Suitable Agro–ecologies for Cashew (*Anacardium occidentale* L.) Production in Ghana

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Summary

Among the non–traditional crops being promoted in Ghana is cashew (*Anacardium occidentale* L.). Cashew production in Ghana is limited to three agro–ecologies, namely the Interior Savanna, Forest Savanna Transition and Coastal Savanna. The paper describes the climatic conditions and soil characteristics, which are suitable for cashew production in these three agro–ecologies. The Forest Savanna Transition is ranked as highly suitable for cashew production. Majority of the soils in this zone are deep (> 100 cm), medium–textured with few limitations and the rainfall amounts are optimum for the crop. The Interior Savanna, which is moderately suitable for the crop, has majority of the soils being gravelly and concretionary. The Coastal Savanna is ranked marginally suitable. Climatic conditions, especially rainfall amounts, constitute the major limitations to the optimum production of the crop in the zone. Irrespective of agro–ecology, the most suitable soils in the three zones are Luvisols, Lixisols and Acrisols. Associated with these soils are Plinthosols and Arenosols, which are marginal for the crop. All the soils are inherently low in fertility.

Introduction

Cashew is ranked among the most important edible nuts in global commerce and the confectionary industry. Apart from the nuts, the tree as a whole has a variety of uses. The bark and leaves of the tree are used in the treatment of gastro–intestinal disorders such as dysentery and diarrhoea. Resins obtained from the tree are of commercial value in the book industry due to their adhesive properties. According to Irvine (1961), wood from the tree is very resistant to termite attack. He also stated that cashew nuts are known to reduce blood cholesterol and related problems while the tree can be easily incorporated in farming systems, especially agro–forestry programmes.

Addaquay & Nyamekye–Boamah (1998) reported that cashew production in Ghana actually began in the 1960s under the then government's savanna afforestation programme. This programme resulted in the establishment of plantations in the Volta, Greater Accra, Eastern and Brong Ahafo regions of the country, but improper care of the plantations and poor management practices in the ensuing years resulted in drastic decline in yields, and the plantations were subsequently abandoned. However, starting from the mid–1990's, a renewed interest has been shown in the cultivation of the crop in Ghana. This is due to the prominent place given to the crop in the non –traditional export sector. Records from the Ghana Export Promotion Council on the export performance of the crop under the Cashew Export Development Programme (1990–1998) show that the export of raw nuts increased from a mere 15 metric tonnes in 1991 (valued at almost US$9,000.00) to over 3,570 metric tonnes (valued at about US$1,844,200.00) in 1997.

Cashew does well under high temperatures especially within a range of 15–35 °C with an optimum range of 24–30

°C. Though the crop is drought resistant, it requires an annual precipitation range of 500–4000 mm. Notwithstanding, the crop needs a distinct dry period of at least 4 months or more for reasonably good yields of about three tonnes per hectare (Sys *et al*., 1993). Cashew can produce flowers twice a year in areas that experience two dry seasons but once, if the dry season is very much pronounced. However, flowering can occur throughout the year with an undefined dry season. Generally, optimum cashew production can be achieved in an environment that experiences 4-6 months dry period and an annual rainfall that ranges between 1000–2000 mm. In addition, the general development of the crop depends on other ecological conditions, especially soils. Though cashew can grow on a wide range of soils, well drained, deep, light to medium–textured soils are more preferable. These environmental conditions, therefore, limit the production of cashew in Ghana to three agro–ecologies, namely the Interior Savanna (i.e. Guinea and Sudan), Forest Savanna and Coastal Savanna (Dedzoe, 1999). This paper describes the climatic conditions and the characteristics of the major soils found to be suitable for cashew production in these agro–ecologies.

Meterials and methods

The soil characteristics and rainfall were used as the key determinants in ranking the Interior Savanna, Forest Savanna Transition and Coastal Savanna agro–ecologies according to their suitability for the production of cashew. Information on the soils found suitable for cashew production was obtained from several detailed–reconnaissance surveys (small–scale at 1:250,000) conducted by the Soil Research Institute in these three agro–ecologies. The soil characteristics considered are effective soil depth, texture, drainage, consistency and the presence or absence of gravels and concretions. The soils were briefly described using these characteristics in broad soil groups or associations. Physical limitations associated with the soils were also stated.

The chemical and fertility characteristics of the soils considered suitable for cashew production in the three agro–ecologies were described in terms of *p*H, organic matter, base saturation, total nitrogen (N), available phosphorus (P) and exchangeable potassium (K). This was to provide further information, which can enhance soil management with regard to cashew production in the three agro–ecologies. Climatic data, especially rainfall amounts in selected towns, obtained from the Ghana Meteorological Services Department, were used to show the suitability of the agro–ecologies for cashew production in terms of moisture requirements.

Climatic conditions of the agro - ecologies

Interior Savanna. The Interior Savanna agro-ecology, found in the northern part of Ghana, occupies nearly two–thirds of the country's total land area. The zone which experiences hot, distinct dry and wet conditions, consists of the Guinea and Sudan Savannas (Fig. 1). The characteristic unimodal rainfall regime of the Guinea Savanna zone starts from April to the end of October (Fig. 2i-iii). Generally, high rainfall amounts occur from mid-July to the end of August or September. However, the southern parts of the zone, for example, areas in and around Damongo and Bole, assume a pseudo-bimodal pattern (Fig. 2(ii)). Though the Sudan Savanna has similar conditions, rainfall amounts are lower (Table 1). The rainfall starts from May to September or mid-October (Fig. 2 (iii)). Consequently, the zone has a much longer dry period than the Guinea Savanna.

season, which starts from November to the end of March or early April. Great variations are observed in the total monthly and annual rainfall amounts. The high rainfall amounts which are recorded in the forested parts of the Forest Savanna Transition zone decrease towards its savanna sections (Fig. 3 i – iii).

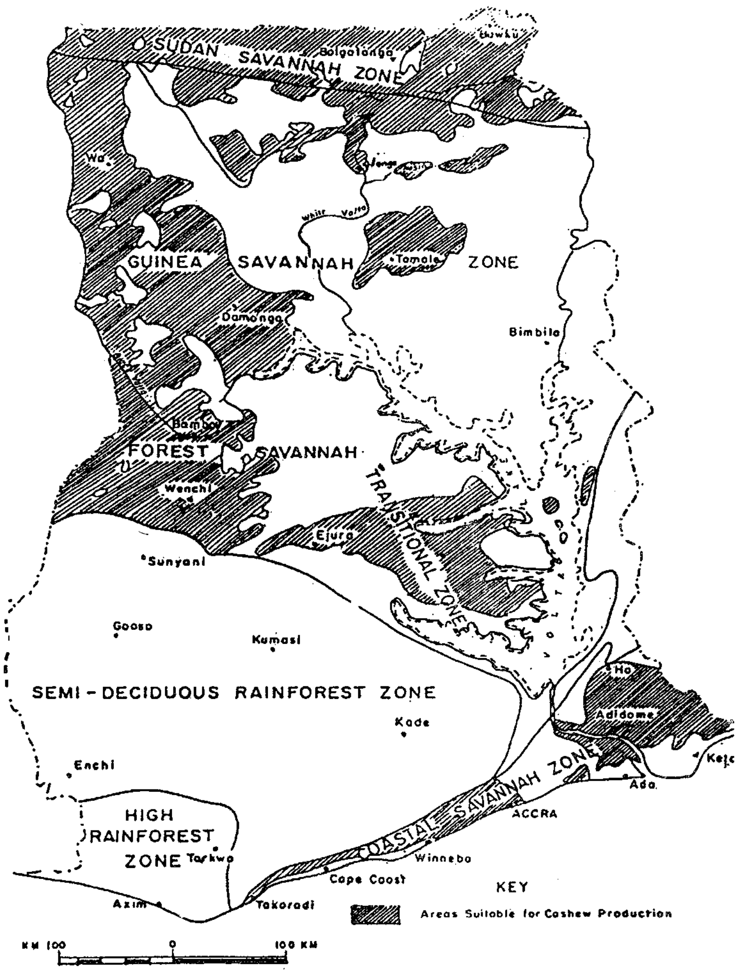
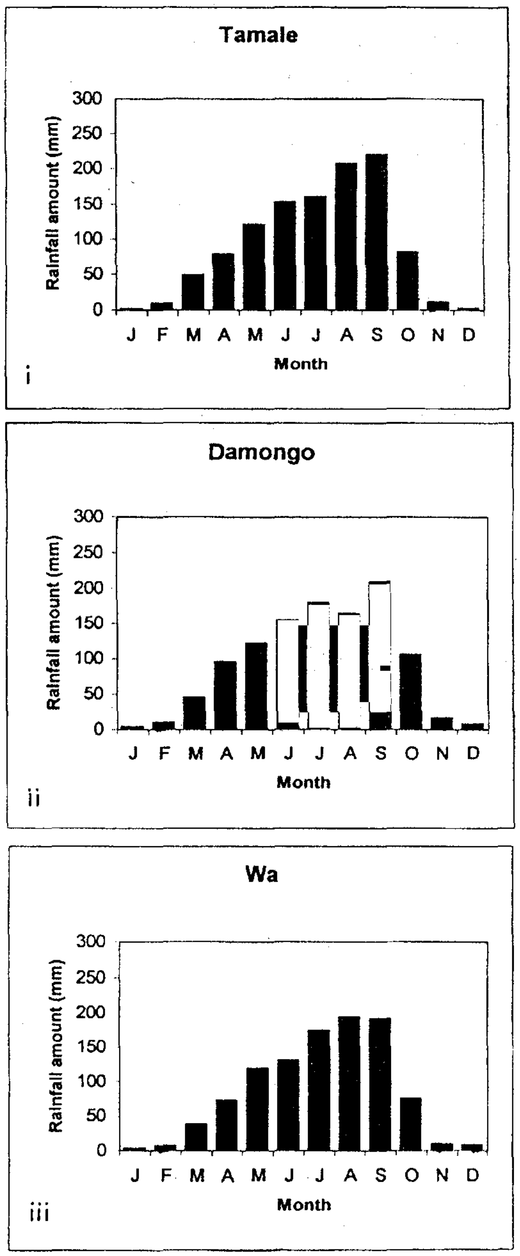


Fig. 1. Suitable areas for cashew production in Ghana

Forest-Savanna Transition. This zone occurs immediately below the Interior Savanna (Fig. 1). Rainfall is characteristically bimodal and ranges from 1200–1400 mm (Table 1). The major season starts from April to about mid-July, with the minor occurring in September and October. The latter season is followed by a long dry

Coastal Savanna. Though the Coastal Savanna experiences a bimodal rainfall regime, annual rainfall amounts are very variable and range from 750–1000 mm (Table 1). Rainfall is very low along the



Source: Ghana Meteorological Services Department

Fig. 2. Mean annual rainfall (1960-1995) for selected towns in the Interior Savanna zone of Ghana

coast (Fig. 4i) but increases towards the inland areas within the zone (Fig. 4ii). The first and major season starts from March or April to mid-July and the second begins at the end of September and terminates in early December. The second season is highly unreliable and may fail in some years.

Soil characteristics

Interior Savanna. The soils suitable for cashew in the Interior Savanna zone are developed from different parent materials, namely granites, phyllites, sandstones and old alluvium. The granitic soils belong to the Varempere-Kupela, Varempere-Tafali-Kupela and Kaleo-Na Associations (Table 2). Among the phyllites, the suitable soil association is Balifoli-Bamkpama, whereas with the sandstone and old alluvium, they are Damongo-Yaroyiri and Sirru-Lapliki respectively. These associations occupy an approximate area of 3,700,000 ha, in the zone. Out of these, 2,450,000 ha can be found in the Guinea Savanna and the remaining 1,250,000 ha in the Sudan Savanna.

Within the associations, the upland members are the most suitable on account of their good physical characteristics and well to moderately well–drained conditions (Table 2). These soils are mainly Lixisols, Luvisols, Acrisols and Plinthosols (ISSS–FAO–ISRIC, 1998). In terms of fertility (Table 3), organic matter levels are generally very low (<1.0%) except for the Lixisols, where values can be above 1.0%. Cashew thrives well in soils with organic matter levels ranging from 1.4–3.0% or more, which represents an organic carbon content of 0.8–1.5% or more.

Apart from the Acrisols, which are strongly acid (*p*H 5.3) in the topsoil and very strongly acid (*p*H 4.8) in the subsoil,

TABLE 1

Climatic conditions in the agro-ecologies suitable for cashew production

Agro-ecology	*Mean max. temp. (°C)*	*Mean min. temp. (°C)*	*Rainfall regime*	*Range*	*Mean annual rainfall (mm)*	*No. of dry months*
Sudan savanna	32-34	20-22	Unimodal	900-1000	950	7
Guinea savanna	-ditto-	-ditto-	-ditto-	1000-1200	1100	6-7
Forest savanna transition	29-33	19-22	Bimodal	1200-1400	1300	5
Coastal savanna	-ditto-	20-24	-ditto-	750-1000	875	405

Source: Ghana Meteorological Services Development (Data from 1961-1995)

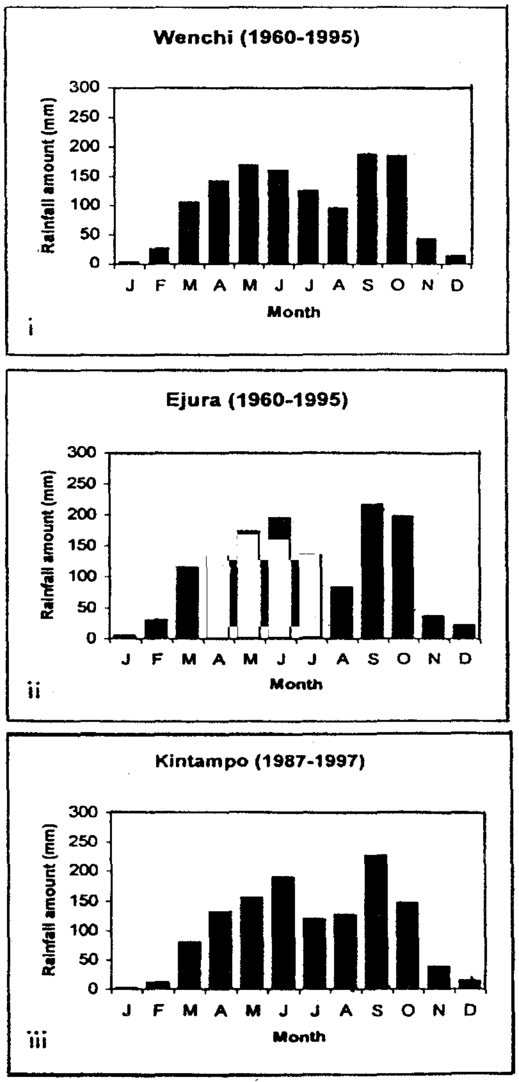
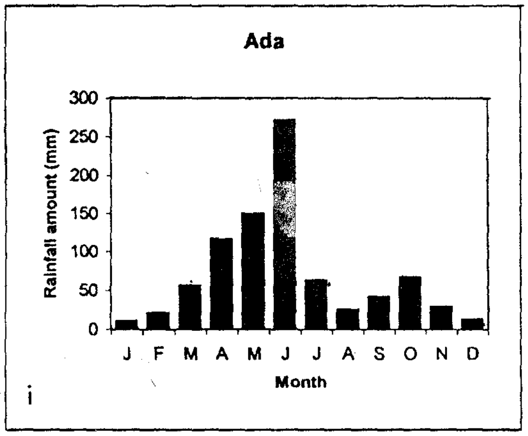


Fig. 3. Mean annual rainfall for selected towns in the Forest-Savanna Transition zone of Ghana
Source: Ghana Meteorological Services Department

the rest of the soils – Luvisols, Plinthosols and Lixisols – have topsoils that have soil reaction ranging between slightly acid (*p*H 6.3) to neutral (*p*H 6.9) conditions. The subsoil conditions vary between moderately acid (*p*H 5.8) and slightly acid (*p*H 6.3). These *p*H levels are suitable for the cashew crop, since it has a wide range of tolerance from *p*H 4.5–8.5 (Sys *et al*., 1993) while optimum values are within *p*H 5.2–7.5. Base saturation values are generally greater than 60% except for the Plinthosols and Acrisols. Total nitrogen (N) and available phosphorus (P) levels are very low in all the soils. The respective ranges of values are 0.05–0.15% N and 2.87–9.60 mg P/kg soil. Exchangeable potassium (K) is generally moderate in all the soils in the zone with values ranging from 0.11–0.21 cmol(+)/kg soil (Table 3).

Forest-Savanna transition. The soils found to be suitable in this zone for cashew production are developed predominantly from sandstone (Adu & Mensah-Ansah, 1995) with a few from Tarkwaian



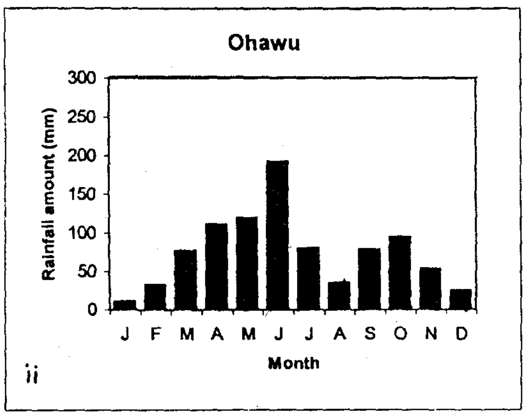


Fig. 4. Mean annual rainfall (1961-1990) for selected towns in the Coastal Savanna zone of Ghana
Source: Ghana Meteorological Services Department

rocks (Table 4). The soils are mainly Luvisols, Lixisols and Acrisols. Altogether, they occupy an area of about 1,550,000 ha within the Brong-Ahafo, Ashanti and Eastern regions of the zone. The Luvisols and Lixisols within the associations (Table 4) are upland soils and medium-textured except for the light-textured Arenosols, which occupy middle to lower slopes.

Soil reaction of the Luvisols and Lixisols is slightly acid (*p*H 6.3) in the topsoil but neutral (*p*H 6.9) in the subsoil of the former and moderately acid (*p*H 5.8) in the latter (Table 3). These levels are suitable for the cashew crop. The Arenosols are, however, very strongly acid (*p*H 4.8) throughout the profile. Organic matter levels are generally very low (<1.0%) for the optimum growth of the cashew crop, though the Luvisols can have values higher than this. Base saturation is high to very high (80–100%). The levels of total N, available P and exchangeable K in the soils follow trends similar to those stated for soils in the Interior Savanna agro–ecology.

Coastal Savanna. The soils in this zone are developed in Tertiary sands, acidic gneiss, quartzites and alluvium (Table 5). In the Tertiary sands group is Toje Consociation, with Doyum-Agawtaw Association developed over acidic gneiss while Toje-Agawtaw Association is developed from the two parent materials (Asiamah, 1995). Oyarifa Consociation and Nyive-Oyarifa Complex comprise soils developed from quartzites with the alluvial soils belonging to the Amo-Tefle and Aveime-Zipa Associations (Brammer, 1967; Asiamah, 1995). Altogether, these soils cover an area of about 235, 000 ha in the zone.

Like the soils in the Forest Savanna Transition zone, the major soils – Luvisols and Acrisols – are medium-textured, while the minor ones (Arenosols) are light–textured (Table 5). The soils are generally strongly (*p*H 5.3) to slightly acid (*p*H 6.3) in their topsoils. However, the subsoil is neutral (*p*H 6.9) in the Arenosols and very strongly acid (*p*H 4.8) to strongly acid (*p*H 5.3) in the other soils (Table 3). These *p*H levels are suitable for the crop. Organic matter levels are generally very low (<1.0%) for the

TABLE 2

Suitable soils in the Interior Savanna (Sudan & Guinea) agro-ecology for cashew production

Soil associations	Suitable soils	Brief description	Places of occurrence
2.1 Granitic origin			
Varempere—Kupela Kaleo-Na	Luvisols (*Tafali* and *Kaleo series*)	Soils occur on summits, upper and middle slopes. They are red to brown, well to moderately well-drained, moderately deep to deep (100-150 cm), concretionary with textures that range from sandy loams to sandy clays	UWR—Wa, Fielman Bekpong watershed, Jirapa-Lambussie Kamba
	Lixisols (*Puga* and *Na series*)	Same as above	NR—Bole, Nakpok, Dariguri, Tuna, Sara Pongeri
			UER—Eastern part of the region, between Black Volta, Kweman Kwesi and Fumbo
2.2 Phyllite origin			
Balifoli—Bamkpama	Luvisols (*Balifoli, Bamkpama* and *Bianya series*)	Soils occur on upper and middle slope sites They are reddish brown to brown, well to moderately well drained and deep (> 120 cm) sandy clays or silty clays. Also found on lower slopes are yellowish brown, moderately deep (50-100 cm) and imperfectly drained silty clays.	UWR—Seilo catchment Bamkpama and Beriyem NR—Banda Nkwanta, Wagawaga and Tinga
2.3 Sandstone origin			
Damongo—Yaroyiri, Mimi—Yaroyiri, Mimi—Techiman Techiman—Tampu	Luvisols & Lixisols (*Damongo, Mimi, Murugu* and *Techiman series)*	These soils can be found on summits and upper slopes. They are red to brown and well to moderately well drained. Most of the soils are deep while some are moderately deep. Textures vary from sandy loams to sandy clay loams.	NR—NE of Bamboi along the Black Volta and Damongo, Bole area: Nalerigu and Tamale
2.4 Alluvial origin			
Sirru—Lapliki	Luvisols (*Sirru* and *Lapliki series*)	The soils occur on terraces of the White Volta, Kulpawn and Sissili rivers. They are deep, red to brown, well to moderately well and imperfectly drained, with textures that range from loamy fine sands to sandy clay loams or sandy clays.	UER—South-western part of areas around Giadema and along the White Volta, Kulpawn and Sissili rivers
			NR—Lower part of the Nasia valley around Kokobila; along the Volta from Nageri through Dibisi and Bulubia to Mishio; Extensive around Janga village
			UWR—Along the Black Volta

UWR —Upper West Region; NR —Northern Region; UER —Upper East Region
Source: Adapted from Adu (1969, 1995a, 1995b, 1996); Dedzoe (1999)

TABLE 3

Some chemical and fertility characteristics of the soils

Agro-ecology	*Soils*	*pH Topsoil Range*	*pH Subsoil Range*	*% O.M. (top so cm)*	*% Base saturation*	*Total N %*	*Available P mg/kg soil*	*Exchange-able K (cmol(+)/ kg soil)*
Interior Savanna	Luvisols (*granitic*)	6.5-7.3	6.1-6.5	<1.0	>80	0.13	3.18	0.21
	Luvisols (*phyllite*)	6.1-6.5	5.6-6.0	0.4-0.5	>80	0.05	6.51	0.12
	Plinthosols (*phyllite*)	6.1-6.5	5.6-6.0	0.4-0.7	>50	0.08	9.60	0.10
	Lixisols (*sandstone*)	6.6-7.3	6.1-6.5	0.5-1.5	60-80	0.07	4.51	0.14
	Luvisols (*alluvium*)	6.6-7.3	6.1-6.5	<1.0	>80	0.06	2.87	0.11
Forest Savanna Transition	Luvisols (*sandstone*)	6.1-6.5	6.6-7.3	0.8-1.8	>80	0.04	9.30	0.16
	Lixisols (*sanstone*)	6.1-6.5	5.6-6.0	<1.0	60-80	0 .04	7.64	0.12
	Arenosols (*sandstone*)	4.6-5.0	4.6-5.0	0.6-0.8	60-80	0.03	1. 56	0.13
	Acrisols (*tarkwaian*)	5.1-5.5	4.6-5.0	<1.0	<50	0. 02	8.2 1	0.13
Coastal Savanna	Luvisols (*Tertairy sands*)	5.6-6.0	5.6-6.0	0.7-.08	60-80	0.02	Trace	0.09
	Arenosols (*Tertiary sands & acidic gneiss*)	5.6-6.0	6.6-7.3	<1.0	40-60	0.05	Trace	0.10
	Acrisols (*quartzite*)	5.6-6.0	4.6-5.0	1.2-2.1	<50	0.10	5.12	0.30
	Luvisols (*alluvium*)	5.6-6.0	5.1-5.5	1.0-3.0	>80	0.05	1.39	0.21

Source: Adapted from Adu (1969, 1995a, 1995b, 1996); Brammer (1967); Adu & Mensah-Ansah (1995); Asiamah (1995); Boateng *et al.* (2000).

development of the crop in the zone. However, for the Acrisols, this can be moderate (>2.0%). Base saturation is low in the Acrisols and moderate to high in the Arenosols and Luvisols respectively (Table 3). Total N, available P and exchangeable K levels are similar to trends described for the suitable soils in the Interior Savanna and Forest Savanna Transition. Available P, in particular, can be considered to be very deficient in the zone as it occurs in traces in some of the suitable soils.

TABLE 4

Suitable soils in the Interior Savanna (Sudan & Guinea) agro-ecology for cashew production

Soil associations	Suitable soils	Brief description	Places of occurrence
4.1 Sandstone origin			
Damongo—Murugu—Tanoso Bediesi—Sutawa—Bejua Ejura— Amantin—Denteso	Luvisols (*Damongo and Murugu series*)	The characteristics of these soils are as described in section 2.3, Table 2.	ASR —Aframso, Ejura, Drobonso, Anwamang, Ejura —Sekyedumasi, Afram watershed & Kwamang
			ER —Around Tease
			BAR —From Drobo through Wenchi and Nkoranza to the southern parts of Kintampo and Atebubu
	Lixisols (*Bediesi, Ejura* and *Amantin series*)	These soils occur on summits, upper to middle slopes. They are red to brown, very deep(> 150 cm), well to moderately well drained sandy clay loams to sandy clays	ASR —Ejura and along Afram watershed, Agogo, Ejura —Sekyedumasi, Mampong, Kumawu.
			BAR —Same as obove
			ER —Afram watershed, Ajwenso, Kwahu Tafo, Mpraeso and Nkwanta
	Arenosols (*Dobidi series*)	These soils occur on middle to lower slopes of the Ejura—Amantin-Denteso Association. They are brown, very deep and imperfectly drained sandy loams to loamy fine sands.	ASR —Ejura and along Afram watershed, Agogo, Ejura —Sekyedumasi, Mampong, Kumawu
4.2 Tarkwaian origin			
Lura—Farmang	Acrisols (*Lura* and *Farmang series*)	These soils occur on upper to middle slope sites. They are red to brown, well to moderately well drained sandy loams. Gravels, stones and concretions may be found in the subsoils.	BAR —Between Jema, Banda —Nkwanta & the Black Volta
	Plinthosols (*Gradaw* and *Ngre series*)	These soils can be found on middle and lower slopes. They are brown to brownish grey, deep (> 120 cm) to moderately shallow (50-70 am), moderately well to imperfctly drained loamy fine sands. Concretions and sheet ironpan may be found in the subsoil.	- ditto -

UWR—Upper West Region; NR—Northern Region; UER—Upper East Region
Source: Adapted from Adu (1969, 1995a, 1995b, 1996); Dedzoe (1999)

TABLE 5

Suitable soils in the Coastal Savanna agro-ecology for cashew production

Soil associations	*Suitable soils*	*Brief description*	*Places of occurrence*
5.1 *Tertiary sands & Acidic gneiss origin*			
Toje—Alajo, Toje—Agawtaw, Toje Consociation, Alajo—Agawtaw, Doyum—Agawtaw	Luvisols (*Toje and Koloidaw series*)	The soils can be found on summits and upper to middle slopes. They are red to brown, deep (120-150 cm) to very deep (> 150 cm), well to moderately well drained fine sandy clay loams to sandy clays.	GAR —Amlakpo, Sege, Awudikope, Old and New Ningo VR —Dzodze, Abor, Akatsi, Tadzewu, Ehie, Haglakope
	Arenosols (*Doyum* and *Agbosume series*)	These soils occur on upper to middle slopes of Doyum—Agawtaw and lower slopes of Toje-Alajo Associations respectively. They are pale brown and grey, deep to very deep and imperfectly drained sandy loams to loamy fine sands.	-ditto-
5.2 *Quartzite origin*			
Oyarifa Consociation Nyive-Oyarifa	Acrisols (*Oyarifa series*)	The soils are found on summits, upper and middle slopes. They are red, deep and well drained. Textures vary from sandy clay loams to sandy clays.	GAR —Ofanko, Abokobi, Oyarifa, Bawalishe, Ayikuma and Agomeda. VR —Tsito, Gbogame, Anyirawase, Ho, Sokode
5.3 *Alluvial origin*			
Amo—Tefle Aveime—Zipa, Aveime—Ada	Luvisols (*Amo, Aveime* and *Zipa series*)	Found on high, middle to low terraces of the Volta. The soils are red to yellowish-brown, deep, well, moderately well drained with textures that vary from silty clay loams to silty clays or fine sandy loams to sandy clays.	VR —From Adidome to Sogakope along the eastern part of the Volta; Aveyime through Battor to Agave; west of the Lupu, Kasu, Nyapia and Zipa lagoons; areas to the west of the Angaw lagoon especially around Amlakpo, Toflokpo and Kaja. GAR —Between Sege and Luchubwa. ER —From Senchi through Kpong to Akuse.

UWR —Upper West Region; NR —Northern Region; UER —Upper East Region
Source: Adapted from Adu (1969, 1995a, 1995b, 1996); Dedzoe (1999)

Limitations of the soils and implications for cashew development

Irrespective of parent material and agro-ecology, there are unsuitable soils among the associations mentioned (Tables 2, 4 and 5). These soils are mainly Leptosols, which are characteristically shallow, rocky and skeletal. Some are crustal with sheet ironpan either exposed at the soil surface or present in the subsoil to impede internal drainage. These Leptosols are common in the Interior Savanna zone. Others occur on scarp summits of eroded uplands in the Forest Savanna Transition zone.

Similarly, in the Interior Savanna, some of the suitable soils such as the Luvisols of granitic and sandstone origin, and the Acrisols are concretionary. This adversely affects water retention capacity of the soils. The Plinthosols have fragments of indurated plinthite and sheet ironpan, which also hinder internal drainage of the soils. The Arenosols in the Forest Savanna Transition and Coastal Savanna zones are characteristically sandy. This significantly affects their water and nutrient retention capacities. Some of the soils within the Tertiary sands group in the Coastal Savanna are underlain by a hard claypan at shallow depth and this is a limitation to effective rooting depth and infiltration of water. The valley bottom soils of all the associations mentioned (Tables 2, 4 and 5) are unsuitable for cashew mainly due to their poor moisture relationships. They are poorly drained and subject to seasonal flooding.

Though the soils in all the three agro-ecological zones are low in fertility, this is not a severe limitation to the development of the crop. This can be corrected through proper soil management practices such as appropriate fertilizer use, since cashew is reported to respond significantly and economically to fertilizer application (EMBRAPA, 1993). Base saturation levels of above 35% are considered suitable for the crop. In the case of soil reaction, almost all the soils have values within the optimum range of *p*H 5.2-7.0 (Table 3). However, the very strongly acid (*p*H 4.8) conditions of the Arenosols in the Forest Savanna Transition and Acrisols are considered marginal for development of the crop (Sys *et al.*, 1993). Organic matter is the most limiting fertility indicator in all the soils. The generally low levels (<1.0%) are likely to affect water and nutrient retention of the soils. These low levels are also reflected in the low amounts of total N and available P of all the soils. The organic matter levels considered suitable for the crop range from 1.4–3.0% or more.

Some of the soils in the Coastal Savanna, especially those developed from acidic gneiss, are sodic with high levels of sodium in the subsoil (Brammer, 1967; Lathbridge, 1970; Senayah & Asiamah, 1998; Boateng *et al.*, 2000). This may also retard the development of the crop and could be considered unsuitable for economic cashew production.

Suitability rating of the agro-ecological zones

On the basis of climatic conditions and soil characteristics, the Forest Savanna Transition is rated as highly suitable for high production of cashew in Ghana. The Interior Savanna is moderately suitable, while the Coastal Savanna is marginally suitable for the crop (Table 6).

Conclusion

The approximate total land area found suitable in the country for the production of cashew is 5,485,000 ha. Out of this 67.5%

TABLE 6

Suitability ratings of the agro-ecologies for cashew production

Agro-ecology	*Rating*	*Remarks*
Forest Savanna Transition	High	Soils are developed predominantly from one parent material. They are deep and mostly medium-textured. Few are light-textured. Associated limitations such as shallowness, gravellines and concretionary nature are not extensive. The soils are granular at the top and become weak to moderate, fine and medium sub-angular blockly in the subsoil. Soil consistency is generally slightly hard, friable, slightly sticky and slightly plastic. The major soils are suitable for mechanical cultivation. Soil moisture and nutrient retention is low to moderate. Rainfall and temperature requirements are optimum for cashew prodection.
Interior Savanna (Guinea & Sudan)	Moderate	Soils are heterogeneous since they are developed from a variety of parent materials. They are deep to moderately deep, medium-textured, mostly gravelly and concretionary. Topsoil structure is granular and this grades to moderate, fine and medium sub-angular blocky in the subsoil. A few of the soils are massive in the subsoil. The soils are hard, firm to very firm, slightly sticky, slightly plastic and, in some cases, sticky and plastic in the subsoil. Plinthite, which occurs in some of them, may change irreversibly to ironpan if the soils are badly managed. Most of the soils can be tilled mechanically. However, the concretionary and stony soils can only be hand cultivated. Soil moisture and nutrient retention is low to moderate. Rainfall and temperature are within optimum range for high cashew production.
Coastal Savanna	Marginal	The soils are not so varied. The suitable soils are deep, light to medium-textured. Some of the soils developed from quartzite are gravelly, concretionary and shallow. The soils are granular at the top and become moderate, fine and medium sub-angular blocky in the subsoil. The less structured soils are single grained. Soil consistency varies from loose, non-sticky and plastic. Most of the soils are suitable for mechanical tillage. Temperature is generally optimum for the growth of the cashew crop but rainfall in the zone is erratic and unreliable.

(i.e. about 3,700,000 ha) can be found in the Interior Savanna about 44.7% in the Guinea Savanna and the remaining 22.8%, in the Sudan Savanna zone. The Forest Savanna Transition zone has about 28.2% (i.e. about 1,550,000 ha) whereas the Coastal Savanna has only 4.3% (i.e. about 235, 000 ha) of suitable land area.

In all the three agro-ecologies, the major soils suitable for cashew production are Luvisols, Lixisols and Acrisols. These are generally deep (> 100–150 cm) and medium-textured. The Plinthosols and Arenosols associated with these soils are marginal for cashew production. The former are concretionary and may be underlain by ironpan, while the light–textures of the latter impart low moisture and nutrient retention capacities.

The Forest-Savanna Transition has the potential for the maximum production of cashew both in terms of climatic conditions and soil characteristics. The Luvisols, Lixisols and Acrisols found in the zone, are highly suitable for the crop. Limitations such as concretions, gravels and stones are few.

The Interior Savanna, though has the most extensive coverage of these soils especially Luvisols, is moderately suitable because the climatic conditions are moderate and the soils are physically too heterogeneous, concretionary, gravelly and stony. These adversely affect effective rooting depth, moisture and nutrient retention. The Coastal Savanna zone is considered marginally suitable for cashew production largely on account of the very low annual rainfall amounts.

Generally, the fertility status of the soils within these agro–ecologies is low to moderate. The low nutrient levels in the soils can be corrected through proper soil management practices especially by the combined application of organic and appropriate mineral fertilizers. The soils found unsuitable within these agro–ecologies have such physical limitations as shallow depth, presence of gravels and stones, and/or ironpan in their subsoils.

References

Addaquay, J. & K. Nyamekye-Boamah (1998). *The Ghana Cashew Industry Study.* Report prepared for the Ministry of Food and Agriculture (MOFA) under the Agricultural Diversification Project.

Adu, S. V. (1969). *Soils of the Navrongo-Bawku Area, Upper Region, Ghana.* Soil Research Institute (SRI) Memoir No. 5.

Adu, S. V. (1995a). *Soils of the Nasia River Basin, Northern Region, Ghana.* SRI Memoir No. 11.

Adu, S. V. (1995b). *Soils of the Bole-Bamboi Area, Northern Region, Ghana.* SRI Memoir No. 14.

Adu, S. V. (1996). *Soils of the Yapei – Sawla Road Area, Northern Region, Ghana.* SRI Memoir No. 16.

Adu, S. V. & J. A. Mensah–Ansah. (1995). *Soils of the Afram Basin, Ashanti and Eastern Region, Ghana.* SRI Memoir No. 12.

Asiamah, R. D. (1995). *Soils of the Ho-Keta Plains, Volta Region, Ghana.* SRI Memoir No. 10.

Boateng, E., C. D. Dedzoe, D. F. K. Allotey & T. Ayamga. (2000). *Soil suitability assessment for Verbofarms Ltd.* SRI Tech. Rep. No. 199.

Brammer, H. (1967). *Soils of the Accra Plains.* SRI Memoir No. 3.

Dedzoe, C. D. (1999). *Suitable areas for cashew production in Ghana.* SRI Misc. Paper No. 263.

EMBRAPA. (1993). Empresa Brasileira de Pesquisa Agropecuria: Centro Nacional de Pesquisa de Agroindustria Tropical. *Circular Tecnica.* Numero 01 Abril 1993. p. 15.

Irvine, F. R. (1961). *Woody Plants of Ghana.* pp 552 - 553. Liondon: Oxford University Press.

ISSS–FAO–ISRIC (1998). *World Reference Base for Soil Resources.* World Soil Resources Report No. 84. Rome: FAO.

Lathbridge, E. F. G. R. (1970). *Report on preliminary soil investigation for Integrated Farming Enterprises Ltd farm site near Sege.* SRI Misc. Paper No 116.

Senayah, J. K. & Asiamah, R. D. (1988). *Report on soil studies of the Dawa village pilot project.* SRI Tech. Rep. No. 146.

Soil Research Institute (SRI) (1996). *Soil map of Lawra-Wa Region.* SRI Cartographic Section.

Sys, C., van Ranst, E., Debaveye, J & Beernaert, F. (1993). *Land Evaluation. Part III. Crop requirements. Agricultural Publications* 7, 39–40. Brussels, Belgium: General Administration for Development Cooperation.

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Dreyfs B., Garcia J.L. and Gillis M. (1988). Characterization of *Azorhizobium caulinodans* gen. sp. Nov., a stem-nodulating nitrogen-fixing bacterium isolated from *Sesbania rostrata. Int. J.Syst. Bacteriol.* 38: 89-98.

Van Rhee J.E. (1963). Earthworm activities and the breakdown of organic matter. In Soil Organisms. Eds. J. Doeksen and J. van der Drift. Pp.55-59. North Holland, Amsterdam.

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