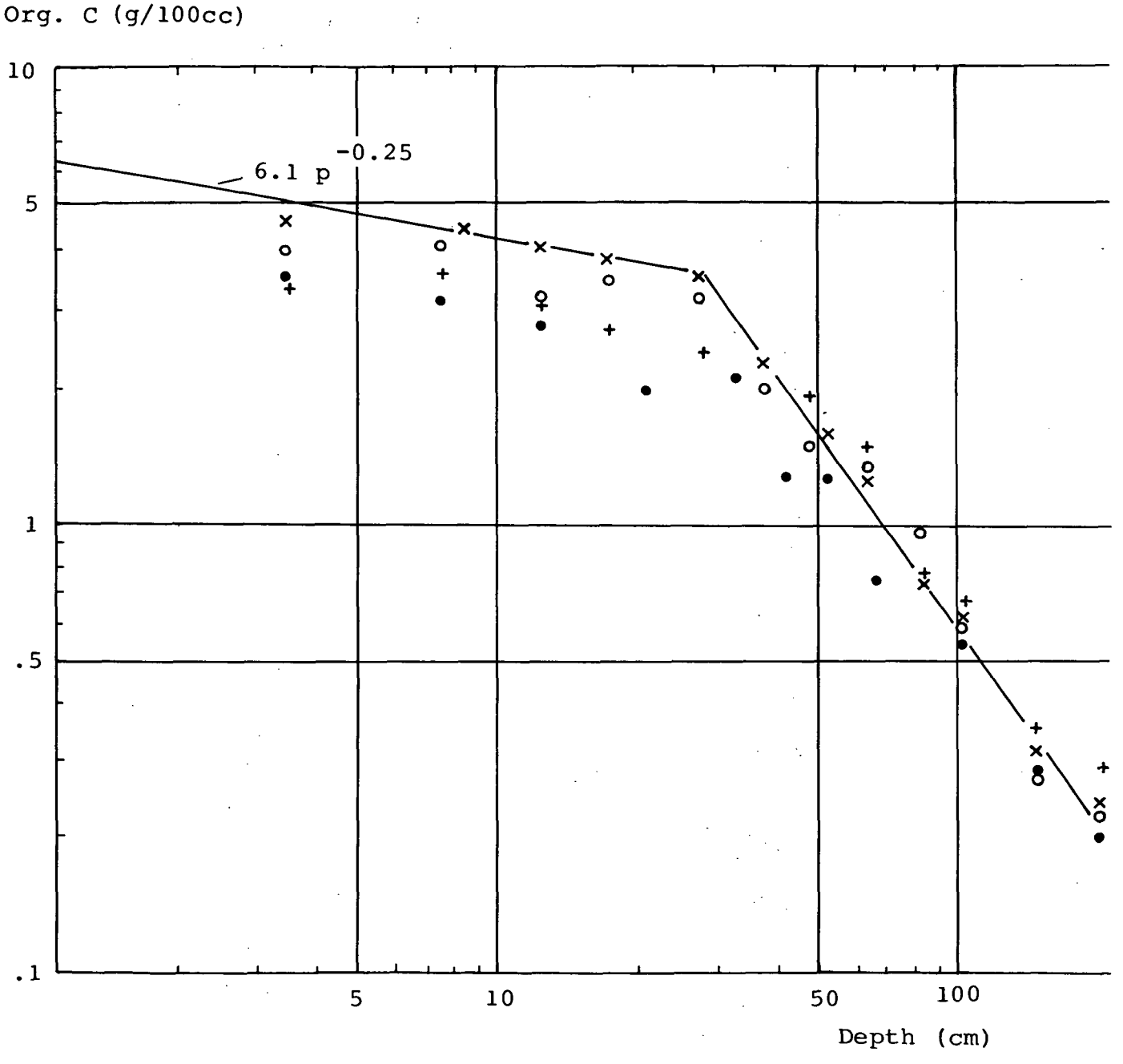
In Table 9 the estimated organic carbon content (tons/ha) will be given. These data show clearly the effect of cultivation on the carbon content. In the first two years, 20 tons of organic carbon disappeared in the top 37.5 cm of soil.

20 tons of carbon corresponds to about 2 tons of nitrogen.

After about 3 years there is a more gradual decrease of carbon in this

top layer i) between 2 and 18 years, with an average of about 1.3 t C/ha/yr, and ii) between 18 and 30 years, with an average of about 0.9 t C/ha/yr.

At about 185 cm there is hardly any change of the organic carbon content during the period of cultivation.



x = profile 154, 0 year under cultivation;
0 = profile 157, 2 years under cultivation;
+ = profile 159, 18 years under cultivation;
. = profile 156, 30 years under cultivation.

Fig. 1. Organic carbon profiles of soil profile 154, 157, 159 and 156.

Table 9 Estimated organic carbon content (tons/hectare)

Depth (cm)		0 year	2 years	18 years	30 years
0 - 27.5		114	97	79	73
27.5 - 37.5		29	26	23	19
37.5 - 52.5		30	26	29	22
52.5 - 62.5		14	14	17	10
62.5 - 82.5		20	23	23	13
82.5 - 102.5		14	18	14	11
102.5 - 145.0		20	19	18	17
145.0 - 185.0		11	11	13	10
	total	252	234	216	175
	profile	154	157	159	156

If we compare the total amount of carbon of each profile with our reference (profile no. 154), we find a decrease of 31% (72 t C) in 30 years (Table 10).

The total amount of carbon is decreasing strongly in the first two years of cultivarion as can be seen in Fig. 2.

In the years between 2 and 18 years of cultivation, there is more gradual decrease, while after 18 years the amount of carbon is decreasing again with a higher rate !!!!

Fig.2 is based on the four selected profiles (154, 157, 159 and 156). However, if we add the total amount of carbon of profile 158 (10 years cultivation) and the total amount of carbon of profile 155 (25 years cultivation), the graph remains more or less than the same !!!!

Table 9 and Table 10 (page 16 and 19) show an absolute enrichment in different layers of profile 157 and profile 159. This "humus"illuviation is mainly found in the layer between 52.5 and 82.5 cm.

These absolute carbon enrichments in certain layers disappear after about 18 years, and this may be the reason for the stronger decrease of carbon after 18 years.

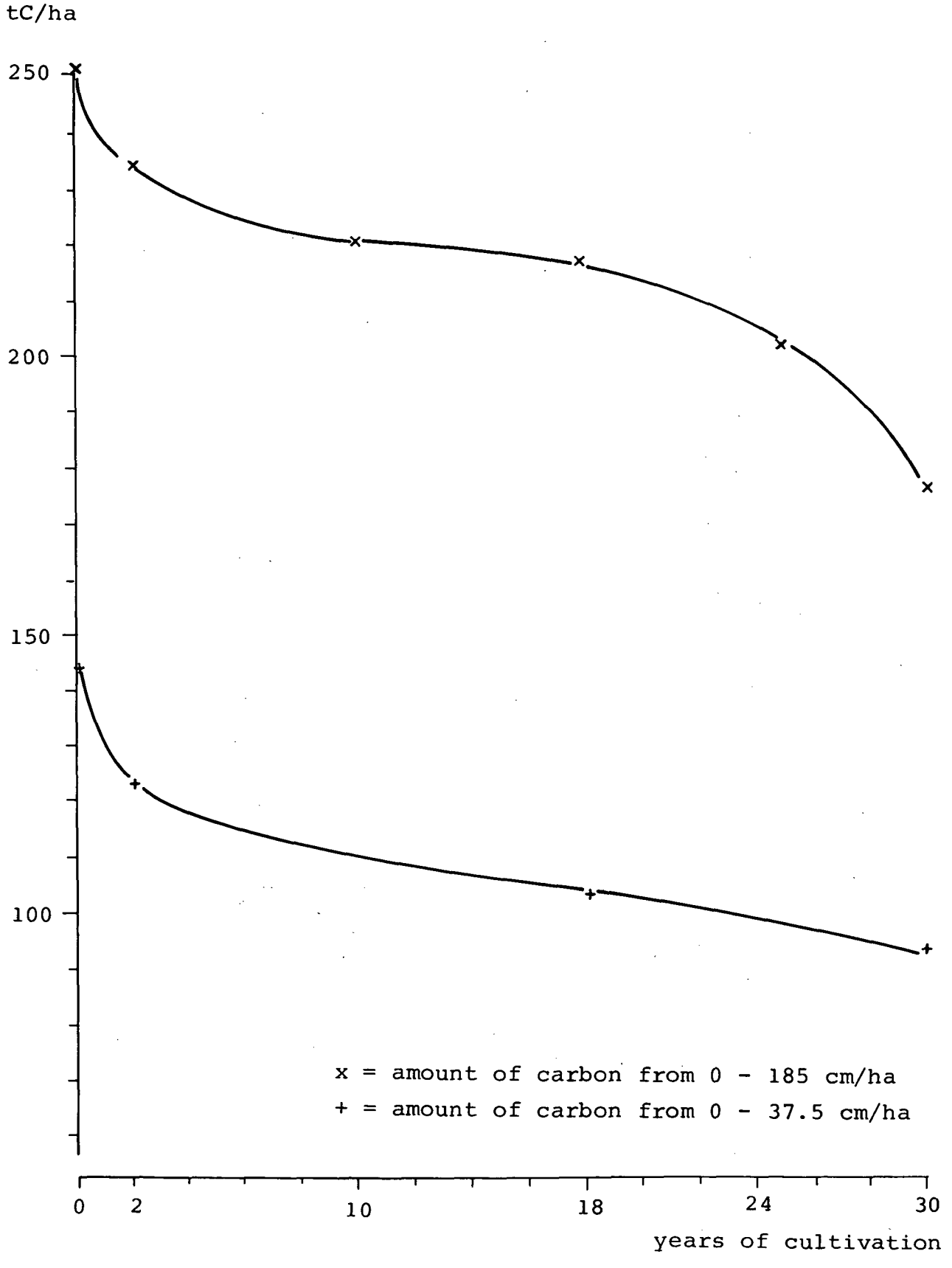


Fig. 2. Decrease of organic C during years of cultivation expressed in tons C per hectare.

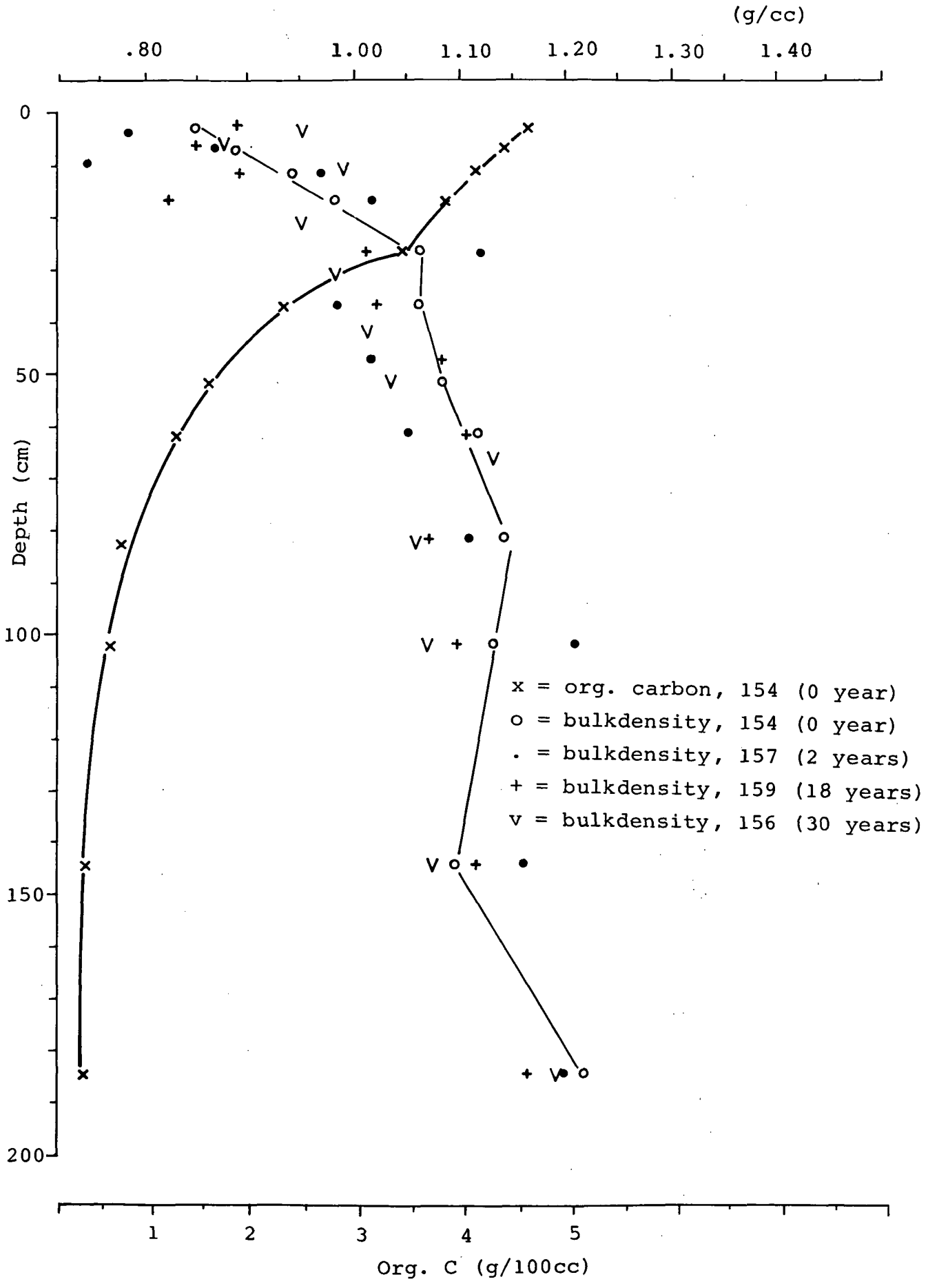


Fig. 3.

Carbon profile of soil profile 154 compared with bulkdensity for soil profile 154, 157, 159 and 156.

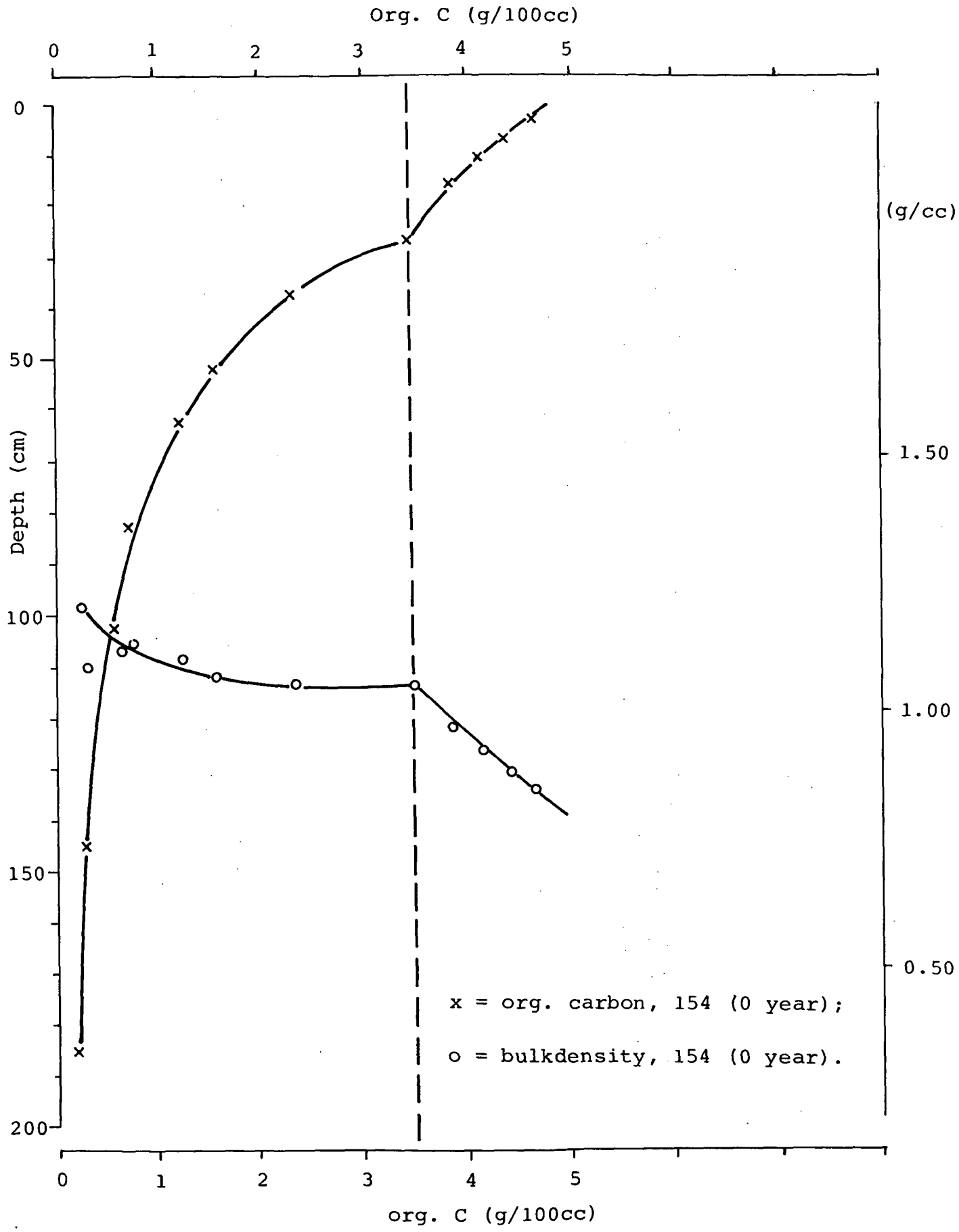


Fig. 4. Carbon profile of soil profile 154 compared with bulkdensity of soil profile 154.

Table 10 Relative carbon content per depth

Depth (cm)	154	157	159	156
0 - 27.5	100%	85%	69%	64%
27.5 - 37.5	100%	90%	79%	66%
37.5 - 52.5	100%	87%	97%	74%
52.5 - 62.5	100%	100%	121%	71%
62.5 - 82.5	100%	115%	115%	65%
82.5 - 102.5	100%	136%	100%	79%
102.5 - 145.0	100%	95%	90%	85%
145.0 - 185.0	100%	100%	118%	92%
total	100%	94%	86%	69%

Fig.2 shows the carbon profile and the bulkdensity of 154, 157, 159 and 156.

The relation between the amount of organic matter and the bulkdensity is clear: the effect of decreasing bulkdensity of soil with increasing organic carbon (Fig.4 and Fig.5).

Conclusions:

- The profile under natural grassland gives here a straight line on logaritmic paper with a breaking point at ± 30 cm.
- The carbon content of the top 40 cm of the profile is decreasing strongly in the first two years (10 t C/ha/yr: ± 1 t N/ha/yr).
- After about two or three years the amount of carbon in the top40 cm is decreasing regular with about 1.1 t C/ha/yr.
- After about 18 years of cultivation there is a more rapid decrease of the total amount of carbon in the profile.
- There is a humus illuviation after a few years of cultivation in the 50 - 80 cm layer.
- Below 140 cm there is hardly any change in the amount of carbon, even after 30 years of cultivation.
- The amount of biopores is increasing with cultivation, not only in the top 30 cm, but also between 100 and 150 cm (Appendix I).
- The bulkdensity of the different layers of the profiles becomes more and more irregular with increasing duration of cultivation.

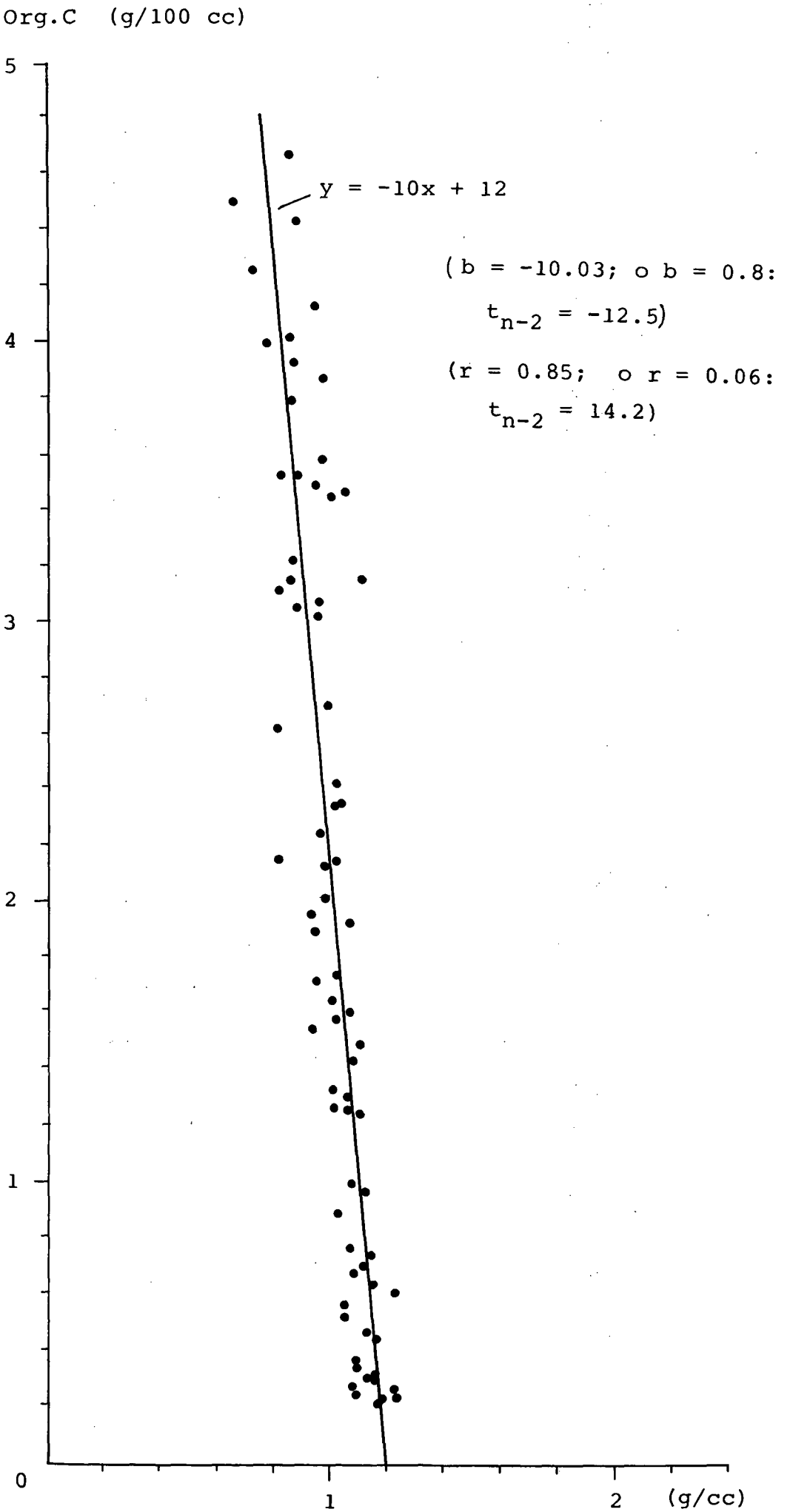


Fig. 5 Relation between Organic carbon contact and bulkdensity.

4.3. Relation between different crops and the carbon profile of the soil demonstrated on two profiles with bananas and maize.

Profile no 151 (bananas) and profile no 150 (maize).

The profiles 151 and 150 are situated in the north-western part of the Kisii District.

The main characteristics of these profiles is the amount of gravel (40 - 60%).

Despite of the different crop pattern, most factors have been kept more or less the same with regard to both profiles.

Until 1969 this area was covered with the original vegetation.

Since 1969, also these marginal areas were cultivated because of landscarcity.

Table 11, profile no.151.

Depth	moisture content	bulkdensity	% sm.th.0.6mm	% carbon (total)
1.5cm	18%	1.23	28%	1.84
5.0cm	27%	1.47	26%	2.00
10.5cm	16.5%	1.04	27%	1.41
19.0cm	17%	1.20	27%	1.58
26.5cm	14%	1.33	19%	0.89
35.5cm	15%	1.24	19%	0.57
45.5cm	12%	1.30	16%	0.33
60.5cm	11.5%	1.62	14%	0.23
80.5cm	9.5%	1.58	15%	0.20
100.5cm	14%	1.47	19%	0.20
140.5cm	13.5%	1.54	21%	0.12
180.5cm	16%	1.26	20%	0.11

In 1969 bananas and coffe have been planted on this plot.

On the plot of profile no.150, twice a year maize have been planted since 1969.

Table 12, Profile no.150.

Depth	moisture content	bulkdensity	% sm.th.0.6mm	% carbon (total)
1.5cm	21.0%	1.09	27%	1.48
5.5cm	18.5%	1.25	25%	1.48
10.5cm	18.0%	1.18	20%	1.02
15.5cm	16.5%	1.15	16%	0.51
23.5cm	17.0%	1.14	18%	0.37
30.5cm	16.5%	1.45	16%	0.49
40.5cm	17.5%	1.27	19%	0.33
60.5cm	15.5%	1.38	14%	0.13
80.5cm	17.0%	1.51	16%	0.12
100.5cm	18.0%	1.33	17%	0.08
140.5cm	16.5%	1.58	18%	0.07
180.5cm	16.5%	1.41	20%	0.05

Profile descriptions will be given in Appendix I.

4.3.1. Discussions and conclusions about relation different crops and carbon content for soil profiles no 151 and no 150.

The graphs of Fig.6 show the organic carbon profiles (151, 150) on logaritmic paper. The line or profile no.151 shows a relative maximum at about 20 cm, probably due to superficial ploughing. Profile no.150 shows a comparable maximum at about 30 cm. Here ploughing is done deeper and more regularly (at least twice a year).

In Table 13, the estimated organic carbon content (in tons/ha) will be given.

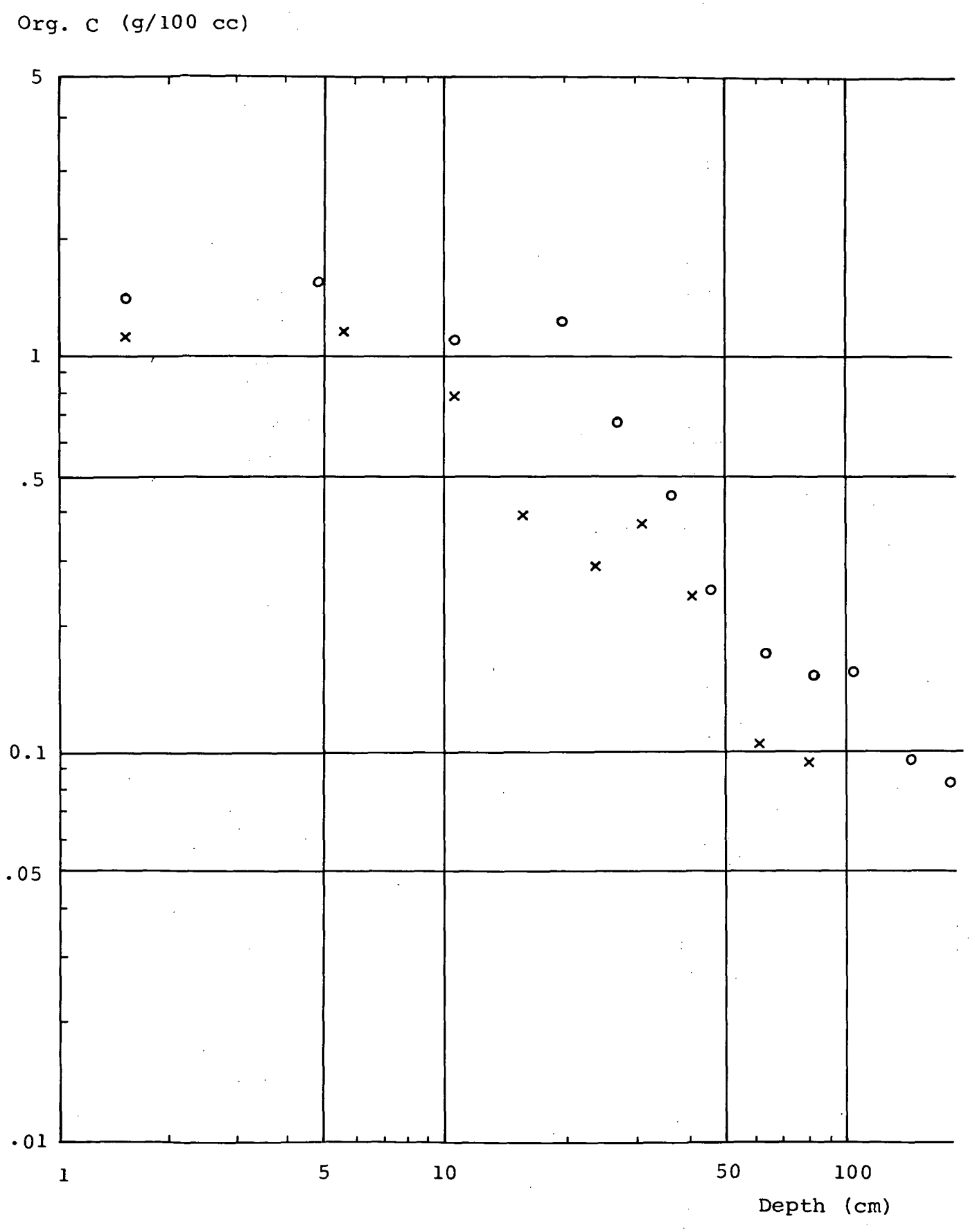
Table 13

Depth	Bananas (151)	Maize (150)
0 - 30.5 cm	44.1	24.5
30.5 - 40.5 cm	6.0	4.1
40.5 - 60.5 cm	6.8	4.6
60.5 - 80.5 cm	4.4	2.4
80.5 - 100.5 cm	4.0	2.0
100.5 - 140.5 cm	6.4	2.8
140.5 - 180.5 cm	4.4	2.4
total	76.1	42.8

These data show clearly the difference between a perennial crop and maize in monoculture.
If we compare both profiles, a total of 34 tons (44%) of organic carbon per hectare is lost in only four years time!
In the top 30 cm, 20 tons of organic carbon per hectare disappeared, which stands for about 2 tons of nitrogen.
In profile no. 151, we find patchy thin humus cutans between ± 28 and 160 cm. In profile no. 150 (maize), we find patchy thin humus cutans between ± 14 and 220 cm and deeper, which means a humus illuviation in the deeper layers.
The wet consistency in the layer between 160 and 200 cm is changing from friable (profile no.151; bananas) to firm (profile no. 150; maize) (Appendix II). In this layer the percentage smaller than 0.6 mm is in both profiles about 20%. However, the bulkdensity varies between 1.26 in 151 and 1.41 in 150.
Between 160 and 200 cm there is a more compact layer in profile 150. Probably due to the cultivation of maize.
Fig.7 shows both organic carbon profiles with their bulkdensities on graphic paper.

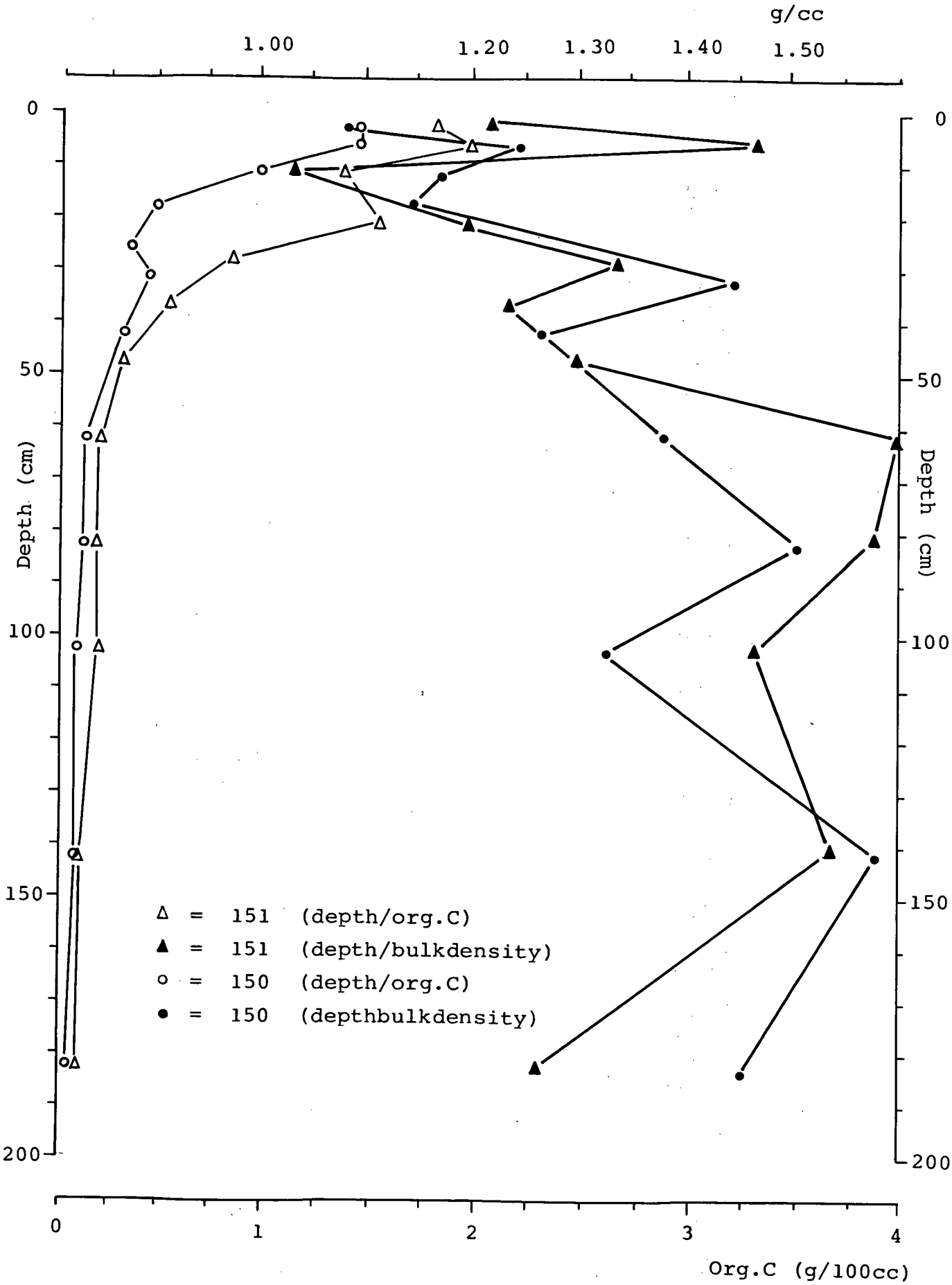
Conclusions:

- The difference between the carbon profile under bananas and the carbon profile under maize is clear. Especially in these marginal areas with very poor parent material, it is important to plant perennial crops or maize with intercropping, instead of a monoculture of maize.
- There is some humus illuviation in deeper layers.
- There is some compaction in the deeper layers of profile no.150, probably due to cultivation of maize.



o = profile 151, bananas;
x = profile 150, maizo.

Fig. 6 Organic Carbon profile of soil profile 151 and 150.



7 Organic Carbon profiles and bulkdensities of soil profiles 151 and 150.

4.4 Relation between different crops and the carbon profile of the soil demonstrated on two profiles with bananas and maize/finger millet. profile no.152 (bananas) and profile no. 153 (maize/finger millet.

The profiles no. 152 and no. 153 are situated not far from the profiles 151 and 150 in the north-western part of the Kisii District. The parent material of these 2 profiles is also Wanjare granite, but these profiles are not gravelly.

In 1959, bananas have been planted on the plot of profile no.152. In the same year the plot of profile no.153 was cultivated for the first time. The farmer rotated maize and finger millet, while maize was usually interplanted with legumes. After every three years of cultivation, there is a fallow period of usually three years.

Table 14, profile no.152 (bananas)

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon (total)
3.5 cm	27.5%	1.03	58%	2.07
7.5 cm	29.0%	0.92	62%	1.82
12.5 cm	27.5%	0.98	62%	1.69
17.5 cm	27.0%	1.08	67%	1.13
27.5 cm	27.5%	1.13	68%	0.94
32.5 cm	28.0%	1.16	67%	0.80
37.5 cm	30.0%	1.16	72%	0.64
52.5 cm	29.5%	1.10	68%	0.39
67.5 cm	28.5%	1.10	66%	0.35
82.5 cm	29.5%	1.17	74%	0.27
102.5 cm	25.5%	1.31	72%	0.29
145.0 cm	27.0%	1.21	69%	0.28
185.0 cm	25.0%	1.14	72%	0.21

Profile descriptions are given in the Appendix I.

Table 15, profile no. 153 (maize/finger millet)

Depth	moisture content	bulkdensity	% sm.th.0.6 mm	% carbon (tot.)
3.5 cm	25.5%	1.02	72%	1.65
8.5 cm	25.5%	1.01	70%	1.57
12.5 cm	24.5%	0.98	67%	1.44
17.5 cm	25.5%	0.98	65%	1.20
27.5 cm	26.0%	0.99	64%	1.05
38.5 cm	26.0%	1.09	63%	0.77
52.5 cm	26.5%	1.06	63%	0.67
67.5 cm	26.0%	1.15	63%	0.51
82.5 cm	25.0%	1.19	63%	0.40
102.5 cm	27.0%	0.99	62%	0.35
142.5 cm	27.5%	1.15	67%	0.23
182.5 cm	25.5%	1.18	67%	0.23

4.4.1 Discussion and conclusions for soil profiles no 152 and no 153

In Fig.8 the graphs show the organic carbon profiles on logaritmic paper. In the top 15 cm, the organic carbon content of profile no. 152 is higher than of profile no.153.
Deeper than 15 cm on the organic carbon content of profile no.153 is higher.
Table 16 gives the estimated organic carbon content in tons per hectare.

Table 16

Depth	Bananas	Maize/finger millet
0 - 27.5 cm	41.2	37.8
27.5 - 38.5 cm	8.6	10.0
38.5 - 52.5 cm	7.0	10.1
52.5 - 67.5 cm	5.6	8.8
67.5 - 82.5 cm	4.7	6.7
82.5 - 102.5 cm	5.6	7.5
102.5 - 145.0 cm	12.7	11.5
145.0 - 185.0 cm	9.6	9.2
total	96.0	101.6

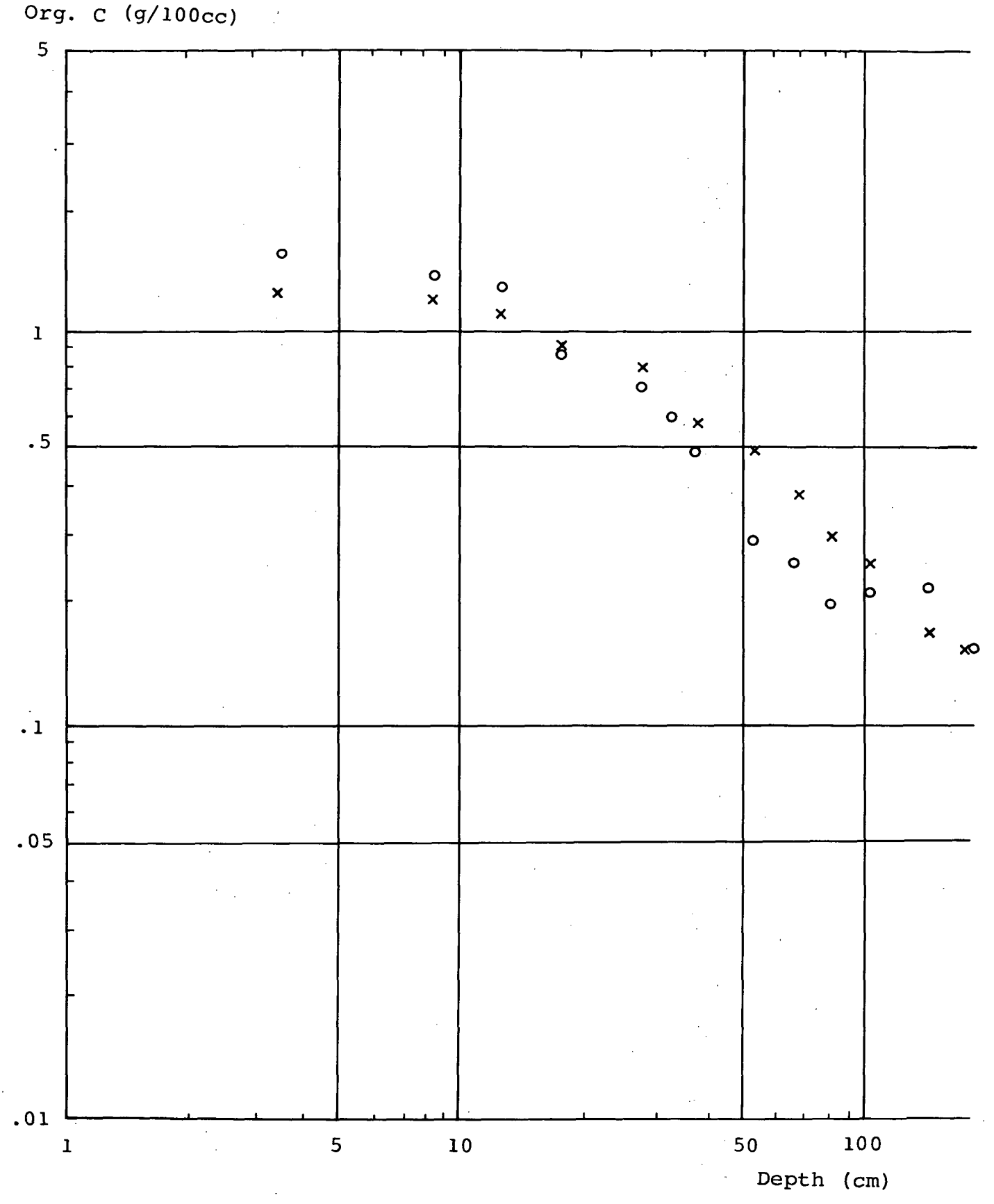


fig. 8 Organic Carbon profile of soil profile 152 and 153.

In the top 27.5 cm, there is a difference in organic carbon of about 4 tons/hectare in the advantage of the profile under bananas. However, the total amount of organic carbon is higher in the profile under maize/finger millet!
Fig.9 shows the two organic carbon profiles together with their bulkdensities on graphic paper.

Conclusions:

- With maize planted in an old rotation system, the total amount of organic carbon in the profile, is as high as in a profile under a perennial crop.
- The distribution of the organic carbon a profile under an annual crop differs somewhat from a profile under a perennial crop.

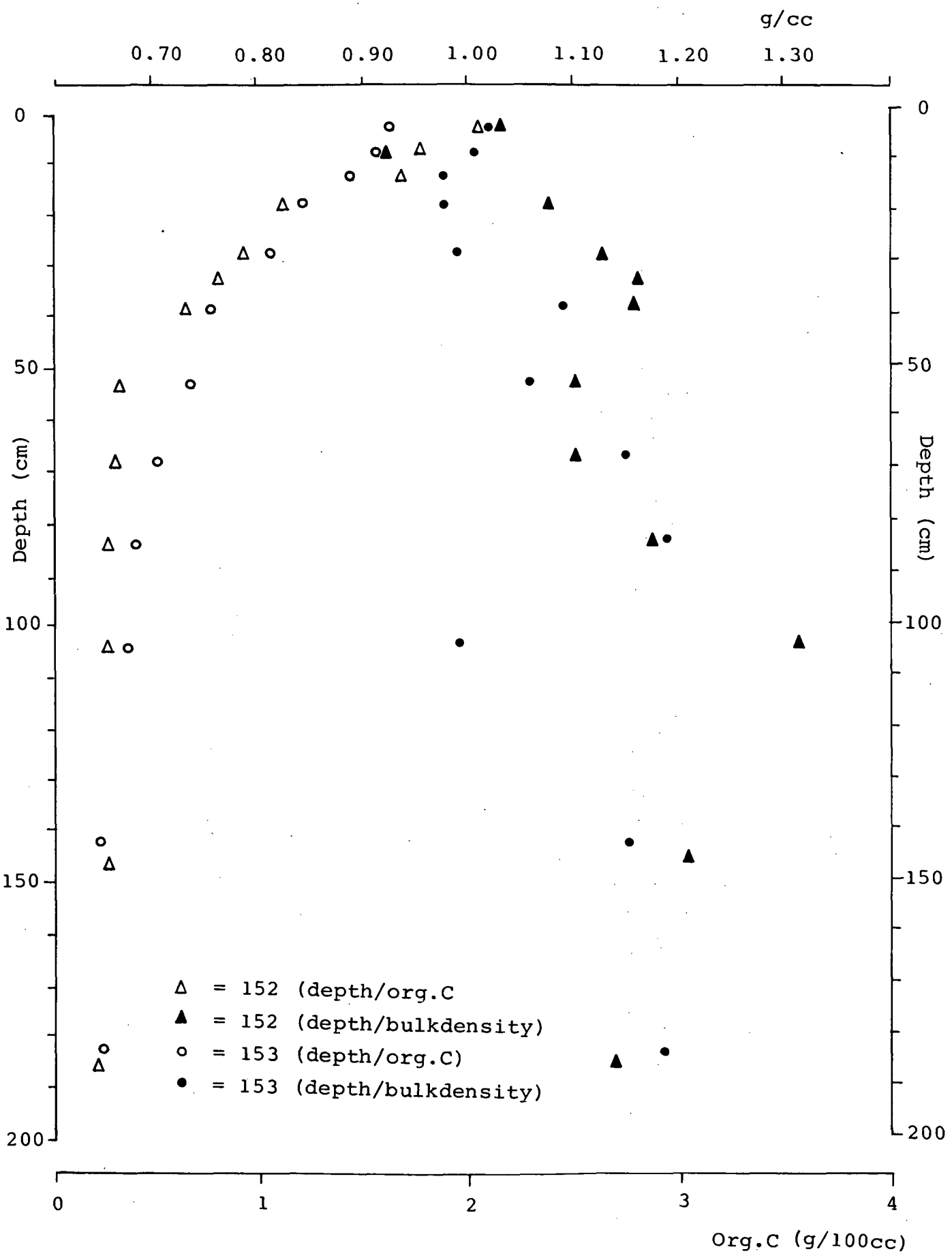


Fig. 9 Organic Carbon profiles and bulkdensities of soilprofiles 152 and 153.

5. Acknowledgements

I am deeply grateful to Ir. W.Wielemaker and Ing.W.Boxem for all the help and advice they have given to me during the period in which I did my organic carbon research in the Training Project in Pedology. I also wish to express my sincere gratitude for the excellent help and cooperation and the friendship that was extended to me by Mogire and Joel Kananga, Samuel, Charles, Peter and James all project assistants. I wish to thank Miss Hanneke Mostert for typing the original version of the report.

6. Literature

- Birch, H.F. and Friend, M.T., 1956.
  The organic matter and nitrogen status of East African soils.
  J.Soil Science 7, 156 - 167.
- Hardy, F., 1944.
  Trop.Agric.Trin., vol. 21, p.203.
- Jagnow, G., 1967.
  Der Humushaushalt tropischer Boden und seine Beeinflussung durch Klima, Bodennutzung, Trocknung und Erhitzung.
  Justus Liebig Universitat, Giessen
- Jenny, H., 1941.
  Factors of soil formation.
  MacGraw-Hill Comp., New York a. London, 2
- Laudelout, H. et Hoore, J.D., 1949.
  Influence du milieu sur les matières humiques
  I.N.E.A.C., Yangambi.
- Laudelout, H., 1966.
  Dynamics of tropical soils in relation to their fallowing techniques.
  F.A.O., Rome
- Nye, P.H. and Greenland, D.J., 1960.
  The soil under shifting cultivation.
  Technical communication no.51, Harpenden.

Appendix I.

Soil profile descriptions

Profile no. 154 : 0 year cultivation

Classification : Soil Taxonomy 1970 - PachicHumoxic Palehumult
Location : Bomachoge, between Magenche and Nyabitunwa
Coordinates : 9894.60 N, 695.30 E.
Elevation : --
Described by : Van Wissen on 10-4-1974
Geomorphology : slightly convex upper slope
Parent Material : non-porphyritic basalt
Relief and slope: normal, sloping (class 3)
Stoniness : no stones
Drainage : well drained
Biology : depth of undisturbed soil more than 90 cm.
Root development: very many roots in top 30 cm (more than 90%)
Landuse : natural grassland

Soil profile:

A 0 9 cm: Dusky red (2.5 YR 3/2) moist; very fine clay; weak very fine crumbs and weak very fine subangular blocky; many very fine and common fine biopores; very hard, firm, non-sticky and non or slightly plastic; clear and smooth boundary;

B21 9- 30cm: Dark reddish brown (2.5 YR 3/3) moisty; very fine clay moderate very fine to fine subangular blocky; many very fine and few fine biopores very hard, friable, non-sticky and non- or slightly plastic; broken to continuous, moderately thick clay cutans; plastered channels, Ø 1 - 1½ cm, 1 - 2/m^2; plastered holes, Ø 2-5 cm, sometimes filled up with dark A or red material; clear and wavy boundary;

B21 30-150 cm: Dark red (2.5 YR 3/5) moist; very fine clay; moderate very fine to fine angular blocky; many very fine biopores (diminishing with depth); hard, very friable, slightly sticky and slightly plastic; broken to continuous, moderately thick clay cutans; gradual and smooth boundary;

B22 150-220 cm: Dark red (2.5 YR 3/7) moist; very fine clay; moderate to strong angular blocky (fine), fine and very fine biopores, hard, slightly sticky and slightly plastic; broken to continuous, thick clay cutans; very few to few prominent mottles (2.5 YR 2/1) black.

Profile no. 157 : 2 years cultivation
Classification : Soil Taxonomy 1970 - Pachic Humoxio Palehumult
Location : Bomachoge, 2 km east of Mokomoni
Coordinates : 9894.50 m - 693.90 E
Elevation : --
Described by : van Wissen, on 11-4-1974
Geomorphology : hill slope
Parent material : non-porphyritic basalt
Relief and slope: regular slope, convex, ± 400m, 6%
Stoniness : class 0 (no stones)
Drainage : well drained
Biology :
Root distribution: many roots in top 20 cm
Land use : maize (third crop); one crop per year

Soil profile:

Ap 0 - 25 cm : Duskey red (2.5 YR 3/2) moist; very fine clay; weak very fine crumbs and very fine subangular blocky; many very fine and common fine biopores; friable slightly sticky and slightly plastic; clear and wavy boundary;

B21 25 - 85 cm : Dark reddish brown (2.5 YR 3/4) moist; very fine clay; moderate subangular blocky, fine to very fine; firm slightly sticky and slightly plastic; patchy thin humus cutans, broken to continuous thick clay cutans; common very fine and few fine biopores; gradual and smooth boundary;

B22 85-145 cm: Dark red (2.5 YR 3/5), moist ; very fine clay, moderate to strong fine angular blocky; very firm, slightly sticky and slightly plastic; broken to continuous thick clay cutans; few very fine and fine biopores; gradual and smooth boundary;

B23 145-220 cm: Dark red (2.5 YR 3/7) moist; very fine clay; moderate to strong fine angular blicky; very firm, slightly sticky and slightly plastic; broken to continuous thick clay cutans; few fine and very fine biopores; black (2.5 YR 2/1) mottles, few;

Profile no. 158 : 10 years cultivation

Classification : Soil Taxonomy 1970 - Pachic Humoxic Palehumult
Location : Bomachoge, 2km south-east of Mokomoni,
Coordinates : 9893.60 N - 692.90 E
Elevation : --
Described by : van Wissen, 11-4-1974
Geomorphology : hill slope
Parent material : non-porfyritic basalt
Relief and slope : irregular slope, convex, 800m, 12%
Stoniness : class 0 no stones
Drainage : well drained
Root distribution : mainly in top 20 cm
Land use : maize from 1964, no crop in 1972 and 1973

Soil profile:

Ap 0 - 20 cm : Dusky red (2.5 Yr 3/2) moist, very fine clay; weak very fine crumbs and very fine subangular blocky, many very fine and common fine biopores friable, slightly sticky and slightly plastic; clear and wavy boundary;

B21 21 - 78 cm : Dark reddish brown (2.5 YR 3/4) moist ; very fine clay; fine to very moderate subangular blocky; firm, slightly sticky and slightly plastic; patchy thin humus cutans, broken thick clay cutans; common very fine, few fine and few medium biopores clear and wavy boundary;

B22 78 - 150 cm : Dark red (2.5 YR 3/6) moist; very fine clay; strong fine angular blocky; very firm slightly sticky and slightly plastic; patchy thin humus cutans, broken to continuous thick clay cutans; few very fine, fine and medium biopores; gradual and smooth boundary;

B23 130 - 158 cm : Dark red (2.5 YR 3/7) moist; very fine clay; continuous thick clay cutans; strong fine angular blocky; few very fine, fine and medium biopores; gradual and smooth boundary;

B24 158 - 220 cm : Dark red (2.5 YR 3/8) moist; very fine clay; strong fine angular blacky; continuous thick clay cutans; few fine and fine biopores; few to common, prominent, black (2.5 YR 2/1) mottles.

Profile no. 159 : 18 years cultivation

Classification : Soil Taxonomy - Pachic Humoxic Palehumult
Location : Bomachoge, 2 km south-east of Mokomoni
Coordination : 9893.65 N - 692.85 E
Elevation : --
Described by : van Wissen, on 12-4-1974
Geomorphology : hill slope
Parent material : non-porfyritic basalt
Relief and slope : regular slope, convex 200 m, 10%
Stoniness : class 0 (no stones)
Drainage : well drained
Root development : mainly in top 20 cm
Land use : 18 years maize/wimbi, cow dung

Soil profile:

Ap 0 - 25 cm : Dusky red (2.5 YR 3/2) moist; very fine clay weak very fine crambs and very fine subangular blocky; many very fine and fine, common medium biopores; friable slightly sticky and slightly plastic; clear and wavy bounday;

B21 25 - 65 cm : Dark reddish brown (2.5 YR 3/4) moist; very fine clay; moderate very fine subangular blocky; firm, slightly sticky and slightly plastic; patchy thin humus cutans; broken thick clay cutans; many very fine, few and medium biopores; gradual and smooth boundary;

B22 65 - 100 cm : Dark red (2.5 YR 3/6) moist, very fine clay; moderate, very fine to fine angular blocky; broken to continuous thick clay cutans; firm, slightly sticky and slightly plastic; common very fine, and fine, few medium biopores; gradual and smooth boundary;

B23 100 - 138 cm : Dark red (2.5 YR 3/7) moist, very fine clay; moderate to strong, fine to very fine angular blocky; continuous thick clay cutans; firm, slightly sticky and slightly plastic; gradual and smooth boundary; common very fine and fine, few medium biopores;

B24 138 - 190 cm : Dark red (2.5 YR 3/8) moist; very fine clay; strong, fine angular blocky; continuous thick clay cutans; very firm slightly sticky and slightly plastic, few very fine, fine and medium biopores; common, prominent very fine to fine, black (2.5 YR 3/1) mottles;

Profile no. 155 : 25 years under cultivation)

Classification : Soil Taxonomy, Pachic Humoxic Palehumult
Location : Bomachogo, 3 km north-east of Magenche
Coordinates : 9895.90N, 693.20 E
Elevation : --
Described by : van Wissen, on 10-4-1974
Geomorphology : hill slope
Parent material : non-porfyritic basalt
Relief and slope : regular slope, convex, 350 m, 10%
Stoniness : class 0 (no stones)
Drainage : well drained
Root distribution : mainly in top 18 cm
Land use : 25 years maize/wimbi

Soil profile:

Ap 0 - 18 cm : Dusky red (2.5 YR 3/2) moist; very fine clay, weak very fine crumbs and very fine subangular blocky; friable, slightly sticky and slightly plastic; many very fine and fine, common medium biopores; gradual and smooth boundary;

B21 18 - 63 cm : Dark reddish brown (2.5 YR 3/4), moist; very fine clay; moderate very fine subangular to angular blocky; broken thick humus cutans; broken thick clay cutans; friable, slightly sticky and slightly plastic; many very fine, common fine and few medium biopores; gradual and smooth boundary;

B22 63 - 90 cm : Dark red (2.5 YR 3/5), moist; very fine clay; moderate to strong, fine to very fine angular blocky; patchy thin humus cutans; broken to continuous thick clay cutans; friable, slightly sticky and slightly plastic; common fine and very fine, few medium; gradual and smooth boundary;

B23 90 - 160 cm : Dark red (2.5 YR 3/7) moist; very fine clay; moderate to strong fine angular blocky; continuous thick clay cutans; friable to firm, slightly sticky and slightly plastic; common very fine, few fine and medium biopores; diffuse and smooth boundary;

B24 160 - 230 cm : Dark red (2.5 YR 3/8), moist; very fine clay; strong fine angular blocky; continuous thick clay cutans; very firm, slightly sticky and slightly plastic; few fine, very fine and medium biopores; common prominent, very fine to fine, black (2.5 YR 3/1 mottles;

Profile no. 156 : 30 years under cultivation
Classification : Soil Taxonomy, Pachic Humoxic Palehumult
Location : Bomachoge, 2.5 km east of Magenche,
Coordinates : 9894.80 N, 694.50 E
Described by : van Wissen, on 10-4-1974
Geomorphology : hill slope
Parent material : non-porfyritic basalt
Relief and slope : regular slope, convex, 300 m, 10%
Stoniness : class 0 (no stones)
Drainage : well drained
Root distribution : mainly in top 18 cm
Land use : 30 years maize/wimbi

Soil profile:

Ap 0 - 18 cm : Dusky red (2.5 YR 3/2), moist, very fine clay, weak very fine crumbs and very fine subangular blocky; friable, slightly sticky and slightly plastic; patchy thin humus cutans; many very fine, common fine and medium; clear and wavy boundary;

B21 18 - 45 cm : Dark reddish brown (2.5 YR 3/3), moist; very fine clay moderate very fine subangular blocky; broken mod. thick humus cutans, broken mod. thick clay cutans; friable to firm, slightly sticky and slightly plastic common very fine, fine and medium biopores; gradual and smooth boundary;

B22 45 - 78 cm : Dark reddish brown (2.5 YR 3/4), moist very fine clay; moderate fine to very fine angular blocky; patchy thin humus cutans, broken to continuous clay cutans; firm, slightly sticky and slightly plastic, common very fine and fine; few medium biopores; gradual and smooth boundary;

B23 78 - 165 cm : Dark red (2.5 YR 3/6), moist; very fine clay; moderate to strong, very fine to fine angular blocky, continuous thick clay cutans; very firm, slightly sticky and slightly plastic; common very fine and fine, few medium biopores; gradual and smooth boundary.

B24 165 - 200 cm : Dark red (2.5 YR 3/8) moist; very fine clay; strong fine angular blocky; continuous thick clay cutans; very firm, slightly sticky and slightly plastic; few very fine, fine and medium biopores common prominent, very fine to fine, black (2.5 YR 3/1)mottles.

Profile no.151	: bananas
Classification	: Soil Taxonomy 1970: fine clayey skeletal kaolinitic acid isothermic Typic Rhodudult
Location	: Wanjare area, Kebuye Range, Irigonga sublocation,
Coordinates	: 9929.32 N, 688,50 E
Described by	: van Wissen, date 5-4-1974
Geomorphology	: hill slope
Relief and slope	: regular slope, convex, 100 m 8%
Parent material	: weathered material of Wanjare granite
Stoniness	: class 1 (interferes with tillage)
Drainage	: well drained, watertable deeper than 220 cm
Moistness	: surface soil moist, subsoil moist
Root distribution	: common roots in top 25 cm
Land use	: bananas and coffee (bad stand), planted in 1969

Soil profile:

Ap 0 - 28 cm : Dark reddish brown (5 YR 3/2), moist; clay, very fine crumbs and weak very fine subangular blocky; very friable, slightly sticky and slightly plastic; common medium, many fine and very fine biopores; ± 30% gravel; clear and wavy boundary;

B21 28 - 56 cm : Dark reddish brown (5 YR 3/3) moist; clay; weak very fine subangular blocky; patchy thin humus cutans; very friable slightly sticky and slightly plastic, few medium common fine and very fine biopores; ± 40% gravel; gradual and smooth boundary;

B22 56 - 80 cm : Dark reddish brown (2.5 YR 3/4) moist; clay; moderate very fine to fine angular blocky; patchy thin humus cutans, broken moderately thick clay cutans; firm, slightly thick clay cutans; firm, slightly sticky and slightly plastic; few medium, and common fine and very fine biopores; ± 45% gravel; gradual and smooth boundary;

B23 80 - 160 cm : Dark red (2.5 YR 3/6) moist; clay; moderate very fine to fine angular blocky; patchy thin humus cutans, broken to continuous moderately thick clay cutans, firm, slightly sticky and slightly plastic; few medium and very fine, and common fine biopores; ± 50% gravel; diffuse and smooth boundary;.

B24 160 - 210 cm : Dark red (2.5 YR 3/8) moist, clay; many small reddish yellow (5 YR 6/8) diffuse mottles; moderate very fine to fine angular blocky; broken to continuous moderately thick clay cutans; friable; slightly sticky and slightly plastic; few medium and very fine, and common fine biopores ≐ 50% gravel;

Profile no. 150 : maize

Classification : Soil Taxonomy 1970, fine clayer skeletal kaolinitic acid isothermic typic thodudult

Location : Wanjare area, Kebuye Range, Irigonga sublocation,

Coordinates : 9929.32 N, 688,50 E

Described by : van Wissen, on 4-4-1974

Geomorphology : hill slope

Relief and slope : regular upper slope, convex, 100 m, 10%

Parent material : weathered material of Wanjare granite

Stoniness : class 1 (interferes with tillage)

Drainage : wel drained, watertable deeper than 220 cm

Root distriburion : few roots only in top 14 cm

Land use : maize (from 1969) 2 times a year

Soil profile:

A1 0 - 14 cm : Dark reddish brown (5 YR 3/2) moist; clay; very weak very fine subangular blocky; very friable, slightly sticky and slightly plastic; many fine and very fine, common medium biopores; ± 35% gravel; clear and wavy boundary;

A3 14 - 46 cm : Dark reddish brown (5 YR 3/3) moist; clay; weak very fine subangular blocky; patchy mod.thick humus cutans; friable, slightly sticky and slightly plastic; common fine and very fine, few medium biopores; ± 40% gravel; abrupt and wavy boundary;

B21 46 - 120 cm: Dark red (2.5 YR 3/8) moist; clay; moderate to strong very fine and fine angular blocky; patchy thin humus cutans, broken to continuous moderately thick clay cutans firm, slightly sticky and slightly plastic; common very fine, few fine and medium biopores; ± 50% gravel; gradual and smooth boundary;

B22 120 - 148 cm: Dark red (2.5 YR 3/7) moist; clay; moderate to strong, very fine to fine angular blocky; patchy thin humus cutans broeken to continuous, mod. thick clay cutans; firm, slightly sticky and slightly plastic; common very fine and fine, few medium pores; ± 50% gravel; gradual and smooth boundary;

B23 148 - 200 cm: Red (2.5 YR 4/8) moist; clay; many small 5 YR 6/8) diffuse mottles; moderate fine to very fine angular blocky; patchy thin humus cutans, broken to continuous moderately thick clay cutans; firm, slightly sticky and slightly plastic; few very fine, fine and medium biopores; ± 50% gravel.

Profile no. 152 : bananas

Classification : Humoxic Palehumult

Location : Wanjare area, Matongo sublocation,

Coordination : 9928.45 N, 690.60 E

Described by	: van Wissen, on 6-4-1974
Geomorphology	: hill slope
Relief and slope	: regular slope, convex, 500 m, 10%
Parent material	: weathered material of Wanjare granite
Stoniness	: class 0 (no stone)
Drainage	: well drained, watertable deeper than 220 cm
Root distribution	: very many roots in top 15 cm
Land use	: bananas

Soil profile:

Ap 0 - 15 cm : Dark reddish brown (5 YR 3/4) moist; fine clay; very fine crumbs and weak very fine subangular blocky; very friable; slightly sticky and slightly plastic; common medium, very fine and fine biopores; clear and wavy boundary;

B21 15 - 42 cm : Dark reddish brown (2.5 YR 3/4) moist; fine clay, moderate very fine angular blocky; patchy thin humus cutans; broken moderately thick clay cutans; friable, slightly sticky and slightly plastic; common very fine, fine and medium biopores; gradual and smooth boundary;

B22 42 - 94 cm : Dark reddish brown (2.5 YR 3/5) moist; fine clay, moderate to strong, very fine to fine angular blocky; patchy thin humus cutans, broken to contunuous thick clay cutans; firm, slightly sticky and slightly plastic; common very fine and fine, few medium biopores; diffuse and smooth boundary;

B23 94 - 145 cm : Dark red (2.5 YR 3/6) moist; fine clay; strong fine angular blocky; broken to continuous thick clay cutans; very firm, slightly sticky and slightly plastic; few very fine and medium, common fine biopores; gradual and smooth boundary;

B24 145 - 210 cm : Dark red (2.5 YR 3/7) moist; fine clay; moderate very fine to fine angular blocky; broken moderately thick clay cutans;friable, slightly sticky and slightly plastic; few very fine and medium, common fine biopores;.

Profile no.153 : maize
Classification : Soil Taxonomy Humoxic Palehumult
Location : Wanjare area, Matongo sublocation,
Coordinates : 9928.45 N, 690.60 E
Described by : van Wissen, date 6-4-1974
Geomorphology : hill slope
Relief and slope : regular slope, convex, 500 m, 12%
Parent material : weathered material of Wanjare granite
Stoniness : class 0 (no stones)
Drainage : well drained, watertable deeper than 220 cm
Distribution of roots: ploughed
Land use : maize/wimbi rotation, maize interplanted with legumes

Soil profile:

Ap 0 - 223 cm : Dark reddish brown (5 YR 3/4) moist; fine clay; very fine crumbs and weak very fine subangular blocky; patchy thin humus cutans; very friable, slightly sticky and slightly plastic; common very fine and fine, few medium biopores; gradual and smooth boundary;

B21 23 - 58 cm : Dark reddish brown (5 YR 3/5) moist; fine clay; weak very fine subangular blocky; patchy thin humus cutans, patchy thin clay cutans; friable slightly sticky and slightly plastic; few very fine and medium, common fine biopores; gradual and smooth boundery;

B22 58 - 160 cm : Dark red (2.5 YR 3/6) moist, fine clay; moderate very fine to fine angular blocky; broken moderately thick clay cutans; firm, slightly stick and slightly plastic; few very fine and medium, common fine biopores; gradual and smooth boundary;

B23 160 - 210 cm : Dark red (2.5 YR 3/7) moist; fine clay; strong fine angular blocky; broken to continuous thick clay cutans; very firm, slightly sticky and slightly plastic; few very fine, fine and medium biopores.