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Soil Characterization and Land Suitability Evaluation for Egusi Melon (*Citrullus mucosospermus*) Cultivation in Bafia, Centre Region of Cameroon

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Abstract

Enhancing the value of indigenous food crops such as Egusi melon, which is considered a "lost crop" in many places around the globe, can significantly contribute to food security of millions of people who depend on agriculture for their livelihood. One of the limitations to optimal production of Egusi melon is the lack of soil and climate information for sustainable crop management. Soils of the Bafia district were characterised and classified in order to assess their suitability for growing Egusi melon. Seven sites, representative of the study area, were identified based on previous studies in the study area. Land evaluation was done using a parametric method. The soils belong to three reference soil groups; Ferralsols, Acrisols and Cambisols. The climate of the area is moderately suitable, with the main limitation being relative humidity. However, 42.9%, 28.57%, 85.71% and 14.29% of the land in the study area is limited by soil physical characteristics (t), topography (t), fertility characteristics (f) and moisture (w), respectively. More specifically, these limitations are related to slope, soil texture, pH, flooding and base saturation. Also, 28.6% of this land is currently unsuitable and potentially suitable (N1), while 71.3% is marginally suitable (S3). Based on this assessment, it is highly recommended to employ appropriate management practices that can improve the physical, chemical and biological properties of the soils.

Keywords

Bafia District, Climatic Index, Egusi, Fertility, Land Evaluation, Suitability Class, Soil Index

1. Introduction

The loss of value of traditional indigenous food crops and their decline in production are becoming increasingly recurrent. The cultivation of these crops would contribute to the food security of millions of people who depend on agriculture for their livelihoods [1]. Egusi melon (*Citrullus mucosospermus*) is a seed vegetable widely grown in the tropics [2]. Although this crop has been classified as an "under-utilised or lost crop" of African origin [3], it is however commercialized in some African countries (e.g. Benin, Cameroon, Ghana, Nigeria, Togo, Namibia, Sudan, etc.), Europe (England, Scotland, Ireland, France, etc.), the United States and Asia (Japan and China), where it is sold as whole seeds or ground [4]. The seeds contain about 50% oil, which is comparable to other oilseed crops [5]. It contains about 29.23% proteins, 56.67% lipids and 9.87% carbohydrates [6]. The nutrient value of Egusi melon thus makes it an interesting oilseed beyond the borders of Africa, where it is mainly grown for consumption and export [7]. In the past few years, a considerable decline in Egusi melon seed yields has been observed in Cameroon. Yields dropped from 414.41 Kg/ha in 2015 to 373.08 Kg/ha in 2019 [8]. In order to ensure sustainable agricultural development and production of this crop, robust and efficient farmland management is needed [9]. The increasing population and food demand in Cameroon exert significant pressure on land resources, particularly affecting the cultivation of Egusi melon. Land evaluation and soil characterization are crucial for growing Egusi melon as they directly influence crop yield and quality. They guide sustainable agricultural practices by identifying suitable areas for cultivation, thereby minimizing land degradation and promoting environmental conservation [10]. Studies have shown that Egusi melon thrives best in fertile, well-drained soils with adequate organic matter and nutrients, particularly nitrogen and phosphorus [11]. Soil pH, Texture, and moisture retention also significantly affect growth, sandy loam soils are preferred due to their drainage properties [11]. Understanding land characteristics aids in adapting cultivation practices to changing climatic conditions, ensuring resilience against potential crops failures [12]. Furthermore, the most productive lands for Egusi melon helps in optimizing fertilizer applications and can enhance their economic returns, contributing to food security and local economics [13]. Land suitability analysis (LSA) is one of the key processes in land use planning [14] and is a prerequisite for achieving optimal use of available land resources [15].

The objective of this study was to assess land suitability for rain-fed Egusi melon cultivation in Cameroon for better sustainable land use and management.

2. Materials and Methods

2.1. Description of the Study Area

The study area is located in the Centre Region of Cameroon, precisely in the Bafia district, between latitudes 4˚40' and 4˚48' North, and longitudes 11˚2' and 11˚8' East (**Figure 1**). Bafia district covers an area of about 1300 km^2. The area is located on the southern Cameroonian plateau with an average altitude of 700 m and elevations that can reach 900 m. The climate is the humid sub-equatorial type, with four seasons (a short rainy season, a short dry season, a long rainy season and a long dry season). Average annual rainfall varies between 1400 mm and 1600 mm. Average temperatures vary between 23˚C and 25˚C. Average Relative humidity is 87%. The vegetation in the area is dominated by gallery forest and shrub savannah. It is fairly well watered by rivers and many marshes, including the Mbam river, Sanaga river, Inoubou and Noun [16]. The soils are sesquioxidic, with acrisols and ferralsols dominating on acid rocks found in the forests and indurated ferralitic soils characterised by iron nodules found in the savannah and in some forests. These soils have metamorphic rocks as dominant parent material (gneiss, orthogneiss, mica schists), belonging to the geological group of Yaoundé [17] [18].

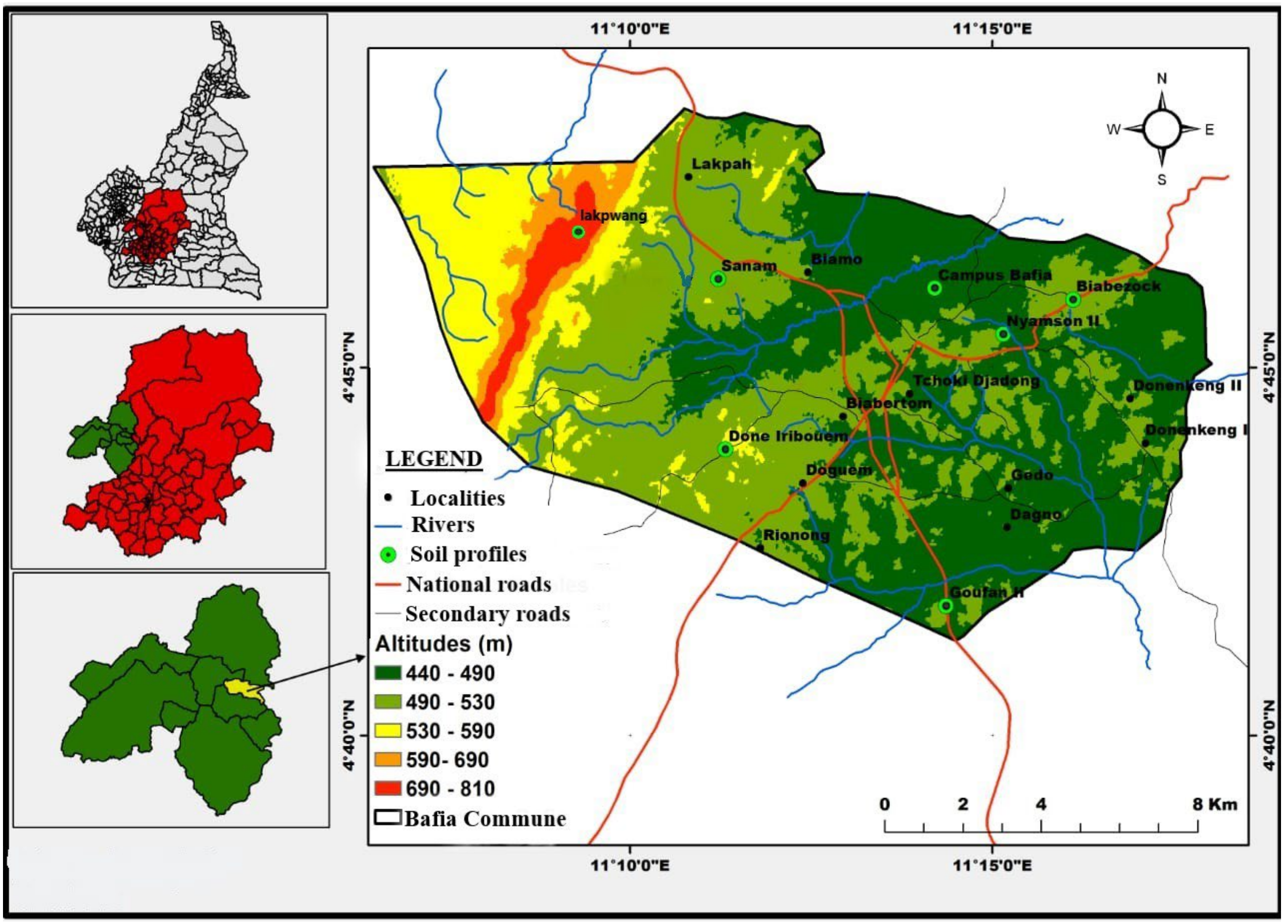

Figure 1. Location of study area showing the sampling sites (soil profiles).

2.2. Field Methods (Soil Description and Sampling)

Seven sites (**Table 1**), representative of the study area, and based on previous survey studies by ORSTOM [19], were identified. The seven sites were selected based on geomorphological features, soil forming factors, and pedogenic processes as depicted in previous studies by ORSTOM in the study area [19]. For each of the sites, a soil profile was realised under natural vegetation and described according to the FAO soil description guidelines [20]. Soil samples were collected following diagnostic horizons, and stored in polythene bags prior to laboratory analyses. Undisturbed samples for bulk density determination were collected using Kopecky rings of 100 cm^3.

Table 1. Geographical coordinates of the various sites.

Sites	Latitude	Longitude	Elevation (m)
LAKPWANG	4˚45.995'N	11˚09.85'E	544
SANAM	4˚46.200'N	11˚11.220'E	519
NYAMSON 2	4˚45.449'N	11˚15.152'E	462
BIABEZOCK	4˚45.920'N	11˚16.114'E	526
DONE IRIBOUEM	4˚43.887'N	11˚11.319'E	536
GOUFAN 2	4˚41.762'N	11˚14.362'E	498
CAMPUS AREA	4˚46.075'N	11˚14.205'E	482

2.3. Laboratory Analysis

Chemical properties were determined according to the procedures described by Pauwels *et al.* [21]. Soil OC content was determined by the Walkley and Black method, while bulk density was determined as the oven dry mass (105˚C) of each undisturbed core sample by volume. Soil pH was determined using 1:2 soil-H_2O and 1:2 soil-KCl ratios for pH_{water} and pH_{KCl}, respectively. Total nitrogen and available phosphorus (P) were determined by the Kjeldahl wet digestion method and the Bray II method, respectively. Exchangeable base cations were determined by the Schollenberger's method using a 1M ammonium acetate solution buffered at pH 7. The concentrations of exchangeable sodium (Na^+) and potassium (K^+) in the solution extract were obtained by flame photometry, while those of calcium (Ca^{2+}) and magnesium (Mg^{2+}) were obtained by complexometry using a 0.002M Na_2-EDTA solution. The cation exchange capacity (CEC) was determined by direct continuation of the Schollenberger's method using a 1N KCl solution for the displacement of ammonium ions. The hydrometer method was used for particle size analysis according to the procedures described by Bouyoucos [22] after soil dispersion with a 1N sodium hexametaphosphate solution.

2.4. Determination of Growing Period and Humid Periods

After obtaining daily rainfall for the study area for the past 30 years, the average monthly rainfall over a 30-year period was determined. Potential evapotranspiration (PET) was estimated using the FAO Penman-Monteith method [23] [24] defined by Equation (1).

$$\mathrm{ETo} = \frac{0.408\Delta(\mathrm{Rn} - \mathrm{G}) + \gamma \dfrac{900}{\mathrm{T} + 273} \mathrm{U2}(\mathrm{es\text{-}ea})}{\Delta + \gamma(1 + 0.34\mathrm{U2})} \quad (1)$$

where:

ETo = Reference evapotranspiration ($mm \cdot day^{-1}$),

Rn = net radiation at the crop surface ($MJ \cdot m^{-2} \cdot day^{-1}$),

G: soil heat flux density (G = 0 because it is assumed that there is a balance between heat loss during the day and night, $MJ \cdot m^{-2} \cdot day^{-1}$),

T: Mean daily air temperature at 2 m height (˚C),

U2: wind speed at 2 m height ($m \cdot s^{-1}$),

γ: psychrometric constant ($KPa \cdot {}^{\circ}C^{-1}$),

es: saturated vapour pressure (KPa),

ea: actual vapour pressure (mbar),

es-ea: saturation vapour pressure deficit (kPa),

Δ: slope of saturation vapour pressure curve ($kPa \cdot {}^{\circ}C^{-1}$).

The potential evapotranspiration determined enable the obtention of the climatic diagram (**Figure 2**) in the study area. Based on the climatic diagram, the humid period begins in early March and ends around mid November, while the growing period starts around the end of the month of March and ends around the end of the month of November.

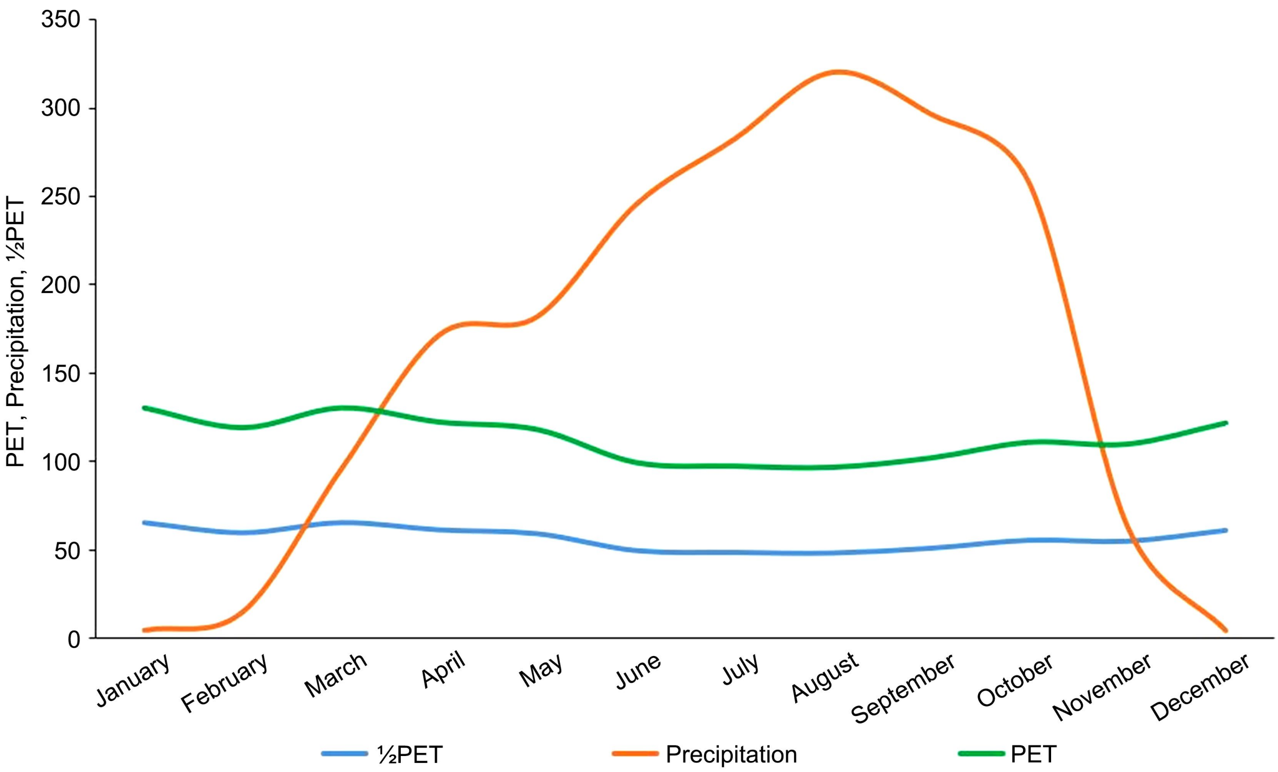

Figure 2. Climatic diagram of study area showing the humid and growing periods.

2.5. Land Use, Crop Requirements and Assessment of Land Suitability

The land use envisaged is rain-fed cultivation of Egusi melon by smallholders. The suitability of the land was assessed using land evaluation tables proposed by Sys *et* *al.* [25] for the needs of watermelon, which belongs to the same family (*Cucurbitaceae*) and genus (*Citrullus*) as Egusi melon, given that the specific needs of Egusi melon are unavailable. A parametric method [25] [26] was used to classify soil suitability into four categories: highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N) (**Table 2**). In this parametric method (Equation (2)), the soil and climate characteristics are defined using different scores [25]

$$I = A \times \sqrt{\frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \cdots \frac{Z}{100}} \tag{2}$$

where I is the specified index and A, B, C, D, E, etc. are the different scores assigned to each parameter making up the crop requirements, with A corresponding to the lowest score. The climatic characteristics are corrected as follows:

$$\text{if CI} < 25, \text{ then CCI} = 1.6\text{xCI}; \tag{3}$$

$$\text{if } 25 < \text{CI} < 92.5, \text{ then CCI} = 16.67 + 0.9\text{xCI}; \tag{4}$$

where, CI = climatic index and CCI = corrected climatic index.

If the climatic value is less than 25, for example, the correction is done using Equation (3). If the value is between 25 and 92.5, correction is done using Equation (4). If the value is 92.5, no correction is required. Land indices, on the other hand, are obtained based on Equation (2), and are corrected using **Table 3** [27]. The values obtained after correction are used to determine a soil's capability. These corrections increase the accuracy of evaluation indices and better reflect soil and environmental conditions. The climatic characteristics considered in this study are rainfall, temperature and relative humidity, while the soil characteristics are topography (slope), moisture (flooding and drainage), soil physical characteristics (texture, percentage of volume of gravel content and soil depth), soil fertility characteristics (CEC, base saturation, organic carbon content, soil reaction), salinity (electrical conductivity) and alkalinity (exchangeable sodium percent).

Table 2. Qualitative land suitability classes for the different land indices.

Land index	Definition	Symbol
90 - 100	Very suitable without limitation	S1-0
85 - 90	Very well suited with slight limitations	S1-0/1
75 - 85	Very well suited with slight limitations	S1-1
60 - 75	Very able to moderately able	S1-1/S2
50 - 60	Moderately able	S2
40 - 50	Moderately to marginally fit	S2/S3
25 - 40	Marginally fit	S3
15 - 25	Marginally fit to unfit	S3/N
0 - 15	Unfit	N

Table 3. Classification of critical fertility levels in soils for organic carbon (OC), total nitrogen (N), available phosphorous (P), cation exchange capacity (CEC), base saturation (BS), exchangeable base cations and soil reaction.

Soil properties	Critical fertility level					
	Very low		Low	Medium	High	Very high
OC (%)	<0.4		0.4 - 1.0	1.0 - 1.8	1.8 - 3.0	>3.0
Total N (%)	<0.05		0.05 - 0.125	0.125 - 0.225	0.225 - 0.30	>0.30
CEC (cmol(+)·kg^{-1})	<6		6 - 12	12 - 25	25 - 40	>40
BS (%)	0 - 20		21 - 40	41 - 60	61 - 80	81 - 100
Ca^{2+} (cmol(+)·kg^{-1})	<2		2 - 5	5 - 10	10 - 20	>20
Mg^{2+} (cmol(+)·kg^{-1})	<0.5		0.5 - 1.5	1.5 - 3.0	3.0 - 8.0	>8.0
K^{+} (cmol(+)·kg^{-1})	<0.1		0.1 - 0.3	0.3 - 0.6	0.6 - 1.2	>1.2
Na^{2+} (cmol(+)·kg^{-1})	<0.1		0.1 - 0.3	0.3 - 0.7	0.7 - 2.0	>2.0
P (mg·kg^{-1})	<7		7 - 16	16 - 46	>46	-
			Good	Medium	Bad	Very poor
C/N			<10	10 - 14	14 - 20	>20
	Very acidic	Acidic	Moderately acidic	Slightly acidic	Moderately alkaline	Alkaline
pH_{water}	<4	4.0 - 5.3	5.3 - 6.0	6.0 - 7.0	7.0 - 8.5	>8.5
	Non - saline		Slightly saline	Moderately saline	Very saline	Extremely saline
EC (dS·m^{-1})	<2		2 - 4	4 - 8	8 - 16	>16

By determining the land index and using the guidelines defined by Sys *et al.* [28], the qualitative land suitability classes (Table 2) and the factors limiting plant growth in the different soil series for the crop were determined. Critical values for nutrients and soil fertility parameters are presented in Table 4 [29]-[31].

Table 4. Corrected land index values according to class.

Ability class	Land index (LI)	Corrected land index (CLI)
S1	75	75 + 0.625 (LI-60)
S2	50 - 75	50 + 0.410 (LI-24)
S3	25 - 50	25 + 0.455 (LI-5)
N1	15 - 25	LI
N2	0 - 15	LI

2.6. Statistical Analysis

Descriptive statistics (mean values, standard error of means, and coefficient of variation) was performed on soil properties. Coefficient of variation (CV %) was used to examine the variability of soil properties and was calculated using Equation (5);

$$CV(\%) = \frac{SD}{X} \times 100 \quad (5)$$

where; SD = standard deviation, x = arithmetic mean of soil property.

Soil properties having CV values < 15% were grouped as least variable, those with CV values between 15% and 35% were grouped as moderately variable and those with CV > 35% indicated high variability [32]. Statistical analysis was facilitated using Microsoft Excel 2016 and SPSS (Version 20).

3. Results and Discussion

3.1. Morphological and Physical Properties

The morphological and physical characteristics of the studied soils are presented in Table 5. The soils of profiles 1 and 2 are dominantly reddish, slightly red at the surface and yellowish red in the subsurface horizons of profile 2. Profile 3 is dominantly greyish, while profiles 4 and 6 are brown at the surface and red in the lower horizons. Profile 5 is yellowish brown at the subsurface horizons and greyish black at the surface, while profile 7 is slightly reddish at the surface and pinkish at the bottom of the profile. Surface colour in tropical soils with high rainfall and leaching is strongly linked to organic matter, while colour of subsurface horizons is generally related to the types of minerals present in the soil [33]. The general negative depth function of organic matter in these soils is consistent with the colours. The soils in the study area are dominated by a sub-angular blocky structure, with the exception of unit 2, where the structure is massive in the subsurface. Unit 3 has both granular and massive structures. This reflects the parent material, and could probably be linked to the type of alluvium deposited, and also to the abrupt break in texture [34]. The soils in the study area are predominantly clayey in texture, with the exception of the soils in unit 3, which are predominantly sandy-clay at the surface and linked to the parent material, which consist of fluvial deposits. All the soils in the study area are friable when dry and hard to soft when wet.

Table 5. Morphological and physical characteristics of the studied soils.

Horizon	Depth (cm)	Colour (moist)	Structure	Consistency		Boundary	Porosity (%)	BD (g/cm³)	Sand (%)	Silt (%)	Clay (%)	% Coarse fraction > 2 mm	Textural class
				Moist	Wet								
					Unit 1 (LAKPWANG)								
Ap	0 - 18	2.5YR3/4	GR	VFR	SST-		57.6	1.12	37	19.5	43.5	0	C
AB	18 - 35	2.5YR4/8	SB	FR	NST	D-W	55.1	1.19	25	8.5	66.5	0	C
Bo1	35 - 70	2.5YR5/6	SB	VFI	NST	A	49.4	1.34	22	13.5	64.5	0	C
Bo2	70 - 200	2.5YR4/8	SB	FI	SST	D-W	47.1	1.40	25	60	15	0	SL

Continued

						Unit 2 (SANAM)						
Ap	0 - 16 cm	2.5 YR4 /2	SB	FR	SST		53.8	1.22	25.5	18.5	56	0	C
Bo1	16 - 63 cm	5YR6/4	MA	FI	SST	D-I	48.8	1.36	14	15	71	0	C
Bo2	63 - 120 cm	5YR6/6	MA	FR	VST	C-B	51.0	1.30	11	16	73	5	C
Bo3	120 - 145 cm	5YR6/6	MA	VFR	ST	D-I	35.7	1.70	27.5	11	61.5	18	C
BC	145 - 200 cm	5YR7/6	MA	FR	SST-ST	D-W	61.0	1.03	26 .5	18.5	55	0	C
						Unit 3 (BIABEZOCK)						
AP	0 - 36 cm	5YR3/1	GR	VFR	NST		42.8	1.52	46	12.5	41.5	3	SC
AB	36 - 63 cm	5YR5/2	GR	VFR	NST	G-I	37.6	1.65	76.5	6.5	17	44	SL
Bw	63 - 94 cm	5YR6/3	GR	FR	NST	G-I	40.4	1.58	70	7.5	22.5	11	SCL
Btg	94 - 120 cm	5YR6/1	MA	FI	ST	D-I	47.2	1.40	51.5	10	38.5	5.5	SC
						Unit 4 (NYAMSON)						
Ap	0 - 27	5YR6/3	SB	FI	ST-SST		50.6	1.31	23	10.5	66.5	0	C
Bw	27 - 65	7.5YR5/4	SB	FI	SST	D-W	41.1	1.56	33	7.5	595	14	C
BC1	65 - 150	7.5YR6/8	SB	FR	NST	D-W	43.5	1.50	65	9	26	4	SCL
BC2	150 - 210	2.5YR5/8	SB	FR	SST	G-W	47.5	1.39	51.5	10	38.5	0	SC
						Unit 5 (DONE IRIBOUEM)						
Ap	0 - 28	5YR4/1	SB	FI	ST		52.9	1.25	44	14.5	41.5	0	SC
AB	28 - 67	10YR5/6	SB	FR	ST	D-W	49.3	1.34	36.5	5	58.5	0	C
Bt1	67 - 140	10YR6/6	SB	FR	ST	A	42.2	1.53	35	10	55	0	C
Bt2	140 - 200	10YR5/6	SB	VFR	SST	A	45.4	1.45	46	4	50	0	C
						Unit 6 (GOUFAN 2)						
Ap	0 - 30	5YR5/4	SB	FR	ST		49.1	1.35	47.5	11	41.5	0	SC
BA	30 - 94	5YR5/8	GR	VFR	NST	A	52.8	1.25	31	11.5	57.5	2	C
Bo1	94 - 152	5YR6/8	SB → GR	FR	NST	C-B	35.5	1.71	58	11	31	23	C
Bo2	152 - 240	2.5YR5/8	SB → GR	FR	SST	A	38.0	1.64	56.5	8.5	35	5.5	SC
						Unit 7 (CAMPUS AREA)						
Ap	0 - 27 cm	5R3/1	SB	FR	ST		55.8	1.17	62	13	25	0	SCL
AB	27 - 70	5R5/3	SB	FR	VST	D-W	52.0	1.27	49.5	15	35.5	0	SC
Bo	70 - 147	5YR7/8	SB	FI	VST	G-W	47.4	1.39	71	10	19	0	SL
BC	147 - 210	7.5YR/4	SB	VFR	NST	D-I	44.7	1.46	51.5	7.5	41	0	SC

SB = Sub angular blocky, GR = Granular, SB → GR = Sub angular blocky parting to Granular, FR = Friable, FI = Firm, VFI = Very firm, ST = Sticky, SST = Slightly sticky, NST = Non-sticky, C = Clear (2 - 5 cm), G = Gradual (5 - 15 cm), D = Diffuse (>15 cm), S = Smooth, W = Wavy, I = Irregular, A = Abrupt. NB: FI = fine (for structure) and firm (for consistence). Source: FAO [20].

Table 6. Chemical characteristics of the representative soil profiles in the study area.

Horizon/ Depth	pH_{water}	pH_{KCl}	ΔpH	OC (%)	Total N (%)	C/N	P Bray II (mg/kg)	Exchangeable base cations (cmol(+)·kg^{-1})				Ca^{2+}/ Mg^{2+}/ K^{+}	SEB (cmol (+)·kg^{-1})	CEC pH7 (cmol (+)·kg^{-1})	BS (%)	ESP (%)	EC (dS·m^{-1})
								K^{+}	Na^{+}	Mg^{2+}	Ca^{2+}						
Profile 1																	
Ap (0 - 18)	4.6	4.4	−0.2	1.18	0.14	8.40	3.89	0.38	0.15	2.64	2.96	49/44/6	6.13	30.40	20.17	0.51	0.08
AB(18 - 35)	4.6	4.3	−0.3	0.86	0.07	12.32	2.60	0.64	0.36	3.12	4.16	53/39/8	8.28	27.20	30.43	1.31	0.02
B_{O1} (35 - 70)	4.8	4.4	−0.4	0.71	0.06	11.20	3.48	1.14	0.42	3.76	5.04	51/38/11	10.37	32.00	32.40	1.32	0.02
B_{O2} (70 - 200)	4.9	4.7	−0.2	0.55	0.06	9.23	1.84	2.53	0.56	6.16	3.36	28/51/21	12.61	25.60	49.26	2.18	0.02
Profile 2																	
Ap (0 - 16)	4.9	4.7	−0.2	1.33	0.07	19.05	3.48	0.38	0.36	4.08	5.28	54/42/4	10.09	28	36.05	1.27	0.04
Bo1 (16 - 63)	5.8	5	−0.8	1.02	0.067	15.33	1.84	2.98	0.09	2.16	5.84	53/20/27	11.06	21.6	51.21	0.40	0.02
Bo2 (63 - 120)	5.8	5	−0.8	1.02	0.098	10.40	1.84	0.22	0.36	4.56	4.80	50/48/2	9.93	17.6	56.44	2.02	0.02
Bw (120 - 145)	6	5.2	−0.8	0.94	0.081	11.69	1.31	1.04	0.56	3.44	6.00	57/33/10	11.04	15.2	72.60	3.68	0.02
BC (145 - 200)	6	5.3	−0.7	0.86	0.109	7.95	3.48	0.30	0.49	4.00	6.24	59/38/3	11.03	18.4	5.93	2.67	0.02
Profile 3																	
Ap (0 - 36)	6.2	4.8	−1.4	1.33	0.112	11.90	3.36	0.55	0.49	2.40	4.16	59/34/8	7.60	16.4	46.35	3.00	0.03
AB (36 - 63)	6	4.5	−1.5	1.10	0.07	15.69	7.70	0.46	0.49	3.44	7.92	67/29/4	12.31	17.44	70.60	2.82	0.03
Bw (63 - 94)	6.2	4.9	−1.3	0.63	0.116	5.43	10.80	1.60	0.63	5.04	10.00	60/30/10	17.27	22.40	77.10	2.80	0.02
Btg (94 - 120)	4.8	4.3	−0.5	0.47	0.053	8.96	10.74	3.95	0.83	9.68	11.44	46/39/16	25.90	46.80	55.35	1.77	0.02
Profile 4																	
Ap (0 - 27)	6.4	5.1	−1.3	1.02	0.081	12.67	8.05	2.11	0.63	4.47	11.20	63/25/12	18.42	28.32	65.04	2.21	0.04
Bw (27 - 65)	6.3	5.3	−1	0.86	0.053	16.43	8.87	0.83	0.15	4.64	9.6	64/31/6	15.23	39.84	38.22	0.39	0.04
BC1 (65 - 150)	6.8	5.8	−1	0.63	0.06	10.55	6.99	0.73	0.15	0.64	4.72	78/11/12	6.25	37.6	16.62	0.41	0.03
BC2 (150 - 210)	6.9	6	−0.9	0.55	0.056	9.80	6.47	0.64	0.29	2.88	7.44	68/26/6	11.25	35.2	31.96	0.82	0.03
Profile 5																	
Ap (0 - 28)	6.3	5.3	−1	2.98	0.084	35.48	9.39	0.30	0.05	5.04	0.64	11/84/5	5.93	38.72	15.31	0.13	0.09
AB(28 - 67)	5.9	5.2	−0.7	1.65	0.07	23.53	11.21	0.83	0.22	4.48	10	65/29/5	15.53	30.8	50.43	0.72	0.04
Bt1 (67 - 140)	5.9	5.2	−0.7	1.49	0.063	23.63	7.58	1.04	0.15	2.64	8.4	70/22/9	12.23	26.08	46.90	0.59	0.02
Bt2 (140 - 200)	6.1	5.7	−0.4	1.33	0.054	14.21	7.93	1.73	0.36	0.72	12.72	84/5/11	15.52	28	55.44	1.27	0.02
Profile 6																	
Ap (0 - 30)	6.3	5.6	−0.7	2.27	0.117	19.46	5.59	1.04	0.15	0.24	1.84	59/8/33	3.27	33.6	9.73	0.46	0.06
BA (30 - 94)	5.4	4.9	−0.5	1.18	0.067	17.51	9.39	0.73	0.09	1.84	3.92	60/28/11	6.58	38.4	17.14	0.22	0.02
Bo1 (94 - 152)	5.8	5.6	−0.2	1.02	0.064	16.01	8.46	0.38	0.15	1.28	3.6	68/24/7	5.41	34.4	15.73	0.45	0.02
Bo2 (152 - 240)	6	5.7	−0.3	1.02	0.067	15.33	8.98	0.73	0.02	0.16	4.16	82/3/14	5.07	33.2	15.28	0.06	0.03
Profile 7																	
Ap (0 - 27)	7.3	6.8	−0.5	3.29	0.14	23.53	10.92	0.64	0.02	4.48	9.76	66/30/4	14.90	28.8	51.73	0.07	0.19
AB (27 - 70)	7.1	6.2	−0.5	1.88	0.126	14.94	9.86	0.55	0.02	1.12	8.4	83/11/5	10.09	34.8	28.99	0.05	0.05
Bo (70 - 147)	7.1	6.1	−1	1.33	0.102	13.14	8.28	0.30	0.02	1.2	6.8	82/14/4	8.31	24	34.64	0.08	0.03
CB (147 - 210)	6.6	5.4	−1.2	1.02	0.039	26.48	10.98	0.30	0.02	3.12	6.06	64/33/3	9.51	33.6	28.32	0.06	0.03

OC = Organic carbon, C/N = carbon to nitrogen ratio, SEB = Sum of exchangeable base cations, CEC = Cation exchange capacity, BS = Base saturation, ESP = Exchangeable sodium percent, EC = Electrical conductivity.

Table 7. Descriptive statistics selected soil properties for the various soils studied.

Sites		pH_{water}	pH_{KCl}	OC	Total N	C/N	P Bray II	K^+	Na^+	Mg^{2+}	Ca^{2+}	SEB	CEC pH7	BS	ESP	EC	Sand	Silt	Clay
				%			mg/kg			(cmol(+)·kg^{-1})				%		dS·m^{-1}		%	
Profil 1	Mean (±SE)	4.72 ± 0.07	4.45 ± 0.09	0.83 ± 0.13	0.08 ± 0.02	10.29 ± 0.90	2.95 ± 0.46	1.17 ± 0.48	0.37 ± 0.09	3.92 ± 0.78	3.88 ± 0.46	9.35 ± 1.39	28.8 ± 1.46	33.07 ± 6.03	1.33 ± 0.34	0.04 ± 0.02	27.25 ± 3.33	25.38 ± 11.76	47.38 ± 11.98
	CV %	3.175	3.892	32.532	46.815	17.429	31.036	81.74	45.736	39.853	23.719	29.738	10.14	36.46	51.28	85.714	24.41	92.68	50.57
Profil 2	Mean (±SE)	5.7 ± 0.20	5.04 ± 0.10	1.03 ± 0.08	0.09 ± 0.01	12.88 ± 1.95	2.39 ± 0.46	0.98 ± 0.52	0.37 ± 0.08	3.65 ± 0.41	5.63 ± 0.26	10.63 ± 0.25	20.16 ± 2.21	44.45 ± 11.3	2.01 ± 0.56	0.02 ± 0.00	20.9 ± 3.48	15.8 ± 1.38	63.3 ± 3.73
	CV %	8.04	4.568	17.241	21.291	33.82	42.606	118.12	48.29	25.272	10.37	5.352	24.53	56.7	62.818	37.268	37.19	19.58	13.19
Profil 3	Mean (±SE)	5.8 ± 0.33	4.63 ± 0.14	0.88 ± 0.20	0.09 ± 0.02	10.49 ± 2.18	8.15 ± 1.75	1.64 ± 0.81	0.61 ± 0.08	5.14 ± 1.61	8.38 ± 1.58	15.77 ± 3.91	25.76 ± 7.13	62.35 ± 7.02	2.6 ± 0.28	0.03 ± 0.01	61 ± 7.28	9.13 ± 1.34	29.88 ± 5.98
	CV %	11.609	5.954	45.395	35.485	41.52	43.02	99.06	26.366	62.56	37.74	49.61	55.39	22.5	21.52	23.094	23.88	29.465	40.06
Profil 4	Mean (±SE)	6.6 ± 0.14	5.55 ± 0.21	0.77 ± 0.11	0.06 ± 0.01	12.36 ± 1.49	7.60 ± 0.53	1.08 ± 0.35	0.30 ± 0.11	3.16 ± 0.93	8.24 ± 1.40	12.79 ± 2.63	35.24 ± 2.49	37.96 ± 10.10	0.96 ± 0.43	0.04 ± 0.00	43.13 ± 9.38	9.25 ± 0.66	47.62 ± 9.35
	CV %	4.46	7.573	28.087	20.26	24.04	14.149	64.287	74.261	58.784	34.068	41.08	14.15	53.23	89.63	16.496	43.51	14.301	39.25
Profil 5	Mean (±SE)	6.05 ± 0.09	5.35 ± 0.12	1.86 ± 0.38	0.07 ± 0.01	24.21 ± 4.36	9.03 ± 0.82	0.98 ± 0.30	0.20 ± 0.07	3.22 ± 0.98	7.94 ± 2.59	12.30 ± 2.26	30.9 ± 2.78	42.02 ± 9.07	0.68 ± 0.24	0.04 ± 0.02	40.38 ± 2.72	8.38 ± 2.43	51.25 ± 3.69
	CV %	3.165	4.449	40.61	18.685	35.99	18.308	60.704	66.798	60.768	65.28	36.77	18	43.19	69.25	77.742	13.47	57.96	14.39
Profil 6	Mean (±SE)	5.86 ± 0.19	5.45 ± 0.19	1.37 ± 0.30	0.08 ± 0.01	17.08 ± 0.92	8.11 ± 0.86	0.72 ± 0.14	0.10 ± 0.03	0.88 ± 0.41	3.38 ± 0.53	5.08 ± 0.69	34.9 ± 1.19	14.47 ± 1.63	0.30 ± 0.1	0.03 ± 0.01	48.25 ± 6.20	10.5 ± 0.68	41.25 ± 5.83
	CV %	6.425	6.783	43.939	32.431	10.72	21.213	37.457	60.338	93.01	31.124	26.966	6.84	22.51	64.97	58.245	25.7	12.895	28.28
Profil 7	Mean (±SE)	7.03 ± 0.15	6.13 ± 0.29	1.88 ± 0.50	0.10 ± 0.02	19.52 ± 3.24	10.01 ± 0.63	0.45 ± 0.09	0.02 ± 0	2.48 ± 0.81	7.76 ± 0.83	10.70 ± 1.45	30.3 ± 2.47	35.92 ± 5.46	0.07 ± 0.01	0.08 ± 0.04	58.5 ± 4.99	11.38 ± 1.65	30.13 ± 4.98
	CV %	4.251	9.367	53.459	43.911	33.22	12.616	38.936	0	65.424	21.346	27.05	16.29	30.39	19.861	102.99	17.05	29.02	33.04

SE: Standard error of means.

3.2. Soil Chemical Properties

3.2.1. Soil Reaction

The pH values observed in the various study sites are presented in **Table 6**. Soils of unit 1 are acidic, while in unit 2, acidity varies from acidic to moderately acidic. In both units, there is a general decrease in acidity with depth. This decrease in pH with depth, especially in tropical soils where heavy rains obtain is mainly due to leaching of bases [35]. Acidity in soils of unit 3 varies from slightly acidic in the surface horizons to acidic in the subsurface horizons, while those in unit 4 are slightly acidic. The decrease in pH in these soils may be related to the accumulation of organic acids in deeper horizons through leaching [36]. In units 5 and 6, the soils are generally slightly acidic throughout the profiles. Unit 7 has a basic character (slightly alkaline) in the upper parts of the profile and slightly acidic in the lower parts of the profile. This degree of alkalinity in soils of unit 7 may be attributed to the recurrent practice of bush burning in the area, a farming practice that releases ash, capable of raising the pH [37] [38]. The coefficient of variation (**Table 7**) indicates that for all soils, pH is least variable, ranging between 3.17 and 11.61 %. This low variability in pH of the soils is influenced by factors of soil formation, and land management [39]. As pH is a good indicator of soil quality, influencing the availability and uptake of nutrients in crops such as Egusi melon, proper management of soil acidity is necessary despite the low variability.

3.2.2. Organic Carbon

Unit 1 has a medium organic carbon content and is of very good quality at the surface. The OC content is generally low and of average quality in the lower parts of the profile. In unit 2, OC content generally varies from low to medium with a general decrease with depth. The quality of the OM in this profile has an inverse depth function. The soils in units 3 and 4 have a low to medium OC content of poor quality at the surface horizons and good quality at the subsurface horizons. Units 5, 6 and 7 have medium to high levels of OC with concentrations generally decreasing with depth. In the latter three soils, the organic matter is of very poor quality. Generally, organic matter decreases with depth as would be expected, linked to the presence of dense vegetation at the surface and the accumulation of organic matter from plant litter [40]. The high variability (CV = 17.24% - 45.40%) of the OM quality observed in the soils corroborates with the variety of vegetation and microorganisms observed in the studied soils [41].

3.2.3. Total Nitrogen

Apart from profiles 1 and 7 where total nitrogen concentrations are relatively higher, all the soils generally have low nitrogen concentrations, which decrease with depth. This low level of nitrogen in the soils may be related to leaching by rainwater [42], given the heavy rainfalls usually recorded in the study area. The correlation tables (**Table S1** to **Table S7**) show both positive and negative, significant to highly significant correlations between total nitrogen and other soil physical and chemical properties, indicating that several parameters can be explanatory of soil nitrogen availability. In Unit 1, there exists a positive and significant correlation between sand and nitrogen (R = 0.98), indicating that the presence of sand in the soil could affect the availability of nitrogen to plants. In Unit 3, the positive and highly significant correlation between total nitrogen and potential acidity (R = 0.99), indicates that the two are linked by biogeochemical processes, such as nitrogen mineralization, which can be linked to certain types of soil microorganisms available with a pH that favours their development.

3.2.4. Available Phosphorus

Soils in units 1 and 2 have very low concentrations of phosphorus (<7 ppm). Soils in units 3 and 6 have P concentrations that vary from low to very low with a general increase with depth. The increase in phosphorus with depth may be linked to less leaching, as the deeper soil horizons are less subject to leaching than the upper layers, which allows a slightly greater retention of phosphorus at depth [43]. In unit 4, the trend is the reverse of the two previous units, with phosphorus levels decreasing with depth, from low to very low. The soils in units 5 and 7, on the other hand, have low levels throughout the soil profile. The low to very low P levels with negative depth functions in these soils may be linked to phosphorus sorption. Highly weathered soils may contain clay minerals such as iron and aluminium oxides, which have a strong capacity to fix phosphorus and make it unavailable [43]. Average phosphorus levels in Bafia soils ranged from 2.39 ± 0.46 ppm to 10.01 ± 0.63 ppm (**Table 7**). This shows the low to very low level of phosphorus, which is a constraint for the production of Egusi melon. Low phosphorus levels lead to a delay in flowering, a significant reduction in above-ground biomass (up to 71%) and root biomass (up to 68%), and a reduction in leaf number and plant size [41]. Phosphorus deficiency also limits interaction with other nutrients, essential for crops, which can lead to a drastic drop in yields [44] [45]. **Table S1** to **Table S7** show a positive and significant correlation between phosphorus and calcium (R = 0.98), and between phosphorus and base saturation (R = 0.98).

3.2.5. Electrical Conductivity

The soils in the study area are generally non-saline (<2 dSm^{-1}) (**Table 4**). This is probably due to the leaching of salts into the lower horizons as a result of the heavy rainfall in the study area.

3.2.6. Cation Exchange Capacity

Cation exchange capacity is high (25 - 40 cmol (+) kg^{-1}) in the soils of units 1, 4, 5, 6 and 7. This may be linked to the accumulation of organic matter in these soils, the clay minerals being essentially low CEC clays [46]. In unit 2, the CEC is average, varying between 15.2 and 28 cmol (+) kg^{-1}, while CEC unit 3 are average at the surface and very high at the subsurface horizons. The nature of the parent materials, which are alluvial deposits and clay content of the soils could be contributing factors for this observation [47]. Leaching of bases down the lower horizons is a possibility [48].

3.2.7. Exchangeable Base Cations

The presence of cations in the soil is generally linked to parent materials and organic matter. **Table 5** indicates that calcium concentration in units 1, 2, 3 and 5 increases slightly with depth, from low (6 - 12 cmol (+) kg^{-1}) high. This can be explained by the accumulation of calcium down the profiles, and by several factors such as pH, organic matter and soil mineralogy [48]. The presence and distribution of these cations in the soil can have an impact on the growth of Egusi melon. It is important to ensure that the soil contains adequate levels of these cations, particularly calcium, which plays a crucial role in plant nutrient uptake and overall growth [49]. Based on the cationic balance ratio Ca/Mg/K, necessary for optimum absorption, which is 76% for calcium, 18% for magnesium and 6% for potassium [50], there is a pronounced imbalance in calcium in units 1, 3 and 4. In units 2 and 5, there is an imbalance in potassium, magnesium and calcium throughout the soil profiles. Unit 6 is characterized by an imbalance in calcium in all horizons, as well as an imbalance in magnesium in the subsurface horizons. In Unit 7, there is an imbalance in magnesium and potassium.

3.3. Soil Classification

Based on soil morphological and physico-chemical properties, and taking into account procedures for naming soils using Reference Soil Groups, principal and supplementary qualifiers [51], three reference soil groups were identified and classified as follows; Profiles 1, 2, 6 and 7 were classified as Haplic Ferralsol (Epic, Ochric, Orthodystric), Haplic Ferralsol (Epic, Ochric, Orthodystric), Gleyic Ferralsol (Dystric, Endic, Profundihumic) and Chromic Ferralsol (Arenic, Endic, Profundihumic) respectively. Profiles 3 and 4 were classified as Eutric Amphifluvic Stagnic Protogleyic Cambisols (Humic) and Rhodic Cambisols (Clayic), respectively. Profile 5, was classified as a Rhodic Acrisol (Clayic, Endic, Humic).

3.4. Land Evaluation

The climatic indices (**Table 8**) indicate that the suitability class for climatic parameters for the three possible growing seasons in the study area is the same (S2, c, with a moderate limitation due to relative humidity). Based on climatic characteristics, Bafia is moderately suitable for growing Egusi melons. Firstly, the identification of a medium suitability class for climate (class S2) is in line with studies that recognise the importance of climatic parameters such as rainfall and relative humidity for the cultivation of crops [52] [53]. For example, drought has been identified as a major factor affecting agricultural productivity in Africa [53]. In the case of Bafia, moderate limitations due to relative humidity could negatively affect crops during certain periods, but could be managed via irrigation systems or adapted agricultural practices. Soil evaluation shows that the soils in units 1 and 2 are currently unsuitable with very severe but correctable limitations. The soils of units 3, 4, 5 and 6 have marginal suitability, while soils in unit 7 have medium suitability. The different constraints for each unit are presented in **Table 9**. It can be observed (**Table 9**) that 42.9%, 28.6%, 71.4% and 14.3% of the land in the study area is limited by the physical characteristics of the soil (s), topography (t), fertility characteristics (f) and moisture (w), respectively. More specifically, these limitations are related to slope, soil texture, pH, flooding, base saturation, organic matter and gravel. Variations in soil suitability between different units could result in common challenges by farmers in areas with heterogeneity in soils and climate. To cope with such variability, practices need to be adapted to ensure stable yields [54]. The presence of correctable limitations suggests that soil management strategies could be put in place to improve soil suitability, such as fertility enhancement or anti-erosion measures. The specific constraints cited, such as slope, soil texture, flooding, etc., are well documented in studies as factors influencing agricultural production [52] [55]. Soil texture, for example, affects water retention and nutrient availability, while steep slopes can increase the risk of erosion. For this reason, organic matter needs to be added to increase the structural stability of the soil in order to resist erosion and ensure good water retention. Organic matter could also raise the pH, thereby reducing acidity. Biochars derived from animal manure and grass, for example, are used to increase soil N, P, K, Ca, Mg and S content [56] [57]. In addition, the use of mineral fertilisers can help in increasing soil fertility levels for melon crops [58]. As strategies that should be implemented to help small-scale farmers in Bafia cope with the Egusi melon production constraints in future, the following are suggested: Adoption of sustainable practices, such as crop rotation and the use of improved seeds, to optimize yields. Rotating crops helps in breaking pest and disease cycles, improving soil health, and increasing nutrient availability. Associating or rotating Egusi melon with legumes can be particularly beneficial as they fix nitrogen in the soil. Using high quality, disease-resistant seeds can significantly enhance yields. Improved seeds are necessary for better germination rates, growth, and resistance to pests and diseases. Combining biological, cropping, and chemical practices to manage pests can reduce the reliance on chemical pesticides and promote a healthier ecosystem [59]. Fertility trials that can inform on optimal fertilizer rates for Egusi melon production are also to be considered as a perspective.

Table 8. Land suitability evaluation for Egusi melon cultivation in the various study sites.

Parameters		Site													
		LAKPWAN		SANAM		BIABEZOCK		NYAMSON 2 LABLE		DONE IRI-BOUEM		GOUFAN 2		CAMPUS AREA	
		V	PV	V	PV	V	PV	V	PV	V	PV	V	PV	V	PV
Climate															
Precipitation of GP (mm)	A to J	503	95	503	95	503	95	503	95	503	95	503	95	503	95
	Ju to S	590.58	96	590.58	96	590.58	96	590.58	96	590.58	96	590.58	96	590.58	96
	S to N	547	100	547	100	547	100	547	100	547	100	547	100	547	100
Mean temperature of GP (˚C)	A to J	25	98	25	98	25	98	25	98	25	98	25	98	25	98
	Ju to S	24.04	95	24.04	95	24.04	95	24.04	95	24.04	95	24.04	95	24.04	95
	S to N	24	95	24	95	24	95	24	95	24	95	24	95	24	95
Relative humidity of GP (%)	A to J	86	70	86	70	86	70	86	70	86	70	86	70	86	70
	Ju to S	87.75	66	87.75	66	87.75	66	87.75	66	87.75	66	87.75	66	87.75	66
	S to N	86	70	86	70	86	70	86	70	86	70	86	70	86	70
CI A to J			**67.54**		**67.54**		**67.54**		**67.54**		**67.54**		**67.54**		**67.54**
CI Ju to S			**63.03**		**63.03**		**63.03**		**63.03**		**63.03**		**63.03**		**63.03**
CI S to N			**68.22**		**68.22**		**68.22**		**68.22**		**68.22**		**68.22**		**68.22**
Topography (t)															
Slope		8%	85	22.67	50.47	1%	98.75	1%	98.75	1%	98.75	1%	98.75	1%	98.75
Humidity (w)															
Flooding		F0	100	F0	100	F1	60	F0	100	F0	100	F0	100	F0	100
Drainage		Good	100	Good	100	Moderate	95	Good	100	Good	100	Good	100	Good	100

Continued

Physical characteristics of soil (s)														
Texture/Structure	C	85	C	60	SC	95	C	60	SC	95	SC	95	SCL	95
Percentage of soil coarse fraction (%)	0	100	0	100	0	100	39.9	55.1	14	85.83	2	96.67	0	100
Soil depth (cm)	200	100	200	100	120	89	200	100	200	100	240	100	210	100
$CaCO_3$	0	100	0	100	0	100	0	100	0	100	0	100	0	100
Gypsum	0	100	0	100	0	100	0	100	0	100	0	100	0	100
Soil fertility characteristics (f)														
Apparent CEC (Cmol(+)·Kg^{-1} clay)	51.23	100	36	100	37.9	100	41.8	100	76	100	70	100	92.9	100
Base saturation (%)	24.27	67	43.12	90.41	46.35	92.56	62.4	100	17.7	60	9.73	60	49.5	94.67
SEB	7	100	10.55	100	7.6	100	18.1	100	6.6	100	3.27	81.16	14.42	100
Organic carbon	1.06	76	1.18	84	1.33	86.63	1	72.5	2.9	100	2.27	100	3.15	100
pH_{water}	4.6	40	5.3	52	6.2	97	6.4	99	6.3	98	6.3	98	7.3	90
Salinity and sodicity (n)														
EC (dS·m^{-1})	0.056	100	0.03	99.95	0.03	99.95	0.04	99.95	0.09	99.85	0.06	99.9	0.18	99.7
ESP (%)	0.83	99	0.9	99.43	3	98.13	2.03	98.73	0.17	99.89	0.46	99.71	0.07	99.96
Corrected LI A to J		**19.83**		**20.13**		**40.18**		**36.07**		**42.63**		**41.74**		**64.87**
Corrected LI Ju to S		**19.17**		**19.44**		**39.58**		**35.62**		**41.95**		**41.10**		**63.23**
Corrected LI S to N		**19.94**		**20.23**		**40.27**		**36.14**		**42.73**		**41.84**		**65.12**

A = April, J = June, Ju = July, S = September, N = November, V = value, PV = parametric value, GP = growing period, CI = climatic index, C = Clay, SC = sandy clay SCL = sandy clay loam, LI = land index, CEC = cation exchange capacity, SEB = sum of exchangeable bases ESP = exchangeable sodium, EC = electrical conductivity.

Table 9. Constraints and potential yields of Egusi melon in the study sites.

Unit	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Class	N1 c, t, s, f	N1 c, t, s, f	S3 c, w	S3 c, s, f	S3 c, f	S3 c, f	S2 c
Potential yields	15% - 25%	15% - 25%	25% - 50%	25% - 50%	25% - 50%	25% - 50%	50% - 75%

4. Conclusion

The aim of this study was to determine the suitability of soils for growing Egusi melon in the Bafia locality. The physical and morphological characteristics of these soils are highly variable, with low to very low levels of phosphorus in all soils. The climate of Bafia has marginal suitability (S2c) class with moderate limitations due to relative humidity for the production of Egusi melon (*Citrullus mucosospermus*). The final assessment of the land in Bafia shows, on the one hand, current unsuitability, but with a potential suitability, (N1/c, t, s, f) and (N1/c, t, s, f), for units 1 and 2 respectively, with very severe but correctable limitations; marginal suitability, with severe limitations (S3/c, w,), (S3c,s,f), (S3/c, s, f) and (S3/c, s, f) for units 3, 5 and 6, respectively. The main constraints to production include both climate (*i.e.* relative humidity), and pedological factors; topography (slope), humidity (flooding), soil physical characteristics (texture, coarse elements and soil depth) and fertility characteristics (base saturation, organic carbon, sum of exchangeable bases and pH) in the Bafia district.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Akinola, R., Pereira, L.M., Mabhaudhi, T., de Bruin, F. and Rusch, L. (2020) A Review of Indigenous Food Crops in Africa and the Implications for More Sustainable and Healthy Food Systems. *Sustainability*, **12**, Article 3493. https://doi.org/10.3390/su12083493

[2] Fajinmi, O.O., Olarewaju, O.O., Arthur, G.D., Naidoo, K. and Coopoosamy, R.M. (2022) A Review of the Role of the Cucurbitaceae Family in Food Security in West Africa. *Journal of Medicinal Plants for Economic Development*, **6**, a155. https://doi.org/10.4102/jomped.v6i1.155

[3] Falade, O.S., Otemuyiwa, I.O., Adekunle, A.S., Adewusi, A.A. and Oluwasefunmi, O. (2020) Nutrient Composition of Watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai) and Egusi Melon (*Citrullus colocynthis* (L.) Schrad.) Seeds. *Agriculturae Conspectus Scientificus*, **85**, 43-49.

[4] National Research Council (2006) Lost Crops of Africa: Volume II: Vegetables.

[5] Achu, M.B., Fokou, E., Tchiégang, C., Fotso, M. and Tchouanguep, F.M. (2005) Nutritive Value of Some Cucurbitaceae Oilseeds from Different Regions in Cameroon. *African Journal of Biotechnology*, **4**, 1329-1334.

[6] Loukou, A.L., Gnakri, D., Djé, Y., Kippré, A.V., Baudoin, J.P., Malice, M. and Zoro Bi, I.A. (2007) Macronutrient Composition of Three Cucurbit Species Cultivated for Seed Consumption in Côte d'Ivoire. *African Journal of Biotechnology*, **6**, 529-533.

[7] Akinoso, R. and Are, O.T. (2018) Elucidation of Energy Requirements in Alternative Robotic Production Methods. *Journal of Biosystems Engineering*, **43**, 128-137.

[8] FAOSTAT (2021) Statistics from the Food and Agriculture Organization of the United Nations.

[9] Montgomery, B., Dragićević, S., Dujmović, J. and Schmidt, M. (2016) A GIS-Based Logic Scoring of Preference Method for Evaluation of Land Capability and Suitability for Agriculture. *Computers and Electronics in Agriculture*, **124**, 340-353. https://doi.org/10.1016/j.compag.2016.04.013

[10] Singha, C. and Swain, K.C. (2016) Land Suitability Evaluation Criteria for Agricultural Crop Selection: A Review. *Agricultural Reviews*, **37**, 125-132. https://doi.org/10.18805/ar.v37i2.10737

[11] Olaniyi, J.O. (2008) Growth and Seed Yield Response of Egusi Melon to Nitrogen and Phosphorus Fertilizers Application. *American-Eurasian Journal of Sustainable Agriculture*, **2**, 255-260.

[12] Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. and Herrero, M. (2013) Adapting Agriculture to Climate Change in Kenya: Household Strategies and Determinants. *Journal of Environmental Management*, **114**, 26-35. https://doi.org/10.1016/j.jenvman.2012.10.036

[13] Nakachew, K., Yigermal, H., Assefa, F., Gelaye, Y. and Ali, S. (2024) Review on Enhancing the Efficiency of Fertilizer Utilization: Strategies for Optimal Nutrient Management. *Open Agriculture*, **9**, Article 20220356. https://doi.org/10.1515/opag-2022-0356

[14] Yu, J., Chen, Y., Wu, J. and Khan, S. (2011) Cellular Automata-Based Spatial Multicriteria Land Suitability Simulation for Irrigated Agriculture. *International Journal of Geographical Information Science*, **25**, 131-148. https://doi.org/10.1080/13658811003785571

[15] Kihoro, J., Bosco, N.J. and Murage, H. (2013) Suitability Analysis for Rice Growing Sites Using a Multicriteria Evaluation and GIS Approach in Great Mwea Region, Kenya. *SpringerPlus*, **2**, Article No. 265. https://doi.org/10.1186/2193-1801-2-265

[16] Santoir, C. and Bopda, A. (1995) Atlas Régional Sud-Cameroun. O.R.S.T.O.M.

[17] Vallerie, M. (1971) Carte pédologique du Cameroun Centre-Sud. Document de l'O.R.S.T.O.M, Centre Yaoundé.

[18] Enyegue, A.N.F.M., Ndougsa, M.T., Njandjock, N.P., Assembe, S. and Manguelle, D.E. (2014) GroundWater Exploration Using Geoelectrical Investigation in Bafia Area. *Cameroon Journal of Earth Sciences and Geotechnical Engineering*, **4**, 61-75.

[19] Vallerie, M. (1973) Contribution à l'étude des sols du Centre Sud Cameroun: Type de différenciation morphologique et pédogénetique sous climat subéquatorial. Paris: ORSTOM, (II)-111p. (Travaux et Documents de l'ORSTOM; 29).

[20] FAO (2006) Guidelines for Soil Description. 4th Edition, Food and Agriculture Organization of the United Nations.

[21] Pauwels, J.M., Van Ranst, E., Verlo, M. and MvondoZe, A. (1992) Manuel de laboratoire de pédologie. Méthodes d'analyses des sols et des plantes, équipement, gestion de stocks de verrerie et de produits chimiques. Publications Agricoles No. 28, AGCD.

[22] Bouyoucos, G.J. (1962) Hydrometer Method Improved for Making Particle Size Analysis of Soil. *Agronomy Journal*, **54**, 464-465. https://doi.org/10.2134/agronj1962.00021962005400050028x

[23] Fisher, D. and Pringle, H. (2013) Evaluation of Alternative Methods for Estimating Reference Evapotranspiration. *Agricultural Sciences*, **4**, 51-60. https://doi.org/10.4236/as.2013.48A008

[24] Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998) Crop Evapotranspiration: Guidelines for Computing Crops Water Requirements. FAO Irrigation and Drainage Paper 56, FAO.

[25] Sys, C., Van Ranst, E. and Debaveye, J. (1993) Land Evaluation. Part 3: Crop Requirements. International Training Centre for Post Graduate Soil Scientists. Ghent University.

[26] Beernaert, F. and Bitondo, D. (1993) Land Evaluation Manual. CUDs.

[27] Sys, C., Van Ranst, E. and Debaveye, J. (1991) Land Evaluation. Part I: Principles in Land Evaluation and Crop Production Calculation. Agricultural Publications No. 7, General Administration for Development Cooperation.

[28] Van Ranst, E. (1983) Evaluation des terres dans les régions tropicales au Cameroun en particulier. Centre Universitaire de Dschang, ENSA.

[29] Euroconsult (1989) Agricultural Compendium for Rural Development in the Tropics and the Subtropics. Elsevier.

[30] Cass, A. (1998) Measuring and Managing Chemical Impediments to Growth. *Australian Grape Grower & Winemaker*, **415**, 13-16.

[31] Hazelton, P. and Murphy, B. (2007) Interpreting Soil Test Results: What Do All the Numbers Mean? CSIRO Publishing. https://doi.org/10.1071/9780643094680

[32] Rizwan, M., Siddique, M.T., Ahmed, H., Iqbal, M. and Ziad, T. (2016) Spatial Variability of Selected Physico-Chemical Properties and Macronutrients in the Shale and Sandstone Derived Soils. *Soil and Environment*, **35**, 12-21.

[33] Fontes, M.P.F. and Carvalho, I.A.J. (2005) Color Attributes and Mineralogical Characteristics, Evaluated by Radiometry, of Highly Weathered Tropical Soils. *Soil Science Society of America Journal*, **69**, 1162-1172. https://doi.org/10.2136/sssaj2003.0312

[34] Usul, M. and Dengiz, O. (2010) Pedological Development on Four Parent Materials. *Anadolu Journal of Agricultural Sciences*, **25**, 204-211.

[35] Roger, K.E., Bernard, P.K.Y. and Georges, K.K. (2016) Soil Physico-Chemical Properties and Land Suitability Evaluation for Maize (*Zea mays*), Beans (*Phaseolus vulgaris*) and Irish Potatoes (*Solanum tuberosum*) in Tephra Soils of the Western Slopes of Mount Kupe (Cameroon). *African Journal of Agricultural Research*, **11**, 4571-4583. https://doi.org/10.5897/ajar2016.11669

[36] Rumpel, C. and Kögel-Knabner, I. (2010) Deep Soil Organic Matter—A Key but Poorly Understood Component of Terrestrial C Cycle. *Plant and Soil*, **338**, 143-158. https://doi.org/10.1007/s11104-010-0391-5

[37] Bodí, M.B., Martin, D.A., Balfour, V.N., Santín, C., Doerr, S.H., Pereira, P., *et al.* (2014) Wildland Fire Ash: Production, Composition and Eco-Hydro-Geomorphic Effects. *Earth-Science Reviews*, **130**, 103-127. https://doi.org/10.1016/j.earscirev.2013.12.007

[38] Frankline, N., Ngoufo Serge, T., Innocent Ngwainbi, A., Tobouah Nyanchi, G. and Robinson, T. (2020) Land Use Change and Livelihoods in the Plantation Nouvelle De Ngambe Tikar (Pnnt) Community Forest, Center Region of Cameroon. *American Journal of Biological and Environmental Statistics*, **6**, 31-42. https://doi.org/10.11648/j.ajbes.20200603.11

[39] Kome, G.K., Tabi, F.O. and Enang, R.K. (2016) Statistical Relationships and Variability of Selected Properties of Xanthic and Rhodic Ferralsols in a Humid Tropical Forest of Cameroon. *International Journal of Agriculture and Forestry*, 6, 187-195.

[40] Ou, Y., Rousseau, A.N., Wang, L. and Yan, B. (2017) Spatio-Temporal Patterns of Soil Organic Carbon and PH in Relation to Environmental Factors—A Case Study of the Black Soil Region of Northeastern China. *Agriculture, Ecosystems & Environment*, **245**, 22-31. https://doi.org/10.1016/j.agee.2017.05.003

[41] Mohammadi, K., Heldari, G., Khalesro, S. and Sohrabi, Y. (2011) Soil Management, Microorganisms and Organic Matter Interactions: A Review. *African Journal of Biotechnology*, **10**, 19840-19849.

[42] Galloway, J.N., Townsend, A.R., Erisman, J.W., Bekunda, M., Cai, Z., Freney, J.R., *et al.* (2008) Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions. *Science*, **320**, 889-892. https://doi.org/10.1126/science.1136674

[43] Reddy, K.R., Kadlec, R.H., Flaig, E. and Gale, P.M. (1999) Phosphorus Retention in Streams and Wetlands: A Review. *Critical Reviews in Environmental Science and Technology*, **29**, 83-146. https://doi.org/10.1080/10643389991259182

[44] Zubairu, Y. and Gudugi, A.S.I. (2018) Effect of Nitrogen and Phosphorus on the Per-

formance of Egusi Melon (*Citrullus lanatus* Thumb.) in Minna, Nigeria. *Annals of Food Science and Technology*, **19**, 558-565.

[45] Boureima, S. and Mahaman, L.I. (2020) Effets de la déficience en phosphore du sol sur la croissance et le développement du sésame (*Sesamum indicum* L.). *International Journal of Biological and Chemical Sciences*, **14**, 1014-1024. https://doi.org/10.4314/ijbcs.v14i3.28

[46] Nelson, P.N., Baldock, A., Oades, J.M., Churchman, G.J. and Clarke, P. (1999) Dispersed Clay and Organic Matter in Soil: Their Nature and Associations. *Soil Research*, **37**, 289-316. https://doi.org/10.1071/s98076

[47] Kome, G.K., Enang, R.K., Tabi, F.O. and Yerima, B.P.K. (2019) Influence of Clay Minerals on Some Soil Fertility Attributes: A Review. *Open Journal of Soil Science*, **9**, 155-188. https://doi.org/10.4236/ojss.2019.99010

[48] Ross, D.S., Matschonat, G. and Skyllberg, U. (2008) Cation Exchange in Forest Soils: The Need for a New Perspective. *European Journal of Soil Science*, **59**, 1141-1159. https://doi.org/10.1111/j.1365-2389.2008.01069.x

[49] Husain, S.H., Mohammed, A., Ch'ng, H.Y. and Khalivulla, S.I. (2021) Residual Effects of Calcium Amendments on Oil Palm Growth and Soil Properties. *IOP Conference Series: Earth and Environmental Science*, **756**, Article 012060. https://doi.org/10.1088/1755-1315/756/1/012060

[50] Martin, D. (1979) Fertilité chimique des sols d'un ranch au Congo. Cahier ORSTOM. *Série Pédologie*, **17**, 47-64.

[51] IUSS Working Group WRB (2022) World Reference Base for Soil Ressources. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. 4th Edition, International Union of Soil Sciences (IUSS).

[52] Derbile, E.K., Chirawurah, D. and Naab, F.X. (2021) Vulnerability of Smallholder Agriculture to Environmental Change in North-Western Ghana and Implications for Development Planning. *Climate and Development*, **14**, 39-51. https://doi.org/10.1080/17565529.2021.1881423

[53] Khezazna, A., Amarchi, H., Derdous, O. and Bousakhria, F. (2017) Drought Monitoring in the Seybouse Basin (Algeria) over the Last Decades. *Journal of Water and Land Development*, **33**, 79-88. https://doi.org/10.1515/jwld-2017-0022

[54] Asfaw, S., McCarthy, N., Lipper, L., Arslan, A., Cattaneo, A. and Kachulu, M. (2015) Climate Variability, Adaptation Strategies and Food Security in Malawi. *International Association of Agricultural Economists* (*IAAE*), Milan, 9-14 August 2015, 76 p. https://doi.org/10.22004/AG.ECON.210961

[55] Roy, P., Pal, S.C., Chakrabortty, R., Saha, A. and Chowdhuri, I. (2022) RETRACTED: A Systematic Review on Climate Change and Geo-Environmental Factors Induced Land Degradation: Processes, Policy-Practice Gap and Its Management Strategies. *Geological Journal*, **58**, 3487-3514. https://doi.org/10.1002/gj.4649

[56] Ippolito, J.A., Cui, L., Kammann, C., Wrage-Mönnig, N., Estavillo, J.M., Fuertes-Mendizabal, T., *et al.* (2020) Feedstock Choice, Pyrolysis Temperature and Type Influence Biochar Characteristics: A Comprehensive Meta-Data Analysis Review. *Biochar*, **2**, 421-438. https://doi.org/10.1007/s42773-020-00067-x

[57] Amoah-Antwi, C., Kwiatkowska-Malina, J., Thornton, S.F., Fenton, O., Malina, G. and Szara, E. (2020) Restoration of Soil Quality Using Biochar and Brown Coal Waste: A Review. *Science of the Total Environment*, **722**, Article 137852. https://doi.org/10.1016/j.scitotenv.2020.137852

[58] Smith, W.B., Wilson, M. and Pagliari, P. (2020) Organomineral Fertilizers and Their

Application to Field Crops. In: Waldrip, H.M., Pagliari, P.H. and He, Z., Eds., *Animal Manure: Production, Characteristics, Environmental Concerns, and Management*, American Society of Agronomy, Inc. Soil Science Society of America, Inc., 229-243. https://doi.org/10.2134/asaspecpub67.c18

[59] Ogunsola, J.F., Ikotun, B. and Ogunsola, K.E. (2020) Incidence of Leaf Blight Disease of Egusi Melon in South-West Nigeria. *African Crop Science Journal*, **28**, 255-265. https://doi.org/10.4314/acsj.v28i2.10

Supplementary Materials

Table S1. Correlation matrix between soil characteristics in unit 1.

	pH_{water}	pH_{KCl}	OC	Total N	Mg^{2+}	Ca^{2+}	CEC	BS	Sand	Silt	Clay	P Bray II
pH_{water}												
pH_{KCl}	0.834											
OC	−0.874	−0.617										
Total N	−0.647	−0.274	0.925									
Mg^{2+}	0.91	0.926	−0.859	−0.61								
Ca^{2+}	0.184	−0.385	−0.415	−0.664	−0.092							
CEC pH7	−0.243	−0.527	0.435	0.331	−0.617	0.429						
BS	0.871	0.818	−0.932	−0.757	0.973*	0.058	−0.666					
Sand	−0.576	−0.13	0.86	0.983*	−0.477	−0.791	0.165	−0.635				
Silt	0.757	0.988*	−0.572	−0.234	0.912	−0.479	−0.637	0.81	−0.074			
Clay	−0.583	−0.934	0.323	−0.043	−0.762	0.69	0.579	−0.619	−0.205	−0.961*		
P Bray II	−0.554	−0.627	0.767	0.673	−0.814	0.091	0.911	−0.891	0.529	−0.686	0.526	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

Table S2. Correlation matrix between soil characteristics in unit 2.

	pH_{water}	pH_{KCl}	OC	Total N	P Bray II	Mg^{2+}	CEC pH7	Sand	Silt	Clay	BS	Ca^{2+}
pH_{water}												
pH_{KCl}	0.924*											
OC	−0.979**	−0.973**										
Total N	0.528	0.654	−0.633									
P Bray II	−0.524	−0.23	0.344	0.229								
Mg^{2+}	−0.213	−0.077	0.143	0.621	0.372							
CEC pH7	−0.927*	−0.85	0.882*	−0.557	0.626	−0.037						
Sand	−0.119	0.226	0	0.061	0.418	0.133	0.058					
Silt	−0.502	−0.337	0.358	0.27	0.904*	0.393	0.63	−0.006				
Clay	0.297	−0.086	−0.133	−0.157	−0.724	−0.27	−0.287	−0.929*	−0.365			
BS	0.119	−0.147	0.073	−0.481	−0.896*	−0.239	−0.319	−0.299	−0.85	0.593		
Ca^{2+}	0.478	0.672	−0.566	0.091	0.094	−0.503	−0.279	0.607	−0.195	−0.493	−0.317	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

Table S3. Correlation matrix between soil characteristics in unit 3.

	pH_{water}	pH_{KCl}	OC	Total N	P Bray II	Mg^{2+}	Ca^{2+}	CEC pH7	BS	Sand	Silt	Clay
pH_{water}												
pH_{KCl}	0.863											
OC	0.66	0.35										
Total N	0.83	0.992**	0.379									
P Bray II	−0.499	−0.309	−0.944	−0.377								
Mg^{2+}	−0.926	−0.666	−0.891	−0.655	0.751							
Ca^{2+}	−0.656	−0.471	−0.963*	−0.524	0.981*	0.855						
CEC pH7	−0.964*	−0.709	−0.806	−0.679	0.627	0.985*	0.755					
BS	0.288	0.216	−0.368	0.096	0.636	−0.025	0.497	−0.193				
Sand	0.347	0.083	−0.097	−0.04	0.419	−0.208	0.302	−0.351	0.925			
Silt	−0.129	0.084	0.306	0.208	−0.602	−0.025	−0.509	0.123	−0.934	−0.972*		
Clay	−0.393	−0.12	0.049	0.002	−0.374	0.259	−0.253	0.399	−0.916	−0.999**	0.959*	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

Table S4. Correlation matrix between soil characteristics in unit 4.

	pH_{water}	pH_{KCl}	OC	Total N	P Bray II	K^{+}	Mg^{2+}	CEC pH7	BS	Sand	Silt	Clay
pH_{water}												
pH_{KCl}	0.943											
OC	−0.901	−0.993**										
Total N	−0.295	−0.595	0.68									
P Bray II	−0.982*	−0.872	0.809	0.126								
K^{+}	−0.544	−0.786	0.853	0.956*	0.384							
Mg^{2+}	−0.789	−0.733	0.731	0.259	0.722	0.514						
CEC pH7	0.105	0.403	−0.509	−0.936	0.083	−0.877	−0.295					
BS	−0.648	−0.796	0.852	0.77	0.496	0.903	0.812	−0.782				
Sand	0.842	0.88	−0.897	−0.541	−0.739	−0.758	−0.946	0.513	−0.936			
Silt	0.385	0.09	0.029	0.706	−0.552	0.539	−0.072	−0.875	0.427	−0.089		
Clay	−0.718	−0.445	0.347	−0.452	0.82	−0.182	0.581	0.565	0.07	−0.416	−0.854	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

Table S5. Correlation matrix between soil characteristics in unit 5.

	pH_{water}	pH_{KCl}	OC	Total N	P Bray II	K^+	Mg^{2+}	Ca^{2+}	CEC pH7	Sand	Silt	Clay	BS
pH_{water}													
pH_{KCl}	0.366												
OC	0.784	−0.286											
Total N	0.516	−0.581	0.932										
P Bray II	−0.078	−0.434	0.284	0.522									
K^+	−0.35	0.733	−0.856	−0.978*	−0.506								
Mg^{2+}	0.203	−0.764	0.746	0.936	0.721	−0.960*							
Ca^{2+}	−0.66	0.448	−0.962*	−0.924	−0.158	0.898	−0.753						
CEC pH7	0.797	−0.168	0.959*	0.898	0.463	−0.786	0.74	−0.848					
Sand	0.824	0.818	0.315	−0.008	−0.205	0.208	−0.289	−0.119	0.422				
Silt	0.565	−0.454	0.843	0.783	−0.112	−0.794	0.593	−0.952*	0.655	0.024			
Clay	−0.979*	−0.304	−0.787	−0.51	0.225	0.369	−0.177	0.714	−0.743	−0.753	−0.676		
BS	−0.767	0.312	−0.986*	−0.904	−0.146	0.846	−0.698	.988*	−0.899	−0.271	−0.919	0.804	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

Table S6. Correlation matrix between soil characteristics in unit 6.

	pH_{water}	pH_{KCl}	OC (%)	Total N	P Bray II	K^+	Mg^{2+}	Ca^{2+}	CEC pH7	BS	Sand	Silt	Clay
pH_{water}													
pH_{KCl}	0.824												
OC	0.667	0.149											
Total N	0.743	0.249	0.994**										
P Bray II	−0.82	−0.426	−0.945	−0.963*									
K^+	0.517	−0.02	0.823	0.824	−0.65								
Mg^{2+}	−0.915	−0.82	−0.437	−0.529	0.558	−0.511							
Ca^{2+}	−0.697	−0.257	−0.966*	−0.964*	0.982*	−0.651	0.399						
CEC pH7	−0.884	−0.990**	−0.247	−0.347	0.496	−0.118	0.89	0.326					
BS	−0.888	−0.495	−0.933	−0.965*	0.982*	−0.725	0.69	0.939	0.579				
Sand	0.582	0.938	−0.165	−0.07	−0.15	−0.363	−0.595	0.011	−0.882	−0.194			
Silt	−0.359	−0.599	0.32	0.227	−0.221	−0.018	0.686	−0.393	0.619	−0.052	−0.581		
Clay	−0.577	−0.928	0.138	0.048	0.185	0.388	0.553	0.034	0.866	0.212	−0.996**	0.501	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

Table S7. Correlation matrix between soil characteristics in unit 7.

	pH_{water}	pH_{KCl}	OC	Total N	P Bray II	K^+	Mg^{2+}	Ca^{2+}	CEC pH7	BS	Sand	Silt	Clay
pH_{water}													
pH_{KCl}	0.968*												
OC	0.791	0.919											
Total N	0.975*	0.951*	0.8										
P Bray II	−0.268	−0.026	0.368	−0.178									
K^+	0.719	0.828	0.913	0.816	0.412								
Mg^{2+}	0.055	0.292	0.608	0.014	0.791	0.401							
Ca^{2+}	0.842	0.932	0.964*	0.894	0.277	0.974*	0.406						
CEC pH7	−0.441	−0.343	−0.1	−0.237	0.645	0.238	0.044	0.013					
BS	0.712	0.835	0.897	0.624	0.248	0.639	0.712	0.763	−0.445				
Sand	0.47	0.376	0.136	0.268	−0.632	−0.203	−0.026	0.023	−0.999**	0.474			
Silt	0.765	0.741	0.641	0.888	−0.036	0.845	−0.149	0.822	0.199	0.294	−0.172		
Clay	−0.725	−0.622	−0.349	−0.563	0.645	−0.077	0.075	−0.296	0.935	−0.573	−0.945	−0.159	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).