Productivity of soils of areas climatically suitable for oil palm cultivation in Ghana

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Abstract

The productivity of some soils within areas climatically suitable for oil palm cultivation and production in Ghana was investigated. Accurate referenced soil maps were superimposed on similarly accurate land development maps so as to demarcate oil palm plots or blocks on different soil types at Kusi and Twifo Praso. Annual individual palm yields of plot/block at Kusi, and field block yields at Twifo Praso and Adum Banso were compiled from available data. Indications of variations in the capacity of the observed soils to support production in early and latter life, and under adverse conditions were noted. Constraints like adverse land characteristics, which contribute to the variations observed were outlined and discussed with their direct management for sustainable oil palm production. The implications stress the need for the selective use of dominant soils which are moderately or marginally suitable for oil palm cultivation and their efficient management to raise their suitability levels. At Kusi, average yields, tons/ha were similar (10.4-10.56 tons), for the middle/lower slope and valley bottom soils of Kokofu and Temang series, but 29% higher than Nzima series, a middle slope soil. Yields on summit and upper slope soils of Bekwai series were lower. Time trend averages were higher –11.6, 13.3 and 12.2 tons/ha/year – on Nzima, Kokofu and Temang series, respectively. The increased yield on Kokofu soils was due more to increase in bunch weight than number. The toposequential trend in yield was similar for soils at Twifo Praso and Adum Banso. Here, the yields on granite soils ranged between 8.7 and 11.7 tons/ha/year over a 3-15 year period.

(Origical Scientific Paper accepted 24 Mar 00.)

Introduction

Oil palm cultivation in Ghana is within the forest zone and it includes areas considered as marginal and unsuitable. Van der Vossen (1969) delineated areas as favorable for oil palm cultivation on the basis of low annual water deficit values of 250 mm or less. These indicate shorter periods of water stress or an even distribution of rainfall. Water deficits of 150 mm or less are considered optimal. An important and effective productive service to be rendered by the Oil Palm Research Institute (OPRI) to the production industry is to advise prospective farmers on the choice of ecologically suitable areas for oil palm cultivation based on a study of climate, soils and their suitability, and location especially where huge investments are involved.

The geology, physical and chemical properties of soils of the OPRI have been described by Ama (1970) and, recently, Asiamah & Senayah (1991). These characteristics were also described for Twifo Praso (Anon., 1979) and Adum Banso (Anon., 1997). Asamoah & Nuertey (1998a, 1998b) provided an inventory with a description of soils at Kusi, Twifo Praso and Adum Banso, which are within the areas climatically suitable for optimal oil palm production. The soil description covered respective land characteristics and physico-chemical properties at each of these sites. The soils were further evaluated for their suitability for oil palm cultivation with limitations impeding the suitability of some individual soils stated. The limitations to be addressed were poor drainage (w), concretions (q), moisture retention capacity (m), the hazard of erosion (e), acidity and low nutrients.

Summit and upper slope soils of Lower Birimian formations, Nzima and Bekwai series, are clay to silty clay in texture containing many to abundant ironstone concretions and quartz gravels. The soils of the lower slopes are colluvial and free from gravels. These impart different characteristics, for example, drainage or available water at field capacity, thus, leading to differences in the duration of water stress, soil nutrient availability and yields. Lands on lower slopes have been identified as more suitable for oil palm cultivation on the basis of a better annual water supply capacity. Recent work at Crops Research Institute (CSIR Annual Report, 1986) indicated yields of 7.5, 5.5 and 4.9 tons of fresh fruit bunch/ha on Bekwai, Nzima and Kokofu series, respectively. Strangely, higher yields were obtained on the gravelly and concretionary Bekwai series for 1986. This could be attributed to the depth of the soil which is deep. Growth and yield on different soils would, thus, need to be quantified and investigated to be related in the long term to the soils capacity to continue to support growth and yield.

Soil characteristics determine oil palm yields and, thus, its economic production. Production forecasting is also important for efficient planning, and this must consider not only climate (rainfall and water deficits) but also the soils. This paper reports on the relative productivity of some soils suitable for oil palm and also analyzes oil palm yields obtained on the basis of soil associations at the three locations mentioned. The agro-management practices necessary to manage the limitations associated with the soils are outlined and recommended for implementation.

Materials and methods

A detailed soil survey map of the location was superimposed on the associated detailed and defined land and land development map. A requirement for the detailed soils survey map is that it should have reference to known points on the legitimate boundaries of the area defined in the location. This requirement will enable the map to be superimposed with precision on the accurate land development map of the location.

Annual field development was accurately blocked on the land map and individual oil palm locations within the field were determined with magnification of the field. With the superimposition, expanses of particular or different soil series were outlined on the land development map and with magnification, soils of the fields were identified with individual palm associations. Inner core palms within any identified soil series were emphasized as useful palms and listed for record taking. At the OPRI, individual palm harvesting and yield recording were made. This method of soil identification with individual palm association was, thus, used for data compilation.

In the development estates, e.g. Twifo Oil Palm Plantation Limited (TOPP) and Benso Oil Palm Plantation Limited (BOPP), palms were normally planted in blocks/plots of 40 ha each in lines of 44 palms. All the palms in the block were harvested and weighed together to give the block yield. At TOPP, where a block covered soil type fully or about 90 per cent or more of the block, block yield was assigned to that soil type. Where two or three different soil types covered the block in similar proportions, block yield was assigned to the group of soils. At BOPP (near Adum Banso), the soil suitability classification of Olivin (1968) was adapted. This is based on landform/terrain (good or bad) and soil quality or physico-chemical properties (good or poor soil, and poorly or well drained) and then translated into good or bad/very bad (poor or very poor) oil palm soils. The good soils were located on good terrain and had well drained good soils, and the bad/very bad on bad land forms and poor soils with imperfect to poor drainage. The soils in the locality were grouped according to the description, and data were compiled.

The main record taken was yield. Yield data as compiled over a period determined by year of planting was extracted for fields/blocks or list of palms in clearly defined soil areas as described above and averaged. Time trend or pattern average yields according to soil type were compiled in cases where data were available or extrapolated where need be. Limitations such as poor drainage, presence of concretions, moisture retention capacity, erosion hazard, acidity and low nutrients observed earlier (Asamoah & Nuertey, 1998b) were described. Recommendations on effective agronomic practices to adopt so as to surmount and manage these soil limitations for high and sustained yields were also made.

Results and discussion

The effects of the different soil types on production at Kusi are presented in Tables 1-5. The major soil series in terms of representations over 19 different year groups of planting were Nzima, Kokofu, Temang, and to a limited extent, Bekwai and Oda series. This is not surprising since the level of representation is a factor of the extensiveness or dominance, or otherwise, of a particular soil series. The soil distribution at Kusi is Nzima (34%), Kokofu (42%), and 21per cent for Temang series (Asiamah & Senayah, 1991: Asamoah & Nuertey, 1998a). These occur, respectively, from middle slope through lower slope to valley bottoms.

Cumulative yield data covering a number of data years obtained for the various fields are presented in Table 1. The data indicate the development of yield in time. These cover soil types for which there were field representations. These are converted into field average yields, tons/ha/annum in Table 2, which is not representative of the time trend averages. Yield (cumulative or average) on Kokofu soils was 28 per cent more than Nzima which averaged 8.16 tons/ha/year. In 16 field observations (Table 1), comparison of yields between Nzima and Kokofu soils showed that Kokofu soils were higher by 20 per cent in 11 (or 69%) of the observations and lower than 10 per cent in only three. However, in two observations, yields on Nzima soils were found to be higher (less than 10%) than those obtained for Kokofu soils.

Average yields on Kokofu and Temang soils

TABLE 1

Cumulative Oil Palm Yields on some Lower Biriman Soils at Kusi (tons/ha)

Field	*Year planted*	*Data years*	*Soil series*				
			Nzima	*Bekwai*	*Kokofu*	*Oda*	*Temang*
K1	1967	10	91.44	-	115.54	-	-
K2	1968	10	142.17	-	149.77	-	-
K3	1969	17	227.58	-	249.08	-	-
K5	1970	20	249.90	-	284.92	-	-
K6	1971	7	26.87	-	41.78	-	47.44
K7	1972	8	63.81	49.04	80.57	-	91.18
K8	1973	8	78.65	-	75.93	-	96.33
K9	1974	8	56.23	-	61.79	-	-
K10	1975	7	34.16	-	58.86	-	70.35
K13	1978	10	77.50	-	94.95	-	128.84
K14	1979	10	-	-	142.08	-	140.92
K15	1980	4	12.79	15.90	-	-	-
K16	1981	10	138.01	-	154.64	-	180.77
K17	1982	8	-	-	66.00	-	63.32
K19	1984	4	29.75	23.94	42.92	-	43.32
K20	1986	6	43.80	-	40.39	-	-
K21	1987	7	66.46	-	79.07	-	87.16
K22	1988	5	16.29	-	37.18	19.32	21.50
K23	1989	5	18.49	-	35.84	-	29.41

Source: Oil Palm Research Institute, 1998

TABLE 2

Average Oil Palm Yields on some Lower Birimian Soils at Kusi (tons/ ha/annum)

Field	*Year planted*	*Data years*	*Soil series*				
			Nzima	*Bekwai*	*Kokofu*	*Oda*	*Temang*
K1	1967	10	9.14	-	11.55	-	-
K2	1968	10	14.22	-	14.98	-	-
K3	1969	17	13.39	-	14.65	-	-
K5	1970	20	12.50	-	14.25	-	-
K6	1971	7	3.84	-	5.97	-	6.78
K7	1972	8	7.98	6.13	10.07	-	11.39
K8	1973	8	9.83	-	9.49	-	12.04
K9	1974	8	7.03	-	7.72	-	-
K10	1975	7	4.88	-	8.41	-	10.05
K13	1978	10	7.75	-	9.50	-	12.88
K14	1979	10	-	-	14.21	-	14.09
K15	1980	4	3.20	3.98	-	-	-
K16	1981	10	13.80	-	15.47	-	18.08
K17	1982	8	-	-	8.25	-	7.92
K19	1984	4	7.44	5.99	10.73	-	10.83
K20	1986	6	7.30	-	6.73	-	-
K21	1987	7	9.49	-	11.30	-	12.45
K22	1988	5	3.26	-	7.44	3.86	4.30
K23	1989	5	3.70	-	7.17	-	5.88
Mean			8.16	5.37	10.43	3.86	10.56

Source: Oil Palm Research Institute, 1998

were similar, 10.5 tons/ha/year. However, in 12 field observations, comparison of yields between Temang and Kokofu soils showed that yields on Kokofu were higher but by less than 10 per cent in seven observations. The similar average yields are possible because the averages are not time trend oriented. Average single bunch weights on Nzima and Temang soils (Table 3) were similar, 9.65 kg ± 3%, but 14 per cent higher on Kokofu soils. Average number of bunches/palm (Table 4) were 6.8 and 7.2 on Kokofu and Temang soils, respectively, and 19 and 26 per cent higher compared to the 5.7 observed on Nzima series. Bunch numbers were lower on Bekwai and Oda soils. Average bunch weight rather than bunch number is contributory to the higher yield obtained on Kokofu soils.

Average yields, time trends, from years 3 to 22 after planting are presented in Table 5. Higher yield levels, mean 7.5 ± 2% tons/ha/year, were achieved earlier, in years 3-7, on Kokofu (lower slope soil) and Temang (valley bottom), followed by Nzima, Bekwai and Oda which were 28, 46 and 49 per cent less, respectively. Yields were increased by over 100 per cent in all cases of soil types between years 8-13. The yield pattern was similar to years 3-7. Between years 3-7 and 8-13, yields on Nzima soils compared to Kokofu were lower by 26 and 15 per cent, respectively. The decrease in the difference indicates a relative increased production on Nzima soils. This suggests a better capacity to support production in time. There were no data for Bekwai and Temang soils beyond year 13. On Nzima and Kokofu soils, the earlier pattern of production was followed as phased through years 14-22. Cumulatively for years 3-22, average yield on Kokofu was 14 per cent more than on Nzima. The time trend average yields of 11.6 and 13.2 tons/ha/year on Nzima and Kokofu soils are more representative of field situations. On Temang soils, once established, the oil palms are able to withstand the

TABLE 3

Average Single Bunch Weight on some Lower Birimian Soils at Kusi (KG)

Field	Year planted	Data years	Soil series				
			Nzima	Bekwai	Kokofu	Oda	Temang
K1	1967	10	9.8	-	10.3	-	-
K2	1968	10	10.9	-	12.2	-	-
K3	1969	17	18.7	-	19.4	-	-
K5	1970	20	22.5	-	23.7	-	
K6	1971	7	4.4		5.1	-	5.3
K7	1972	8	11.8	10.0	13.5	—	12.3
K8	1973	8	8.8	-	9.8	-	10.8
K9	1974	8	8.5	-	9.9	-	-
K10	1975	7	7.3	-	8.7	-	9.1
K13	1978	10	8.2	-	10.6	-	12.3
K14	1979	10	-	-	12.8	-	12.2
K15	1980	4	4.5	5.4	-	-	-
K16	1981	10	12.7	-	11.5	-	13.9
K17	1982	8	-	-	7.9	-	5.9
K19	1984	4	9.7	8.2	11.7	-	10.8
K20	1986	6	9.0	-	8.6	-	-
K21	1987	7	6.1	-	8.3	-	10.2
K22	1988	5	6.4	-	7.4	5.8	5.1
K23	1989	5	4.3	-	6.6	-	4.9
Mean	-	-	9.9	7.9	11.0	5.8	9.4

Source: Oil Palm Research Institute, 1998

waterlogging from poor drainage and probably utilize such water in periods of water stress. The soils, therefore, appear to have a better annual water supply capacity and this is reflected in later yields.

Yield data on the soils at Twifo Praso are presented in Table 6. The soils on which data could be individually compiled were Nsaba, Akroso and Nzima to confirm the soil distribution pattern observed by Asamoah & Nuertey (1998a) and Anon. (1979). The major soils were Akroso (43%) and Nsaba (23%) series, with Asuansi , Nta, Ofin, and Kokofu series contributing a sub-total of 21 per cent about equally and the others 14 per cent. The dominant soils occur on gentle middle to lower slopes. Mean yields on Nzima, Nsaba, Akroso series for years 6-15 and 3-17, respectively, were similar, 9.4 ± 3% and 8.2 ± 4% (Table 5).

Data were also compiled on Ofin/Nta/Chichiwere, Akroso/Asuansi, Nzima/Kobeda and Akroso/Nsaba soil combinations. As earlier stated, block yield was assigned to a group of soils. Data bases were limited and compiled from two data sets for the first three, and three for the last group of soils. Ten years data over years 6-15 for which data were available for all the combinations, suggest similar yields, 11.53 tons/ha/year, for Ofin/Nta/Chichiwere, and Akroso/Nsaba soil combinations. Ofin/Nta/Chichiwere consist of soils on river flat/valley bottoms. The Chichiwere soils have a loose sandy texture because of little development and have moisture and nutrient limitations. The soils are very susceptible to drought and this adversely affects oil palm yields. Yields on the summit and upper slope soils combination of Kobeda/Nzima were lower. In their natural state, the Ofin/Nta/Chichiwere soils are marginal to not suitable for oil palm cultivation. Their indicative higher yield compared to the other relatively more suitable soils appears anomalous since these soils had

TABLE 4

Average Number of Bunches /Palm Produced on some Lower Birimian Soils at Kusi

Field	*Year planted*	*Data years*	*Soil series*				
			Nzima	*Bekwai*	*Kokofu*	*Oda*	*Temang*
K1	1967	10	6.6	-	8.3	-	
K2	1968	10	9.2	-	9.0	-	
K3	1969	17	4.6	-	4.9	-	
K5	1970	20	4.4	-	5.2	-	
K6	1971	7	5.8	-	8.1	-	9.2
K7	1972	8	4.7	3.3	5.1	-	6.6
K8	1973	8	5.9	-	5.7	-	7.5
K9	1974	8	5.2	-	4.4	-	-
K10	1975	7	4.4	-	6.2	-	6.0
K13	1978	10	5.5	-	5.8	-	5.1
K14	1979	10	-	-	7.9	-	8.2
K15	1980	4	4.0	3.6	-	-	-
K16	1981	10	7.1	-	9.1	-	8.7
K17	1982	8	-	-	6.4	-	7.1
K19	1984	4	5.0	6.1	6.2	-	.6.9
K20	1986	6	5.7	-	5.2	-	-
K21	1987	7	7.9	-	8.9	-	8.5
K22	1988	5	5.0	-	6.8	4.3	4.9
K23	1989	5	6.2	-	8.6	-	7.3
Mean	-		5.7	4.3	6.8	4.3	7.2

Source: Oil Palm Research Institute, 1998

TABLE 5

Yield Trends/Patterns and Soil Production Capacity - Kusi

Soil series	*Year 3-7*	*Year 8-13*	*Year 14-18*	*Year 19-22*	*Grand total*
1. Bekwai					
Total production	20.27	48.82	-	-	69.09
Av. yield tons/ha	4.05	8.14			6.28
2. Nzima					
Total production	26.78	80.44	76.76	48.34	232.32
Av. yield tons/ha	5.36	13.41	15.35	12.09	11.62
3. Kokofu					
Total production	36.19	90.33	88.28	47.98	265.78
Av. yield tonslha	7.32	15.69	17.65	12.00	13.29
4. Temang					
Total production	38.42	94.12	-	-	132.54
Av. yield tons/ha	7.68	15.69			12.32
5. Oda					
Total production	19.32	-	-	-	19.32
Av. yield tonslha	3.86				3.86

Source: Summarized from Oil Palm Research Institute (1998)

TABLE 6

Yield Trends /Patterns and Soil Production Capacity - Twifo Praso

Soil series	No of Blocks	Data Years	Year 3-5	Year 6-15	Year 16-17	Total
1. Nsaba	7	15				
Cumulative yield			16.16	96.37	12.89	125.42
Av. yield tons/ha /yr			5.38	9.64	6.45	8.36
2. Akroso	5	13				
Cumulative yield			10.57	91.95	25.31	127.83
Av. yield tons/ha /yr			3.52	9.20	12.66	8.52
3. Nzima	3	12				
Cumulative yield			12.02	93.32	11.58	116.92
Av. yield tons/ha /yr			4.01	9.32	5.79	7.80
4. Ofin/ Nta/Chichiwere	2	9				
Cumulative yield			-	117.01	-	117.01
Av. yield tons/ha/yr				11.70		11.70
5. Nzima/ Kobeda	2	11				
Cumulative yield			-	94.56	4.44	99.00
Av. yield tons/ha /yr				9.46	2.22	8.25
6. Akroso /Asuansi	2	9				
Cumulative yield			3.79	87.44	-	91.23
Av. yield tons/ha /yr			1.26	8.74		6.08
7. Akroso /Nsaba	3	12				
Cumulative yield			7.33	113.48	-	120.81
Av. yield tons/ha /y			2.44	11.35		8.05

Source: Summarized from Twifo Oil Palm Plantation Limited (1998)

not undergone any special soil amendment measures. The only soil amendments, fertilizers, were applied to the whole plantation.

Yield data on the soils at Adum Banso are presented in Tables 7 and 8. The good soils are located on good terrain and are well drained; and the bad/very bad soils on bad terrain with imperfect to poor drainage (Table 7). The soils observed in the survey of Adum Banso were listed and placed in the categories defined above in Table 8. The major soils Nkwanta, Akroso and Agona series were grouped under various categories of the good oil palm soils by Olivin (1968). The river flat/valley bottom soils were in the bad/very bad category. Average annual production of 11.33 tons/ha on the good soils did not vary by more than 5 per cent from each other but were 15 per cent higher than on bad/ very bad soils. Under combinations of adverse conditions, hilly areas or slopes greater than 30 per cent, average annual yields were reduced in trend by 10 per cent to suggest possible greater yield reduction effects at higher slopes.

The listing and toposequence of soils on granites and associated rocks, lower Birimian formations and alluvial deposits are shown in Tables 9 and 10. On granites the major soils are Akroso, Nsaba, Nkwanta and Agona series. The minor soils are Nta, Ofin, Asuansi and, to a lesser extent, Nyanao, Swedru, Omappe and Firam series. On Lower Birimian, the major soils are Kokofu, Nzima, and Temang series with the minor being Bekwai, Oda and Kobeda series. Generally, the summit and upper to middle slope soils are more extensive and, thus, predominant. In the valley bottoms, Temang series is the most dominant.

TABLE 7

Yield Trends/Patterns and Soil Production Capacity - Adum Banso

Soil suitability class	*Description*	*No. of blocks*	*Slope %*	*Production year 3-15 tons/ha*	*Average production tons/ha*
1.00 Good oil palm soils	1.01 Good terrain	3	0-2.3	148.64	11.43
	1.02 Good soil	1	1.4	140.38	10.80
	1.03 Good terrain & Good soil	4	0-15.4	148.03	11.39
Mean 1.00				147.30	11.33
2.00 Bad and very bad (poor or very poor) soils	2.01 Bad serrain	2	12-18.4	129.17	9.94
	2.02 Poor soils	3	2-7	129.42	9.96
	2.03 Bad terrain & Poor soils				
	2.03.1	3	14-19	134.17	10.32
	2.03.2	2	22-24	133.23	10.25
	2.03.3	3	31-40	124.65	9.59
Mean 2.03				130.65	10.05
	2.04 Hilly	1		118.94	9.15
	2.05 Poor drainage	2		115.7	8.9
Mean 2.00				127.49	9.81

Source: Summarized from Bensó Oil Palm Plantation Limited (1998)

TABLE 8

Suitability Classification for Oil Palm Soils at Adum Banso

Suitability class	*Soils*	*Location*	*Slope %*	*Comment*
1.00 Good oil palm soils				
Class IIa	Nkwanta	Summit, upper & middle slopes	4-15	Well drained
	Akroso	Middle to lower	4-6	Moderately well drained
Class IIb	Agona	Summit, upper & middle slopes	4-15	Well drained
Class III	Agona	Summit, upper	2-8	Well drained
	Omappe	Summit, upper	2-8	Well drained
	Kakum	River flat	0-2	Imperfectly drained
2.00 Bad/Very bad soils (Poor and very poor)				
Class IVa	Nta	Lower slope	2-4	Imperfectly drained
	Oda	River flat	0-2	Poorly drained
Class IVb	*Ofin*		*0-2*	*Poorly drained*
	Firam	River valley	0-2	Poorly drained
	Temang	River flat	0-2	Poorly drained

Source: Summarized from Olivin, J., 1968; Anon., 1997

Productivity (growth and yield) is a factor of soil limitations and suitability. Using the land suitability classification of FAO (1983), the majority of the soils on the Lower Birimian, granites and associated rocks and alluvial formations were rated as moderately (S2) or marginally (S3) suitable (Asamoah & Nuertey, 1998b) for oil palm cultivation and production.

TABLE 9

List of Soils Identified at Kusi Praso and Adum Banso

Soils parent material/Series	*Twifo Praso*	*Kusi*	*Adum Bando*	*Common soils*
1. *Granites and associated rocks*				
1.1 Kumasi Series (KS)	+	-	-	-
1.2 Asuansi Series (AS)	+	-	-	-
1.3 Swedru Series (SW)	+	-	-	-
1.4 Nsaba Series (NS)	+	-	-	-
1.5 Akroso Series (AK)	+	-	+	AK
1.6 Nta Series (NT)	+	-	+	NT
1.7 Ofin Series (OF)	+	-	+	OF
1.8 Adiembra Series (AD)	+	-	-	-
1.9 Nyanao (NY)	+	-	-	-
1.10 Agona(AG)	-	-	+	-
1.11 Nkwanta (NK)	-	-	+	-
1.12 Firam (FI)	-	-	+	-
1.13 Omappe (OM)	-	-	+	-
2. *Birimian rocks*			-	-
2.1 Bekwai Series (BK)	+	+	-	BK
2.2 Nzima (NZ)	+	+	-	NZ
2.3 Kokofu Series (KF)	+	+	-	KF
2.4 *Oda Series (00)*	+	+	+	OD
2.5 Temang Series (TE)	+	+	+	TE
2.6 Kobeda Series (KO)	+	-	-	-
3. *Alluvial deposits*				-
3.1 Kakum Series (KA)	+	-	+	KA
3.2 Chichiwere Series (CH)	+	+	-	CH
Total	17	6	10	10

+/- Present/Absent

Source: Asamoah & Nuertey (1998a) : Summarized from from Asiamah & Senayah, 1991; Anon., 1979, 1997.

TABLE 10

Physiograph of Listed Soils

Location/ Formation	*Granites*	*Lower/ Upper Birimian*	*Allivial deposits*
1. Summit	NK, AG, OM, SW, KS NY	NZ, KO, BK	-
2. Upper slope	NK, AG,OM, SW, NS, AD, AS, NY	NZ, KO, BK,	-
3. Middle slope	NK, AG, NS, AD, AS, AK	NZ	-
4. Lower slope	NT, AK	KF	-
5. Valley bottom	OF, FI	OD, TE	CH, KA.

Source: Asamoah & Nuertey, 1998a: Summarized from Asiamah & Senayah, 1991; Anon., 1979, 1997).

On Birimian soils (Lower and Upper), Bekwai and Nzima series were rated moderately suitable (S2) whilst Oda and Temang series were marginally suitable (S3). Kokofu series was rated highly suitable (S1) whilst Kobeda and Chichiwere series were rated not suitable (N). On granites, Akroso, Swedru, Nsaba, Adiembra, Agona, Nkwanta, Omappe and Kakum series were rated moderately suitable (S2). Kumasi, Asuansi, Nta, Ofin and Firam series were marginally suitable (S3). Nyanao series was rated not suitable.

The physical limitations observed for soils of similar toposequence positions, e.g. summit and upper slopes or middle slope of Lower Birimian or granite formations (Table 10) vary and reflect differences of soil textural origin due to percentage variations in sand, silt and clay components in the soil. Soils may also have a high content of gravels and ironstone concretions. These characteristics, in varying proportions, determine water retention capacity (water movement and permeability, drainage, leachability), root development (effective soil and rooting depth, penetrability of roots), and aeration, all of which affect oil palm productivity. The limitations of the individual soils were *w* (drainage), *q* (concretions or gravels), *m* (moisture availability), *e* (erosion hazard), *n* (nutrient availability), *s* (slope), *d* (effective depth) and *r* (rockiness). The limitations observed range from none, slight to severe and, thus, indicate whether or not available agro-management technologies can be used to economically manage, improve or leave a particular limitation.

Options for improving a suitability class and, thus, productivity, growth and yields could be through the management of these physical or chemical limitations. On poorly drained soils, the limitation is excessive water from occasional flooding and high water table. Erosion hazard is associated with soils located on higher slopes with gradient of 15 per cent or more. On poorly drained soils, management is by construction of trenches to carry away the excess water. This option is not practicable on small scale farms. At initial field planting of transplantable seedlings, the mound in hole system of planting is used to prevent waterlogging of roots and poor aeration. Cover crops can be planted to check erosion or water flow downhill. Pruned fronds spread orderly or laying cordons of bunch stalks in the direction of water flow in areas prone to erosion can also check erosion. Erosion hazard can also be managed by planting on contour terraces. This, however, is an expensive option which can be implemented only at the development estate level. The alternative option which is more practicable for small scale farmers is by individual terracing (Nuertey *et al.*, 1993). Individual terracing in checking water flow also harvests and stores water for future use by the palm.

At Kusi, Adum Banso and Twifo Praso, the soils were poor in nutrients (Asiamah & Senayah, 1991; Asamoah & Nuertey, 1998b; Anon., 1979; Anon., 1997). The soils generally were extremely acid to strongly acid. Acid soils without corrective methods are very poor especially in P and Mg leading to very reduced yields under extremely severe acid conditions. Organic matter and total nitrogen levels were low to moderate with levels decreasing with depth. Exchangeable base levels were low for Ca, Na, K and CEC. Mg levels were low to moderate. Average exchange acidity (Al + H) values were, however, moderate to high. Average available P (p.p.m., Bray 1) levels were low reaching trace levels in some instances to indicate soil P deficiencies. Average available K (p.p.m., Bray 1) levels were low to high. Base saturation levels were also low to moderate.

The problem of high soil acidity can be managed by the following: i. application of liming materials namely hydrated lime, rock phosphate and dolomite. To raise the *p*H level of acid soils in Ghana by one unit, 1.0-1.5 tons /ha of calcium carbonate must be applied (Soil Research Institute, 1979; Dennis, 1982; Dennis *et al.*, 1988); and ii. maintenance of a high water table by limiting drainage and inter-row slashing in the dry season to reduce competition for soil moisture are both corrective measures for high soil *p*H.

The low nutrient levels can be improved or managed by the application of NPKMg fertilizers. Oil palm soils in Ghana respond to NPK fertilizer applications as increase in fresh fruit bunch production (van der Vossen, 1970; Asamoah, 1998). However, in application, the type and time would need to be considered since these can have consequences for soil acidity, leachability, fertilizer solubility and run off, persistence and seepage.

Soil organic matter (OM) levels which are low can be managed by i. Planting leguminous cover crops, e.g. *Pueraria phaseoloides*. The advantages of leguminous cover crops under oil palms in Ghana have been reviewed (Marfo-Ahenkora & Nuertey, 1999); ii. Spreading of pruned fronds evenly in alternate inter-rows in oil palm plantations to decompose and add organic matter, especially to the top soils. The spreading is interchanged periodically to prevent over concentration of OM in particular inter-rows, and iii. Application of bunch and mill effluent to the palms to achieve high soil OM levels. The addition of OM and planting of cover improve soil structure through improvement in soil bulk density and, thus, the penetrability of roots in the surface horizons of compacted soils (Peralta *et al.*, 1985).

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). Management options for improving a suitability class have always emphasized soil chemical management more than on the physical. However, studies of the effects of other soil physical characteristics such as compaction (Carrow, 1980; Aguero & Alvarado, 1983), mechanical impedance (Shumacher & Smucher, 1981) and soil strength (Voorhees *et al.*, 1975) on soil aeration, oxygen and growth indicated that soil physical effects were greater and can have consequences for soil nutrient availability. In the study of drainage effects, Peralta *et al.* (1985), concluded that in poorly drained soils, more absorptive roots are produced especially in the surface soil horizons than in well drained soils where water tables are superficial, and porosity is reduced. Superficial water tables reduce yield, growth, NPK absorption and negatively influenced inflorescence sex differentation.

Conclusion

Yields were estimated on the major and minor soils in the climatically suitable areas for oil palm production in Ghana. On Nzima and Kokofu soils at Kusi, yields were 11.6 and 13.3 tons ffb/ha/year. Yields were similar, 8.23 tons/ha, on Nsaba, Akroso and Nzima series at Twifo Praso. On the good soils of Adum Banso-Nkwanta, Akroso and Agona series, yields of 11.33 tons ffb/ha/year were achieved. Yields on the river flat/valley bottom soils, with poor drainage were, however, good; 11.7 tons/ha/year for Ofin/Nta/Chichiwere soil combinations, 12.52 tons/ha/year on Temang soils but a low of 8.9 tons/ha/year on the poorly drained soils of Adum Banso.

For economic production of oil palm in the sub-optimal climatic conditions prevalent in West Africa, average yields obtained should be more than 10 tons fresh fruit bunches/ha/year (MacFarlaine & Oworen, 1965) which levels are obtainable in the climatically optimal areas of Ghana. The above yields obtained reflect the limitations of the individual soils defined by the land suitability sub-classes as drainage, concretions or gravels, moisture availability, erosion hazard, soil nutrient availability, slope, effective depth and rockiness. These levels can further be enhanced through the application of recommendations to mitigate the effects of the surmountable soil limitations namely low soil nutrients, high soil acidity, erosion hazard and poor drainage. The recommended agro-management options are

i. The application of fertilizers, bunch refuse/empty fruit bunch, mill effluent and liming materials, and cover cropping and spreading of pruned fronds in inter-rows for improving soil nutrient status.
ii. Terracing, planting on contours, cover cropping and spreading of pruned fronds in inter-rows check erosion.
iii. Construction of drainage trenches to control poor drainage in addition to special planting methods.

Acknowledgement

Sincere thanks go to the staff of the Agronomy Division of the Oil Palm Research Institute for their help in compiling relevant data, the development estates Twifo and Benso Oil Palm Plantations for provision of some data, Ms Doris A. Mawuse for word-processing and to the Director, Dr. J. B. Wonkyi-Appiah, for his kind permission for publication.

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