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Research Article

Characteristics and Suitability of Mayo-Lemie Soils for Corn Production

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Abstract

A study conducted in the Mayo-Lemi é region of southwestern Chad aimed to determine the physicochemical characteristics and suitability of a soil for maize cultivation. A soil profile was established and described in the field, and soil samples were then collected from the different horizons. These samples were oven-dried for two weeks, crushed, labeled, and sent to the laboratory for routine analysis. The results of the analyses showed that all the samples analyzed ranged from slightly acidic to acidic with pH between 5.1 and 6.5; similarly, all exchangeable cations were poorly represented. The sum of exchangeable cation decreases with depth, as do the values of other nutrients. The results of the laboratory analyses were compared white the climatic data of the study area for evaluation according to the FAO. The climate assessment shows that the climate is very suitable for maize cultivation with an adjusted climate index of 88.03. It also appears from this study that the land unit concerned is marginally suitable for maize production with a parametric value of 31.82. The sandy texture remains the main limitation. To improve the situation, crop rotation is necessary, stubble should be returned to the fields after harvest, and mineral and organic fertilizers should be applied to improve the physical and chemical characteristics of the soil in order to increase yields.

Keywords

Cultivation Suitability, Corn, Texture, Fertilization

1. Introduction

Cultivation of soils leads to a rapid decline in soil fertility, while by 2030 the world population could increase by three billion people and food production will have to double [1]. High rates of population growth, combined with widespread poverty and poor land use, are accelerating land degradation [2, 3]. The loss of arable land is a fundamental problem for the future of humanity [4]. Declining soil fertility causes declines in agricultural production, which exacerbates food insecurity in sub-Saharan African countries [5-7]. The physical and socio-economic characteristics of arid and semi-arid areas make them highly vulnerable to climate change and degradation; yet the soils of arid and semi-arid

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areas constitute a significant portion of land reserves and ecological resources for the future [8, 9]. To better control the conditions of production and exploitation of soils, it is necessary to know their aptitudes [10]. The Sahel-Sudan region has already largely exceeded its carrying capacity based on traditional agricultural and livestock systems. Thus, when soils are degraded and no longer allow them to ensure functions such as agricultural production and water retention, users have no choice but to migrate to other more productive soils or to limit themselves to subsistence resources [11]. Crises and food shortages can also lead to conflicts resulting in migration [11]. The need to give priority to agricultural production remains essential because it is necessary to meet the growing needs of a constantly increasing population. The objective of this work is to seek to diversify crops by evaluating the suitability of soils for other more promising crops such as maize.

2. Methods and Materials

2.1. Study Area

The study area is located in South-Western Chad, in the middle of the sudano-Sahelian environment. It extends from 10 °31' to 11 °06' North and 15 °00' to 16 °30' East (Figure 1). The climate is characterized by a long dry season from October to May and a short rainy season, from June to September. The mean annual rainfall is about 652 mm and the average temperature is 28 °C. The main activities of the population are agriculture and animal breeding. Sorghum is the main crop. The geological formations are fluviolacustrine or fluvial, deposited during the various transgressive or regressive phases of the Chad Lake, from the beginning of the Quaternary era to present. The dominant soils are sandy tropical ferruginous soils, poor in organic matter. The vegetation consists of a shrub savannah dominated by Acacias and Balanites, depending on the type of soil, with a grassy carpet made up of Andropogonea.

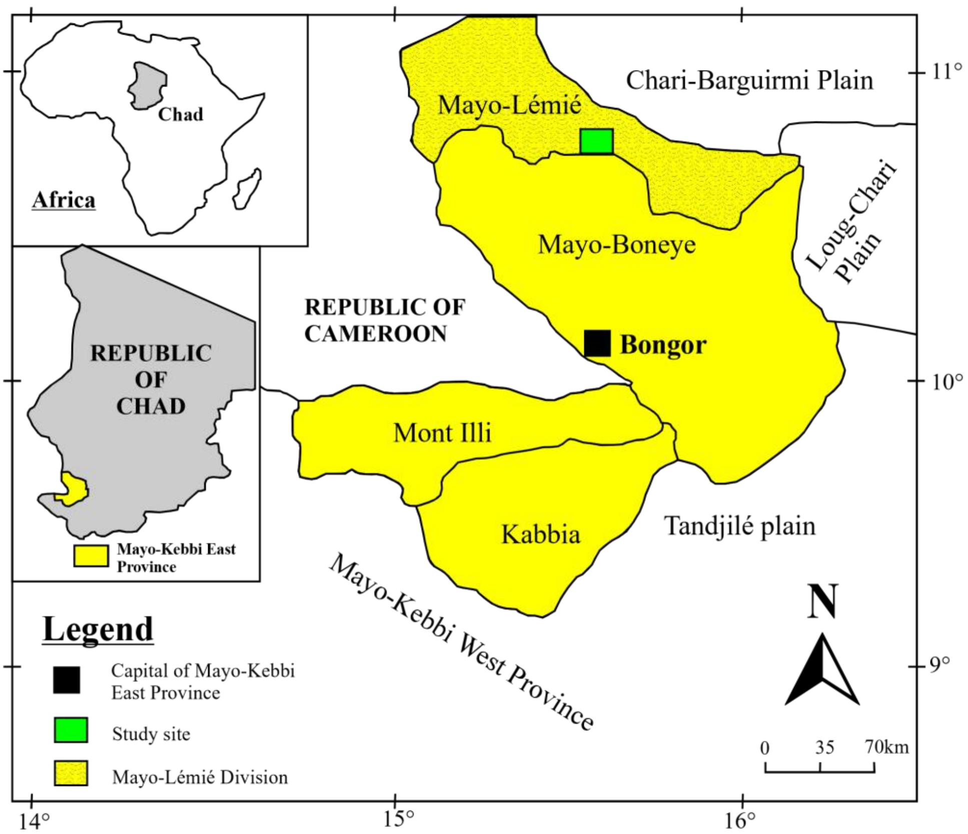

Figure 1. *Location of the Study Area.*

2.2. Methods

A soil profile was driven into a ferruginous soil. The profile was described according to [12]; the description concerned the thickness and limit of the horizons, the color, texture, structure, consistency, porosity, etc. A soil sample was taken from the middle of each horizon to be sent to the laboratory for physicochemical analyses. In addition, climatic data of about thirty years were taken to allow the climatic assessment.

Based on the information on the study site, soil suitability was determined for rainfed maize cultivation. The FAO approach for rainfed agriculture was used as described by Sys [13]. Six suitability classes are used:

1. S1-0: Very high ability, no limitations;
2. S1-1: High ability, slight limitations;
3. S2: Average ability, moderate limitations;
4. S3: Marginal ability, severe limitations;
5. N1: Current inability, very severe but correctable limitations;
6. N2: Permanent inability, very severe limitations that cannot be corrected with the current level of knowledge.

To determine the suitability classes, the three methods for determining land suitability levels were used according to the FAO approach; these are obviously the lowest class method, the method of the number and degree of limitations and then the parametric method.

3. Results

3.1. Morphological Organization of the Profile

The profile named G1 has a thickness of approximately 260 cm. It is located at an altitude of approximately 313 m at 10°54'631" N and 15°33'132" E. It presents from top to bottom the succession of the following horizons (Figure 2):

0 - 19 cm. Reddish-yellow horizon (7.5YR7/8) when dry, sandy texture, very weakly expressed polyhedral structure; friable and fragile when dry and non-plastic when wet; presence of numerous roots and rootlets; significant biological porosity, very strong matrix porosity. The limit is progressive and regular;

19 - 124 cm. Red-colored horizon (10YR5/8) when dry. Sub-blunted polyhedral structure, sandy-clayey texture, friable when dry and non-plastic when wet. Presence of millimetric roots and rootlets, low biological porosity, high matrix porosity; the transition with the lower horizon is gradual and regular;

124 - 190 cm. Yellowish-red horizon (5YR, 5/8) when dry; weakly expressed polyhedral structure; sandy-clayey texture, friable when dry and non-plastic when wet. Presence of tiny roots; extremely low biological porosity; high matrix porosity; presence of ferruginous elements (about 5%) of millimetric size; progressive and regular limit;

190 - 200 cm. Yellowish-red horizon (7.5YR, 8/6) when dry; essentially sandy; particulate structure; absence of roots and rootlets.

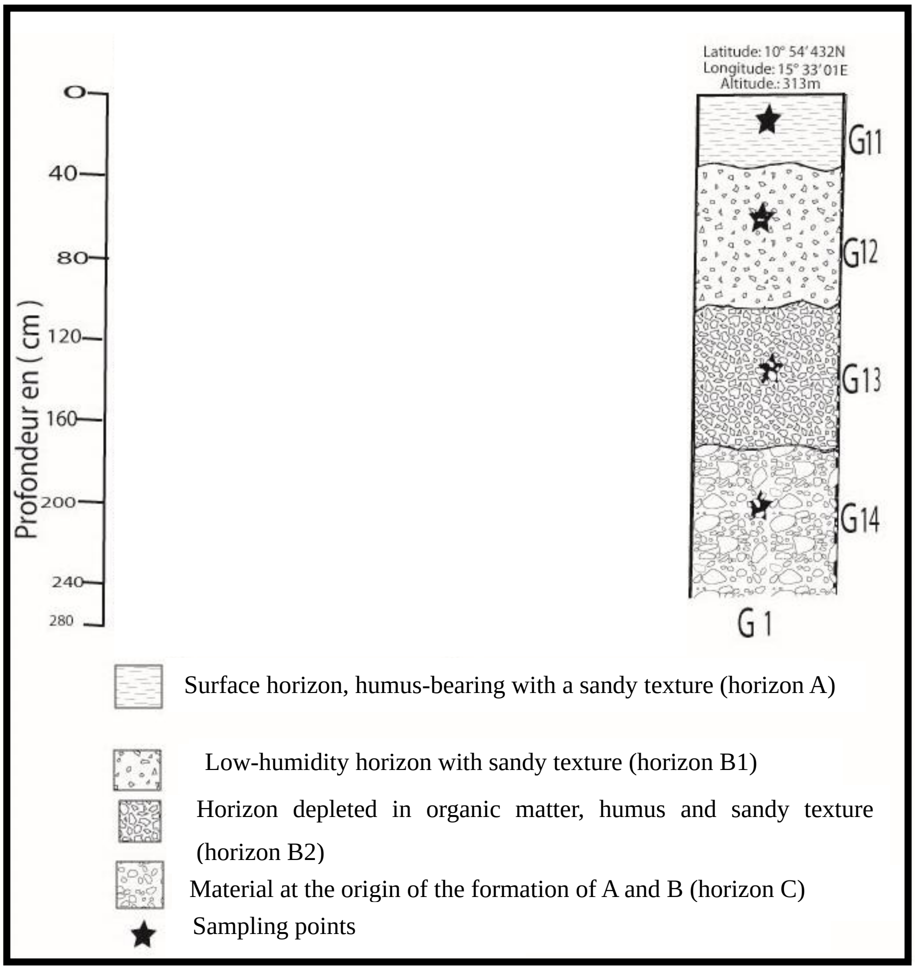

Figure 2. Morphological Organization of the Profile.

3.2. Physicochemical Characterizations of the G1 Profile

The results of the physicochemical analyses of the soil samples in profile G1 are reported in Table 1; they clearly show that the sandy fraction is the most quantitatively important granulometric fraction followed by the clay fraction and then the silt fraction. Its contents vary from 72.5 to 88.00% with an average of 78.16% and a standard deviation of 5.68. In the first horizon (0-19 cm), a content of 84.5% is observed. Between 19-124 cm, the content decreases to 77.5%; it is 72.5% between 124 and 190 cm; it rises to reach a maximum value beyond 190 cm which represents the last horizon (88%). The clay fraction varies from 10.5 to 21.5% with an average of 16.66% and a standard deviation of 6.02. The increase in clay content is regular from top to bottom up to a depth of 190 cm (21.5%) before decreasing to 10% at the base of the profile. Silt varies from 2 to 6%; an average content of 5% and a standard deviation of 1.00 are obtained. In the four horizons of the profile, the contents are respectively 5%; 4%, 6% and 2%. Grain size analysis of all samples shows that textures vary from sandy to sandy-clayey. All soil samples analyzed were found to be acidic to weakly acidic with pH values ranging from 5.1 to 6.5. Values are higher in the surface horizons and decrease with increasing depth. pHkcl ranges from 4.1 to 5.6 in all horizons. In each horizon, the pHkcl value is lower than the pHwater. The pH variation ($\Delta pH = pH\ KCL - pH\ H_2O$) is negative throughout the profile. All exchangeable cations are poorly represented. Calcium contents range from 1.32 to 2.64 meq/100g. The highest content is observed at the surface with an average of 2.09 meq/100g. The sodium content does not vary along the profile; it is 0.32 meq/100g. The sum of exchangeable bases varies slightly along the profile (2.64 to 4.32 meq/100g); an average of 3.79 meq/100g is obtained. Surface horizons have higher sums of exchangeable bases than deep horizons. Cation exchange capacities vary from 11.64 to 21.66; unlike some of the elements mentioned above, the highest value is observed from 19-124 cm depth. Magnesium contents range from 0.9 to 1.36 along the profile. Organic carbon contents range from 1.08 to 2.13%. The highest content is observed in the surface horizon. This value decreases progressively with depth. Nitrogen is found in very small quantities in all horizons of the profile. A decrease in its content is also observed with depth (0.37-0.22). The C/N ratio has values ranging from 4.67 to 6.06. The available phosphorus does not vary throughout the profile with a fixed value of 0.5 ppm.

Table 1. *Physicochemical Characteristics of Profile G1.*

Depth (cm)	0- 19	19-124	124-190	190-200	Min	Max	Average	Standard deviation
Texture (%)								
Clay	10,5	18,5	21,5	10,00	10,5	21,5	16,66	6,028
Total silt	5,0	4,0	6,0	02,00	2,0	6,00	5,00	1,000
Sand	84,5	77,5	72,5	88,00	72,5	88,0	80,62	5,686
Textural class	S	SA	SA	S				
Organic carbon (%)	2,13	2,00	1,45	1,08	1,08	2,13	1,80	0,361
Organic matter (%)	3,66	3,44	2,49	1,85	1,85	3,66	3,19	0,622
Total nitrogen (%)	0,37	0,33	0,31	0,22	0,22	0,37	0,30	0,078
C/N	5,75	6,06	4,67	4,90	4,67	6,06	6,13	0,425
pH_{H2O} (1/2,5)	6,5	5,7	5,10	5,10	5,10	6,50	5,76	0,702
pH_{KCl} (1/2,5)	5,6	4,4	4,10	4,20	4,10	5,60	4,70	0,794
P Bray II (ppm)	0,5	0,5	0,50	0,50	0,50	0,50	0,50	0,00
Exchangeable bases (meq/100 g of soil)								
K+	0,31	0,30	0,12	0,01	0,01	0,31	2,43	0,107
Na+	0,32	0,32	0,32	0,32	0,32	0,32	0,32	0,00
Ca++	2,64	2,00	1,64	1,32	1,32	2,64	2,09	0,506
Mg++	1,04	1,08	1,36	0,90	0,90	1,36	1,16	0,174
Sum of exchangeable bases	4,32	3,62	3,44	2,64	2,64	4,32	3,79	0,960

Depth (cm)	0- 19	19-124	124-190	190-200	Min	Max	Average	Standard deviation
Base saturation	37,11	16,71	25,59	20,88	16,74	37,11	25,07	0,465
CEC7 (meq/100g of soil)	11,64	21,66	13,44	12,64	11,64	21,66	15,58	5,342
CEC (meq/100g of clay)	110,85	117,08	159,97	126,4	117,1	159,9	138,5	21,88
EC (ms/cm)	0,016	0,01	0,01	0,02	0,01	0,02	0,015	0,004
ESP (%)	2,71	1,47	2,38	2,53	1,47	2,71	2,09	0,00

3.3. Evaluation of Cultivation Suitability

3.3.1. Climatic Evaluation of Maize

The climate assessment of maize cultivation shown in Table 2 shows that the climate is very suitable for maize cultivation with an adjusted climate index of 88.03. This value is obtained thanks to the various parameters which are generally favorable for maize cultivation. The rainfall during the growth cycle being 677 mm occupies the S1 class. It does not represent a limitation. The obtained parameter value is 98.7. The precipitation collected in the first month of the growth cycle and that received in the third month of the cycle have very high values and are therefore not constraints for corn production. The average temperature during the growth cycle gives the smallest parameter value in the table, but the minimum temperatures give an acceptable parameter value (94.75). Relative humidity and other parameters have very high parameter values. The calculated climate index (Table 2) is 88.03; the climate is therefore very suitable for growing maize.

Table 2. *Climate Assessment of Corn.*

Features	Values	Classes	Limitations	Parametric values
Groupe I: Precipitation				
Growth cycle precipitation (mm)	677	S1-1	0	98,7
1st month precipitation of the growth cycle (mm)	127	S1	0	99,8
3rd month precipitation of the growth cycle (mm)	221,6	S1-1	1	94
Groupe II: Temperature				
Average temperature of the growth cycle (℃)	27,5	S1	1	87,5
Minimum temperature during the growth cycle (℃)	21,9	S1-0	1	94,75
Relative humidity during the 2nd month	78	S1-1	1	98,8
Relative humidity of the 4th month (%)	61	S1-1	1	89,4
n/N of the cycle during the cycle	0,68	S1	0	100
Calculated Parameter Value (CR)		S1		88,03

3.3.2. Determination of the Suitability of Soil G1 for Growing Maize

The pedoclimatic assessment of profile G1 for maize cultivation is reported in Table 3. It appears from this table that soil G1 is marginally suitable for maize cultivation. The soil index gives a parametric value of 31.82. The class corresponding to this parametric value is S3.s. From the table summarizing the assessment made (Table 3), it appears that the texture and structure constitute moderate limitations (parametric value 40, class S3). Base saturation is a parameter that constitutes a slight limitation (class S2, parameter value 67.29). Apart from the two parameters that constitute limitations, the other parameters are optimal for corn cultivation.

Table 3. *Determination of the Suitability of G1 Soil for Growing Corn.*

Features	Values	Classes	Limitations	Parametric values
Topography (t)				
Slope (%)	1	S1-1	0	95
Humidity (w)				
Flood	zero	S1-0	0	100
Drainage	Good	S1-0	0	100
Physical characteristics of the soil (s)				
Texture/structure	S	S3	3	40
Soil depth (cm)	> 90	S1-0	0	100
Rough fragment (0-1 m) (%)	-	S1-0	0	100
$CaCO_3$ (%)	0	S1-0	0	100
Gypse (%)	0	S1-0	0	100
Soil fertility (f)				
Apparent CEC of clay (meq /100 g of clay)	125,41	S1-0	0	100
Base saturation (%)	32,15	S2	2	67,29
Organic carbon (0-15 cm) (%)	2,20	S1-0	0	100
pH- H_2O (0-15 cm)	6,3	S1-0	0	100
Salinity and sodicity (n)				
ESP (%)	2,71	S1-0	0	100
Calculated Earth Index (Is)		S3.s		31,82

4. Discussion

All samples were characterized by low nutrient levels. The low OM levels observed during the analysis of soil samples could be due to the continuous cultivation of fields and the burning of crop residues as mentioned [14]; it could also be the result of rapid mineralization of biomass under the effect of climatic, chemical and physical factors of the soil [15-17]. Indeed, the importance of organic matter lies in the fact that it releases adsorbed mineral elements and stores nutrients which constitute the source of food for plants. It also plays a physical role in the soil for cohesion, structure, porosity, retention or storage of water, etc. [18]. It also plays a biological role in stimulating biological activity [16]. Thus, it is a potential indicator of the sustainability of cropping systems since it plays an important role in many edaphic properties that partly determine plant production and soil and water conservation [19, 17]. The very low levels of nitrogen, phosphorus and other nutrients are explained by the low level of organic matter [20, 21]. In addition, the type of vegetation and the competition between agriculture and livestock farming accentuate the nutrient deficiency [22, 23]. Soil acidity is characteristic of ferruginous soils [24]; it is correlated with low base saturation as shown by the work of [9]. pH and organic matter levels decrease with depth as listed by [25, 26]. The decrease in pH and CEC in deep horizons could be explained by the fact that calcium, which is leached or absorbed by plants, is gradually replaced by H+ ions at depth (Sébastien et al., 2008). This decreases in CEC at depth reveals the importance of organic matter in exchange properties. The pHKCl - pHH_2O difference is negative; this result shows the predominance of the negative charge in soils and demonstrates that these soils are well cultivable [27]. The obtained clay CECs are very high (Table 2); These obtained values correspond to the 2:1 type mineral which are often found in low rainfall environments where leaching is not very advanced [28, 29]. The low potassium content can also be attributed to the sandy texture because a soil with low clay and silt content has a reduced capacity to retain potassium. Similarly, phosphorus deficiency in the soil is explained by the fact that its fixation on the clay-humic complex depends on the percentage of organic matter, the percentage of clay, pH and calcium [30]. In semi-arid and sub-humid regions of Africa, phosphorus deficiency in soils is considered one of the major biophysical constraints to agricultural production [31, 32]. The soil is marginally suitable for growing maize; the soil index gives a parametric value of 31.82. This class corresponding to the parametric value is S3.s. Crops under plant cover, direct seeding, inputs of organic matter to the soil and agroecology can be used to improve the fertility of this soil [21, 33]. They have the advantage of increasing the quantity of organic matter and stopping soil erosion. For [34], monoculture is one of the causes of the decline in agricultural productivity; thus, for many authors, [21, 35] fallow land can be mentioned to compensate for the production which is only decreasing because they promote the production of OM which has the advantage of raising the level of soil fertility on the one hand and limiting its erosion on the other hand.

Abbreviations

FAO	Food And Agricultural Organization of the United Nations
CEC	Cation Exchange Capacity

Conflicts of Interest

The authors declare no conflicts of interest.

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