Physico-chemical characteristics and suitability of soils of areas climatically suitable for optimal oil palm production in Ghana

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Abstract

Soil physico-chemical data and land characteristics were used to assess the suitability of soils for oil palm production in areas climatically optimum for oil palm cultivation. The toposequence of soils on the three geological formations, Birimian, granites and associated rocks, and alluvial deposits, in these optimum areas were indicated. The soils were categorized into summit and upper slopes, middle slope, and lower slope/valley bottom soils. Qualitative data on soil physical characteristics were provided for soils of Kusi and Adum Banso to describe the soils as categorized above and to support soil textural description. Physical differences in soils such as depth, colour, slope and texture were noted. Chemical data including *p*H (water), organic matter, total N, exchangeable bases and exchange acidity, CEC and available K and P were provided for summit and upper slopes, middle slope and lowland soils for specified depths at Kusi and Adum Banso to quantify nutrient status. The soils were generally found to be acidic and low in nutrients. The suitability of the soils for oil palm cultivation was then assessed on the basis of physico-chemical characteristics described. The soils were classified and rated as moderately or marginally suitable with the majority of them falling in the latter suitability class. Limitations to the suitability of some individual soils were poor drainage, concretions, low moisture retention capacity, the hazard of erosion, acidity and low nutrients.

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Introduction

The suitability of soils for the cultivation of oil palms has been defined in terms of soil physical and chemical characteristics (Olivin, 1968; Ng, 1968). Asamoah & Nuertey (1998a) listed 21 soils observed Kusi, Twifo Praso and Adum Banso, which were zoned as being climatically suitable for optimal oil palm cultivation in Ghana. The soils were formed over granites, Birimian rocks and alluvial deposits, were briefly described quantitatively, and associations between them drawn. The predominant soils were Nzima, Kokofu and Temang series on Birimian formations, and Akroso, Nsaba, Nkwanta and Agona series on granites. This paper provides detailed information on the general physical and chemical properties of the soils, and land characteristics for the suitability classification of these soils for oil palm cultivation and production.

Materials and methods

Soils were grouped into summit and upper slope, middle slope, and lower slope/valley bottom lands, and each group sampled at depths of 0-30 cm, 30-60 cm, and 60-90 cm. At Kusi, soil samples data were obtained to cover specific soils and variations with profile depths but were averaged and categorized as above. At Adum Banso, data used had been categorized into upland (summit, upper and middle slopes) and lowland (lower slope and valley bottom), and sampled at depths of 0-30 cm and 30-60 cm. In such data presentation, surface horizon (0-15 cm) effects will, thus, be masked. Technical data on soil physic- chemical properties were produced to cover soils of Kusi area using data for the Oil Palm Research Institute by Asiamah & Senayah (1991) and for Adum Banso by Anon. (1997). Mean values were calculated and range of values provided. The data on physical properties comprised silt-clay-sand (%) at various depths. These were used to describe texture. To quantify soil nutrient status, chemical data was obtained on *p*H (water), organic C (%) and organic matter (%), total N (%), exchangeable base levels (m.e. /100 g soil), exchange acidity and available P and K (p.p.m.,

Bray 1).

The soils were then evaluated and rated for their suitability for oil palm production. The FAO (1983) guidelines for the evaluation of soils were used. The major land characteristics used to classify the soils are texture, quantity/absence of gravels and concretions, effective soil depth, water permeability or lack of drainage, slope, erosion hazard, and chemical or nutrient status. Similarities or variations in these characteristics allow soils to be grouped together under one suitability class, or otherwise.

The land suitability orders determine whether a land is suitable, S, or not, N, for a specific use which, in this case, is for oil palm production. The land suitability classes reflect the degrees of suitability of orders as S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), N1 (currently not suitable), and N2 (permanently not suitable). The land suitability sub-classes define major limitations associated with the individual soils as described. The limitations are designated as follows: *w* (drainage), *q* (concretions or gravels), *m* (moisture availability), *e* (erosion hazard), *n* (nutrient availability), *s* (slope), *d* (effective depth) and *r* (rockiness).

Land characteristics as determined in the criteria are rated in different forms to define soil suitability orders and classes for oil palm production in Table 1. Similarly, the ratings for nutrient/chemical characteristics, are shown in Table 2. Ratings were done by matching the characteristics of each soil series against the requirements for oil palm production. All the soils listed were rated using the FAO (1983) and Halm (1965, 1968) systems. Limitations noted were indicated, and their corrective measures recommended.

Results and discussion

Soil physico-chemical properties

Quantitative data on particle size distribution, i.e. % sand, % clay and % silt, of the various soils identified at Kusi and Adum Banso are presented in Table 3. The summit and upper slope soils of Kusi have topsoils (0-30 em) with textures that ranged from loam to sandy loam and subsoils, and clay loam to clay. The lowland/valley bottom soils of Oda and Temang series are basically sandy loam, with Chichiwere series being entirely sandy to loamy sand. At Adum Banso, the summit and upper slope soils are sandy clay loam to clay

TABLE 1

Land Use Requirements and Suitability Ratings for Oil Palm Production

Land characteristics	*Highly suitable S1*	*Moderately suitable S2*	*Marginally suitable S3*	*Not suitable N*
Slope %	0-5	5-8	8-15	> 15
Erosion hazard	Very slight	Slight	Moderate	Severe
Soil drainage	Well to moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained
Texture				
Topsoil	Loam, sandy loam, silty loam	Sandy clay loam	Sandy clay, silty clay, loamy sand	
Subsoil	Sandy clay loam, clay loam, silty clay loam	Clay, sandy loam	Loamy sand heavy clay	
Concretions and gravels	Nil to very few	Few	Many	
Effective depth (cm)	Over 120	80-120	60-80	Less than 60

Source: Asiamah & Senayah (1991).

TABLE 2

Ratings for Nutrient Characteristics

Rating/Parameter	*Very low*	*Low*	*Moderate*	*High*	-
Organic matter %	-	0-1.5	1.5-3.0	>3.0	
Total N%	-	0-0.1	0.1-0.2	>0.2	
Exch. Mg m.e./100g	-	0-1.0	1.0-2.0	>2.0	
Exch. Ca m.e./100 g	-	0-5.0	5.0-10,0	>10.0	
CEC m.e./100 g	0 -8.0	8.0-16.0	16.0-24.0	>24.0	
AI+ H m.e./100 g	-	0-0.5	0.5-1.0	>1.0	
P.p.m. (Bray 1) K	-	0-50.0	50.0-100.0	>100.0	-
P.p.m. (Bray 1) P		0-10.0	10.0-20.0	>20.0	
*p*H (Water)	Very strongly acid Less than 5.0	Strongly acid 5.0-5.5	Moderately acid 5.5-6.0	Slightly acid 6.0-6.5	Neutral to near acid 6.5-7.0

Source: Halm, A. T. (1965, 1968); Tetteh, F. M. (1997)

TABLE 3

Texture of Soils of Kusi and Adum Banso

Kusi

Summit and upper slopes	*Depth (cm)*		
	0 - 30	*30 - 60*	*60 - 90*
Sand	46.8 (41.6-62)*	29.7 (21-41.5)	23.5 (21-27)
Silt	36.2 (31.8-42)	30.2 (25-33.8)	29.5 (19-35.8)
Clay	17.0 (4.7-34)	40.2 (26.8-50)	47.0 (43.3-54)
Texture	L / SL	CL / SC	C
Middle slope			
Sand	41.5 (38-48)	35.5 (32-39)	30.0
Silt	37.8 (33-42)	33.1 (32-34)	33.1
Clay	20.7 (10-29)	31.4 (28-35)	37.2
Texture	L / SL	L / CL	CL
Lowland			
Sand	55.2	58.7 (55-63)	67.8 (62-73)
Silt	39.8 (37-42)	32.2 (27-37)	23.3 (19-28)
Clay	5.0 (3.0-8.0)	9.0 (8-10)	9.0 (8-10)
Texture	SL	SL	SL

Adum Banso						
	Upland (depth,cm)			*Low land (depth, cm)*		
Parameter	*0-30*	*30-60*	*60-90*	*0-30*	*30-60*	*60-90*
Sand	49.5	41.0	33.1	61.0	52.5	41.5
Silt	21.0	14.0	16.4	16.0	15.5	16.5
Clay	29.5	45.0	50.4	22.5	32.0	42.0
Texture	SCL	C	C	SCL	SCL	C

L - Loam(y), S - Sand (y), CL - Clay loam, C - Clay, SCL - Sandy clay loam, Si - Silty, SiCL - Silty clay loam, SiL - Silty loam, SiC - Silty clay.

* Range of values in parentheses

Source: Summarized from Asiamah & Senayah, 1991; Anon., 1997.

with depth, and in the lowlands sandy clay loam to heavy clay.

Derived qualitative information on some physical characteristics of the soils developed over Birimian rocks are provided in Table 4. It shows differences in soil colour, texture and structure for the same and different soil series at different locations, especially at Kusi and Twifo Praso. The upland soils, Bekwai and Nzima series, have silty loam textures at the top. This overlies silty clay loam to silty clay subsoils. The structure consists of weak and granular top soils, with subsoils being weak, fine, moderate to medium subangular blocky and slightly firm to firm consistence. These characteristics are conducive for high water retention capacity, improved root penetration, water movement and aeration, and are highly favorable for oil palm growth.

The chemical properties of the soils at Kusi and Adum Banso are presented in Tables 5, 6 and 7. The upland soils at the two locations are extremely acid with *p*H varying between 4.0-4.5 (Table 5). However, at the lowlands, the Kusi soils are strongly acid (*p*H 5.3-5.5) while- at Adum Banso they are extremely acid (*p*H 4.1-4.2). Organic matter levels are low to moderate (1.5-3.0%) generally. Levels are sometimes high (3.0-4.7%) in the topsoils and very low to low (<0.0-1.5%) in the subsoils at both locations. Levels are relatively higher in the topsoils of summit, upper and middle slopes than the lowlands at both locations. These levels, however, decrease with depth. Total nitrogen levels are low at Kusi (0.03-0.10%) and low to moderate at Adum Banso (0.09-0.13%). These levels also decrease with depth.

Exchangeable base levels are low (Table 6). Exchangeable Mg levels are low to moderate (0.0-2.0 m.e./100 g) with a greater proportion of values in the lower end of the range. Levels are relatively higher in the uplands soils, especially in the top 30 cm, and decrease similarly with depth in all cases. The trend is the same for Ca, Na, K and the CEC levels. Average exchange acidity (AI + H) values are moderate to high in all locations (0.83-3.43 m.e./100 g). With the exception of the lowlands at Kusi which have moderate values (0.80-0.85 m.e./100 g), levels are high, (1.14-3.52 m.e./100 g) irrespective of topographic position at the two sites. Levels increase with depth at all toposites at the two locations.

Average available P (p.p.m., Bray 1) levels are low. Values range from trace amounts to 5.68 p.p.m. (Table 7) to indicate deficiency of P in the soils. Topsoil values are higher in all cases but decrease with depth. Average available K (p.p.m., Bray 1) levels are low and range from low (0.0-50.0 p.p.m.) in the summit and supper slopes, to very low (7-24 p.p.m.) in the middle and lowland soils. The levels decrease with depth in all cases.

Base saturation levels are low to high. About 70 per cent of the mean values are moderate (40-55%). Base saturation levels do not vary much with depth in the middle slope and lowlands of Kusi, and upland and lowlands of Adum Banso. Mean base saturation levels are comparatively higher in the lowlands than the uplands. At Adum Banso, the levels are moderate with the mean lowland value being 54 per cent and the upland 52 per cent. At Kusi, the levels are high (> 70%) for the lowland soils irrespective of depth. But the levels vary from (> 70%) in the top 30 cm and decrease to low levels (< 40%) with depth in the summit and upper slope soils. The mean values for the middle slope soils at Kusi are low (< 40%).

Land suitability classification

A total of 21 soils of the climatic area were evaluated and rated into suitability classes for the economic production of oil palm under rain-fed conditions using the FAO (1983) system (Tables 8a, 8b, 8c and 8d). The soils at the three locations vary in characteristics with physiographic positions; from summit, upper, middle and lower slopes to the valley bottoms. General toposequence variations in drainage conditions, concretions and gravel content, texture, slope and erosion hazard were also noted. Lower slope and valley bottom soils only were different, being generally free of gravels and

TABLE 4

Soil Texture, Colour and Structure of Birimian Soils of Kusi (A) and Twifo Praso (B)

Soil series	*Texture*	*Colour*	*Structure and consistence*
Bekwai			
1.A Top	Silty loam	Dark brown, 10 YR 3/3	Friable, weak, fine granular
Transitional	Silty loam	Brown, 7.5 YR 4/4	-
Subsoil	Silty clay	Reddish brown, 5 YR 4/4	Weak, fine subangular blocky
1.BTop	Clay loam	Dusky red 10 YR 3/4	Moderate medium subangular blocky
Subsoil	Gravelly clay	Red 7.5 YR 4/6	Moderate to medium subangular blocky and firm
2.A *Nzima*			
Top	Silty loam	Dark brown, 10 YR 3/3	Friable and granular
Transitional	*Silty clay loam*	*Brown 10 YR 4/3*	-
Subsoil	Silty clay	Strong brown, 7.5 YR 5/8	Moderate to medium subangular blocky with firm consistence
2.B Top	Clay loam	Yellowish red, 5 YR 4/6	Moderate fine and medium subangular, friable
Sub	Clay	Yellowish red, 5 YR 5/6	Moderate fine and medium subangular, firm
3.A *Kokofu*			
Top	Sil y loam	Dark brown, 10 YR 3/3	Weak, fine granular
Transitional	Silty clay loam	Brown 10 YR 4/3	-
Subsoil	Silty clay	Yellowish brown, 10 YR 5/6	Weak, fine and medium subangular blocky, slightly firm
3.B Top	Fine sandy clay loam	Greyish brown, 10 YR 5/2 to dark brown, 10 YR 3/3	Fine and medium weak subangular blocky of firm consistence
Subsoil	Silty clay loam	Yellowish brown to brownish yellow, *10 YR 5/4 -10 YR 6/8*	Moderate fine and weak angular blocky with firm consistence
4.A *Temang*			
Top	Sandy loam	Dark brown, 10 YR 3/3	Weak, fine granular
Subsoil	Sandy clay	Light grey, 2.5 YR 7/1 - Grey, 2.5 YR 6/1	Moderate to medium sub angular blocky with firm consistence
4.B Top	Fine sand/sandy loam	Dark brown, 10 YR 313	Weak fine granular, friable
Top	Stratified sands silt clay and clays	Light brownish grey to brown mottled strong brown, 10YR 6/2-7.5 YR 5/6	Weak fine granular, friable
5.A *Oda*			
Top	Silty clay loam and	Very dark greyish brown 10YR 3/2	Friable, fine weak granular
5.B Top	Silty clay loam and clays	Greyish brown to grey mottled yellowish brown 10YR 3/2 - 19YR 4/8	Moderate medium coarse subangular blocky, firm

Source: Asamoah & Nuertey, 1998a : Summarized from Asiamah & Senayah (1991) and Anon. (1979).

TABLE 5

Chemical Properties (pH, Total N, Organic C and Matter) of Soils of Kusi and Adum Banso

Kusi

Summit and upper slopes	*Depth (cm)* 0.30	30-60	60-90
*p*H %	4.5 (4.1-5.2) *	4.3 (4.2-4.3)	4.2 (4.2-4.3)
Organic C %	1.41 (0.53-2.71)	0.45 (0.38-0.53)	0.34 (0.25-0.43)
Total N %	0.10 (0.02-0.27)	0.03 (0.03-0.04)	0.03
Organic matter %	2.45 (1.0-4.7)	0.93 (0.8-1.0)	0.79 (0.5- 1.07)
Middle slope	*0-30*	*30-60*	*60-90*
*p*H%	4.1 (4.0-4.3)	4.1 (4.0-4.2)	4.2
Organic C %	1.35 (0.53-2.31)	0.49 (0.45-0.53)	0.44 (0.42-0.45)
Total N %	0.03 (0.02-0,04)	0.04 (0.03-0.04)	0.03 (0.02-0.03)
Organic matter %	2.30 (0.9-4.0)	0.90 (0.8-0.9)	0.80
Lowland soils	*0-30*	*30-60*	*60-90*
*p*H%	5.3 (5.0-5.5)	5.5	5.4 (5.2-5.4)
Organic C %	0.92 (0.22-1.84)	0.14 (0.06-0.22)	0.06
Total N %	0.09 (0.04-0.15)	0.04	0.04 (0.03-0.04)
Organic matter %	2.45 (0.4-3.2)	0.25 (0.1-0.4)	0.10

Adum Banso

Parameter	*Upland* 0-30 cm	30-60 cm	*Lowland* 0-30 cm	30-60 cm
*p*H	4.1	4.2	4.2	4.2
Organic C %	1.3	0.61	0.81	0.34
Total N %	0.16	0.13	0.13	0.09
Organic matter %	2.29	1.15	1.39	0.07

* Range of values in parentheses.

Source: Summarized from Asiamah & Senayah (1991); Anon, (1997)

concretions. This trend appears common also in the soils developed over granites and associated rocks; the colluvial soils were rated moderately suitable for oil palm production with respective limitations described where applicable. In all cases, the soils were generally low in nutrients and acidic.

On the Upper and Lower Birimian soils (Tables 8a and 8b), the surrounding land forms are gently undulating at Kusi, and gently to steeply undulating at Twifo Praso with slope gradients being steeper for the same soils at Twifo Praso (Asamoah & Nuertey, 1998a; Anon., 1997). Gradients at Kusi were almost flat (1-2% for Bekwai, 3-4% for Nzima and 2% for Kokofu). The respective gradients at Twifo Praso were 0-12%, 0-8% and 2-6%. The major limitations were *q* and *e*, and, to a smaller extent, *d* for summit and upper slope soils; and varying levels of *w*, as drainage imperfections for middle slope to lowland and valley bottom soils. Bekwai and Nzima series are rated moderately suitable (S2) whilst Temang and Oda series are rated marginally suitable (S3). Kokofu series is rated highly suitable (S1) with Chichiwere and Kobeda series being rated not suitable (N).

On alluvial depositions (Tables 8a and 8b), limitations were *w* and *m*. Kakum and Chichiwere series are rated moderately (S2) and not (N) suitable, respectively. On granites (Tables 8b, 8c and 8d), the major limitations were *m*, *e* and *q* for middle to upper slope and summit soils, and *w*

TABLE 6

Exchangeable Base Levels (m.e./100 g) of Soils of Kusi and Adum Banso

Kusi

	Depth (cm)		
Summit and upper slopes	*0-30*	*30-60*	*60-90*
Exch. K	0.25 (0.10-0.57)'	0.10 (0.08-0.12)	0.11 (0.09-0.13)
Exch. Na	0.17 (0.12-0.21)	0.17 (0.11-0.21)	0.17 (0.11-0.20)
Exch. Ca	3.71 (1.05- 9.00)	1.78 (1.60-1.98)	1.09 (0.70-1.98)
Exch. Mg	1.07 (0.22-2.10)	0.81 (0.35-1.60) .	0.41 (0.30-0.47)
TB	5.20 (2.06-11.57)	2.86 (2.43-3.39)	1.78 (1.20-2.75)
A1+H	1.14 (0.75-2.00)	2.25 (1.18-2.98)	3.29 (2.98-3.58)
CEC	6.34	5.11	5.07
Middle slope	*0-30*	*30-60*	*60-90*
Exch. K	0.19 (0.15-0.21)	0.10 (0.04-0.21)	0.05 (0.04-0.06)
Exch. Na	0.67 (0.20-1.40)	0.30 (0.20-0.40)	0.25 (0.20-0.30)
Exch. Ca	1.73 (1.10-3.00)	1.05 (1.00-1.10)	0.80 (0.60-1.00)
Exch. Mg	0.21 (0.19-0.24)	0.24	0.22 (0.19-0.24)
TB	2.83 (1.65-4.79)	1.73 (1.50-1.95)	1.32 (1.13-1.50)
A1+H	2.22 (1.63-2.63)	3.01 (2.63-3.38)	3.43 (3.38-3.45)
CEC	5.05	4.74	4.75
Lowlands soils	*0-30*	*30-60*	*60-90*
Exch. K	0.17 (0.10-0.29)	0.10 (0.09-0.10)	0.11 (0.09-0.13)
Exch. Na	1.40 (0.80-1.80)	1.40 (1.20-1.60)	1.40 (1.20-1.60)
Exch. Ca	2.17 (1.00-3.50)	1.10 (1.00-1.20)	1.55 (1.20-1.90)
Exch. Mg	0.49 (0.32-0.72)	0.66 (0.59-0.72)	1.46 (0.33-0.59)
TB	4.22 (3.42-5.91)	3.26 (2.08-3.42)	3.52 (3.08-3.96)
A1+H	0.83 (0.80-0.85)	0.85	0.85
CEC	5.05	4.11	4.37

Adum Banso

	Upland		*Lowland*	
Parameter	*0-30 cm*	*30-60 cm*	*0-30 cm*	*30-60 cm*
Exch. K	0.16	0.17	0.06	0.07
Exch. Na	0.07	0.08	0.06	0.09
Exch. GA	1.80	1.30	1.08	1.10
Exch. Mg	0.87	0.68	0.64	0.74
TB	2.89	2.23	1.84	2.00
A1+H	2.07	2.27	1.56	1.77
CEC	4.96	4.50	3.39	3.76

Range of values in parentheses
Source: Summarized from Asiamah & Senayah (1991); Anon. (1997)

and *m* for lower slope and valley bottom soils. Kumasi, Asuansi, Nta, Adiembra and Firam series are rated marginally suitable (S3); Nyanao series is rated not suitable (N). The moderately suitable (S2) soils comprise Akroso, Swedru, Nsaba, Agona, Nkwanta and Omappe series.

TABLE 7

P, K and Base Saturation Levels of Soils of Kusi and Adum Banso

Kusi

	Depth		
Summit and upper slopes	*0-30*	*30-60*	*60-90*
Base saturation %	76.5 (58.5-94.0) *	50.8 (46.0-58.5)	33.3 (27-46)
P Bray (p.p.m.)	1.07 (0.15-4.00)	0.2 (0.15-3.00)	0.1 (nil-o.15)
P Bray (p.p.m.)	114.8 (50-235)	55.3 (30-77)	45.0 (25-59)
Middle slopes	*0-30*	*30.60*	*60-90*
Base saturation %	33.0 (17-42) *	36.0(30-42)	31.0(30-31)
P Bray (p.p.m.)	2.07(0.5-4.9)	0.5	0.5
K Bray (p.p.m.)	30.70(13-61)	13.0(8.0-18.0)	7.5(7-8)
Lowland soils	*0-30*	*30-60*	*60-90*
Base saturation %	82.3(80-87)	79.0(78-80)	80.0(78-82
P Bray (p.p.m.)	2.5(0.6-4.8)	0.6	0.6
K Bray (p.p.m.)	14.3(9-24)	8.0(7-9)	8.0(7-9)

Adum Banso

	Upland		*Lowland*	
Parameter	*0-30 cm*	*30-60 cm*	*0.30 cm*	*30-60 cm*
Base saturation %	55.0	49.0	55.0	53.0
P Bray (p.p.m.)	5.68	0.75	1.10	0.58
K Bray (p.p.m.)	85.68	80.82	24.43	23.03

* Range of values in parentheses:
Source: Summarized from Asiamah & Senayah (1991); Anon. (1997)

Discussion

Oil palm can be grown on a wide range of tropical soils, however, the growth is not synonymous with suitability. In determining suitability, soil physical property, water availability in rooting depth, previous land usage, and soil nutrient status are generally taken into consideration. Oil palm soils must, thus, be well drained, deep enough and well structured to allow extensive root development, sustainable growth and production. The textural suitability and the depth of concretions determine important soil atbibutes such as effective depth and depth of rooting, penetrability of roots, water permeability, drainage, leachability, water holding capacity and availability. Varying suitability classification methods have been developed for oil palm (Obeng & Smith, 1963; Olivin, 1968; Ng, 1968; FAO, 1976,1983). Soil physico- chemical properties are used in arriving at the suitability classes derived. Olivin (1968) divided soils into two main orders, good oil palm soils, and poor/very poor soils, with 3 (IIa, IIb, III) and 1 (IV) classes, respectively, to total 4. Textural suitability was the major criterion used. The limitation of this classification is that accuracy is compromised when used under extremes of climatic conditions for production forecasting.

The major limitations of the Lower Birimian soils (Tables 8a and 8b) were *q* and *e* for summit and upper slope soils, and *w* for middle slope to lowland and valley bottom soils. Other summit

TABLE 8a

Suitability Classification of Soils of Areas Optimum for Oil Palm Production in Ghana

	Bekwai *		*Nzima* *		*Kokofu* *		*Temang* *		*Oda**		*Chichiwere* *	
Effective depth (cm)	Over 150	S1	200	S1	180	S1	Over 150	S1	Over 150	S1	-	
Drainage	Well drained	S1	Moderately well drained	S1	Imperfectly drained	S2	Poor	S3	Very poor	S3	Excessively drained	N
Slope	2-3	S1	3-5	S1	2-3	S1	0 -1	S 1	0 - 1	S1	-	
Texture												
Topsoil	Silty loam	S1	Silty loam	S1	Silty loam	S 1	Sandy loam	S1	Silty loam	S1	S. loam-loamy sand	S2
Subsoil	Silty clay	S1	Silty clay	S1	Silty clay	S 1	Sandy loam -sandy clay	S2	Silty clay	S1	Sand	N
Concretions and gravels	15-40% by vol. Frequent	S3	15-45% by vol. Frequent	S3	Encountered at 100 cm	S1	Encountered at 100 cm	S1	-		-	
Erosion	Slightn	S2	Moderate	S3	Very slight	S1	Very slight	S1	Very slight	S1	-	
Rating		S2		S2		S1		S3		S3		N
Limitations		q		q e		-		w		w		*w, m.*
Suitability class		S2 q		S2 q e		S1		S3 w		S3 w		N w m

* Birimian (Lower and Upper)

** Alluvial depositions

TABLE 8b

Suitability Classication of Soils of Areas Optimum for Oil Palm Production in Ghana

	Kobeda *	*Kakum* **	*Kumasi* ***	*Asuansi* ***	*Nta* ***	*Akroso* ***
Effective depth (cm)	Shallow >20 N	Deep 180 plus S1	Deep 150 plus S1	Deep 150 plus S1	90-120 S2	90 - 150 S2
Drainage	Well drained S1	Moderately well to imperfectly drained S2	Well drained S1	Moderately well drained S1	Imperfectly to poorly drained S3	Moderately well to perfectly drained S2
Slope	0-2, 25-35, 35-70 S1, N, N	0-4 S1	0-2, 3-8 S1/ S2	0-8 S1/ S2	2-4 S1	2-6 S1
Texture						
Topsoil Subsoil	Loamy soils S1	Clay loams S2 Clays S2	Clay loams S2 Clays S2	Gritty c. l. S3 Clays S2	Sand N Sandy loam S2	Clay loam S2
Concretions and gravels	Nil S1	Nil S1	10-35% by volume. Common to many S2-S3	10-40% by volume. Common to many S2-S3	Nil S1	Nil S1
Erosion	Slight/ Very severe S3	Slight S2	Moderate S3	Moderate S3	Slight S2	Slight S2
Rating	N	S2	S3	S3	S3	S2
Limitations	e	w, m	m, e, q	m, e, q	w, m	w, m
Suitability class	N e	S2wm	S3meq	S3meq	S3wm	S2wm

* Birimian (Lower and upper)
** Alluvial depositions
*** Granites

TABLE 8c

Suitability Classification of Soils of Areas Optimum for Oil Palm Production in Ghana

	Swedru ***		*Nsaba* ***		*Ofin* ***		*Adiembra* ***		*Nyanao****	
Effective depth (cm)	Deep 150	S1	Deep 150	S1	90-200	S1	60 - 120	S3	Shallow > 20	N
Drainage	Well drained	S1	Well drained	S1	Poor to very poorly drained	N	Well to moderately drained	S1	Well drained	S1
Slope	0-2, 3-8	S2	0-2,.3-8	S2	0-2	S1	2-6	S1	S1	
Texture										
Topsoil	Clay loams	S1	Clay loams	S1	Loamy sands	S3	Clay loams	S1	Loamy	S1
Subsoil	Clays	S2	Clays	S2	Sandy loams.	N	Clays	S2		
Concretions and gravels	10-35% by volume Frequent	S3	10-40% by volume Common to many	S3	Nil. Encountered 90+	S1	10-30% by volume - Common to many	S3		
Erosion	Moderate	S3	Moderate	S3	Very slight	S1	Moderate	S3		
Rating	S2		S2		S3		S2		N	
Limitations	e, q		e, q		w, m		e, q		e, d	
Suitability class	S2eq		S2eq		Nwm		S3eq		Ned	

*** Granites

TABLE 8d

Suitability Classification of Soils of Areas Optimum for Oil Palm Production

	Agona ***		*Nkwanta* ***		*Firam* ***		*Omappe* ***	
Effective depth (cm)			90-150		-		-	
Drainage	Well drained	S1	Well drained	S1	Poorly drained	S3	Well drained	S1
Slope %	4-15	S1- S3	4-15	S3	0-2	S1	2-8	S2
Texture								
Topsoil Subsoil	Sandy clay loams S2		Sandy clay loams S2		Sand / Gritty clays S2		Sandy clay loams S2	
Concretions and gravels	Moderate/Few S2		Nil S1		Nil S1		Nil S1	
Erosion	Very slight to above moderate S1 - N		Very slight to above moderate S1 - N		S1		Moderate S3	
Rating	S2		S2		S3		S2	
Limitations	q, e		e		w, m		e	
Suitability class	S2eq		S2e		S3wm		S2e	

** Granites

and upper slope soils, e.g. Kobeda series, developed from the same geology, are very shallow. On alluvial depositions (Tables 8a and 8b), limitations were *w* and *m*. The major limitations of the soils developed over granites (Tables 8b, 8c and 8d) were *m*, *e* and *q* for middle to upper slope and summit soils, and *w* and *m* for lower slope and valley bottom soils. Soil textural differences are associated more with the limitations observed for soils of similar toposequence, e.g. summit and upper slope or middle slope on the above two formations.

The majority of the soils were rated moderately (S2) or marginally (S3) suitable for oil palm cultivation. Kobeda, Chichiwere and Nyanao series were rated not suitable. The major limitations described and associated with the soils reflect limitations which may be improved. These limitations also take cognizance of the need for sustainability of production and, thus, indicate whether or not available agro-management technologies can be used to economically manage these limitations now, in time, or not all, to define the land suitability classes. The limitations noted range from none and slight to severe, and these invariably classify the soils such that the extent of a particular limitation is manageable. The sustainability of the 21 soils observed for oil palm cultivation in Ghana, placed within the context of suitability of land for general agricultural use in cropping has been described by the USDA Soil Classification System. Data on the extent of land coverage by the various soil series were extrapolated from

Asamoah & Nuertey (1998a)

The major oil palm soils at the three locations, however, fall mainly into agricultural land classes S2 or S3 which are classified respectively as good (Akroso, Nsaba), moderately good (Nzima, Kokofu, Temang), or fair agricultural lands (minor soil series of Kumasi-Ofin, Swedru-Nsaba, and Bekwai-Nzimal/Oda associations). The classification for agricultural land use is not synonymous with soil suitability for oil palm cultivation. The suitability of soils for the cultivation of oil palms is defined in terms of soil physical and chemical characteristics. Management options for improving a suitability class must, thus, emphasize improvement of soil chemical or fertility and physical limitations.

Conclusion

The physical limitations observed on the Birimian, granitic and alluvial soils at Kusi, Twifo Praso and Adum Banso were *q, e, w* and *m*. The soils were all generally acidic and low in nutrients. These soils were evaluated and rated to be moderately (S2) or marginally (S3) suitable but mostly towards the S2 class. On Birimian soils, Bekwai and Nzima series were evaluated and rated as moderately suitable (S2) whilst Oda and Temang series were marginally suitable (S3). Kokofu series was found to be highly suitable (S1) whilst Kobeda and Chichiwere series were not suitable (N). On granites, Akroso, Swedru, Nsaba, Adiembra, Agona, Nkwanta, Omappe and Kakum series were evaluated to be moderately suitable (S2) with Kumasi, Asuansi, Nta and Firam series being marginally suitable (S3). Nyanao and Ofin series were not suitable. Depending on soil series and characteristics, some of the limitations are manageable and surmountable. Nutrient levels, which were generally low, and the high acidity in all the soils are limitations which can be corrected through appropriate management practices.

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