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Qualitative land suitability evaluation for maize (*Zea mays* L.) production on four benchmark soils in the forest-savanna transition agro-ecological zone of Ghana

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Abstract

Maize is an important cereal crop, however, its production is constrained by soil, terrain and, climatic limitations that lead to food security problems. A study was conducted on four benchmark soil series in Ghana; Bediesi, Techiman, Denteso, and Amantin to evaluate their suitability for maize production, identify the major biophysical limitations of each soil and suggest remediation measures. Biophysical land evaluation using the simple limitation approach by Food and Agriculture Organization (FAO) was carried out to assess the land suitability of the soil series for maize production. The length of the growing period for the study area was determined using the decade interpolation method. The area has two humid periods; April 21st to August 2nd and August 28th to October 25th. Maize growth and production requirements were matched against soil, landscape, and climatic characteristics to arrive at the final suitability classes for the four benchmark soils. The generalized climatic characteristics of the study area were found to be highly suitable for major season maize production except for unpredictable dry spells that plague agriculture in the area. Major yield reductions were attributed to the soil and landscape characteristics. Bediesi series was moderately suitable (S2f), Techiman and Amantin series were marginally suitable (S3s and S3sf, respectively) whereas Denteso series was currently not suitable (N1fw) for major season maize production. Thus, soil fertility management and soil and water conservation interventions such as organic matter application and making drainage channels are recommended to improve the potential suitability ratings of the soils.

Keywords: Land evaluation, maize, actual and potential suitability, soil series, soil suitability rating, simple limitation

Introduction

Agriculture is the traditional core competency of Ghana and the move to grow the economy is inextricably limited to improvements in the agricultural sector (Government of Ghana, 2003). To achieve this goal, soils must be consistently evaluated and analyzed since they play a dominant role, particularly in the cultivation of food and cash crops such as cassava, yams, millet, cowpea, maize, plantain, and sorghum among many others.

Maize (*Zea mays* L.) is a major staple food and, after rice and wheat, the world's third most important cereal crop in terms of production (IITA, 2009). It is a significant component of the Ghanaian population's diet. Maize has been grown in Ghana for hundreds of years. It quickly established itself as an important food crop in the southern part of the country after being introduced in the late 16th century. Very early on, maize also drew the attention of commercial farmers, although it never surpassed the economic importance of traditional plantation crops like cocoa and oil palm. However, the declining profitability of many plantation crops served to strengthen the interest in commercial food crops, including maize (WABS, 2008; Essilfie *et al*., 2011). Maize is currently Ghana's most important cereal crop accounting for 50-60% of total cereal production (MiDA, 2010). It is cultivated by the vast majority of rural households in all parts of the country, mostly in the Forest-Savanna and Forest Transition agro-ecological zone (WABS, 2008).

The study area, Ejura - Sekyedumasi Municipality remains the food basket and leading producer of maize and yams in the Ashanti Region of Ghana (MoFA, 2022) and is also endowed with rich arable land for maize production

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more than any other food crop (ESMA, 2018). Ejura farms which was once the largest commercial maize producing centre in Ghana is located in the municipality. Hence, both the crop under study (maize) and the area (Ejura - Sekyedumasi) are strategic in addressing food security problems in the Ashanti Region. The major soils of the area are developed from Voltaian sandstones (Adu and Mensah-Ansah, 1995). Even though these soils are suitable for growing millet, maize, yams, groundnuts, and many other food crops, the major soils vary in their potential for sustainable maize production. A careful assessment to identify and correct major limitations will enhance maize production and reduce land degradation.

Land degradation is a major threat to agricultural development in Ghana as pertains to most parts of sub-Saharan Africa (SSA). Assessments by FAO (2000) show that 67% (16.1 million km^2) of the total land area of SSA as degraded to a point where their original biotic functions have been completely lost. The problem is exacerbated by the conventional low-input management, practiced by many farmers, which is slowly reducing many soils to almost inert systems due to a lack of mineral nutrient replenishment (Stoorvogel and Smaling, 1990). Remarkably, more than 4 decades of African research and development have not resulted in the 3 - 5% annual increase in agricultural growth that most African countries need to ensure agricultural productivity and the prospect of food security in the near future (Badiane and Delgado, 1995). Although it is generally known that farmers have an adequate understanding of the soils they work with, by classifying based on some criteria such as colour, depth, texture, and concretions (Asiamah *et al.,* 1997), nutrient mining, soil degradation, and food insecurity are major problems in Ghana and many other African countries as a whole.

Soil properties change over time and space, and management and mismanagement can hasten these changes. Unfortunately, most farmers do not evaluate soils initially to examine the exact physical and chemical composition of the soils before planting; hence, the widespread decline in crop yields over the years. A thorough evaluation of cropland characteristics is necessary since it reveals the current potential and major limitations of land and is a valuable decision support tool. In addition, a good database on soil properties and related site characteristics is needed for one to be able to use the land in the best possible manner (Msanya *et al*., 2003). It is against this background that our research was founded. Benchmark soils are extensive, widely used, and well characterized. It is hoped that the output from the evaluation of the four benchmark soils namely Bediesi, Techiman, Denteso, and Amantin series in the Ejura- Sekyedumasi Municipality in the forest-savanna transition agro-ecological zone of Ghana for maize production, will serve as an important resource for planning and extension in the municipality, as well as provide information for farmers to maximize yields and reduce land degradation through the judicious use of soils.

The objectives of the study were to: (i) compile the physico-chemical properties of four major benchmark soil series in the study area and identify the major limiting factors in the soils affecting maize production; (ii) evaluate the suitability of four major benchmark soil series for maize production; and (iii) suggest sustainable agronomic and management interventions that will improve upon the fertility status of the soils for sustainable maize production.

Materials and Methods

Description of the study area

The study area, Ejura-Sekyedumasi Municipality is the fifth largest district among the 27 districts of the Ashanti Region of Ghana, having a land area of about 1782.2 km^2. The area lies within longitudes 1º5′W and 1º39′W and latitudes 7º9′N and 7º36′N, within the transitional zone between the semi-deciduous forest to its south and Guinea Savannah zone to its north. The area is marked by a bimodal rainfall pattern with the rainy season beginning in April and ending in November with two distinct growing seasons for annuals of relatively short growing cycles (3 - 4 months). The major season is between April and late July and the minor is between late August and November. The dry season is between November and April (ESMA, 2018; MoFA, 2022). The municipality experiences on average 1300 mm of annual rainfall however, erratic and occasionally unreliable. However, the number of rivers and streams in the study area serves as a potential for dams to be constructed to supplement the water requirement of farmers during the dry season (ESMA, 2018; MoFA, 2022).

Mean daily temperatures of 21°C – 30°C are generally experienced, with March and April being the warmest months whereas July-September is the coolest period. The rainy periods are associated with high relative humidity such as 90% particularly in June (ESMA, 2018; MoFA, 2022).

The Southeastern part of the Municipality consists of semi-deciduous forest vegetation, whereas the northern part has Guinea Savanna vegetation made up of tall grasses, such as *Andropogon, Pennisetum* and *Beckeropsis* interspersed with short fire-resistant trees like *Vitellalia* and *Daniella.* The cultivated areas have been put under arable crop cultivation, especially cereals occupying about 80% of the land. The major food crops cultivated in the area include yam (*Dioscorea spp*.), cassava (*Manihot esculenta*), maize (*Zea*

Table 1: Physical characteristics of the benchmark soil series in the study area

			Physical characteristics			
Soil series	**Horizon**	**Depth (cm)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Texture**
Bediesi	Ap1	0 - 9	71.7	13.7	14.6	fsl
	Ap2	9 –20	72.0	11.0	17.0	fsl
	BA	20 - 30	63.6	9.9	26.5	scl
	Bt1	30 - 51	52.5	9.4	38.1	sc
	Bt2	51 - 71	39.4	8.0	52.6	c
	Bt3	71 - 90	37.4	8.5	54.1	c
	Bt4	90 - 114	35.4	9.2	55.4	c
Techiman	Apc	1 – 12	77.1	15.8	7.1	ls
	ABcs1	12 – 32	73.4	18.0	8.6	sl
	ABcs2	32 – 54	73.8	18.2	8.0	fsl
	Btcs1	54 – 96	64.7	13.9	21.4	scl
	Btcs2	96 - 130	59.3	13.5	27.2	scl
Denteso	Ap1	0 – 11	75.2	21.2	3.6	lfs
	Ap2	11– 30	73.8	22.0	4.2	fsl
	BC	30 – 60	73.3	22.5	4.2	fsl
	C	60 - 130	84.8	15.2	-	lfs
Amantin	Ap1	0 – 9	73.4	21.8	4.8	fsl
	Ap2	9 – 33	71.1	22.1	6.8	fsl
	E	33 – 49	68.4	23.7	7.9	fsl
	Bt1	49 – 79	61.9	24.0	14.1	fsl
	Bt2	79 - 109	51.6	22.7	25.7	scl

c – clay, fsl – fine sandy loam, lfs – loamy fine sand, ls – loamy sand, sc – sandy clay, scl – sandy clay loam, sl – sandy loam

Table 2: Fertility characteristics of the benchmark soil series in the study area

Fertility characteristics (f)												
							Exchangeable basic cations ($cmol_{(+)}kg^{-1}$)					
Soil series	Horizon	Depth (cm)	pH, 1:1 H_2O	OC (%)	Total N (%)	Av. Bray P (mg kg^{-1})	Ca^{2+}	Mg^{2+}	K^+	Na^+	TEB ($cmol_{(+)}kg^{-1}$)	CEC ($cmol_{(+)}kg^{-1}$)
Bediesi	Ap1	0 - 9	6.7	1.06	0.11	10.1	3.6	1.7	0.1	-	5.4	5.4
	Ap2	9 –20	5.7	0.88	0.09	3.6	2.6	0.9	-	-	3.5	5.1
	BA	20 - 30	5.9	0.60	0.09	1.7	2.3	0.5	-	-	2.8	4.7
	Bt1	30 - 51	5.7	0.49	0.07	0.9	2.2	0.5	tr	-	2.7	4.9
	Bt2	51 - 71	5.6	0.42	0.07	0.6	1.7	0.5	-	-	2.2	5.2
	Bt3	71 - 90	5.6	0.35	0.07	0.4	1.6	0.6	-	-	2.2	5.2
	Bt4	90 - 114	5.8	0.30	0.05	0.3	1.4	0.9	-	-	2.3	5.1
Techiman	Apc	1 – 12	6.6	0.94	0.09	3.2	4.4	1.2	0.3	-	5.9	6.1
	ABcs1	12 – 32	6.7	0.90	0.08	2.0	5.6	1.2	0.1	-	6.9	6.8
	ABcs2	32 – 54	6.7	0.73	0.08	2.2	4.4	1.0	0.1	-	5.5	5.7
	Btcs1	54 – 96	6.1	0.33	0.07	0.3	2.8	2.7	0.1	-	5.6	8.6
	Btcs2	96 - 130	5.9	0.28	0.05	0.3	2.7	3.3	0.1	-	6.1	9.8
Denteso	Ap1	0 – 11	4.9	0.39	0.07	1.1	0.4	0.1	tr	tr	0.5	1.4
	Ap2	11– 30	4.7	0.27	0.05	1.1	0.2	tr	-	-	0.2	1.3
	BC	30 – 60	5.0	0.18	0.05	3.2	0.2	tr	-	-	0.2	1.2
	C	60 - 130	5.5	0.01	0.01	0.4	tr	tr	-	-	tr	tr
Amantin	Ap1	0 – 9	6.2	0.44	0.06	3.1	1.7	0.4	0.1	-	2.2	2.0
	Ap2	9 – 33	6.0	0.36	0.04	3.2	1.9	0.5	-	-	2.4	2.4
	E	33 – 49	6.1	0.19	0.04	2.3	1.2	0.4	tr	-	1.6	2.0
	Bt1	49 – 79	6.0	0.17	0.05	1.3	1.3	0.7	tr	-	2.0	2.4
	Bt2	79 - 109	4.9	0.17	0.06	0.4	1.2	0.8	0.1	-	2.1	4.1

CEC- cation exchange capacity, OC- total organic carbon, TEB- total exchangeable bases, tr – traces

mays), cowpea (*Vigna unguiculata*), and groundnut (*Arachis hypogaea*). Mango (*Mangifera indica*) and cashew (*Anacardium occidentale*) are the main tree crops. Vegetable crops especially eggplants (*Solanum melongena*), tomatoes (*Solanum lycopersicum*), and fruits like watermelon (*Citrullus lanatus*) are also cultivated (MoFA, 2022).

Materials and Methods

Materials and existing resources used for the study were:

i. Secondary soil characterization data, from the United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Soil Survey Laboratory, Lincoln, Nebraska.

ii. Climatic data for 11 years (1990 - 2000) on rainfall, temperature, and radiation in Ejura.

A data set on four benchmark soils for which a full description of the physical and chemical properties was available, was used. The selected benchmark soils are different soil types and are characterized by a high degree of heterogeneity:

- Benchmark soil 1. Bediesi series (Fine, mixed, isohyperthermic Typic Kandiustults)

- Benchmark soil 2. Techiman Series (Fine- loamy, parasesquic, isohyperthermic Typic Rhodustalf)

- Benchmark soil 3. Denteso series (Sandy, siliceous, isohyperthermic Oxyaquic Dystrudept)

- Benchmark soil 4. Amantin series (Fine- loamy, kaolinitic, isohyperthermic Typic Kandiustalf).

The physical and fertility characteristics of the benchmark soil series used in this study are presented in Tables 1 and 2.

Land suitability evaluation

The land suitability assessment focused on biophysical land evaluation using a simple limitation approach; an approach described in the Food and Agriculture Organization's (FAO) Framework for land evaluation (FAO, 1976) and guidelines for evaluating rainfed agriculture (FAO, 1983). The land-use requirements for maize were adopted from Sys *et al*. (1993). Soil and biophysical land characteristics were matched against the growth requirements of maize to determine the most critical land limitation(s).

The suitability classes and scores that were used in the land evaluation were; S1 as Highly suitable (75 – 100), S2 as Moderately suitable (50 – 75), S3 as Marginally suitable (25 - 50), N1 as Actually unsuitable but potentially suitable (10 – 25) and N2 as Actually and potentially unsuitable (0 - 10). The land suitability subclasses which were also used to define the type of limitation were: c (climatic), t (topography), w (wetness), n (salinity or alkalinity), f (fertility), and s (physical) limitation.

The simple limitation approach involved three phases:

Phase I: Data sets on the necessary characteristics

For phase I, data sets on climatic characteristics, landscape and soil characteristics were used for the evaluation. These have been described in the following section.

Climatic characteristics

Climatic data on rainfall, temperature, and radiation of Ejura were used for the evaluation. Evapotranspiration,

Table 3: Climatic requirements for maize

Climatic characteristics	Climatic class, degree of limitation and rating scale					
	S1		S2	S3	N1	N2
Precipitation of growing cycle (mm)	750 – 900	900 – 1200	1200 – 1600	> 1600	-	-
	750 – 600	600 – 500	500 – 400	400 – 300	-	< 300
Precipitation of the 1st month (mm)	175 – 220	220 – 295	295 – 400	400 – 475	-	> 475
	175 – 125	125 – 100	100 – 75	75 – 60	-	< 60
Precipitation of the 2nd month (mm)	200 – 235	235 – 310	310 – 400	400 – 475	-	> 475
	200 – 175	175 – 150	150 – 120	120 - 70	-	< 70
Precipitation of the 3rd month (mm)	200 – 235	235 – 310	310 – 400	400 – 475	-	> 475
	200 – 175	175 – 150	150 – 120	120 – 70	-	< 70
Precipitation of the 4th month (mm)	165 – 210	210 – 285	285 – 400	400 – 475	-	> 475
	165 – 125	125 – 100	100 – 80	60 – 80	-	< 60
Mean temp. of the growing cycle (°C)	24 – 22	22 – 18	18 – 16	16 – 14	-	< 14
	24 – 26	26 – 32	32 – 35	35 – 40	-	> 40
Mean min. temp. of the growing cycle (°C)	17 – 16	16 – 12	12 – 9	9 – 7	-	< 7
	17 – 18	18 – 24	24 – 28	28 – 30	-	> 30
Relative humidity of devel. stage (%) (2nd month)	65 – 50	50 - 42	42 - 36	36 – 30	-	< 30
	65 - 80	> 80	-	-	-	-
Relative humidity maturation stage (%)	40 – 30	30 – 24	24 – 20	< 20	-	-
	40 - 50	50 -75	75 – 90	> 90	-	-
Insolation (n/N) develop. Stage (2nd month)	0.55 – 0.5	0.5 – 0.35	< 0.35	-	-	-
	0.55 – 0.6	0.6 – 0.75	> 0.75	-	-	-
Insolation (n/N) maturation stage	> 0.7	0.7 – 0.5	< 0.5	-	-	-

Source (Sys *et al.,* 1993)

relative humidity, wind speed, and insolation data were interpolated from Prang and Mampong- Ashanti synoptic weather stations. This data was used to determine the start of the season, length of growing and humid periods as well as the overall climatic limitations. The rainfall and evapotranspiration data were interpolated using decade data input equations (Sys *et al*., 1991a). In this study, a decade refers to 10 days assuming each month has 30 days.

Landscape and soil characteristics

The slope, drainage, and flooding characteristics of the land were directly derived from the profile description. The overall texture and rock fragments were recalculated using weighting factors for the different profile sections. The profile was divided into four equal sections over the 100 cm and the weightings of 1.75, 1.25, 0.75, and 0.25 were assigned to the various sections down the profile (Sys *et al*., 1991b). The uppermost section (0 – 25 cm) was assigned a higher weight of 1.75 since it has a higher influence in the early stage of crop development.

The soil fertility indicators considered were:

a) Apparent cation exchange capacity (ACEC) - The CEC of the clay fraction ($cmol_{(+)}$ kg^{-1} clay) at a depth of 50 cm was calculated after correcting for organic matter (2.6 $cmol_{(+)}$ per 1% of Organic carbon)
b) Acidity (pH: H_2O) - The critical pH layer in the upper 25 cm of the soil was considered.
c) Organic carbon - The weighted average expressed in % was calculated for the upper 25 cm of the soil profiles.

Phase II: Determination of the requirements of the land utilization type

Climatic and soil requirements for the considered land utilization type (maize under low input) were adapted from the requirement tables for maize (*Zea mays*) by Sys *et al.* (1993) as presented in Tables 3 and 4.

Phase III: The evaluation sensu stricto

By comparing the land characteristics with the requirements of the land utilization type, the land suitability classes were determined using the simple/maximum limitation method; where the land characteristics are compared with the requirements and the land suitability rating is recorded. The final land suitability class is attributed to the less favourable characteristic of the land. This concept of simple/maximum limitation is similar to Liebig's law of minimum which states: "The amount of plant growth is regulated by the factor present in the minimum and increases or falls accordingly, as this factor is increased or decreased in amount."

Results

Rainfall trends in the study area

The area experiences a bimodal rainfall pattern as presented in Figure 1. This confirms the reports of ESMA (2018) and MoFA (2022). The two rainy seasons occur from April through early August and from late August to October. As illustrated in Figure 1, rainfall rises until it reaches a peak of 169.3 mm in June, gradually declines to 75.3mm in August and rises again to the second peak of 183.4 mm in September, and finally reduces to 29.1 mm in November. During the 1st decade of November, ½ ET_0 is greater than rainfall (17.92 mm) received which is not favourable for plant growth.

Growing period of the study area

The growing period can be defined as the continuous period of the year when precipitation is greater than half of the potential evapotranspiration making agricultural production possible because of adequate moisture availability and the absence of temperature limitations (FAO, 1996). Plants will grow when precipitation is greater than ½ ET_0 hence the growing period starts when precipitation exceeds ½ ET_0. The results of the decade values of rainfall, ET_0 and ½ ET_0 (Figure 2) showed that the area has one long growing period with two humid periods that follow the bimodal rainfall pattern notable in the semi-deciduous agro-ecological zone. The growing period is stretched over 245 days starting from March 19th until November 24th when an assumed 100 mm of soil water, stored at the end of the rains had evaporated. The end of the rains is in the 1st decade of November. Based on these climate characteristics of the region, a maize variety with a maximum growing cycle of 100 days can be cultivated twice during the growing period in the municipality.

Length of humid period

According to Sys *et al.* (1991a), the beginning and the end of the humid period coincide with the times at which the lines representing the onset of rainfall and ET_0 meet. That is the two successive decades where $R_1 < ET_{01}$ and $R_2 > ET_{02}$. From the results of the data analyzed, the two humid periods lie between April 21st – August 2nd and August 28th – October 25th.

Table 4: Landscape and soil requirements of maize

Landscape Characteristic	Class, degree of limitation and rating scale					
		S1	S2	S3	N1	N2
	0 No	1 Slight	2 Moderate	3 Severe	4 Very severe	
Topography (t)						
Slope (%) (1)	0 – 1	1 – 2	2 – 4	4 – 6	-	> 6
(2)	0 – 2	2 – 4	4 – 8	8 – 16	-	> 16
(3)	0 – 4	4 – 8	8 – 16	16 – 30	30 – 50	> 50
Wetness (w)						
Flooding	F.	-	-	F_1	-	F_{2+}
Drainage (4)	good	moderate	imperf.	poor and	poor,	poor,
(5)	imperf	moderate	good	aeric	but drainab	not drainab
Physical soil characteristics(s)						
Texture/struct.	C<60s, Co, SiC, SiCL,Si, SiL, CL	C<60v, SC,C>60s, L, SCL	C>60v, SL, LfS, LS	fS, S, LcS	-	Cm, SiCm cS
Coarse frag.(vol%)	0 – 3	3 – 15	15 – 35	35 – 55	-	> 55
Soil depth (cm)	> 100	100 – 75	75 – 50	50 – 20	-	< 20
$CaCO_3$ (%)	0 – 6	6 – 15	15 – 25	25 – 35	-	> 35
Gypsum (%)	0 – 2	2 – 4	4 – 10	10 – 20	-	> 20
Soil fertility characteristic(f)						
Apparent CEC (cmol$_{(+)}$ kg^{-1} clay)	> 24	24 – 16	< 16(-)	< 16(+)	-	-
Base saturation (%)	> 80	80 – 50	50 – 35	35 – 20	< 20	-
Sum of basic cations (cmol$_{(+)}$ kg^{-1} soil)	> 8	8.0 – 5.0	5.0 – 3.5	3.5 – 2.0	< 2	-
pH (H_2O)	6.6 – 6.2	6.2 – 5.8	5.8 – 5.5	5.5 – 5.2	< 5.2	-
	6.6 – 7.0	7.0 – 7.8	7.8 – 8.2	8.2 – 8.5	-	> 8.5
Organic carbon (%)						
(6)	> 2.0	2.0 – 1.2	1.2 – 0.8	< 0.8	-	-
(7)	> 1.2	1.2 – 0.8	0.8 – 0.5	< 0.5	-	-
(8)	> 0.8	0.8 – 0.4	< 0.4	-	-	-
Salinity and Alkalinity (n)						
Ece (dS m^{-1})	0 – 2	2 – 4	4 – 6	6 - 8	8 - 12	>12
ESP (%)	0 – 8	8 – 15	15 - 20	20 – 25	-	> 25

Source (Sys *et al*., 1993)

F_0 – no flood limitation; F_1 – severe flood limitation; F_{2+} - very severe flood limitation; Co – clay, oxisol structure; SiC – silty clay; SiCL – silty clay loam; Si – silt; SiL – silt loam; CL – clay loam; C<60s – clay,blocky structure; C<60v – clay, vertisol structure; SC – sandy clay; C>60s – very,fine clay, blocky structure; L – loam; SCL – sandy clay loam; C>60v – very fine clay, vertisol structure; SL – sandy loam; LfS – loamy fine sand; LS – loamy sand; fS – fine sand; S – sand; LcS – loamy coarse sand; Cm – massive clay; SiCm – massive silty clay; cS – coarse sand.

The meanings of the numbers associated with some characteristics on the table are as follows:

(1) Irrigated agriculture, basin furrow irrigation; (2) High level of management with full mechanization; (3) Low level of management, animal traction or handwork; (4) Medium and fine textured soils; (5) Coarse textured soils (sandy families); (6) Kaolinitic materials; (7) non-kaolinitic, non-calcareous materials; (8) Calcareous materials.

The growing period and humid periods are presented in Table 5. The decade rainfall and evapotranspiration pattern of Ejura- Sekyedumasi Municipality including the humid periods are presented in Figure 2.

Biophysical suitability evaluation

Climatic suitability evaluation

Climate forms a major part of land evaluation and determines the types of crops to grow. The results of the average climatic characteristics of the study area on rainfall, relative humidity, temperature, insolation, wind speed, and evapotranspiration are presented in table 6. The rated climatic characteristics for maize in the municipality obtained by comparing Table 3 with Table 6 are presented in Table 7.

From the comparison made, the climatic characteristics are highly suitable (S1) for major season maize production but moderately suitable (S2) for minor season maize production if planting is done in late July to mid-August. Late planting in September for minor season maize crops is

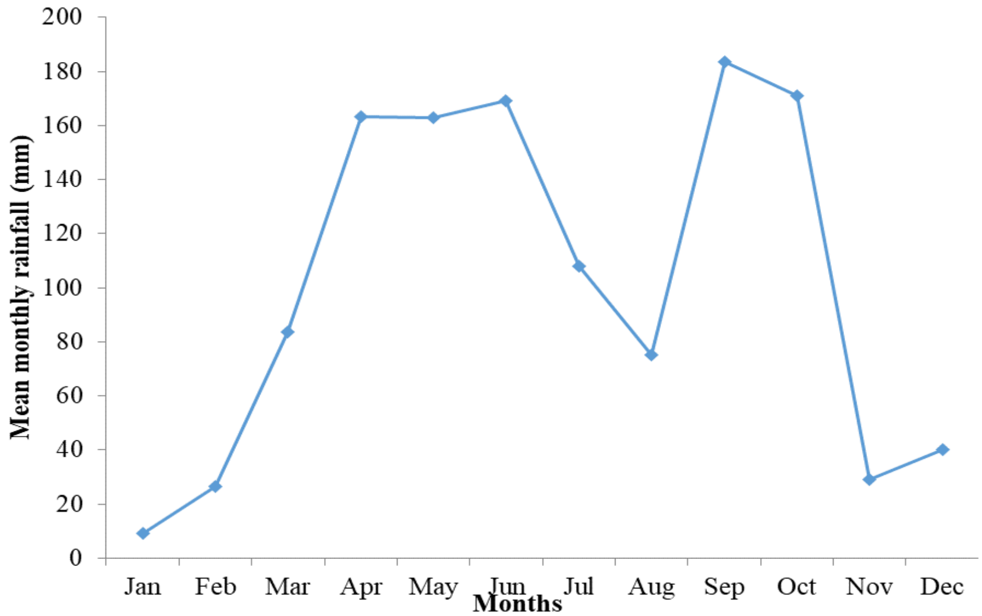

Figure 1: Mean monthly rainfall pattern of Ejura

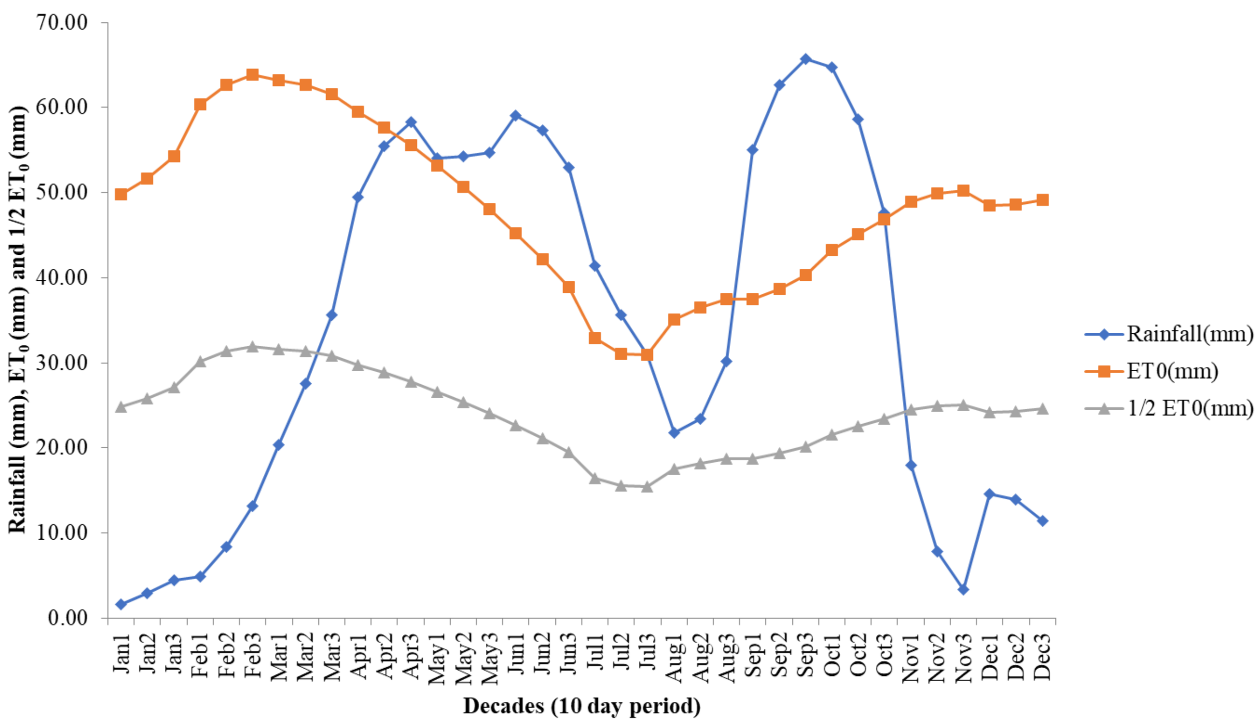

Figure 2: Decade rainfall and evapotranspiration pattern of Ejura

currently not suitable because of the low rainfall in November.

Landscape and soil suitability evaluation

The results of the matching exercise between the characteristics of the four benchmark soils of the area and the landscape and soil characteristics requirements for maize are presented in Table 8. From this Table, it is observed that the suitability rating for maize differs for the various benchmark soils. The major limiting factors for the benchmark soils are drainage, texture, and low fertility.

accordance with this, a matching exercise was carried out between the climatic characteristics and soil and landscape properties of the four benchmark soils understudied;

Table 5: Summary of the growing period at Ejura

Period	Start of period	End of rains	End of period	Duration
Growing period	March 19th	November 3rd	November 24th	245 days
Major humid period	April 21st		August 2nd	101 days
Minor humid period	August 28th		October 25th	57 days

Table 6: Climatic characteristics of Ejura

Characteristic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Mean Temp (°C)	33.6	35.5	34.9	33.7	32.6	31.0	29.7	30.4	30.2	31.2	32.2	32.2
Min Mean Temp (°C)	20.6	21.4	23.1	22.9	22.5	22.1	21.7	21.5	21.6	21.6	21.4	20.4
Mean Monthly Temp (°C)	27.1	28.4	29.0	28.3	27.6	26.6	25.7	26.0	25.9	26.4	26.8	26.3
Rainfall (mm)	9.0	26.4	83.6	163.3	163.0	169.3	108.1	75.3	183.4	171.0	29.1	40.0
Insolation (n/N)	0.59	0.64	0.57	0.58	0.56	0.45	0.33	0.29	0.36	0.52	0.64	0.58
Windspeed (m/s)	2.1	2.7	3.2	3.0	2.6	2.6	2.9	3.0	2.9	2.9	2.7	2.4
Mean-Relative Humidity (%)	51.9	51.3	61.0	68.2	73.7	79.5	90.5	82.0	81.9	77.9	71.3	64.4
Calculated ET_0 (mm)	155.7	187.0	187.5	172.8	152.0	126.4	95.0	109.1	116.6	135.1	149.1	146.2
½ Calculated ET_0 (mm)	77.9	93.5	93.8	86.4	76.0	63.2	47.5	54.6	58.3	67.6	74.6	73.1

ET_0: Evapotranspiration

Table 7: Rated climatic characteristics for maize in the municipality

	Major Season		Minor Season	
Climatic characteristic	**Value**	**Rating**	**Value**	**Rating**
Precipitation of growing cycle (mm)	597.7	S1	458.8	S2
Precipitation of 1st month (mm)	163.3	S1	75.3	S2
Precipitation of 2nd month (mm)	163.0	S1	183.4	S1
Precipitation of 3rd month (mm)	169.3	S1	171.0	S1
Precipitation of 4th month (mm)	108.1	S1	29.1	N1
Mean Temp. of growing cycle (°C)	27.1	S1	26.3	S1
Mean min. Temp. of growing cycle (°C)	22.3	S1	21.5	S1
Relative humidity of devel. stage (%) (2nd month)	73.7	S1	81.9	S1
Insolation (n/ N) develop. Stage (2nd month)	0.56	S1	0.36	S2
Overall Climatic Rating		S1		S2

Overall biophysical land evaluation

The results of the overall biophysical land evaluation of the four benchmark soil series in the study area are presented in Table 9. Generally, the results showed that drainage, texture, ACEC, pH, and organic carbon are the most limiting factors on the soils understudied in the municipality.

Discussion

Overall biophysical land evaluation

According to De la Rosa and Van Diepen (2009) and Verheye *et al*. (2009), land evaluation is a process of comparing a series of selected land qualities to land use requirements, and thus, land evaluation of agro-ecological zones is required for sustainable food production. In Bediesi, Techiman, Denteso, and Amantin series. The results showed that drainage, texture, ACEC, pH, and organic carbon are the most limiting factors on the soils understudied in the study area.

Bediesi series (Fine, mixed, isohyperthermic Typic Kandiustults) had a slope of 2% which is highly suitable for maize production (Sys *et al*., 1993). The slope has a low erosion hazard and is favourable for field operations including mechanization. It is well-drained meaning it has moderate hydraulic conductivity and moderate water holding capacity, which facilitates oxygen availability in the soil to enhance plant growth. This fulfills the conditions stated by Ritung *et al*. (2007) that generally, plants need good soil drainage to promote oxygen availability. The soil has a sandy loam texture in the topsoil and no coarse fragments throughout the profile, which make it easily

Table 8: Rated landscape and soil characteristics for maize in Ejura

Benchmark soil series	Soil physical characteristics (s)					Soil fertility characteristics (f)			Rating	Limitation	Actual suitability
	Slope (%)	Drainage	Texture	Coarse fragment (%)	Depth (cm)	ACEC	pH	Organic carbon (%)			
Bediesi	2.0 S1	Well S1	SCL S1	0.0 S1	100.0 S1	9.5 S2	6.1 S1	0.9 S1	S2	f	S2f
Techiman	2.0 S1	Well S1	SL S2	50.4 S3	100.0 S1	47.5 S1	6.7 S1	0.9 S1	S3	s	S3s
Denteso	2.0 S1	Poor N1	LS S2	0.0 S1	100.0 S1	17.4 S1	4.8 N1	0.3 S3	N1	wf	N1fw
Amantin	3.0 S1	Moderately well S1	SL S2	0.0 S1	100.0 S1	13.9 S2	6.1 S1	0.4 S3	S3	sf	S3f

ACEC: Apparent cation exchange capacity. The coarse fragment content is the weighted average over rooting depth.

Table 9: Overall land suitability ratings of the four benchmark soils for maize production in the study area

Benchmark soil series	Suitability class (climate)	Suitability class (landscape and soil)	Actual suitability	Potential suitability rating
Major season maize production				
Bediesi	S1	S2f	S2f	S1
Techiman	S1	S3s	S3s	S3s
Denteso	S1	N1fw	N1fw	S2s
Amantin	S1	S3f	S3f	S1
Minor season maize production				
Bediesi	S2	S2f	S2cf	S1
Techiman	S2	S3s	S2cs	N2s
Denteso	S2	N1fw	N1fw	S2s
Amantin	S2	S3f	S3f	S1

workable. It is moderately acidic (pH = 6.1) in the topsoil and has a very low organic carbon content according to the ratings of Motsara and Roy (2008) and Landon (2014), respectively. These properties are highly favourable for maize production. However, the ACEC of 9.5 $cmol_{(+)}$ kg^{-1} clay suggests the dominance of low-activity clay. This xfertility indicator was rated moderately suitable for maize production since it leads to low retention of nutrients in the upper part of the soil. From the analysis made, the actual suitability of Bediesi series for major season maize production is S2f, that is, moderately suitable for maize production with fertility limitations due to the low ACEC in the soil. Therefore, under low-level management, if this limitation is corrected by adding organic matter to the soil, Bediesi series is potentially highly suitable for major season maize production. The soil is currently classified as (S2cf) moderately suitable for minor season maize production.

Techiman series (Fine- loamy, parasesquic, isohyperthermic Typic Rhodustalf) also had a slope of 2%, which is highly suitable for maize production (Sys *et al*., 1993). It is well-drained, with a loamy sand topsoil with many ironstone concretions and gravels, which make the topsoil highly workable and suitable for maize. The pH is slightly acidic (6.7). The soil has very low organic carbon content. The ACEC of 47.5 makes the soil highly suitable for maize production. However, the soil has abundant coarse fragments (weighted average over rooting depth of 50.41%) which make the soil marginally suitable for maize since it will adversely influence the moisture and nutrient contents of the soil. The sandy loam texture of the soil also makes it moderately suitable for maize production. Based on our evaluation, the actual suitability of Techiman series is S3s, that is, marginally suitable for major season maize production with limitations in the soil physical characteristics, particularly the coarse fragment percentage. Little can be done to amend the coarse fragment limitation of the soil and therefore the soil is actually and potentially marginally suitable for major season maize production with severe physical limitations in the soil. However, it is currently moderately suitable (S2cs) for minor season maize production.

Denteso series (Sandy, siliceous, isohyperthermic Oxyaquic Dystrudept) had a slope of 2%, which is highly suitable for maize production. It has no coarse fragments making it highly suitable for maize production. However, the loamy sand texture throughout the profile imparts low moisture and nutrient retention capacity and makes the soil moderately suitable for maize. The organic carbon content of (0.3%) also rated it marginally suitable for maize. The greatest limitation posed by Denteso series is the poor drainage condition and the very strongly acid nature of the soil, which makes the soil currently unsuitable for the production of maize. From the suitability rating, the actual suitability of Denteso series is N1fw, that is, currently not suitable for both major season and minor season maize production because it is limited by poor drainage conditions and acidity. Therefore, if this limitation is corrected by adding organic matter to the soil and creating drainage channels in the soil, the Denteso series will be improved to become potentially moderately suitable for maize production.

Amantin series (Fine- loamy, kaolinitic, isohyperthermic Typic Kandiustalf) has a slope of 3%, which is highly suitable for maize production. It is moderately well-drained. The soil had no coarse fragments and which makes the soil highly workable and highly suitable for maize. The pH is 6.1 making the soil moderately acidic. The limitations posed by the sandy loam texture of the soil and the low ACEC (13.9 cmol $_{(+)}$ kg^{-1}) make the soil moderately suitable for a maize crop. The worst limitation on the soil is due to the very low organic carbon level of 0.4% in the upper 25 cm of the soil, which makes the soil marginally suitable for production. From the analysis made, the actual suitability of Amantin series is S3f, that is, marginally suitable for maize production but with fertility limitations. Therefore, under low-level management, the fertility limitation can be corrected, for example, through organic matter application to make the soil potentially highly suitable for the production of maize.

Conclusions

This study has compiled the physico-chemical properties of the Bediesi, Techiman, Amantin, and Denteso soil series and evaluated their suitability for maize production. From the results obtained, the climatic characteristics of the municipality are highly suitable for major season maize production except for unpredictable dry spells that plague agriculture in Ghana. Bediesi series is actually moderately suitable but potentially highly suitable for major season maize production if the fertility limitation posed by low ACEC is corrected. Techiman series is actually and potentially marginally suitable for major season maize production. It is skeletal with abundant coarse fragment (50.41%) limitation, which is difficult to correct. Denteso series is currently not suitable for major season maize production due to poor drainage and strongly acid reaction (pH 4.8). It is potentially moderately suitable for maize production when limitations due to poor drainage fertility posed by low pH as well as the very low organic carbon content of the soil are corrected. Amantin series is potentially highly suitable for maize production if the fertility limitations are corrected.

From the considerations made in the study, the recommendations suggested are: further studies should be conducted to determine the actual nutrient limiting in the soils for the appropriate remediation, and minor season maize should be sown latest by August 24th to take advantage of the second humid period in the growing cycle. Since the study is intended for a low level of management of agriculture, agronomic interventions such as organic matter application to Bediesi, Techiman, Denteso and Amantin series is recommended to improve soil fertility. Furthermore, Denteso series can be drained by making drainage channels and furrows to address the poor drainage conditions.

References

Adu, S.V. and J.A. Mensah-Ansah. 1995. Soils of the Afram basin: Ashanti and Eastern Regions, Ghana. Soil Research Institute (Council for Scientific and Industrial Research). Memoir no. 12:17-53.

Asiamah, R.D., J.K. Senayah, T. Adjei-Gyapong and O.C. Spaargaren. 1997. Ethno-pedology surveys in the semi-arid savanna zone of Northern Ghana. An ILEIA initiated project. Report 97/04. Soil Research Institute, Kwadaso-Kumasi and International Soil Reference Information Centre (ISRIC), Wageningen. vi. + 38p+ 2 maps.

Badiane, O. and C.L Delgado. 1995. A 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 4. Intl. Food Policy Research Inst., Washington DC. 56 pp.

De la Rosa, D. and C.A. Van Diepen. 2009. Qualitative and quantitative land evaluations. *Land Use, Land Cover and Soil Sciences* 2: 59-77.

ESMA. 2018. Ejura-Sekyedumasi Municipal Assembly. Town profile. Online: https://esma.gov.gh/about-us/town-profile/ [Accessed: May 19, 2022].

Essilfie, F.L., M.T. Asiamah and F. Nimoh. 2011. Estimation of farm level technical efficiency in small scale maize production in the Mfantseman Municipality in the Central Region of Ghana: A stochastic frontier approach. *Journal of Development and Agricultural Economics* 3(14): 645-654.

FAO. 2000. Food and Agricultural Organization. FAOCLIM2—World Wide Agroclimatic Data Base CD-ROM. Food and Agriculture Organization—Agro-meteorology Group, Rome.

FAO. 1976. Food and Agriculture Organization of the United Nations. A framework for land evaluation. Soils

Bulletin 32. FAO, Rome, Italy vii + 72p. ISBN 92 5 100508 7.

FAO. 1983. Food and Agriculture Organization of the United Nations. Guidelines: Land evaluation for rainfed agriculture. FAO Soil Bulletin 52. FAO, Rome. 237p.

FAO. 1996. Agro-Ecological Zoning Guidelines. FAO Soil Bulletin 76. Soil Resources, Management and Conservation Service. FAO Land and Water Development Division. Food and Agriculture Organization of the United Nations, Rome. 78p.

IITA. 2009. Cereals and Legumes Systems. International Institute of Tropical Agriculture.

Landon, J.R. 2014. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Routledge. 530p.

MiDA. 2010. Millenium Development Authority. Maize, Soya and Rice Production and Processing. Online: http://www.mida.gov.gh/site/wpcontent/uploads/2010/07/Food_Grain_BOMFinal_Draft2.pdf. [Accessed: March 10, 2021].

MoFA. 2022. Ministry of Food and Agriculture. Ejura-Sekyeredumase District Information. https://mofa.gov.gh/site/sports/district-directorates/ashanti-region/164-ejura-sekyeredumase [Accessed: May 19, 2022].

Motsara, M.R. and R.N. Roy. 2008. Guide to laboratory establishment for plant nutrient analysis. Food and Agriculture Organization of the United Nations. FAO Fertilizer and Plant Nutrition Bulletin No. 19. 204 pp.

Msanya, B.M., A.K. Kaaya, S. Araki, H. Otsuka and G.I. Nyadzi. 2003. Pedological characteristics, general fertility and classification of some benchmark soils of Morogoro District, Tanzania. *African Journal of Science and Technology* 4(2): 101-111.

Ritung, S., F. Wahyunto and H. Hidayat. 2007. Land Suitability Evaluation with a case map of Aceh Barat District. Indonesian Soil Research Institute and World Agroforestry Centre, Bogor, Indonesia.

Stoorvogel, J.J. and E.M.A. Smaling. 1990. Assessment of soil nutrient depletion in Sub-Saharan Africa: 1983-2000. Winand Staring Centre for Integrated Land, Soil, and Water Research, Netherlands.

Sys, C., E. Van Ranst and J. Debaveye. 1993. Land evaluation. Part 3: Crop requirements. Agricultural Publications 7,3. General Administration of Development Cooperation of Belgium, Brussels. 199p.

Sys, C., E. VanRanst and J. Debaveye. 1991a. Land evaluation. Part 1: Principles in land evaluation and crop production calculation. General Administration for development cooperation. Agricultural Publications No: 7. Brussels, Belgium, 174pp.

Sys, C., E. VanRanst and J. Debaveye. 1991b. Land evaluation. Part II: Methods in land evaluation. General Administration for development cooperation. Agric. Publ. No: 7. Brussels, Belgium, 247 p.

Verheye, W., A.P. Koohafkan and F. Nachtergaele. 2009. The FAO guidelines for land evaluation. Encyclopedia of land use, land cover and soil sciences: *Land Evaluation* 2: 78-100.

WABS. 2008. Draft report: Maize Value Chain Study in Ghana: Enhancing Efficiency and Competitiveness. WABS Consulting Ltd. 57 pp.