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DETERIORATION OF PROPERTIES OF SOME ZAMBIAN SOILS WITH CULTIVATION

by

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RESUME

Des recherches ont été menées sur des sols du type "sandveld" tant dans les champs que dans les zones non cultivées voisines afin de déceler les effets des cultures continues de maïs sur les caractéristiques du sol. La vitessse d'infiltration, la densité apparente, la porosité totale, l'humidité au pF de 2,5 et l'eau utile ont été mesurés dans l'horizon supérieur. La différence entre les zones cultivées et non cultivées est très significative pour les trois premiers caractères ($P < 0{,}01$) et significative pour les deux derniers ($P < 0{,}1$). La densité apparente diminue et, par conséquent, la porosité augmente vers le bas dans presque tous les profils étudiés.

Une mesure de la teneur en matières organiques, en azote total, en ions Ca et Mg échangeables ainsi que du pH a aussi été faite dans l'horizon superficiel. Les différences entre champs et zones non cultivées sont aussi très significatives ($P < 0{,}01$). Par contre, aucune différence significative n'a été trouvée pour la capactié d'échange totale, le phosphore, le potassium, la densité des particules et l'humidité au point de flétrissement.

Il a été enregistré une diminution de 40 à 50 °/o dans les rendements par rapport aux deux ou trois premières années de mise en culture, environ quinze ans plus tôt. Cette diminution s'est produite malgré d'excellentes façons de culture et l'apport d'engrais ; elle est attribuée à une détérioration des propriétés chimiques et physiques du sol.

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IMPORTANCE AND REVIEW OF LITERATURE

The importance of soil properties to its productivity and indeed to the survival of the systems of agriculture receives evergrowing recognition. It is a common knowledge that crop yields fall in the successive seasons particularly in tropics and subtropics, but the rate of the decline varies greatly depending on several factors (C.C. WEBSTER and P.N. WILSON, 1973 ; M.P. AHN, 1970). The soil factors contributing to this decline are themselves complex and include in varying degrees, a loss of physical properties, a lowering of the nutrients status, changes in the microbial population, physical erosion and removal of the topsoil. Nevertheless, the decline in the soil physical properties is usually the most important cause especially in the permanent monoculture of the cereals such as maize (F. ARNOLD, 1971).

When old grassland is ploughed and cultivated, the physical conditions of the soil are usually found to be near the optimum for crop growth. As soon as the soil is cultivated, these desirable properties begin to depreciate, although the rate varies with the system of management, climatic conditions and soil type (P.H. NYE and D.J. GREENLAND, 1960 ; G. WRIGLEY, 1969). PEREIRA et al. (1954) found that in a red clay the favourable constitution developed by a three-year rest under grass was largely lost after a year of cropping. Similarly, the rate at which a virgin grassland loses its desirable properties was described by R. BRADFIELD (1937) and N.J. ROSENBERG (1964). The harmful effects of cultivation tend to accumulate from year to year if the exhausive crops are grown continuously. Aggregate destruction can occur quickly where as aggregate formation is usually a slow process with many factors involved. The physical conditions of the soil surface control the amount of water entering the soil (J.F. PARR and A.R. BERTRAND, 1960 ; N.P. REMEZOV and P.S. POGREBNYAK, 1969 ; H.C. PEREIRA, 1955). Traditional mechanical tillage practices used to prepare seedbeds and other operations during the growth periods mostly create soil physical conditions that restrict water infiltration (R.E. BURWELL et al., 1968). Immediately after the stirring of the dispersed soil, the uptake of water may be rapid, but due the unstable aggegates the surface is sealed by the released of the silt and clay particles. BOUMA et al. (1975) very recently reported that the capacity of the two cultivated soils to transmit water was reduced as compared with the virgin soils.

In voluminous literature (T.B. SHAW, 1952 ; N.J. ROSENBERG, 1964 ; A.C. TROUSE, 1971), it has been pointed out that the productivity of the compacted soils is affected by the increased mechanical impedance, reduced aeration, altered moisture availability and heat flux which follow from increased soil density and reduced pore space caused by the soil structure deterioration. At any one time, one or more of these factors may become critical for the growth of the plants.

This paper describes changes in both physical and chemical properties of soils cultivated for several years under maize monoculture and adjacent virgin soils. Brief mention will also be made of the reduction in yield after such years of cultivation.

GENERAL FEATURES OF THE AREA AND SOILS

The studies were conducted at Zamic (Zamanglo-American Industrial Corporation), Agricultural Division, Chisamba Farms. The area is 40 km North-East of Lusaka, at approximately latitude 15°.05' E and longitude 28°.30' S. The elevation is 1158 m above mean sea level. The mean annual rainfall is 837 mm. More than 90 per cent of the total rain falls is the period November to March and 75 per cent in the three wettest months, December to February. The absolute maximum temperature is 37.7° C in October – November and absolute minimum 3.9° C in June and July.

The soils are entirely of sandveld type and classified as Ntendere sandy loam and Choma sand. They are designated as Mapping Units (M.U.) 1 and 2, respectively. The soils are deep and yellowish red to strong brown, 5-7.5 YR 5/6 colour. A layer of gravel overlying lateritic concretion and weathered rock is encountered at variable depths, usually below 120 cm in both the cases. The two soils differ in their textural profiles. In M.U.1, sandy loam (SL) topsoil overlies sandy clay loam (SCL) upper subsoil and SCL and sometimes sandy clay (SC) lower subsoil. It is classified as Class I soil. In M.U.2, loam (L) or SL topsoil overlies sandy clay loam (SCL) upper subsoil and SCL lower subsoil. It is classified as Class II soil. The M.U. 1d and M.U. 2d are the shallow phases of the main units, respectively. The gravel often lies between 30 – 60 cm in M.U. 1d and between 20 – 50 in M.U. 2d. Apart from these, both the subunits are identical to their main units. The studies were conducted in the soils of these selected mapping units because they are the more important in terms of agricultural potential in the area. Pits 1, 2 and 3 were those in the cultivated area. Pits 9, 10, 11 and 12 were in the adjacent virgin soils. The soils around Pits 1,2 and 3 have been used continuously for maize monoculture for the last 15 years with adequate fertilization of NPKS. Annually, 250 kg/ha of D-mixture (10 N, 20 P_2O_5, 10 K_2O, 10 S) used as a basal dressing and 300 kg/ha of urea during the early growth of the crop.

The differences between all the cultivated and virgin soils for clay and USDA silt contents in 0 – 13 cm layer were non-significant (Table 2).

PHYSICAL MEASUREMENTS AND ANALYTICAL METHODS

1. Water infiltration rates and soil sampling

The water infiltration studies were conducted in the field in April, 1974, following the technique given by HAISE et al. (1956). Five infiltrometers about 10 meters apart were installed randomly in 10 meters radius around each Pit. Accumulated water infiltration rates for first, second and third hours were recorded in cm/hour.

Enough soil samples were taken from each infiltrometer site (0 - 13 cm) and from Pits Nos 1, 2, 3, 9, 10, 11 and 12. Pit depth varied according to the depth at which gravel and weathered rock occurred in the profile. Core soil samples were taken and used for bulk density determination. For laboratory analysis, the samples were air-dried and passed through a 2-mm sieve.

2. Bulk density (B.D.)

Core-soil sampler having an inside ring : diameter 4 cm and length 13 cm was used to collect the undisturbed soil samples in the field from each Pit and adjacent to each infiltrometer site. Sampling was achieved by driving the core into the soil either vertically (in case of topsoil samples) or horizontally (in case of subsoil samples - within the Pits). The mass was determined after drying the soil to a constant weight at 105° C.

3. Particle density (P.D.)

It was done in the laboratory by the pycnometer method using about 25 g of soil.

4. Total porosity (T.P.)

It was calculated using the following relationship :

$$\text{T.P.} = \frac{(\text{P.D.} - \text{B.D.})}{\text{P.D.}} \times 100$$

5. Soil moisture retentions at 1/3 and 15 bar pressures (1/3.M. and 15.M.) and available moisture (A.M.)

The soil samples were saturated with water on porous ceramic plates before extraction at 1/3 and 15 bars in the ceramic plate extractors supplied by the Soilmoisture Equipment, Santa Barbara, California, U.S.A. The difference in the two moisture contents was calculated and called as available moisture.

6. Texture

Fifteen ml of sodium hexametaphosphate (44 g/l) and sodium carbonate (8 g/l) solution was used as a dispersing agent. Clay and silt were determined by the hydrometer method given by C.S. PIPER (1950). International and USDA sand classes were determined by dry sieving. USDA silt was calculated as 100 - (clay + USDA sand). In the paper only clay and USDA silt are given.

7. Stability of soil aggregates

It is the percentage aggregation of the soil particles less than 20 microns and determined by the procedure given by L.A. RICHARDS (1954).

8. Organic carbon (O.C.), total nitrogen (T.N.) and phosphorous (P)

By Walkley-Black, modified Kjeldahl and Bray and Kurtz-No. 1 solution, methods, respectively as described by M.L. JACKSON (1958).

9. Exchangeable cations and exchange capacity (CEC)

The exchangeable cations, were determined in the ammonium acetate (1 N) extract of soil at pH 7. Calcium (Ca) and magnesium (Mg) were determined by atomic absorption-meter and potassium (K) and sodium (Na) by flame photometer. Excess ammonium acetate from the above soil was removed by washings with alcohol. Ammonium saturated soil was leached with 1 N sodium chloride. Ammonia was distilled in a Kjeldahl flask and back titrated with standard hydrochloric acid.

10. pH

By glass electrode in 0.01 M calcium chloride suspension. Soil to solution ratio was 1:5.

RESULTS AND DISCUSSION

Water infiltration rates

Accumulated water infiltration rates as expected declined with time on all the cultivated and adjacent virgin soils (Table 1). The rates on the virgin soils (Pits, 11 to 12) are invariably greater than that on the cultivated soils (Pits, 1, 2 and 3). First hour infiltration rate in the cultivated M.U.1 soil has reduced by about 20 per cent. During the succeeding hours the water infiltration rates are further reduced as unstable structure continued to collapse with time. The third hour water rate on the cultivated soil is 38 per cent of the rate found on the virgin soil under the water saturation conditions. Differences in the results between the cultivated and virgin soils of M.U.2 unit are more prominent than on the M.U.1 soils. It is pointed

TABLE 1

SUCCESSIVE HOURLY ACCUMULATED WATER INFILTRATION RATES IN THE SOILS OF SELECTED MAPPING UNITS (in mm)

Pit No.	M.U.	Hour	R1	R2	R3	R4	R5	$\bar{X}$	S.E.	C.V.
2	1	1	12.3	10.5	12.0	15.7	11.8	12.5	0.9	16.0
2	1	2	3.5	3.6	4.5	4.3	5.3	4.2	0.3	17.2
2	1	3	2.5	2.7	2.7	3.6	3.1	2.9	0.2	15.1
10	1	1	12.4	17.3	18.1	10.6	10.6	13.8	1.6	26.0
10	1	2	5.2	6.1	5.9	4.8	4.2	5.2	0.4	14.9
10	1	3	4.8	6.1	5.2	5.6	5.8	5.5	0.2	9.3
12	1d	1	14.5	14.3	15.5	15.6	22.2	16.4	1.5	20.0
12	1d	2	8.0	12.8	12.6	15.6	10.7	11.9	1.3	23.5
12	1d	3	5.7	9.8	9.6	9.4	9.3	8.8	0.8	19.6
1	2	1	2.8	2.8	7.7	2.3	2.1	3.5	1.0	66.0
1	2	2	1.5	4.1	3.1	1.7	1.1	2.3	0.6	54.4
1	2	3	1.1	1.7	2.1	0.8	0.9	1.3	0.3	42.4
9	2	1	27.6	11.6	19.2	25.9	17.5	20.4	2.9	32.0
9	2	2	13.4	9.2	15.0	16.4	10.9	13.0	1.3	22.7
9	2	3	10.8	7.6	11.0	11.2	8.3	9.2	1.0	17.3
3	2d	1	2.8	4.7	3.4	5.5	3.6	4.0	0.5	27.0
3	2d	2	1.6	1.4	2.0	1.8	1.5	1.7	0.1	14.5
3	2d	3	1.6	1.5	1.6	1.7	1.3	1.5	0.1	9.7
11	2d	1	24.5	25.0	39.0	22.3	42.8	30.7	4.2	31.0
11	2d	2	10.0	9.7	16.5	10.3	16.0	12.7	1.5	26.0
11	2d	3	7.7	7.6	11.1	7.4	12.5	9.3	1.1	25.6

Pit No = The determinations were made around selected pits.
M.U. = Mapping Unit.
R. = Infiltrometer site at selected pit.
$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation.

out that Class I soil may take a longer time comparatively to deteriorate than Class II soil, although it depends on several other factors which would not be discussed here. The shallow phase of M.U.2 has not shown any difference in water infiltration. Average accumulated water infiltration rate for the third hour on M.U.2 virgin soils is 9.3 cm/hour but the corresponding value on the cultivated soil is very low which is only 1.4 cm/hour. The difference in water intakes for the three succeeding hours between the virgin and cultivated soils on M.U.1 and M.U.2 separately as well as combined are statistically very highly significant (P< 0,01).

The adverse effects of long period of maize monoculture cultivation on the breakdown of soil structure (to be discussed later) and as a result low water intake, have been clearly shown by this study as well as by others (J. BOUMA et al. 1975 ; H.B. WOOD, 1971 ; H.C. PEREIRA, 1955). When rain is unable to infiltrate into the soil due to the deterioration of soil structure it could cause soil erosion and impoverish the quality of the topsoil which is the most valuable, nutrient-rich part of the soil. It can also prove to limit the water supply to the plants in time of need especially in the dry spell of a rainy season. This effect may be exaggerated in the soil with low water holding capacity.

The physical and chemical properties including the water infiltration rates of the soils would have changed gradually. From year to year trends in all the characteristics reported are not known because this research was initiated after the soils had been in use for several years.

Soil density and moisture

Adverse effects of the cultivation on B.D. and T.P. of the surface layers are distinctly shown (Table 2) by the soils. These have reduced considerably as compared with the virgin soils ($P < 0.01$). An intersting feature of the soils is the decrease in B.D. with depth and concurrent increase in T.P. in almost all the profiles studied. During the field investigations the soils were found to be spongy at the lower depths. Particle density varies in the profiles. It has not shown any statistical difference in the surface layers of the cultivated and virgin soils, as is the case with the clay and silt contents.

Moisture contents (1/3.M. and 15.M.) usually increase with an increase in clay content of the soils but it does not necessarily increase the quantity of A.M. In almost all the profiles percentage of clay increases with the soil depth. Mean A.M. in the virgin soils (8.3) is greater than the mean (7.0) obtained in the cultivated soils ($P < 0,1$). Moisture retained at 15 bar pressure has not shown any significant difference between the soils. In the long-worked soils, the reduction in the available moisture and porosity as a result of compaction due to their continuous use could prove critical for the crop growth especially in the long droughts (F. ARNOLD, 1971 ; R.J. LEEPER and al. 1975 ; R. BRADFIELD, 1936). This aspect needs further investigation.

TABLE 2

PHYSICAL CHARACTERISTICS OF THE SOILS OF SELECTED MAPPING UNITS

Pit	M.U.	R.	Depth, cm	B.D.	P.D.	T.P.	1/3.M	15.M.	A.M.	C,	S.	TEXTURE
2	1	–	0–13	1.47	2.72	46.0	13.1	6.5	6.6	15.0	10.9	SL
2	1	–	20–28	1.42	2.50	43.2	17.0	7.9	9.1	30.0	10.3	SCL
2	1	–	40–48	1.44	2.70	46.7	18.3	8.1	10.2	34.0	10.2	SCL
2	1	–	66–72	1.39	2.60	46.5	18.2	10.9	7.3	37.0	11.3	SC
2	1	–	104–112	1.33	2.63	49.5	16.6	8.1	8.5	38.0	12.0	SC
–	1	1	0–13	1.58	2.80	43.6	14.9	6.7	8.2	17.0	12.4	SL
–	1	2	0–13	1.58	2.61	39.5	14.0	6.0	8.0	16.0	8.8	SL
–	1	3	0–13	1.46	2.40	39.2	14.0	7.5	6.5	19.0	12.4	SL
–	1	4	0–13	1.51	2.54	40.6	13.2	7.2	6.0	15.2	10.6	SL
–	1	5	0–13	1.53	2.60	41.3	14.5	6.5	8.0	12.2	9.0	SL
10	1	–	0–13	1.52	2.51	39.4	13.9	6.4	7.5	19.2	10.7	SL
10	1	–	26–34	1.45	2.60	44.2	14.9	7.9	7.0	25.2	10.0	SCL
10	1	–	60–68	1.42	2.50	43.2	16.6	9.1	7.5	31.2	9.7	SCL
10	1	–	78–86	1.39	2.60	46.5	17.3	7.2	10.1	33.2	11.0	SCL
10	1	–	110–118	1.32	2.82	53.2	18.1	9.2	8.9	33.2	12.5	SCL
–	1	1	0–13	1.46	2.71	46.1	16.2	5.9	10.3	16.4	15.8	SL
–	1	2	0–13	1.45	2.82	48.6	17.2	5.6	11.6	16.6	14.3	SL
–	1	3	0–13	1.50	2.62	42.7	14.0	5.4	8.6	15.4	12.8	SL
–	1	4	0–13	1.47	2.50	41.1	14.1	6.4	7.7	6.7	13.4	SL
–	1	5	0–13	1.65	2.61	36.8	15.5	6.6	8.9	10.4	16.4	SL
12	1d	–	0–13	1.48	2.61	43.3	15.1	4.8	10.3	20.2	10.2	SL
12	1d	–	22–30	1.50	2.30	34.8	18.3	7.4	10.9	20.0	14.0	SL/SCL
–	1d	1	0–13	1.54	2.80	45.0	15.9	5.7	10.2	13.2	10.4	SL
–	1d	2	0–13	1.61	2.63	38.8	13.7	4.4	9.3	13.2	9.2	SL
–	1d	3	0–13	1.57	2.43	35.4	13.7	4.3	9.4	11.2	10.3	SL
–	1d	4	0–13	1.69	2.90	41.7	13.1	4.5	8.6	12.7	10.6	SL
–	1d	5	0–13	1.60	2.85	43.9	10.2	4.2	6.0	11.2	9.3	SL
1	2	–	0–13	1.57	2.66	41.0	13.0	3.4	9.6	10.0	8.1	LS
1	2	–	30–38	1.55	2.51	38.2	19.9	7.2	12.7	24.0	7.8	SCL
1	2	–	54–62	1.39	2.48	43.5	18.2	8.8	9.4	29.0	7.4	SCL
1	2	–	84–92	1.33	2.45	45.7	17.2	8.6	10.6	29.0	9.4	SCL
1	2	1	0–13	1.46	2.58	43.4	12.3	4.7	7.6	10.0	10.3	LS/SL
1	2	2	0–13	1.52	2.68	43.2	13.5	4.3	9.2	11.5	13.9	SL
1	2	3	0–13	1.48	2.55	42.0	15.4	4.5	10.9	9.0	14.1	SL
1	2	4	0–13	1.56	2.54	38.5	15.9	4.7	11.2	8.0	11.1	LS
1	2	5	0–13	1.60	2.74	41.6	15.3	5.3	10.0	11.0	17.9	SL

TABLE 2 (continued)

PHYSICAL CHARACTERISTICS OF THE SOILS OF SELECTED MAPPING UNITS

Pit	M.U.	R.	Depth, cm	B.D.	P.D.	T.P.	1/3.M.	15.M.	A.M.	C,	S.	TEXTURE
9	2	–	0–13	1.59	2.60	38.8	15.1	5.1	10.0	12.4	8.2	SL
9	2	–	28–36	1.50	2.60	42.3	18.1	7.9	10.2	24.4	5.8	SCL
9	2	–	60–68	1.40	2.60	46.1	17.2	8.2	9.0	34.4	6.9	SCL
9	2	–	130–138	1.31	2.65	50.6	19.2	10.4	8.8	35.4	9.8	SC
9	2	1	0–13	1.35	2.60	48.1	11.4	5.8	5.6	6.4	8.8	LS
9	2	2	0–13	1.49	2.55	41.6	13.3	5.9	7.4	7.4	10.0	LS
9	2	3	0–13	1.32	2.50	47.2	12.0	4.7	7.3	8.4	9.8	LS
9	2	4	0–13	1.56	2.50	37.6	11.9	4.9	7.0	7.4	9.6	LS
9	2	5	0–13	1.38	2.40	42.5	12.8	5.7	7.1	7.4	9.5	LS
3	2d	–	0–13	1.60	2.60	38.5	13.5	7.0	6.5	10.0	13.8	SL
3	2d	–	32–40	1.46	2.51	41.8	14.0	7.3	6.7	14.0	14.4	SL
3	2d	–	60–68	1.51	2.90	47.9	16.0	9.4	6.6	23.0	11.9	SCL
3	2d	–	80–88	1.61	2.70	40.4	17.3	8.3	9.0	25.0	13.3	SCL
3	2d	1	0–13	1.64	2.60	36.9	8.2	3.9	4.3	9.0	13.4	SL
3	2d	2	0–13	1.45	2.43	40.3	7.3	3.7	3.6	8.0	14.3	SL
3	2d	3	0–13	1.64	2.64	37.9	8.4	3.6	4.7	8.0	12.0	LS
3	2d	4	0–13	1.51	2.51	39.9	7.1	3.9	3.2	8.0	11.1	LS
3	2d	5	0–13	1.61	2.72	40.8	8.5	3.8	4.7	8.0	14.2	LS
11	2d	–	0–13	1.36	2.61	47.9	13.0	4.4	8.6	9.4	8.2	LS
11	2d	–	30–38	1.49	2.70	44.8	11.6	5.4	6.1	15.4	8.6	SL
11	2d	–	60–68	1.49	2.74	45.6	20.5	8.6	11.9	24.9	8.0	SCL
11	2d	1	0–13	1.55	2.31	32.6	12.7	6.0	6.7	10.9	10.8	SL
11	2d	2	0–13	1.48.	2.65	44.2	13.6	5.9	7.7	10.4	12.0	SL
11	2d	3	0–13	1.47	2.63	44.1	11.9	4.2	7.7	9.4	10.9	LS/SL
11	2d	4	0–13	1.47	2.50	41.2	13.3	5.0	8.3	10.9	11.1	SL
11	2d	5	0–13	1.43	2.70	47.0	14.5	7.6	6.9	10.4	12.4	SL

B.D. = Bulk density g/cc
P.D. = Particle density g/cc
T.P. = Total porosity
M : = Moisture at different bars
A.M. = Available moisture
C : = Clay percentage, less than 0.002 mm
S. = Silt percentage, 0,05-0.002 mm
TEXTURE = SL = sandy loam, SCL = sandy clay loam
SC = sandy clay, LS = loamy sand

TABLE 3

WATER STABILITY OF SOIL AGGREGATES AT ZAMIC FARMS, CHISAMBA

Aggregation percentage

Pit	MU	R1	R2	R3	R4	R5	$\bar{X}$	SE
2	1	60	52	51	60	59	56	2
10	1	88	93	92	87	87	89	2
12	1d	93	83	81	82	84	85	2
1	2	56	50	61	58	55	56	2
9	2	83	92	86	85	86	85	2
3	2d	54	60	58	51	62	57	2
11	2d	89	85	88	90	90	88	1

R = Replication around each selected pit.

Aggregation : A measure silt + clay particles that are bound into water-stable aggregate larger than 20 microns in size.

MU : Mapping Unit.

$\bar{X}$: Mean.

SE : Standard error.

Stability of soil aggregates

The water stable aggregates in the surface layer gave a very high significant results between the virgin and cultivated soils (P < 0,01). All the virgin soils showed a higher degree of soil aggregation. Mean aggregation percentages are 86 and 56 in the virgin and cultivated soils, respectively (Table 3). The findings are in agreement with the other investigations (R.E. GISH and G.M. BROWNING, 1948 ; L.D. BAVER, 1956 ; R. BRADFIELD, 1937 ; A.J. LOW, 1950).

The most prominent effect of the cultivation is found on the stability of the soil aggregates. It should be looked after because it is an important characteristic which governs the water infiltration, erosion and several other physical properties vital for the normal growth of the plants. The preparatory cultivation before each seasonal crop and other operations during the growth of the crop tend to destroy organic matter and hence the stable aggregates. The dispersed soil particles seal the soil pores resulting in low water infiltration as pointed out before. The cropping practice such as maize which does not maintain a continuous protective cover, exposes the bare soil to rains at the beginning of each season. If successive maize crops are grown, there will be a more marked deterioration in the soil structure. It is one of the reasons of low percentage of soil aggregation in the cultivated fields discussed here. Although a compacted soil may be loosened temporarily by the mechanical means, the soil will easily recompact with further cultivation under the influence of rain.

TABLE 4

CHEMICAL ANALYSIS OF SOILS AT DIFFERENT SITES

R	Depth cm	O.C.	T.N.	Ca	Mg	K	Na	Ex. Cap	P	pH
			Pit 2, M.U.1							
–	0–13	0.42	0.030	0.8	0.5	0.22	–	5.1	16	4.3
–	20–28	0.47	0.040	0.6	0.4	0.24	–	6.5	–	4.3
–	40–48	0.43	0.030	0.4	0.3	0.18	–	6.4	–	4.2
–	66–72	0.31	0.030	0.4	0.3	0.16	–	6.1	–	4.3
–	104–112	0.43	0.030	0.4	0.4	0.16	–	6.7	–	4.3
1	0–13	0.30	0.028	1.1	0.6	0.25	0.08	4.6	21	4.4
2	0–13	0.34	0.036	1.2	0.5	0.16	0.06	4.2	10	4.1
3	0–13	0.38	0.030	1.0	0.5	0.19	0.06	3.9	19	4.1
4	0–13	0.32	0.028	0.9	0.6	0.26	0.08	4.7	10	4.5
5	0–13	0.36	0.024	0.9	0.6	0.24	0.06	4.4	20	4.3
			Pit 10,M.U.1							
–	0–13	0.82	0.062	2.0	0.6	0.20	–	6.5	29	5.5
–	21–34	0.51	0.051	0.6	0.5	0.12	–	7.1	6	4.3
–	60–68	–	–	0.5	0.4	0.12	–	6.6	–	4.2
–	78–86	–	–	0.5	0.5	0.17	–	6.5	–	4.2
–	110–118	–	–	0.40	0.6	0.26	–	5.8	–	4.4
1	0–13	0.71	0.056	2.4	0.4	0.12	0.10	4.9	16	5.6
2	0–13	0.70	0.070	2.0	0.4	0.16	0.05	5.3	15	4.6
3	0–13	0.73	0.068	2.8	0.4	0.12	0.06	3.8	26	5.4
4	0–13	0.61	0.052	1.9	0.3	0.12	0.08	4.0	27	4.2
5	0–13	0.62	0.062	1.8	0.6	0.35	0.11	4.7	22	4.9
			Pit 12,M.U.1d							
–	0–13	0.56	0.050	1.3	1.32	0.12	–	4.4	15	5.6
–	22–30	0.51	0.036	0.5	0.40	0.14	–	4.9	7	4.4
1	0–13	0.51	0.052	1.3	0.6	0.11	0.08	3.0	20	5.3
2	0–13	0.47	0.052	1.2	0.6	0.18	0.06	2.8	15	4.9
3	0–13	0.47	0.052	1.2	0.6	0.17	0.06	3.0	16	5.2
4	0–13	0.51	0.052	1.4	0.7	0.18	0.11	3.0	12	5.1
5	0–13	0.43	0.052	1.5	0.6	0.16	0.10	2.7	10	5.4
			Pit 1,M.U.2							
–	0–13	0.39	0.044	1.0	0.5	0.23	0.08	2.8	35	4.7
–	30–38	0.35	0.028	1.2	0.6	0.16	0.08	3.2	–	4.7
–	54–62	–	–	1.5	1.4	0.13	0.08	3.7	–	5.3
–	84–92	–	–	1.7	1.5	0.25	0.10	3.8	–	5.8
1	0–13	0.40	0.042	1.5	0.5	0.25	0.13	3.7	30	5.4
2	0–13	0.42	0,038	1.6	0.6	0.19	0.15	3.1	25	5.4
3	0–13	0.40	0.045	0.9	0.5	0.18	0.13	2.7	35	4.9
4	0–13	0.43	0.044	1.1	0.5	0.23	0.23	2.8	34	5.1
5	0–13	0.42	0.044	1.7	0.6	0.10	0.10	3.6	28	5.4

Table 4 (Cont)

R	Depth, cm	O.C.	T.N.	Ca	Mg	K	Na	Ex.Cap	P	pH
			Pit 9, M.U. 2							
–	0–13	0.90	0.050	4.0	0.9	0.29	–	6.2	36	6.8
–	28–36	0.43	0.022	1.2	0.4	0.20	–	3.7	21	5.4
–	60–68	–	–	1.1	0.7	0.54	0.06	3.5	–	5.1
–	130–138	–	–	–	–	–	–	–	–	–
1	0–13	0.70	0.054	3.4	0.9	0.22	0.08	3.5	31	5.6
2	0–13	0.68	0.052	2.3	0.8	0.18	0.08	3.4	21	5.5
3	0–13	0.64	0.060	2.9	0.7	0.16	0.11	4.0	48	5.6
4	0–13	0.58	0.054	2.3	0.7	0.10	0.08	3.7	29	5.2
5	0–13	0.82	0.072	3.3	1.1	0.19	0.15	4.9	21	5.6
			Pit 3,M.U.2d							
–	0–13	0.86	0.051	1.8	0.4	0.16	–	6.5	9	4.8
–	32–40	0.35	0.030	1.1	0.5	0.12	–	4.3	3	4.6
–	60–68	0.27	0.030	1.2	1.6	0.22	–	6.6	3	5.1
–	80–88	0.29	0.030	2.0	1.6	0.26	–	6.9	3	5.7
1	0–13	0.51	0.056	1.9	0.5	0.18	0.06	3.7	32	4.7
2	0–13	0.46	0.038	1.8	0.8	0.23	0.10	3.8	24	4.7
3	0–13	0.51	0.052	1.5	0.6	0.13	0.07	3.8	25	4.3
4	0–13	0.51	0.054	1.9	0.6	0.15	0.05	3.2	18	4.7
5	0–13	0.46	0.040	2.3	0.8	0.23	0.08	3.8	31	5.0
			Pit 11,M.U.2d							
–	0–13	1.20	0.096	3.6	1.0	0.21	–	8.9	40	5.0
–	30–38	0.39	0.024	1.3	0.5	0.09	–	4.0	4	5.6
–	60–68	–	–	1.1	1.8	0.19	0.10	3.8	–	5.4
1	0–13	0.66	0.054	1.8	0.9	0.18	0.10	3.7	19	5.4
2	0–13	0.68	0.058	2.3	1.0	0.30	0.10	4.3	35	5.4
3	0–13	0.73	0.056	2.9	1.0	0.21	0.12	4.5	16	5.3
4	0–13	0.64	0.058	3.7	1.4	0.28	0.11	4.8	37	5.8
5	0–13	0.82	0.072	2.8	1.2	0.23	0.08	5.6	25	5.3

O.C. = Organic carbon in percentage

T.N. = Total nitrogen in percentage

Ca,Mg,K and Na are the exchangeable cations, me/100g

Ex.Cap. = Exchange capacity, me/100g

P = Phosphorous, ppm

Chemical analysis

Data (Table 4) help to visualize the net changes in the soil chemical constitution after many years of maize monoculture. The contents of O.C., T.N., Ca, Mg and pH of the top 0-13 cm layer have dropped after 15 years of continuous use. The differences between the virgin and cultivated soils for these chemical characteristics are very highly significant ($P < 0.01$). The findings are based on 18 observations in the cultivated soils and 24 in the virgin soils. Overall reduction in T.N. is roughly equal to the reduction in O.C. It could be explained to some extent that the originally built up organic matter in the virgin soils has been destroyed by the continuous use and has not been replenished by the soil management practices. Degradation of the soil aggragation is correlated with the decrease in organic matter (Tables 3 and 4). Although O.C. and T.N. are significantly reduced in the cultivated soil but C:N ratio (1:11) in both the cases remained almost unchanged.

In the virgin soils on an average Ca and Mg are 2.34 and 0.78 me/100 g soil as compared with the cultivated soils where the corresponding values are 1.38 and 0.57, respectively. In other words after cultivation Ca and Mg are 59 and 73 per cent of the original contents found in the virgin soils. The differences in Ca and Mg may be attributed to their continuous uptake by the crop in addition to other natural losses through water erosion and leaching. It may be mentioned that no lime was administrated during the cultivation years. Mean pH value in the virgin soils is 5.3. It is reduced to 4.7 in the cultivated soils.

Exchange capacity, P and K of the topsoils have not shown any significant differences between the virgin soils and the cultivated ones. It would have been partly that an adequate amounts of P and K were added every year, in addition to the residual effect of P and K dislodged from the clay minerals. In most of the profiles, the chemical constituents declined with soil depths. Sodium makes only a small part of the exchange complex and hence has not been discussed.

Crop yield

Actual yields of maize during the course of cultivation of the soils are not available. Information given here is based on the personal communication by the General Manager of the Farms where these investigations were conducted. It is reported that the yields have fallen by about 40 percent on the best soils (M.U.1) and 50 per cent on the second best (M.U.2) soils as compared with the yields obtained during the early 2/3 years when the virgin soils were opened up 15 years ago. The average yield for the first three years was about 6000 kg/ha with all the good management practices. The yield could not be maintained at the initial levels inspite of the fact that annually 250 kg/ha of D-mixture as a basal dressing and 300 kg/ha of urea have been applied during the early stages of maize growth with the same management practices.

A general impression of agriculturists is that on most soils, yield gradually falls even if fertilizers are applied and this is mostly due to a loss of soil structure (H.C. PEREIRA, 1955). It was reported by P.H. NYE and D.J. GREENLAND (1960) that the yield of maize in monoculture was reduced in the 7th year after clearing the forest by about 40 per cent on the plots receiving NPKCa fertilizer. Similar results were also reported by C.C. WEBSTER and P.N. WILSON (1973) and D.J. EAGLE (1972).

The summation of the effects of decreased organic matter, T.N., Ca, Mg, pH, impact of raindrops on exposed soil and mechanical manipulation of tillage implements, is the deterioration of soil physical properties and eventually leads to the reduction of soil productivity. It may be said that fertilizers on the soils with poor structure is no substitute for soils in good tilth. It is apparent from this investigation that greatest return from the soils is obtained in optimum physical conditions.

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