SOIL RESOURCES APPRAISAL FOR DEVELOPMENT

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RESUMEN

VALORACION DE LAS POTENCIALIDADES DEL SUELO

Esta metodología experimental ha pasado por varias fases de aproximación, dando resultados satisfactorios con mapas a pequeña escala y más aún con cartografías detalladas. Consiste, en esencia, en un análisis sistemático e interpretación de aquellas propiedades individuales del suelo, o las propiedades de los tipos medios de un país que son más importantes para la producción de cultivos y aplicación agrícola. Se calcula el grado de productividad a partir de las siete propiedades del suelo enumeradas y también el grado de potencialidad, basado en estas propiedades mejoradas por el laboreo, de acuerdo con las propiedades deficientes o los factores ambientales (relieve, clima y otros).

Se producen normalmente dos clases de mapas interpretativos, ambos derivados de los mapas de suelos: un mapa de la productividad actual del suelo y un mapa de potencialidades del suelo. El primero indica las condiciones actuales del suelo con sus limitaciones a la producción agrícola; el segundo representa las potencialidades de los suelos cuando hayan sido introducidas las mejoras del suelo y otros adelantos tecnológicos normales. La comparación de los dos mapas da el «coeficiente de mejora» mostrando zonas de suelo que responden al tratamiento en diferentes grados. Estos estudios interpretativos han empezado ya a dar resultados sorprendentes en la identificación de zonas donde debiera concentrarse el esfuerzo por el desarrollo.

INTRODUCTION

With so many agricultural development programs being implemented throughout the world in this Decade of Development, soil studies and soil surveys have become of primary importance. Soil survey data are however often difficult even for specialists to understand, because of

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the peculiar nomenclature and soil classification system they employ. Soil surveyors have considered their task complete when they have prepared their maps and reports. On the other hand, people who have to use the information contained in these maps and reports are often discouraged by an inability to understand their meaning. In only a few countries has the interpretation of soil surveys gone as far as it should if agricultural and economical development is to benefit from them; some system is needed to convert conventional soil maps into maps that show both climates and soils in a language understood to those who have to use them for development projects. An attempt to meet this difficulty is reflected in the support given by Governments and FAO to the organization of soil surveys. Many systems and methods have been proposed and used. The present paper attempts to explain one such method of evaluating soils and presenting the results of soil surveys in terms of soil productivity and soil potentiality.

The system is well suited to detailed soil surveys of project areas, but with small scale soil maps the difficulty is often that the surveys themselves do not give the information needed to define all the environmental factors regarding crops, forestry and animal production. One has to consider, simultaneously if not in advance, ecological factors and crops, or better still different forms of land use, which should then be taken as the focus around which all the other information should be built up. Does one know for instance, the relationship between climate and crops, and between soils and crops within a broad framework of climate? If so, the suitability of the environment for a given crop is shown by an appropriate analysis of the properties of the soils. These considerations have led recently to the adoption of ecological soil phases but it still seems better to consider the broad ecological areas where different kinds of soil occur.

The method

The method here described is based on an analysis of the soil properties which most directly influence land-use and soil productivity. The basic factors considered are: effective soil depth, soil moisture, plant nutrients and organic matter. The specific characteristics chosen include: depth (P), texture and structure (T), base saturation (N), salinity (S), organic matter (O), nature of clay (A), mineral reserves (M) and drainage (D). Water (H), which is vital to productivity, and for which we have not direct measurements in terms of soil moisture, is deduced from meteorological information for the locality, taking into consideration the number of months in which the soil water is deficient for crop production. (See Table 1: Soil Characteristics used to Determine Productivity).

TABLE 1

Soil characteristics used to determine productivity

H: Soil moisture content.

H_1	Soil extremely dry, below wilting point all year round.
H_2	Soil dry, below wilting point for 9-11 months of the year.
H_3	Soil dry, below wilting point for 6-8 months of the year.
H_4	Soil dry, below wilting point for 3-5 months of the years and wet below field capacity for more than 6 months.
H_5	Soil wet above wilting point and below field capacity during most of the year.
H_6	Soil waterlogged for long periods, almost always above field capacity (see drainage).

D: Drainage.

D_{1a}	Waterlogging, water table almost reaches the surface all year round (hydromorphic surface horizon at a depth of 30 cm or less).
D_{1b}	Waterlogging for periods from 2-4 months.
D_{2a}	Water table being sufficiently close to the surface to harm deep rooting plants (hydromorphic horizon surface at a depth of 30-60 cm).
D_{2b}	Waterlogging for periods from 8 days to 2 months.
D_{3a}	Good drainage, water table sufficiently low not to impede crop growing (hydromorphic horizon over a depth of 60 cm below the surface).
D_{3b}	Possible waterlogging for brief periods (flooding) less than 8 days each time.
D_4	Soil well drained, deep water-table (hydromorphic horizon at over 120 cm below the surface) no waterlogging in profile (see H).

P: Effective soil depth.

P_1	Soil thickness: nil or soil pocket with rock outcroppings.
P_2	Soil thickness: less than 30 cm.
P_3	Soil thickness: from 30-60 cm.
P_4	Moderately deep soil. Soil thickness: from 60 to 90 cm.
P_5	Deep soil. Soil thickness: from 90-120 cm.
P_6	Very deep soil over 120 cm.

TABLE 1 (Cont.)

T: Texture and structure of A horizon.

T_1 Pebbly, rocky or gravelly.
T_{1a} Pebbly, stony, gravelly, up to 60 per cent in weight.
T_{1b} Pebbly, stony, gravelly, from 40 to 60 per cent in weight.
T_{1c} Clay and stones from 20 to 40 per cent in weight.
T_2 Very coarse-textured soils.
T_{2a} Pure sand particles.
T_{2b} Very coarse-textured soil (up to 45 per cent coarse sand).
T_{2c} Soil with non-decomposed «raw» humus.
T_3 Dispersed clay of unstable structure or swelling, sticky and impermeable clay.
T_4 Light-textured soil: fine sand, loamy sand or coarse sand and silt.
T_{4a} Unstable structure.
T_{4b} Stable structure.
T_5 Heavy-textured soil: clay or silty clay.
T_{5a} Massive to prismatic structure.
T_{5b} Angular to crumb structure (or massive but highly porous, e. g. soils with high sesquioxide content).
T_6 Medium-heavy soil: sandy clay, clay loam and silty clay loam.
T_{6a} Massive to prismatic structure.
T_{6b} Angular to crumb structure (or massive but porous).
T_7 Soil of average, balanced texture: loam, sandy loam and sandy clay loam.

N: Base status.

N_1 Soil strongly leached, $V = S/T$ less than 15 per cent.
N_2 Strongly leached soil, $V = 15$ to 35 per cent.
N_3 Moderately leached soil, $V = 35$ to 50 per cent.
N_4 Slightly leached soil, $V = 50$ to 75 per cent.
N_5 Very slightly leached soil, V above 75 per cent.
N_6 Soil saturated with calcium ion (calcareous soil) $V = 100$.

S: Soluble salts content.

S_1 Total soluble salts less than 0.2 per cent.
S_2 Total soluble salts between 0.2 and 0.4 per cent.
S_3 Total soluble salts between 0.4 and 0.6 per cent.
S_4 Total soluble salts between 0.6 and 0.8 per cent.
S_5 Total soluble salts between 0.8 and 1.0 per cent.

TABLE 1 (Cont.)

S_6	Total soluble salts 1 per cent and over. If sodium carbonate is present in soils (alkali soil).
S_7	Total soluble salts (including sodium carbonate) from 0.1 to 0.3 per cent.
S_8	Total soluble salts (including sodium carbonate) from 0.3 to 0.6 per cent.
S_9	Total soluble salts (including sodium carbonate) over 0.6 per cent.

O: Organic matter of A_1 horizon.

O_1	Very little organic matter, less than 1 per cent.
O_2	Little organic matter, 1-2 per cent.
O_3	Average organic matter content, 2-5 per cent.
O_4	Fair organic matter content, over 5 per cent.
O_5	Very high content, but C/N over 25.

A: Mineral exchange capacity and nature of clay en B horizon.

A_0	Capacity for exchange less than 5 meq/100 g (probably sesquioxydes).
A_1	Capacity for exchange from 5 to 20 meq/100 g (probably kaolin and sesquioxides).
A_2	Capacity for exchange from 20-40 meq/100 g (probably a mixture of clays or hydrous micas «illite»).
A_3	Capacity for exchange over 40 meq/100 g (probably montmorillonite or allophane).

M: Reserves of alterable minerals in B horizon.

M_1	Reserves very low to nil.
M_2	Reserves fair.
M_{2a}	Minerals derived from sands, sandy materials, ironstone.
M_{2b}	Minerals derived from acid rocks.
M_{2c}	Minerals derived from basic or calcareous rocks.
M_3	Reserves great.
M_{3a}	Acid rocks.
M_{3b}	Basic and calcareous rocks.

The present productivity of the soil (p) is a function of the above characteristics and can be expressed by:

$$p = f(P, T, N, S, O, A, M, D, H). \tag{1}$$

Some of these factors completely limit the productivity of the soil, while others only reduce it. Each factor is given an index (see Table 2) and the productivity of the soil p is then calculated from the following formula:

$$p = P \times T \times N \times S \times O \times A \times M \times D \times H. \tag{2}$$

The advantage of a multiplication formula is that the most limiting factors overrule the others since not all factors are given equal weight. (See Table 2: Rating of various soils characteristics).

TABLE 2

Rating of various soil characteristics

		Crops			Tree crops	
H						
H_1		5			5	
H_2	10	20	40		10	
	11 months	10 months	9 months (dry)			
H_3	50	60	70	10	20	40
	8 months	7 months	6 months (dry)			
H_4	80	90	100	70	90	100
	5 months	4 months	3 months (dry)			
H_5		100			100	

	Crops $H_4H_5H_2H_3$	Tree crops
D		
D_1	10 — 40	5
D_2	40 — 80	10
D_3	80 — 90	40
D_4	100	100

	On lower slopes	On slopes or plateau	Tree crops
P			
P_1	5	5	5
P_2	20	20	5
P_3	50	30 — 40	20
P_4	80	60 — 70	60
P_5	100	100	80
P_6	100	100	100

T			
T_{1a}	10		
T_{1b}	30		
T_{1c}	60		
	$H_4H_5H_6$ AB	H_3	H_1H_2
T_{2a}	10	10	10
T_{2b}	30	20	10
T_{2c}	30	30	30

TABLE 2 (Cont.)

	On lower slopes	On slopes or plateau	Tres crops
T_3	30	20	10
T_{4a}	40	30	30
T_{4b}	50	40	60
T_{5a}	60	70	20
T_{5b}	80	80	60
T_{6a}	80	80	60
T_{6b}	90	90	90
T_7	100	100	100

N	
N_1	40
N_2	50
N_3	60
N_4	80
N_5	100
N_6	80

Crops

S	$T_1T_2T_4$	$T_5T_6T_7$
S_1	100	100
S_2	70	90
S_3	50	80
S_4	25	40
S_5	15	25
S_6	5	15
S_7	60	90
S_8	15	60
S_9	5	15

<table>
<tr><th>O</th><th>$H_1H_2H_3$ D_3D_4</th><th>H_4H_5 D_1D_2 AB</th></tr>
<tr><td>O_1</td><td>85</td><td>70</td></tr>
<tr><td>O_2</td><td>90</td><td>80</td></tr>
<tr><td>O_3</td><td>100</td><td>90</td></tr>
<tr><td>O_4</td><td>100</td><td>100</td></tr>
<tr><td>O_5</td><td colspan="2">70</td></tr>
</table>

A	
A_0	85
A_1	90
A_2	95
A_3	100

TABLE 2 (Cont.)

	$H_1H_2H_3$	H_4H_5 AB
M		
M_1	85	85
M_{2a}	85	90
M_{2b}	90	95
M_{2c}	95	100
M_{3a}	90	95
M_{3b}	95	100
M_{3c}	100	100

The rating in this table has been checked against groundnuts crops at nineteen research stations in Madagascar (fig. 1). The values obtained for each soil were plotted against frequency of occurrence to obtain the five following preliminary classes of soil, in which the ideal soil for production has a rating of 100:

(1) Very high productivity (65 to 100).
(2) High productivity (35 to 64).
(3) Medium productivity (20 to 34).
(4) Low productivity (8 to 19).
(5) Very low productivity (0 to 7).

The Unit of Capability

The unit of capability (UC) may be defined as follows: «one hectare of a soil with a rating of 100» (ideal soil). For small scale soil maps, however, the hectounit (HUC) or the kilounit (KUC) are more suitable, the hectounit being equal to 100 UC and the kilounit to 1,000 UC. This concept has proved very useful in expressing the productivity of different soil regions and gives, for the first time, the necessary common denominator for a quantitative comparison of the capabilities of different soils.

A number of relationship can now be established, for example the population pressure on the land. Thus one HUC supporting 100 inhabitants is equivalent to one hectare of ideal soil per caput. It is estimated that soils below 0.20 UC are not generally suitable for agriculture production, while soils of very high quality have UC values generally above 0.64.

RATING OF SOIL PRODUCTIVITY FOR PEANUTS AS A FUNCTION OF SOIL CHARACTERISTICS (RIQUIER INDEX)

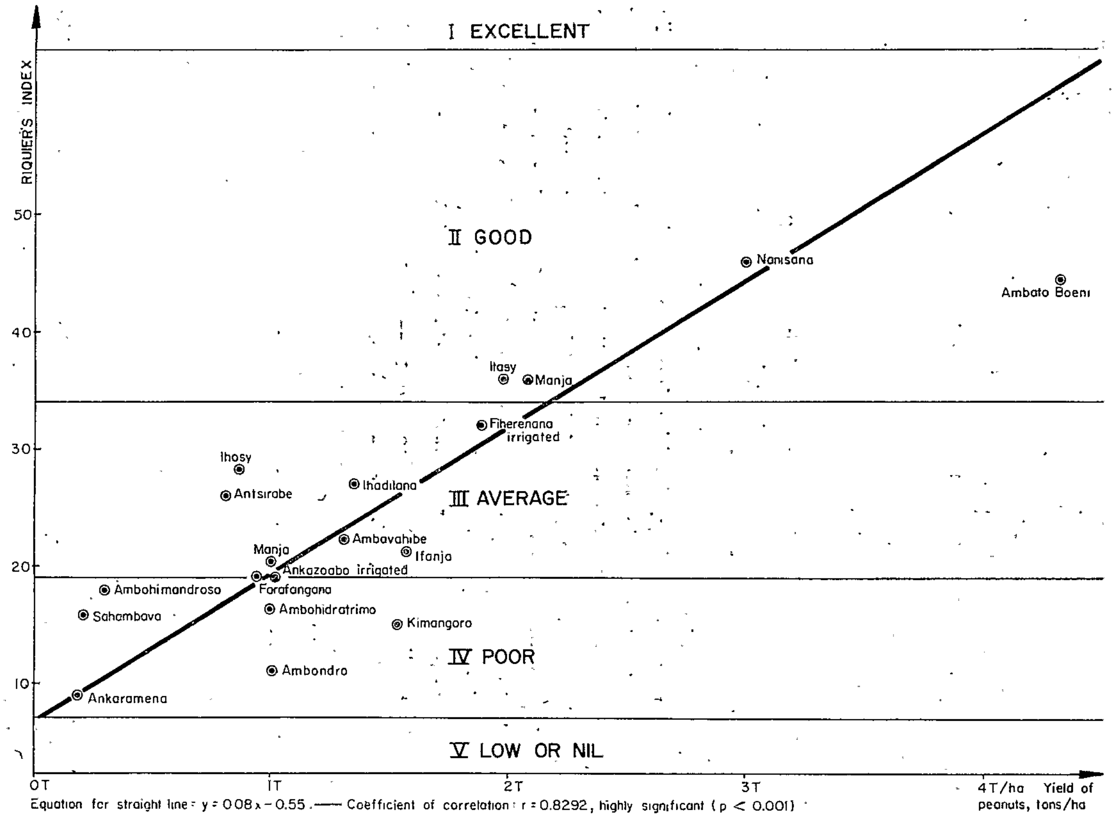


Fig. 1.

Map of Present Soil Productivity

This map is prepared, following the method briefly explained above, from the basic Soil Map and distinguishes areas which are predominantly of a certain productivity level under *present* management systems. It thus gives a general picture of the present conditions of the soils and their present capabilities for production, based on their natural fertility and on the use of traditional agricultural practices.

Map of Soil Potentialities

Some of the limitations expressed in the function (1), such as effective soil depth, texture, mineral-exchange capacity of the soil, nature of the clay and mineral reserves are fairly constant. Others can be corrected, or even eliminated, by normal soil management practices such as drainage, liming, fertilization, reclamation of saline soils, and improvement of organic matter content. (See list of improvements Table 3). Moisture deficiency can be eliminated only by irrigation. For small scale maps when detailed irrigation plans are not available it is assumed that not more than 10 per cent of any large region will be irrigated, in one way or another. Specific management practices will be required according to (*a*) deficiencies in soil factors — for example: (N_1) soil strongly leached necessitates the use of fertilizers (F), and (*b*) external conditions and environment — for example: a steep slope necessitates intensive water erosion control (K). The necessary improvements and the soil characteristics may, however, often be incompatible (see Table 4).

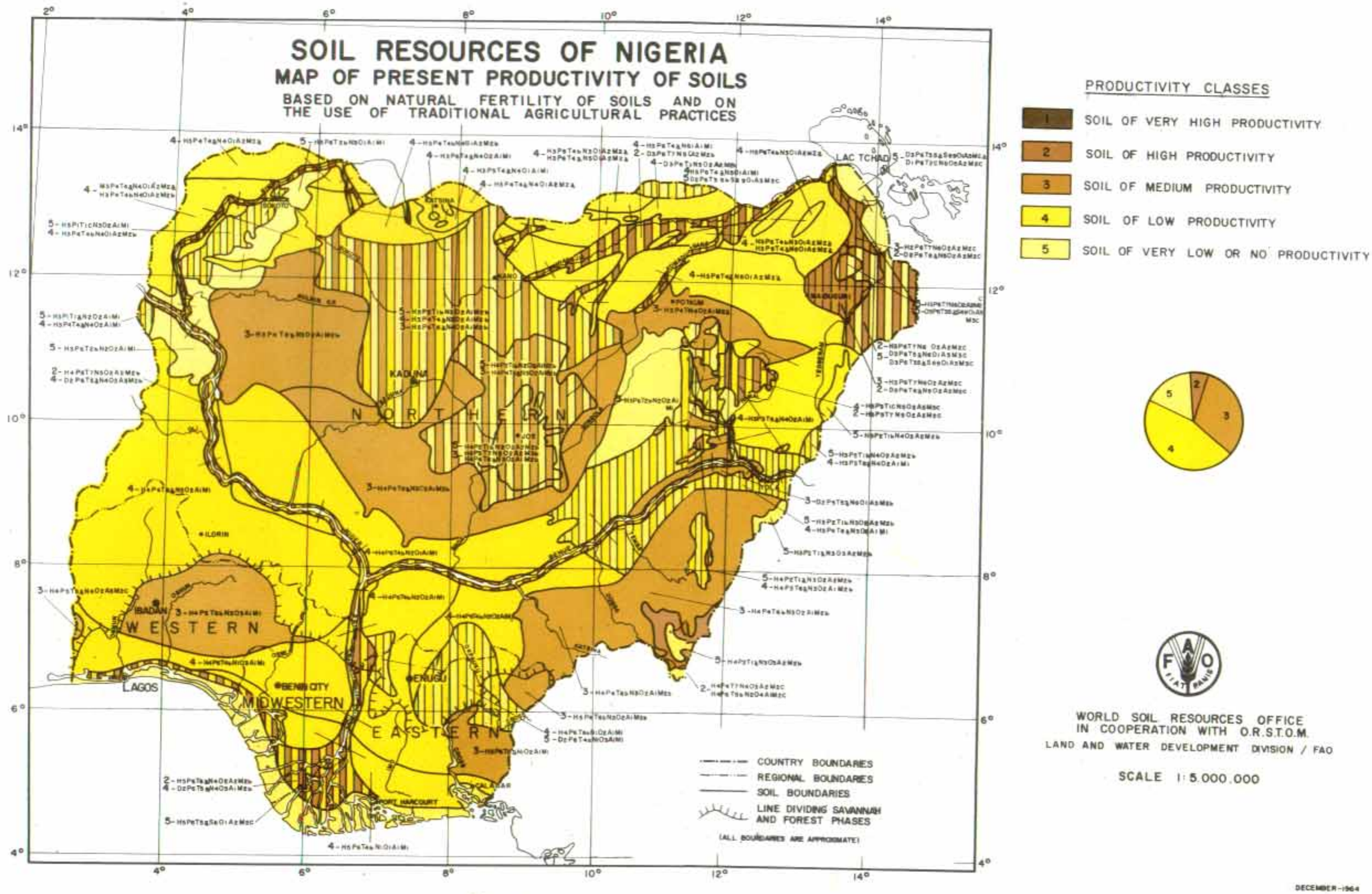
In accordance with the above, function (1) can now be rewritten as follows:

$$p = f\,(N, S, O, D, H, P_c, T_c, A_c, M_c) \qquad (3)$$

the parameters with an index *c* referring to constant soil properties while the others relate to properties that are capable of modification. If p_1 represents the future potentiality of the soils, then

$$p_1 = f\,(N_1, S_1, O_1, D_1, P_c, T_c, A_c, M_c) \qquad (4)$$

where $N_1 = N + \delta$ and $S_1 = S + \delta_1$, etc. δ, δ_1 etc. being the treatments needed for the correction of the respective soil limitations.



SOIL RESOURCES OF NIGERIA
MAP OF PRESENT PRODUCTIVITY OF SOILS
BASED ON NATURAL FERTILITY OF SOILS AND ON THE USE OF TRADITIONAL AGRICULTURAL PRACTICES
PRODUCTIVITY CLASSES
1 SOIL OF VERY HIGH PRODUCTIVITY
2 SOIL OF HIGH PRODUCTIVITY
3 SOIL OF MEDIUM PRODUCTIVITY
4 SOIL OF LOW PRODUCTIVITY
5 SOIL OF VERY LOW OR NO PRODUCTIVITY
LAC TCHAD
KANO
KADUNA
NORTHERN
JOS
ILORIN
IBADAN
WESTERN
LAGOS
BENIN CITY
MIDWESTERN
ENUGU
EASTERN
PORT HARCOURT
CALABAR
COUNTRY BOUNDARIES
REGIONAL BOUNDARIES
SOIL BOUNDARIES
LINE DIVIDING SAVANNAH AND FOREST PHASES
(ALL BOUNDARIES ARE APPROXIMATE)
WORLD SOIL RESOURCES OFFICE IN COOPERATION WITH O.R.S.T.O.M.
LAND AND WATER DEVELOPMENT DIVISION / FAO
SCALE 1: 5.000.000
DECEMBER-1964

Fig. 1

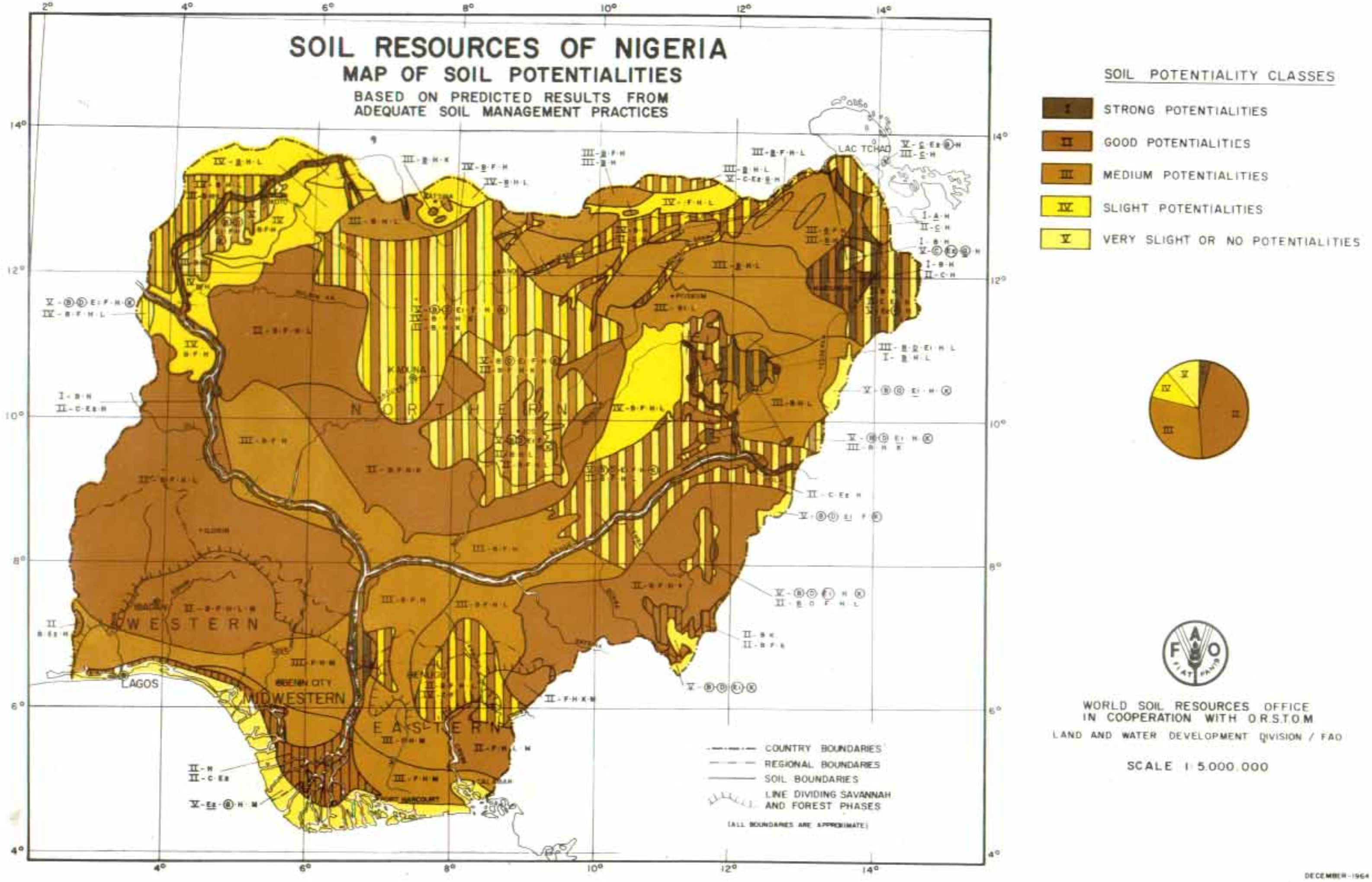

SOIL RESOURCES OF NIGERIA
MAP OF SOIL POTENTIALITIES
BASED ON PREDICTED RESULTS FROM
ADEQUATE SOIL MANAGEMENT PRACTICES
SOIL POTENTIALITY CLASSES
I STRONG POTENTIALITIES
II GOOD POTENTIALITIES
III MEDIUM POTENTIALITIES
IV SLIGHT POTENTIALITIES
V VERY SLIGHT OR NO POTENTIALITIES
NORTHERN
WESTERN
MIDWESTERN
EASTERN
LAGOS
LAC TCHAD
KADUNA
BENIN CITY
COUNTRY BOUNDARIES
REGIONAL BOUNDARIES
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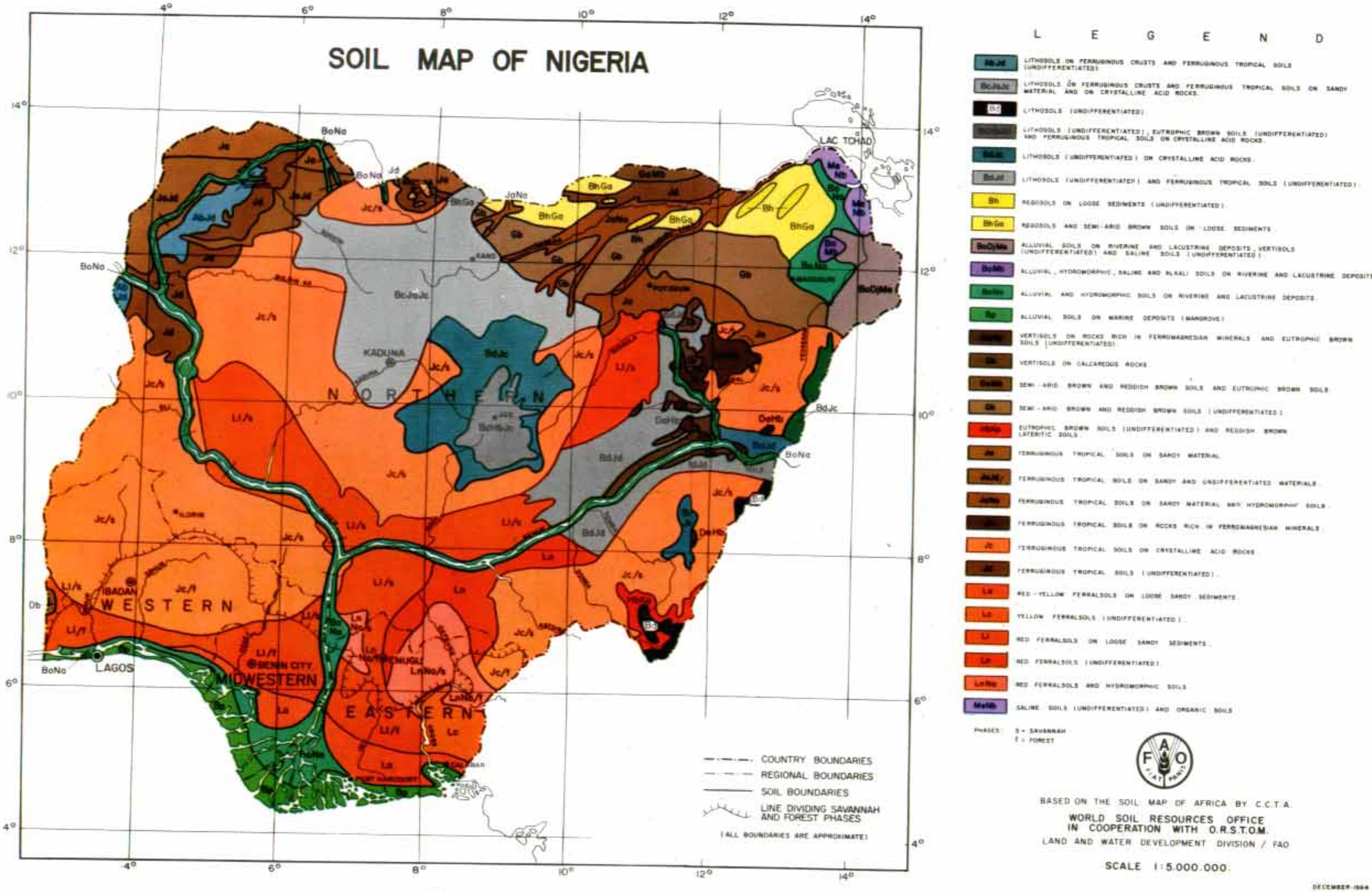
Fig. 2



SOIL MAP OF NIGERIA
LAC TCHAD
KADUNA
NORTHERN
WESTERN
MIDWESTERN
EASTERN
IBADAN
LAGOS
BENIN CITY
ENUGU
LEGEND
LITHOSOLS ON FERRUGINOUS CRUSTS AND FERRUGINOUS TROPICAL SOILS (UNDIFFERENTIATED)
LITHOSOLS ON FERRUGINOUS CRUSTS AND FERRUGINOUS TROPICAL SOILS ON SANDY MATERIAL AND ON CRYSTALLINE ACID ROCKS.
LITHOSOLS (UNDIFFERENTIATED)
LITHOSOLS (UNDIFFERENTIATED), EUTROPHIC BROWN SOILS (UNDIFFERENTIATED) AND FERRUGINOUS TROPICAL SOILS ON CRYSTALLINE ACID ROCKS.
LITHOSOLS (UNDIFFERENTIATED) ON CRYSTALLINE ACID ROCKS.
LITHOSOLS (UNDIFFERENTIATED) AND FERRUGINOUS TROPICAL SOILS (UNDIFFERENTIATED).
REGOSOLS ON LOOSE SEDIMENTS (UNDIFFERENTIATED).
REGOSOLS AND SEMI-ARID BROWN SOILS ON LOOSE SEDIMENTS.
ALLUVIAL SOILS ON RIVERINE AND LACUSTRINE DEPOSITS, VERTISOLS (UNDIFFERENTIATED) AND SALINE SOILS (UNDIFFERENTIATED)
ALLUVIAL, HYDROMORPHIC, SALINE AND ALKALI SOILS ON RIVERINE AND LACUSTRINE DEPOSITS.
ALLUVIAL AND HYDROMORPHIC SOILS ON RIVERINE AND LACUSTRINE DEPOSITS.
ALLUVIAL SOILS ON MARINE DEPOSITS (MANGROVE)
VERTISOLS ON ROCKS RICH IN FERROMAGNESIAN MINERALS AND EUTROPHIC BROWN SOILS (UNDIFFERENTIATED)
VERTISOLS ON CALCAREOUS ROCKS.
SEMI-ARID BROWN AND REDDISH BROWN SOILS AND EUTROPHIC BROWN SOILS
SEMI-ARID BROWN AND REDDISH BROWN SOILS (UNDIFFERENTIATED)
EUTROPHIC BROWN SOILS (UNDIFFERENTIATED) AND REDDISH BROWN LATERITIC SOILS.
FERRUGINOUS TROPICAL SOILS ON SANDY MATERIAL
FERRUGINOUS TROPICAL SOILS ON SANDY AND UNDIFFERENTIATED MATERIALS.
FERRUGINOUS TROPICAL SOILS ON SANDY MATERIAL AND HYDROMORPHIC SOILS.
FERRUGINOUS TROPICAL SOILS ON ROCKS RICH IN FERROMAGNESIAN MINERALS.
FERRUGINOUS TROPICAL SOILS ON CRYSTALLINE ACID ROCKS
FERRUGINOUS TROPICAL SOILS (UNDIFFERENTIATED).
RED-YELLOW FERRALSOLS ON LOOSE SANDY SEDIMENTS.
YELLOW FERRALSOLS (UNDIFFERENTIATED).
RED FERRALSOLS ON LOOSE SANDY SEDIMENTS.
RED FERRALSOLS (UNDIFFERENTIATED).
RED FERRALSOLS AND HYDROMORPHIC SOILS
SALINE SOILS (UNDIFFERENTIATED) AND ORGANIC SOILS
PHASES: S = SAVANNAH
f = FOREST
COUNTRY BOUNDARIES
REGIONAL BOUNDARIES
SOIL BOUNDARIES
LINE DIVIDING SAVANNAH AND FOREST PHASES
(ALL BOUNDARIES ARE APPROXIMATE)
BASED ON THE SOIL MAP OF AFRICA BY C.C.T.A.
WORLD SOIL RESOURCES OFFICE
IN COOPERATION WITH O.R.S.T.O.M.
LAND AND WATER DEVELOPMENT DIVISION / FAO
SCALE 1:5.000.000.
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Fig. 3

TABLE 3

Practices envisaged for the development of soil resources

A Irrigation essential and drainage usually necessary.

B Supplementary irrigation.

B_1 Supplementary irrigation by sprinkling.

B_2 Supplementary irrigation by flood or furrow irrigation.

C Elimination of excess water: reclamation, drainage or flood protection.

D Ridging, deep ploughing, breaking up of the crust.

E Improvement of structure and texture.

E_1 Stone removal.

E_2 Difficult and costly tillage, requiring special machinery.

E_3 Improvement of organic soils.

F Fertilizers including trace elements, and soil amendments.

G Reclamation of saline soils.

G_1 Irrigation and drainage.

G_2 Irrigation and drainage + application of gypsum.

H Improvement of organic matter content by manuring, fodder crops, mulching and rotations.

J Wind-erosion control measures.

K Intensive water-erosion control measures including benching and terracing.

L Light water-erosion control measures. Contour ploughing, strip cropping, etc.

M Large-scale land clearing.

NOTE: The letters from A to M correspond to the symbols used in the Map of Soil Potentialities.

TABLE 4

Incompatible management practices and characteristics

A and B_2 with P_{12}, $P_3 + T_{1247}$, $P_4 + T_{1a2}$, T_3

B_1 with P_1 and T_3

C with T_3 (C and T_3 are compatible if G_2 is used)

D with T_1

E_1 with T_{1a1b}

E_2 with T_3

F with Ao; however F + H is compatible with Ao

L with P_{12}, T_3, T_5

K with P_{123}, T_3, T_5

TABLE 5

Improvement of soil characteristics or properties by management

Management practices.	A	B_1B_2	C	D	E_1	E_2	E_3	F + H (with A_0)	F (with A_1 or A_2)	F (with A_3) (*)
Initial soil properties.	H_1H_2	H_3H_4	D_1D_2	P_1 P_2 P_3	T_{1bc}	T_{5a} T_{6a}	T_{2c}	N_1N_2	$N_1N_2N_3$	$N_1N_2N_3N_4$
Improved soil properties.	H_5	H_5	D_3	P_2 P_3 P_4	T of fine soil materials	T_{5b} T_{6b}	T of subsoil	N_3	N_4	N_5

Management practices	G_1	G_2	H		J	KL	M
Initial soil properties	S_3 S_4	S_9	O_1 O_2	O_5	H_1H_2 + $T_1T_2T_4$		
Improved soil properties	S_1 S_2	S_7	Add 10 % to final index	O_4 ($T_{2c} \rightarrow$ T of subsoil)	Add 10 % to final index	Add 20 % to final index (10 % if amendment H have already been made)	0 %

For G_1 and G_2: For T_6 and T_7 For T_2, improvement of 4 soil classes rated according to salinity. For T_5 improvemeot of a single soil class rated according to salinity.

(*) A_0, A_1, A_2 and A_3 refer to CEC data.

If a system of management is possible, then either (i) it improves one of the soil characteristics according to Table 5 — for example: drainage (C) changes (D_1) and (D_2) into (D_3) and the rating of this characteristic is then higher; or (ii) it increases all the characteristics ratings by perhaps 10 % to 20 % — for example: improvement of organic matter (H) increases soil structure and nutrient percentage, decreases erosion, etc.

The new potentiality Index is calculated by formula (3), but using the improved characteristics (N_x, S_x, O_x, D_x) according to Table 5. A Potentiality Map is thus prepared showing the soil potentialities under modern management practices.

Maps of soil productivity and soil potentiality for Nigeria are shown in fig. 2-3).

Coefficient of improvement

Since p (the present productivity of the soil) is a measure of the present level of development of the soil resources, while p_1 (the potentiality of the soil) is the measure of the capability of the fully developed soil resource, their ratio given by:

$$\frac{p_1}{p} = C$$

is here referred to as the «coefficient of soil resources development». This coefficient C permits an evaluation of the extent to which soil conditions can be improved, and gives an estimate of the expected magnitude of the improvement.

Summary

This experimental methodology has passed through several stages of approximation and is now giving satisfactory results both with small scale maps, and even more so, in detailed soil surveys. It consists, in its essence, in a systematic analysis and interpretation of those properties of individual soils, or the properties of the average soil types in a country, which are most important for crop production and land use. A productivity rating is calculated from the seven soil properties enumerated and also a potentiality rating, based on these properties as improved by management, according to deficient properties or environmental factors (relief, climate and so on).

Two kinds of interpretative maps, both derived from the soil maps, are normally produced: a map of a present soil productivity and a map of soil potentialities. The first indicates present soil conditions with their limitations to agricultural production; the second represents the potentialities of the soils when soil amendments and other normal technological advances have been introduced. The comparison of the two maps gives a «coefficient of improvement» showing soil areas that respond to treatment in

varying degrees. These interpretative studies have already begun to give some surprising results in the identification of areas where development effort should be concentrated

Bibliography

AANDAHL, A. R. 1958. Soil Survey Interpretation, theory and purpose. Soil Sci., of America Proceed. 22, 160-163.

ABLEITER, J. K. 1940. Productivity Ratings of Soil Type in «The Classification of Land», Missouri Agra. Expt. Sta. Bul., 421, p. 13-24.

AUBER, G. et FOURNIER. Les cartes d'utilisation des terres. Projet de légende, Sols Africains, vol. 3, no. 1.

BOWSER, W. E. and Moss. 1950. Soil rating and classification for irrigation, lands in Western Canada. Can. Jour. of Agric. Sci., 30, p. 165-171.

BRAMAO, D. LUIS. 1964. The role of soil resources and appraisal in the world's battle against hunger, Madrid, October.

CLARKE, G. R. 1950. Productivity Rating. Trans. IV Int. Congrès of Soil Science, vol. 1, p. 345.

CUTLER, E. J. B. 1962. Soil capability classification based on the genetic soil map. Trans. of Intern. Soil Conf. New Zealand, p. 743.

HOCKENSMITH, R. D. 1950. Classifying land according to its capabilities, Trans. IV Intern. Congr. Soil Sci., vol. 1, p. 342-345.

JACK, G. V. Land Classification. Imperial Bureau of Soil Science. Technical Communication, no. 43.

GLINGEBIEL, A. A. and MONTGOMERY, P. H. 1961. Land capability classification, U. S. D. A. Mandbook 210.

ODELL, R. T. 1950. Soil Survey Interpretation. Yield production. Soil Sci. Soc. America, Proc. 22, p. 157-160.

RIQUIER, J. 1954. Les cartes d'utilisation des sols à Madagascar. Conférence interafricaine des sols, Leopoldville, p. 1189.

SIMONSON, R. N. and ENGIEHORN, A. J .1938. Methods of estimating the productive capacities of soils. Soil Sci. Soc. Amer. Proc., 3, p. 247-252.

STORIE, R. E. 1937. An index for rating the agricultural values of soils. Berkeley, California, Bull. 556.

STORIE, R. E. 1944, 1948 and 1955. Revision of the soil rating chart. Univ. Calif. Agric. Exper. Sta. Berkeley, California.

VINK, A. P. A. 1963. Aspects de pédologie appliquée. A la baconnière. Neuchatel (Suisse).

UNITED STATES DEPARTMENT OF AGRICULTURE. Climate and Man, 1941. The Yearbook of Agriculture 1955, Soil Survey Manual Handbook no. 18, 1951. Govt. Print. Off. Washington, D. C.

UNITED STATES DEPARTMENT OF INTERIOR. Bureau of Reclamation Manual. Vol. V, part Land Classification Handbook. Gov. Print. Office, Washington, D. C.

MINISTRY OF FINANCES OF THE GERMAN DEMOCRATIC REPUBLIC. Soil appraisal and technics instructions to its calculation; Berlin.

FOOD AND AGRICULTURE ORGANIZATION. *Études agricoles*. No. 20. La prospection des sols en vue de la mise en valeur des terres, Progrès et mise en valeur. No. 18. Classification des terres aux fins du développement agricole.

——— N.º 2. First Meeting on Soil Survey, Correlation and Interpretation for Latin America, Rio de Janeiro, 28 May 1962. Troisième Session du groupe de travail pour la classification et la cartographie du sol, Athène (Grèce) 22-26 May 1961. No. 5. Quatrième Session du groupe de travail pour la classification et la cartographie des sols. Lisbonne (Portugal), 6-10 Mars, 1963.

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