# An Assessment of the Possibilities of Oil Palm Cultivation in Western Division, The Gambia

Ministry of Overseas Development

# An Assessment of the Possibilities of Oil Palm Cultivation in Western Division, The Gambia

by

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## OF THE DIRECTORATE OF OVERSEAS SURVEYS

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# PARTS 1 - 6

# PART I. INTRODUCTION

## PREFACE

Work began on this project in 1965 and a draft report was submitted to the Government of The Gambia in 1968. It is now published with their kind permission.


## ACKNOWLEDGEMENTS

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## ABSTRACT


The climate, geology, relief, vegetation and soils of the Western Division of The Gambia are described. Most of the environmental factors are unfavourable for optimum oil palm growth, in particular the low rainfall and long dry season of seven months. The unfavourable conditions are reflected in the poor establishment and growth of planted palms.

High establishment costs and low yields suggest that the profitability of oil palm development in The Gambia is very doubtful, but such development may be desirable for social or other reasons. If so, development should be on the least unsuitable sites for oil palm growth, which have been selected, and mapped, principally on the basis of soil and soil moisture characteristics interpreted in terms of the growth of wild palms.


## RÉSUMÉ


Le climat, la géologie, le relief, la végétation et les sols de la Division Occidentale de La Gambie sont décrits. La plupart des constituants du milieu physique sont défavorables à la culture du palmier à huile, en particulier les pluies éparses et la saison sèche longue de sept mois. Ces conditions défavorables se manifestent dans la croissance insuffisante des palmiers plantés.

A cause des frais élevés de l'établissement des palmeraies et des rendements bas de l'huile, la rentabilité du palmier à huile dans la Gambie serait douteuse, mais le développement de cette culture pourrait etre souhaitable pour des raisons sociales entre autres. En ce cas, le développement devrait être dans les localités les moins défavorables au palmier à huile On a distingué les localités les moins défavorables en considérant surtout les caractéristiques des sols et la croissance actuelle des palmiers sauvages. Les limites des localités sont indiquées sur des cartes.

## DESCRIPTORS FOR CO-ORDINATE INDEXING

The Gambia/potential land use/climatology/rainfall/air temperature/humidity/
evapotranspiration/geology/geomorphology/savanna/soil survey/luvisol/
ferralsol/gleysol/soil water/oil palm/plant ecology/plant water requirement/
crop yield/plant breeding/

# PART 2. THE PROJECT

## ORIGIN OF THE PROJECT

In 1965 the Government of The Gambia asked the Land Resources Division to undertake a survey of the Western Division of the country with the following terms of reference:

1. To investigate and map the landform units and their associated soils.
2. To map the areas at present occupied by wild palms.
3. To assess the potential for the cultivation of oil palms, and to map the most suitable areas
4. To assess the possibilities of growing citrus, cashews and rice, and to indicate the most suitable sites for each crop.

## PROCEDURE

The project began in October 1965 when the author was assigned to the project.

Initially, the relevant literature and maps were consulted and reviewed. Next, the air photography at a scale of 1:25 000 (made in 1962 by Fairey Surveys Limited) was examined stereoscopically, a provisional analysis of the landform units was made, and the distribution of naturally occurring palms mapped at a scale of 1:50 000. Field investigations were made from March 1966 to May 1967. These included a check and revision of the air photo interpretation, a landform analysis, a reconnaissance soil survey and measurements of the growth and rooting of wild and planted palms.

This report contains an assessment of the potential of the area for growing oil palms. More detailed information on the geomorphology and soils of Western Division is contained in a provisional report on the soils of Western Division (Hill, 1969). Time did not allow a full assessment of the area for citrus, cashews and rice, but the soil data and reconnaissance soil map contained in the provisional report will provide a basis for such an assessment.

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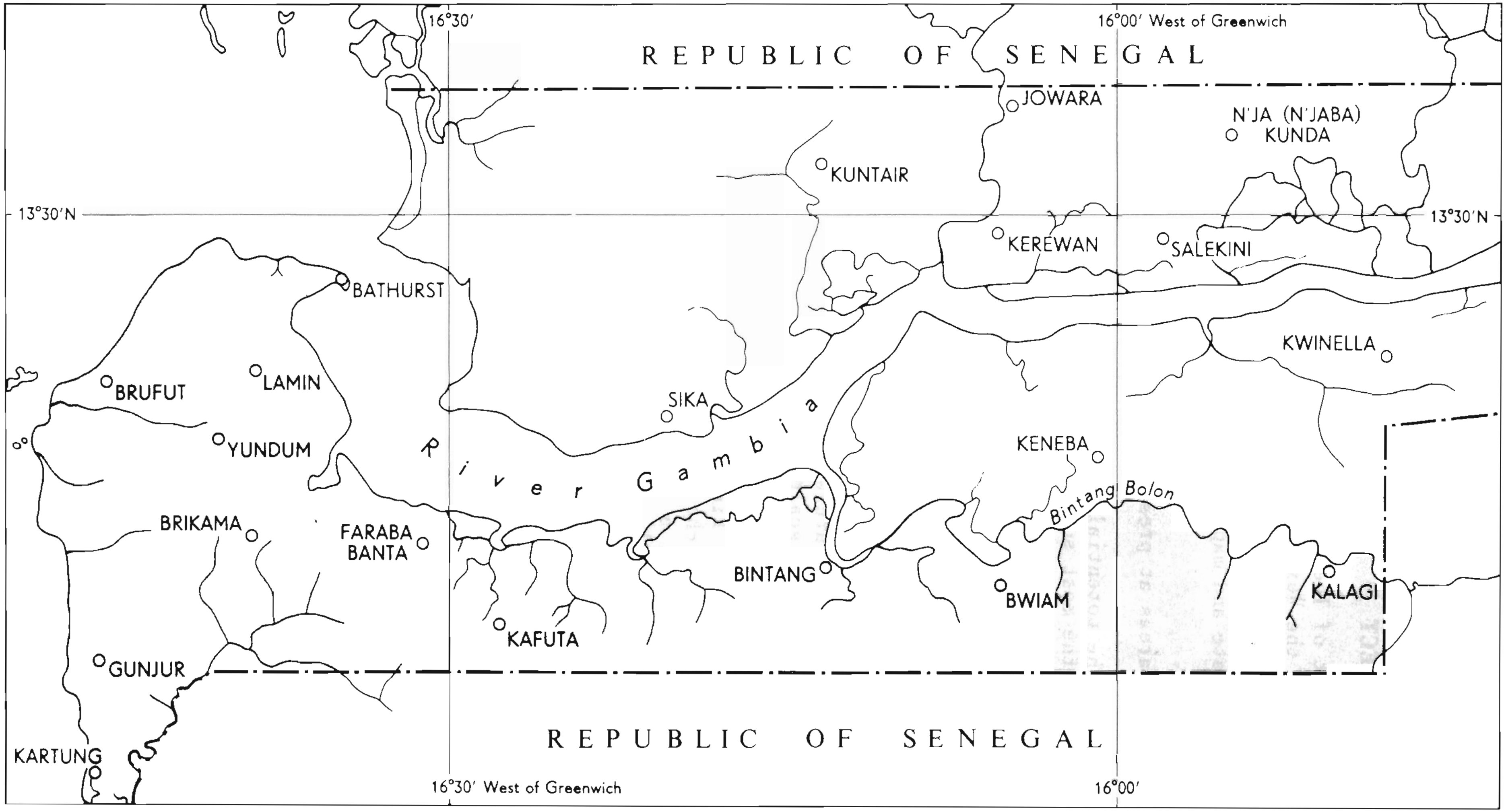



Study area

Scale 1:500,000 (Approx)

TEXT MAP 1 Location and drainage of the study area

# PART 3. THE ENVIRONMENT

## LOCATION

The Gambia, lying between latitude 13°N and 14°N, forms a narrow band on either side of the Gambia river, extending into the Republic of Senegal for some 500 km (300 mi): boundaries are political and correspond to no geographical features.

The area of this study, approximately 1 500 km$^2$ (600 mi$^2$), corresponds to the administrative unit of Western Division. It extends approximately 108 km (67 mi) inland from the coast and is bounded in the north by the swamps on the south bank of the Gambia river and its tributary the Bintang Bolan, in the south by the international boundary with Senegal (Text Map 1)

## CLIMATE

The Gambia has a Sahelo-Soudan type of climate (Aubréville, 1949) characterised by a long dry season, and a short intense wet season. Near the coast the climate changes to the Guinean-Lower Casamance type, which differs mainly in having a higher rainfall.

Kendrew (1961) and Cochème and Franquin (1967) have analysed the climate of this part of West Africa which is controlled by two main influences: the north-easterly harmattan, a dry continental air mass coming from the Sahara, and the south-westerly monsoon, a humid oceanic air mass. They meet in the belt of low pressure known as the intertropical convergence zone, where their interaction produces thick low cloud and heavy rain, with thunderstorms. The northward migration of this convergence zone brings rain to the area from June to October. In winter the convergence zone moves southwards, anticyclonic conditions prevail and the area is mainly dry.

The main features of the climate are described below. Unless otherwise stated the temperature, rainfall and wind records shown in the tables were supplied by the Meteorological Office, Yundum.

### Rainfall

The rainfall is mainly convectional and torrential, though spells of cloud and steady rain are common. Within Western Division rainfall decreases eastwards from Yundum which has an annual average of 1 326 mm (52.28 in). The markedly seasonal rainfall distribution is shown by rainfall data in Table 1 and the histograms in Figure 1. The rainfall in any one month may vary widely from year to year as shown by the values in Table 1 for standard deviation from the mean rainfall, whilst the decrease in rainfall to the north and east of the area is illustrated by the data for Keneba, Kerewan, Georgetown and Basse. The latter two towns lie east of the project area, in MacCarthy Island Division and Upper River Division, respectively.

Rainfall during June and July governs the earliest date at which oil palms may be planted. The percentage probabilities of obtaining certain amounts of rain during June have therefore been calculated using the method of Glover and Robinson (1953) and are shown in Table 2. These data are considered in relation to the soil moisture deficit on page 26 of this report.

TABLE 1 Mean monthly rainfall and standard deviation (1) values for stations in The Gambia

| Month | Yundum 1949-66 | | | Bwiam 1949-58 | | | Keneba (2) 5 yrs | | Kerewan 1949-58 | | | Georgetown 1949-65 | | | Basse 1949-66 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | in | s.d., in | mm | in | s.d., in | mm | in | mm | in | s.d., in | mm | in | s.d, in | mm | in | s.d., in |
| Jan. | 1 | 0.05 | - | 0 | 0.00 | - | 0 | 0.01 | 0 | 0.00 | - | 0 | 0.01 | - | 0 | 0.00 | - |
| Feb | 1 | 0.05 | - | 1 | 0.04 | - | 0 | 0.00 | 3 | 0.13 | - | 0 | 0.01 | - | 1 | 0.02 | - |
| Mar. | 0 | 0.00 | - | 0 | 0.00 | - | 0 | 0.00 | 0 | 0.00 | - | 0 | 0.00 | - | 0 | 0.00 | - |
| Apr. | 0 | 0.00 | - | 0 | 0.00 | - | 0 | 0.00 | 0 | 0.00 | - | 0 | 0.00 | - | 2 | 0.08 | - |
| May | 8 | 0.30 | - | 7 | 0.29 | - | 0 | 0.03 | 5 | 0.21 | - | 11 | 0.45 | - | 24 | 0.94 | - |
| June | 76 | 2.97 | 1.39 | 99 | 3.87 | 1.47 | 136 | 5.33 | 84 | 3.30 | 2.26 | 122 | 4.82 | 2.24 | 119 | 4.70 | 2.04 |
| July | 317 | 12.50 | 3.10 | 315 | 12.41 | 4.71 | 188 | 7.39 | 256 | 10.08 | 2.14 | 226 | 8.88 | 2.58 | 224 | 8.83 | 3.36 |
| Aug. | 498 | 19.63 | 7.70 | 343 | 13.51 | 5.33 | 481 | 18.94 | 356 | 14.04 | 6.68 | 333 | 13.12 | 5.18 | 348 | 13.69 | 4.55 |
| Sept. | 315 | 12.43 | 4.04 | 291 | 11.46 | 5.00 | 249 | 9.81 | 249 | 9.78 | 4.90 | 230 | 9.05 | 3.62 | 261 | 10.27 | 3.34 |
| Oct. | 99 | 3.89 | 2.80 | 129 | 5.06 | 2.53 | 94 | 3.68 | 97 | 3.83 | 3.49 | 95 | 3.75 | 2.86 | 95 | 3.74 | 2.30 |
| Nov. | 10 | 0.41 | - | 6 | 0.26 | - | 0 | 0.06 | 21 | 0.84 | - | 5 | 0.19 | - | 11 | 0.43 | - |
| Dec. | 1.25 | 0.05 | - | 0 | 0.00 | - | 0 | 0.00 | 2 | 0.08 | - | 1 | 0.02 | - | 0 | 0.01 | - |
| Year | 1 326 | 52.28 | | 1 191 | 46.90 | | 1 148 | 45.25 | 1 073 | 42.29 | | 1 023 | 40.30 | | 1 085 | 42.71 | |

(1) Standard deviation (s.d.) was calculated only for the period June to October, because rainfall during the rest of the year was too low to give meaningful figures. Standard deviation was not calculated for Keneba as rainfall records were available for a five year period only.

(2) Data from Giglioli and Thornton (1956)

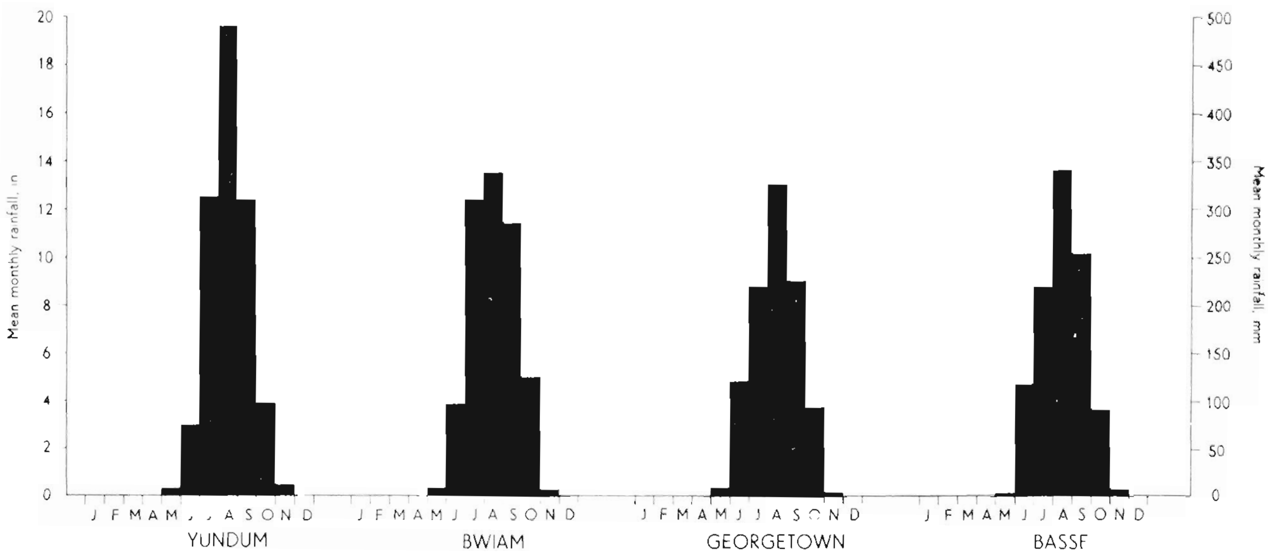



FIGURE 1 Mean monthly rainfall for four stations in The Gambia

TABLE 2 Percentage probability of June rainfall exceeding certain amounts

| Station | Extent of record | Percentage probability of June rainfall exceeding | | | | | |
|---|---|---|---|---|---|---|---|
| | | 25 mm (1 in) | 50 mm (2 in) | 75 mm (3 in) | 100 mm (4 in) | 150 mm (6 in) | 200 mm (8 in) |
| Yundum | 1949-66 | 91.4 | 75.5 | 45.2 | 26.1 | 2.7 | 0.0 |
| Bwiam | 1949-58 | 97.4 | 90.3 | 66.3 | 48.0 | 8.1 | 0.3 |
| Kerewan | 1949-58 | 83.4 | 69.5 | 52.4 | 41.6 | 14.6 | 0.0 |
| Georgetown | 1949-65 | 95.1 | 87.2 | 77.3 | 65.7 | 30.6 | 0.0 |
| Basse | 1950-63 | 96.1 | 90.9 | 77.6 | 64.4 | 27.4 | 5.0 |

These figures show that at Yundum, for example, in nine years out of ten June rainfall exceeds 25 mm (1 in) but only in two to three years out of ten does June rainfall exceed 150 mm (6 in).

## The Dry Season

The long dry season of seven months generally begins in mid-October and ends in the second half of June. During this period the days are usually very hot and the nights cool. The harmattan wind carries Sahara desert dust and causes haze and very low humidity. Potential evapotranspiration exceeds rainfall by over 88 mm (35 in) and desiccation is intense.

## Temperature

The mean monthly temperatures in Table 3 show that the eastern part of The Gambia is hotter throughout the year.

TABLE 3 Mean monthly temperature data for three stations in The Gambia

| Month | Mean monthly temperature (1) | | | | | |
|---|---|---|---|---|---|---|
| | Yundum 1949-66 | | Georgetown 1949-65 | | Basse 1950-63 | |
| | °C | °F | °C | °F | °C | °F |
| January | 23.3 | 73.9 | 24.8 | 76.7 | 24.7 | 76.4 |
| February | 24.6 | 76.2 | 27.1 | 80.7 | 27.2 | 80.9 |
| March | 25.2 | 77.3 | 29.2 | 84.5 | 29.6 | 85.2 |
| April | 25.5 | 77.9 | 30.4 | 86.7 | 31.3 | 88.4 |
| May | 25.7 | 78.3 | 31.4 | 88.6 | 32.1 | 89.8 |
| June | 27.1 | 80.8 | 29.8 | 85.6 | 29.8 | 85.7 |
| July | 26.7 | 80.0 | 27.6 | 81.6 | 27.7 | 83.0 |
| August | 26.3 | 79.4 | 26.9 | 80.5 | 27.1 | 80.7 |
| September | 26.5 | 79.7 | 27.3 | 81.1 | 27.3 | 81.2 |
| October | 26.6 | 79.9 | 28.0 | 82.4 | 27.9 | 82.2 |
| November | 25.6 | 78.1 | 27.2 | 80.9 | 27.4 | 81.4 |
| December | 23.4 | 74.1 | 24.3 | 75.8 | 24.3 | 75.7 |
| Mean monthly | 25.5 | 78.0 | 27.8 | 82.1 | 28.0 | 82.5 |

(1) ½ (Monthly mean minimum) + ½ (Monthly mean maximum).

The range of temperature is considerable as shown by the maximum and minimum temperature figures shown in Table 4. Mean monthly minimum temperatures fall below 18°C (65°F) from December to March at Yundum and Georgetown, whilst from February to May mean monthly maximum temperatures rise above 32°C (90°F) at Yundum, and during March, April and May they rise above 37°C (100°F) at Georgetown and Basse.

TABLE 4 Mean monthly maximum and minimum temperature data for three stations in The Gambia

| | Yundum 1949-66 | | Georgetown 1949-66 | | Basse 1950-63 | |
|---|---|---|---|---|---|---|
| | °C | °F | °C | °F | °C | °F |
| Mean maximum | 31.6 | 88.9 | 35.1 | 95.2 | 35.8 | 96.4 |
| Mean minimum | 20.1 | 68.2 | 20.5 | 68.9 | 20.3 | 68.5 |
| Extreme maximum | 41.7 | 107.1 | 43.9 | 111.0 | - | - |
| Extreme minimum | 7.8 | 46.0 | 8.3 | 46.9 | - | - |

**Relative Humidity**

Throughout the country the highest relative humidity occurs during the rainy season. Figures for percentage relative humidity are available only for Yundum and these are given in Table 5.

TABLE 5 Mean monthly percentage relative humidity at Yundum

| Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | 51 | 55 | 63 | 69 | 75 | 82 | 87 | 85 | 82 | 73 | 59 |

**Winds**

The region is influenced by three air currents: the hot, dry, dusty harmattan, a north-easterly wind which often brings haze; a hot and damp south-westerly wind, which blows during July, August and September, and the north-east trade wind, affecting only the coastal areas.

**Potential Evapotranspiration**

Estimates of evapotranspiration were calculated for Yundun, Georgetown and Basse using the formula of Thornthwaite (1948). Similar estimates using Penman's formula (1948) could only be made for Yundum as there are insufficient data for the other stations. These figures are presented in Table 6 but it must be stressed that they are only estimates based on theoretical considerations. Garnier (1956) has shown that during the dry season in Northern Nigeria estimates of evapotranspiration computed by the Thornthwaite method are lower than measured evapotranspiration; during the wet season the Thornthwaite figures are higher than measured evapo-transpiration. Cochème and Franquin (1967) indicate on a generalised sketchmap a Penman estimate of annual potential evapotranspiration of less than 1 600 mm (63 in) for the whole of The Gambia, a figure which is considerably lower than those given here.

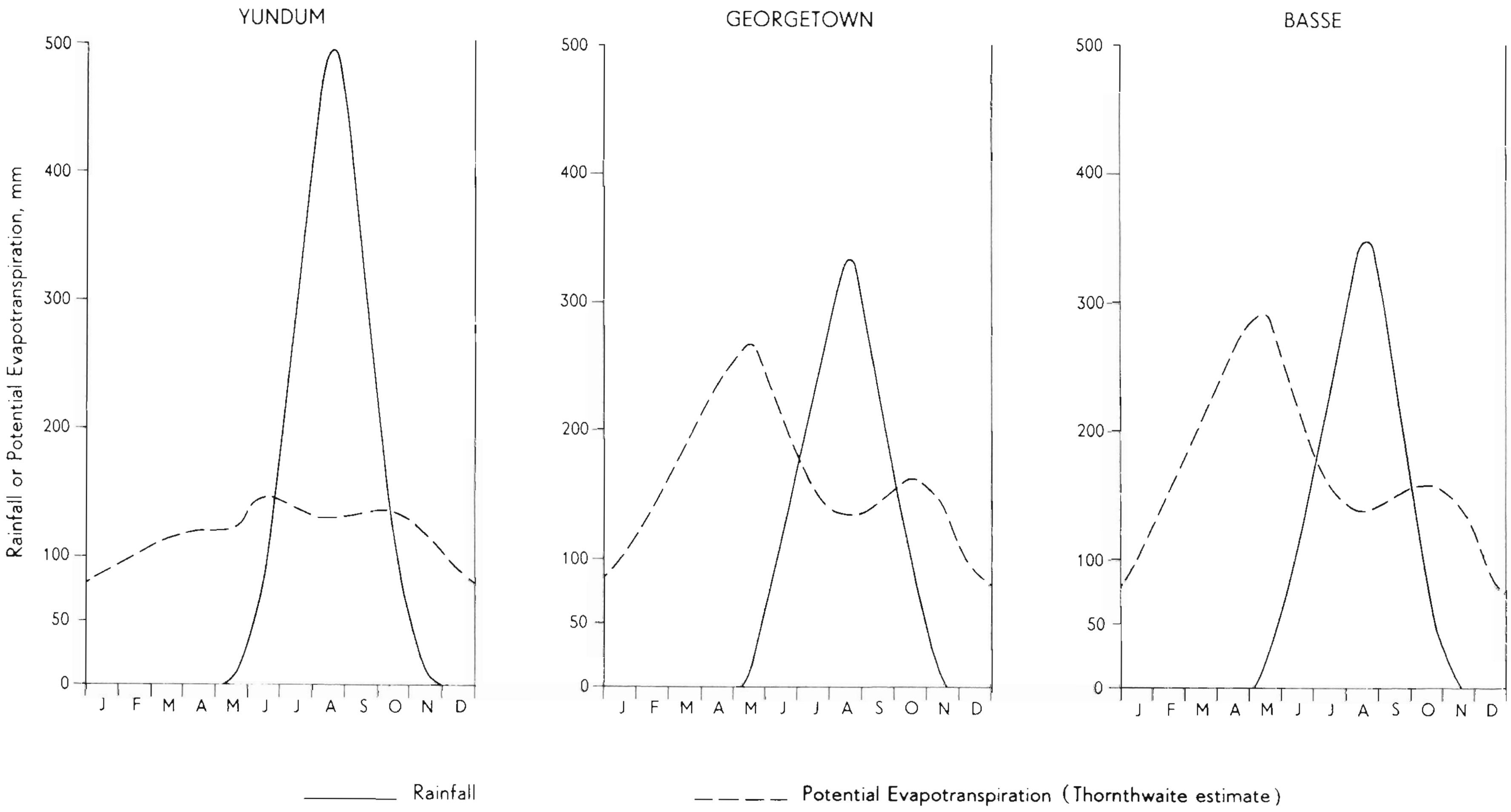



FIGURE 2 The relationship between rainfall and Thornthwaite estimates of potential evapotranspiration; based on mean monthly figures for the period 1949-64

TABLE 6 Average monthly and annual potential evapotranspiration in millimetres and inches for stations in The Gambia, based on data for the period 1949 to 1966

| | Penman estimate | | Thornthwaite estimates | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Yundum | | Yundum | | Georgetown | | Basse | |
| | mm | in | mm | in | mm | in | mm | in |
| Jan. | 145 | 5.70 | 86 | 3.40 | 95 | 3.73 | 93 | 3.66 |
| Feb. | 169 | 6.66 | 104 | 4.08 | 140 | 5.53 | 143 | 5.63 |
| Mar. | 199 | 7.84 | 114 | 4.50 | 196 | 7.72 | 208 | 8.19 |
| Apr. | 213 | 8.40 | 119 | 4.68 | 232 | 9.14 | 262 | 10.33 |
| May | 209 | 8.23 | 121 | 4.77 | 267 | 10.53 | 294 | 11.56 |
| June | 194 | 7.63 | 145 | 5.72 | 211 | 8.31 | 213 | 8.39 |
| July | 172 | 6.76 | 138 | 5.43 | 152 | 5.97 | 158 | 6.24 |
| Aug. | 159 | 6.27 | 130 | 5.13 | 137 | 5.37 | 139 | 5.49 |
| Sept. | 157 | 6.19 | 135 | 5.32 | 144 | 5.67 | 147 | 5.79 |
| Oct. | 150 | 5.90 | 135 | 5.32 | 164 | 6.46 | 159 | 6.24 |
| Nov. | 131 | 5.17 | 119 | 4.68 | 144 | 5.67 | 147 | 5.79 |
| Dec. | 135 | 5.33 | 88 | 3.48 | 86 | 3.42 | 87 | 3.43 |
| Total | 2 033 | 80.08 | 1 434 | 56.51 | 1 968 | 77.52 | 2 050 | 80.74 |

The relationship between rainfall and potential evapotranspiration is shown in Figure 2. It can been seen that there are only 3 months in the year during which rainfall exceeds evapotranspiration.

## RELIEF AND DRAINAGE

The area is part of a Tertiary plateau, which has been partially dissected. The landform of the area is greatly influenced by the presence of two layers of cuirasse or ironstone, and by relative uplift of the land (greatest in the east) in the early Quaternary period. This has given rise to a broadly undulating terrain, with slopes rarely greater than $3^{o}$. In the west, the low hills are separated by depressions up to three miles in width. Frequently the lower parts of these depressions are infilled by sandy colluvium, giving an almost flat plain often a mile in width. In the east the valleys are narrower and often separated by broad, almost flat interfluves, probably remnants of the Tertiary plateau.

The drainage of the area is controlled principally by the Gambia River and its tributary the Bintang Bolon (Text Map 1). Both are tidal throughout Western Division and fringed with mangrove swamps. Temporary streams, flowing during the rainy season, have cut into the Tertiary plateau and flow mainly north to north-eastwards. The Allahein River drains a system of broad flat valleys in the south-west and is tidal for much of its meandering course. There is little information regarding streamflow and the extent and depth of flooding of any of the Gambian rivers, but the extreme flood rise of up to 12 m (40 ft) reported in the east of The Gambia during the rains, does not occur in Western Division. During the rains many of the valleys do become flooded, but the very sandy permeable soils drain rapidly so that, in general, the watertable has fallen by November.

## GEOLOGY

Only a brief outline of the geology is given below. More detailed accounts will be found in Cooper (1927), Tessier and Alloiteau (1952), Michel (1960), Sénégal, Service des Mines et de la Géologie (1962) and Maignien (1965).

The area is one of late Tertiary, mainly continental deposits, overlying early Tertiary and Cretaceous marine sediments.

The deposits outcropping in Western Division are generally referred to the Continental Terminal, and Tessier and Alloiteau (1952) have dated them as Pliocene. They are mainly pink, beige and variegated clayey sands with interbedded clays and sands of variable thickness. Dabin *et al* (1967) point out that during the late Cretaceous there was a humid climate in much of West Africa south of the Sahara. Ferrallitic soils were formed and the Continental Terminal largely represents the remains of these soils reworked by aeolian and fluviatile agents (Jacquet and Nickles 1943). During the early Quaternary, lateritic cuirasse or ironstone was formed in these deposits and then hardened (Michel 1960 and Maignien 1965). Generally the ironstone is a cellular indurated layer overlying vesicular material with mottled white and yellow interstitial material. In places it forms a massive purplish ferruginous sandstone.

Late Quaternary marine deposits are fragmentary in The Gambia. Small areas of terrace are found on the coast and close to the Gambia River; beach boulders occur at Cape St. Mary and fragments of raised beach along the coast. Recent deposits of alluvium form a complex pattern over the river floodplain.

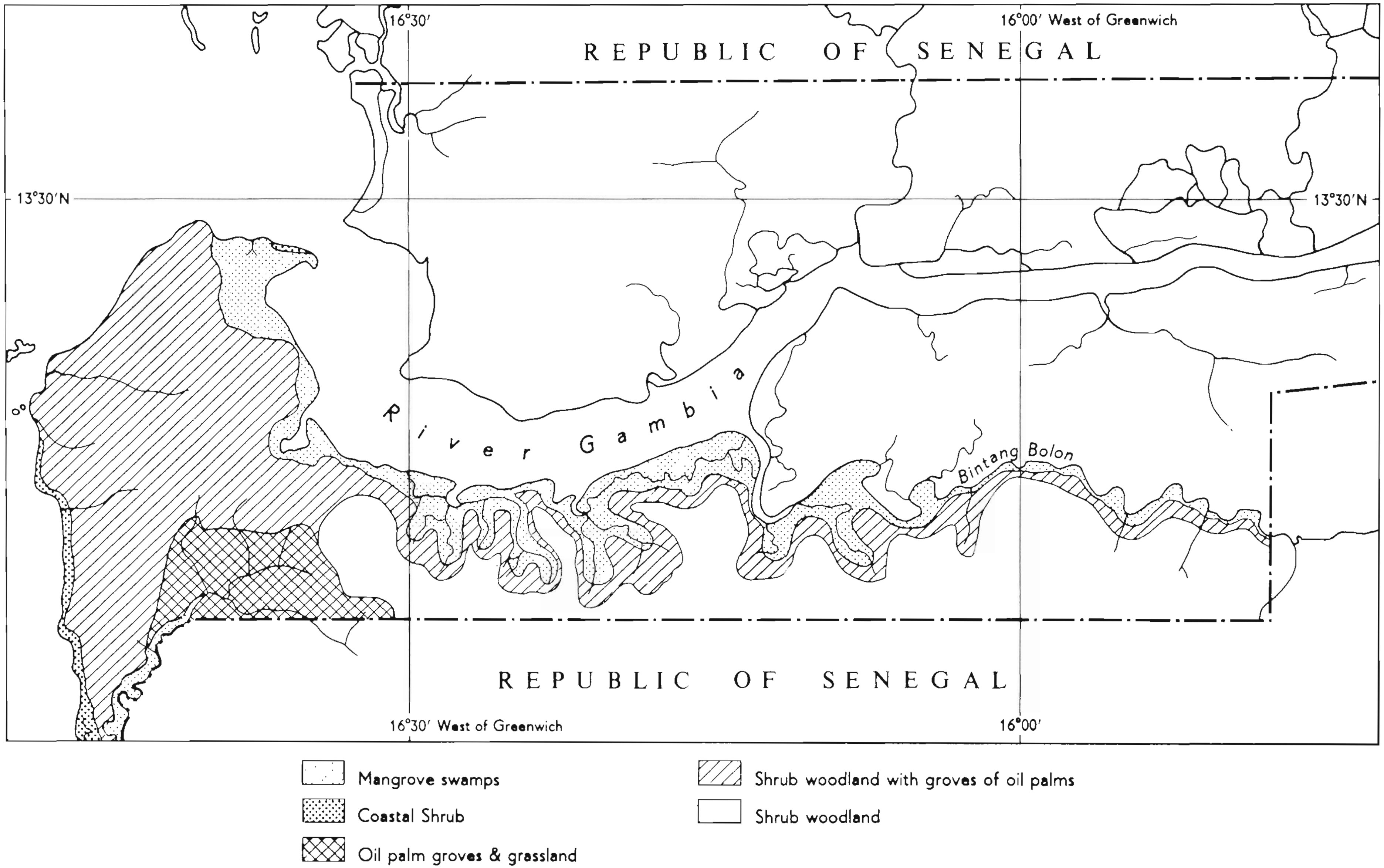
## VEGETATION

The vegetation of The Gambia is commonly referred to as Guinea savanna. Keay (1959) classed it as undifferentiated relatively moist savanna woodland as most of the trees are fire-tolerant and grass is dominant in the herb layer. Aubréville (1949) classified most of the vegetation of Western Division as Sudano-Guinean forest savanna, often degraded by cultivation; Blair Rains (1967) places the vegetation in the shrub woodland physiognomic unit.

A list of the species commonly occurring in The Gambia has been compiled by the Government of The Gambia, and Dawe (1922), Ruxton (1949), Roberty (1962) and Naegele (1967) have also listed the principal species. In the upland areas these include *Terminalia albida*, *Parkia biglobosa*, *Daniella oliveri*, *Acacia senegal*, *Pterocarpus erinaceus* and *Cassia sieberiana*. Other common species are *Piliostigma thonningii*, *Anona senegalensis*, *Guiera senegalensis*, *Dichrostachys glomerata* and *Combretum* spp. *Adansonia digitata*, *Ceiba pentandra* and *Mangifera indica* occur in areas that have been cleared and cultivated.

Towards the west, palms occur in the area classed as 'oléo-palmerai en garenne culturale' by Roberty (1962) and as 'Guinean-Lower-Casamance' by Aubréville (1949); *Borassus aethiopum* is widely distributed while *Elaeis guineensis*, the wild oil palm, is mainly restricted to the depressions. In many of the swampy valley bottoms the oil palms occur in small clumps, frequently raised above the surrounding grasses or rice fields on old termite mounds. The distribution of wild palms is discussed later on page 29 of this report.

Grasses occur throughout the woodland, but become dominant in cleared areas; *Hyparrhenia* spp., *Andropogon* spp. and *Diheteropogon* spp. are commonest. The grasses are usually burnt during the dry season.




TEXT MAP 2 Distribution of the main vegetation types (after Roberty, 1962)

Extensive *Rhizophora* and *Avicennia* mangrove swamps occur along the main rivers and Giglioli and Thornton (1965) have discussed some aspects of these vegetation types. A stunted vegetation is associated with the narrow belt of dunes occurring along the coast. The distribution of the main vegetation types is shown in Text Map 2.

## SOILS

The soils of the Western Division are described in detail in a provisional report by the author (Hill, 1969) which is accompanied by a Reconnaissance Soil Map showing the boundaries of the map units which are discussed briefly below. The units are classified (see Table 7) according to a system set out by Aubert (1965) and Aubert and Ségalen (1966).

The typical occurrence of the soils in relation to the topography is shown in Figure 3. Descriptions of some typical profiles with analytical data are given in Appendix I, together with definitions of high, medium and low nutrient levels given by Metson (1956).

In general, all the soils are extremely low in available nutrients, whilst reserves of phosphorus, potassium and magnesium, as shown by the figures for total P, K and Mg, are also very low. Even in the surface horizons the nutrient levels remain low because there is little organic matter present. Potassium is often only just detectable in the laboratory, a serious deficiency for the cultivation of oil palms which are gross potassium feeders. The fairly high percentage base saturation of the soils is due to calcium and magnesium on the exchange complex. As both the Ca/K and Mg/K ratios are greater than 2, the level of exchangeable calcium and magnesium makes little difference to the oil palm at present, but the low levels of both nutrients are potentially limiting factors because the addition of potassium fertiliser would depress the ratios

These data show that the soils in The Gambia would need much fertiliser before they could support oil palms successfully. In addition, the extremely sandy surface horizon, the low exchange capacity and the lack of organic matter, combined with the intense rainy season, make it probable that much of the added nutrients would be lost by leaching.

### Ferrallitic Soils

**Map Unit 40. Tubakuta** These soils are found principally on the crests of ridges and grade downslope into the Jambanjeli Unit. Always more than two metres deep, they are well drained, very red soils. They are sandy throughout and although there are higher clay contents in the lower parts of the profiles, the soils remain friable, giving a very fine granular structure in which pseudo-sand is commonly found. The highly weathered soils have mainly kaolinitic clay minerals, a very low cation exchange capacity and a high percentage base saturation. The pH in water ranges from 5 to 6, the profiles becoming more acid at depth. The soils dry out rapidly at the end of the rains, particularly in the sandier upper horizons. The soils are frequently cultivated although in some areas they may be under shrub woodland.

TABLE 7 The soils of Western Division classified according to Aubert (1965) and Aubert and Ségalen (1966)

| Class | Subclass | Group | Subgroup | Family | Map unit number and name |
|---|---|---|---|---|---|
| Ferrallitic soils | Weakly desaturated soils | Depleted soils | Modal soils | Soils on sandy clays and sandstones | 40. Tubakuta |
| | | | | | 41. Jambanjeli |
| Soils with sesquioxides | Tropical ferruginous soils | Depleted soils | Soils with mottles and concretions | Soils on sandy clays and sandstones | 43. Mayo |
| | | | | Soils on sandy colluvium | 30. Nyambai<br>34. Bwiam |
| | | | | Soils on sandy colluvium over cuirasse | 30. Nyambai<br>33. Kalaji |
| | | | Hydromorphic soils | Soils on sandy colluvium | 30. Nyambai |
| Hydromorphic soils | Soils with little organic matter | Gleyed soils | Soils gleyed throughout the profile | Soils on sandy colluvium | 22. Jabang<br>20. Abuko (1) |
| | | Pseudo-gleyed soils | Soils with mottles and concretions | Soils on sandy colluvium | 32. Sifoe |
| Raw mineral soils | Soils of non-climatic origin | Soils of accumulation | Soils of aeolian origin | Soils over cuirasse | 42. Bintang |
| Weakly developed soils | Soils of non-climatic origin | Soils of accumulation | Modal soils | Soils on recent beach sands | 23. Solifor (1) |
| | | | | Soils on early Quaternary sands | 44. Sanyang (1) |
| | | | | Soils on Quaternary marine terraces | 24. Mandinari (1) |

(1) These mapping units are of little importance for this report and are not described here. They are described in the author's provisional account of the soils of Western Division (Hill, 1969).

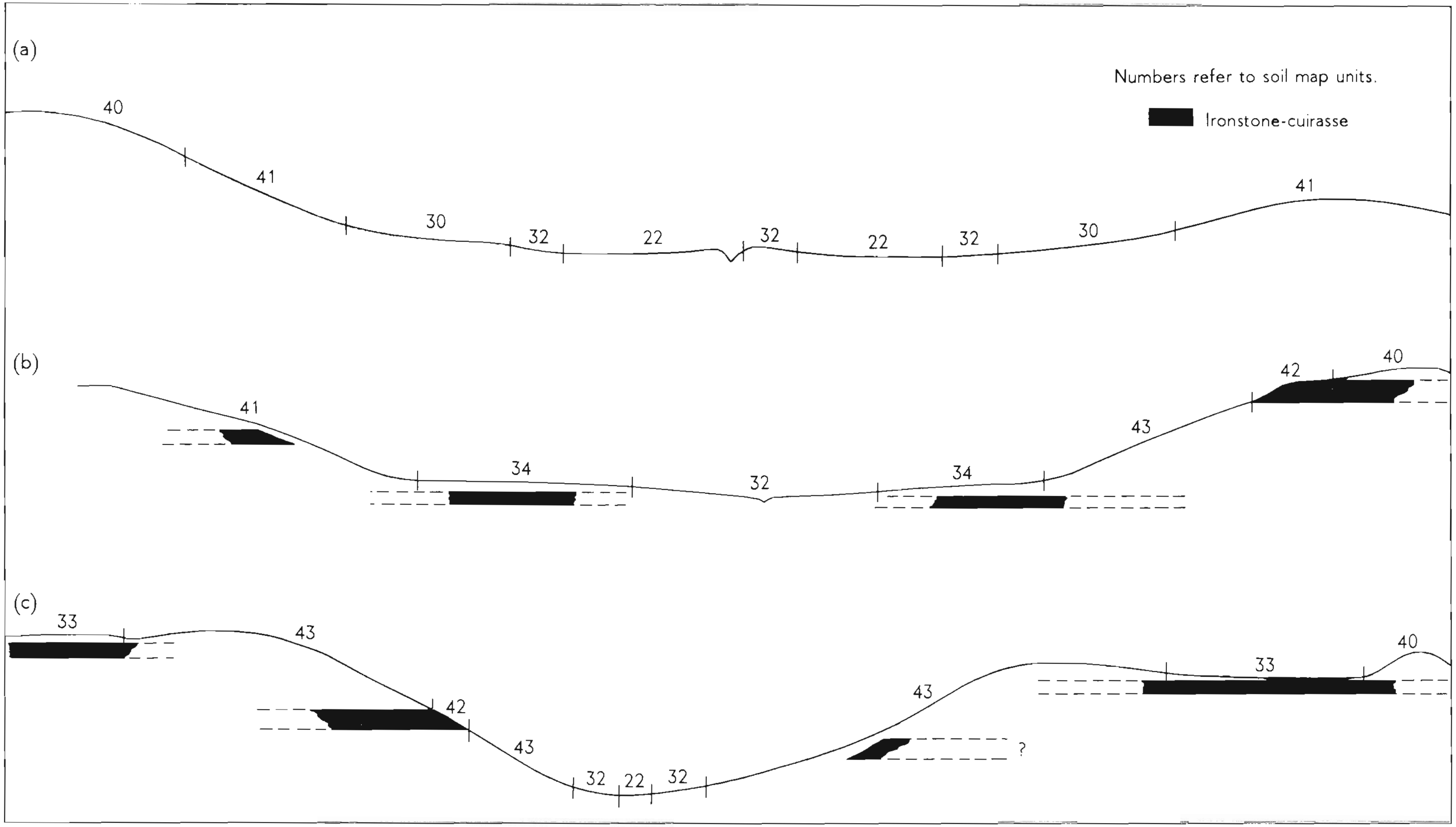



FIGURE 3 Idealised sections across valleys showing the typical occurrence of the main soils (a) West of Brikama (b) South of Bwiam (c) East of Bwiam

**Map Unit 41. Jambanjeli** The soils in this unit are very similar to those mapped in the Tubakuta Unit. They generally occur on the mid-slopes below the Tubakuta soils but may occur on some low ridges; they merge downslope into hydromorphic soils.

Generally reddish or yellowish brown, the soils may be mottled at depth, though evidence of impeded drainage is uncommon.

## Tropical Ferruginous Soils

**Map Unit 43. Mayo** These soils occur on the margins of the broad, almost flat, interfluves in the east of the area. They are deep reddish soils, well drained in the upper parts of the profile, though mottling at depth indicates some drainage impedance. A very sandy surface horizon overlies the more clayey lower horizons. Low in nutrients, these soils probably form an inter-grade from ferrallitic to ferruginous soils. The massive structure, the absence of pseudo-sand, pH 6.0 in the surface horizon falling to pH 5.0 at depth, and a percentage base saturation of more than 60% suggest that these soils should be classed with the tropical ferruginous soils. These soils are generally cultivated, but are sometimes under shrub woodland.

**Map Unit 30. Nyambai Complex** This complex occurs mainly in depressions in the western part of the area, and grades into soils of the Sifoe Unit. Profiles* 100, 97 and 5 represent the range of variation in the soils mapped in this unit. Reference to Table 7 shows that soils belonging to three families occur within the same mapping unit, but they are difficult to separate at the 1:25 000 mapping scale as they differ mainly in the depth at which a concretionary layer occurs, and in drainage. Thus Profile 97 is representative of the soil more than 2m (6 ft) in depth with mottles and concretions in the lower part of the profile. Much of the iron segregation may be fossil, and in some cases the concretions may be reworked cuirasse included in the parent colluvium. Profile 5 is typical of the shallow phase of this soil, with less than 1m (3 ft) of material overlying reworked or massive cuirasse. Profile 100 represents the more poorly drained soils within this complex. Present-day iron segregation is taking place, but may take the form of additions to fossil concretions.

All the soils within this complex are of yellowish-brown colour, and are imperfectly drained. They all have a distinct textural change from a loamy sand surface horizon to sandy clay loam lower horizons. Associated with the textural change is a structural change from friable crumb structure to massive blocky structure. All the soils are acid with a pH of about 5.0. Percentage base saturation is low, with the exception of the surface horizon, and the soils are low in nutrients. The soils are rarely cultivated and generally support shrub woodland, frequently with many scattered wild oil palms.

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* These profiles are not described in detail in this report. They are described in the author's provisional account of the soils of Western Division (Hill, 1969).

**Map Unit 34. Bwiam** These soils are similar to many soils found in the Nyambai complex. They occur mainly in the depressions of the undulating area south of Bwiam. Generally about 2m (6 ft) in depth, the soils are yellowish-brown, imperfectly drained, with mottles and concretions in the lower horizons, many of which may be fossil. A textural change from the sandy surface horizons to the more clayey lower horizons is associated with a change from friable surface structures to strong angular blocky structures. The soils are acid with a pH of 5.0. Percentage base saturation is low except in the surface horizon and the soils are low in nutrients. These soils are rarely cultivated and generally support shrub woodland.

**Map Unit 33. Kalaji** These soils are found on the interfluves in the east of the area. Generally less than 1m (3 ft) in depth, they are yellowish-brown in colour and have a dark humus-stained surface horizon. They are imperfectly drained and overlie massive or reworked cuirasse. Some mottling may be present-day, but most of the concretions are fragments of reworked fossil cuirasse. A sandy surface horizon overlies sandy clay loam material, and associated is a structural change from a friable crumb structure to a strong angular blocky structure. Acid, with a pH of 5.0, these soils are low in nutrients. Percentage base saturation is low These soils are hardly ever cultivated and are covered with shrub woodland.

## Hydromorphic Soils

**Map Unit 22. Jabang** These soils typically occur on wide flats in many of the valley bottoms. They may grade into the Sifoe Unit soils or into mangrove swamps. Deep, almost white in colour with a dark humus-stained surface horizon, they are poorly drained, very sandy soils, and virtually structureless. They are acid, with a pH of about 5.0 and have a very low nutrient status. The soils are completely flooded during the rains, but the watertable falls fairly rapidly to at least 1m (3 ft) in the dry season. The soils are widely used for growing rice and are referred to as 'banta faro' in Mandinka; when not cultivated they support rough grasses with scattered wild oil palms.

**Map Unit 32. Sifoe** These soils occur next to the Jabang soils forming a narrow band on the lower parts of valley slopes. Generally more than 2m (6 ft) deep, the soils are grey or yellowish grey in colour. They are imperfectly drained, and reddish brown mottles are commonly found through most of the profile. A sandy topsoil overlies the slightly more clayey lower horizons, which have correspondingly a more massive structure. Poor in nutrients, with a pH of about 5.0, the soils dry out during the dry season, and the watertable is frequently below two metres. They are not widely cultivated, and the vegetation is usually shrub woodland with dense groves of wild palms (Plate 1). Descriptions of typical profiles are given in Appendix 1.

## Raw Mineral Soils

**Map Unit 42. Bintang** These are skeletal soils occurring over massive iron-stone or cuirasse. They are of no agricultural value.

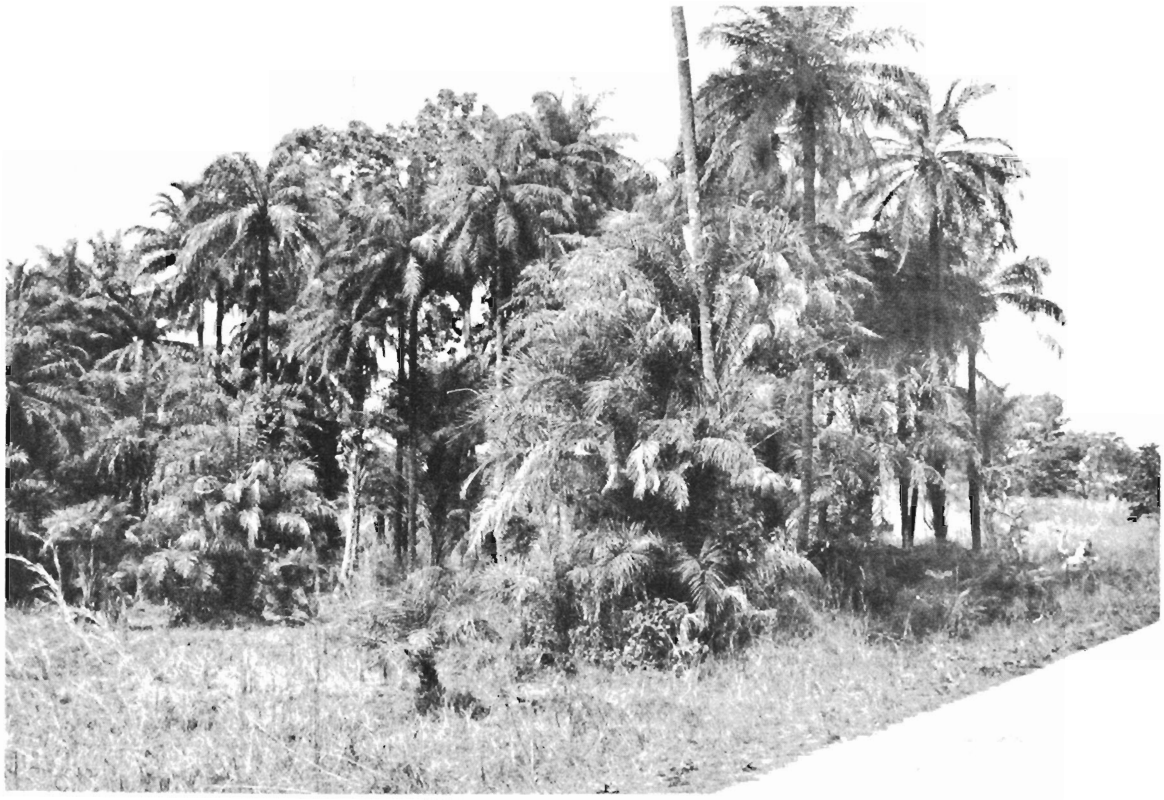
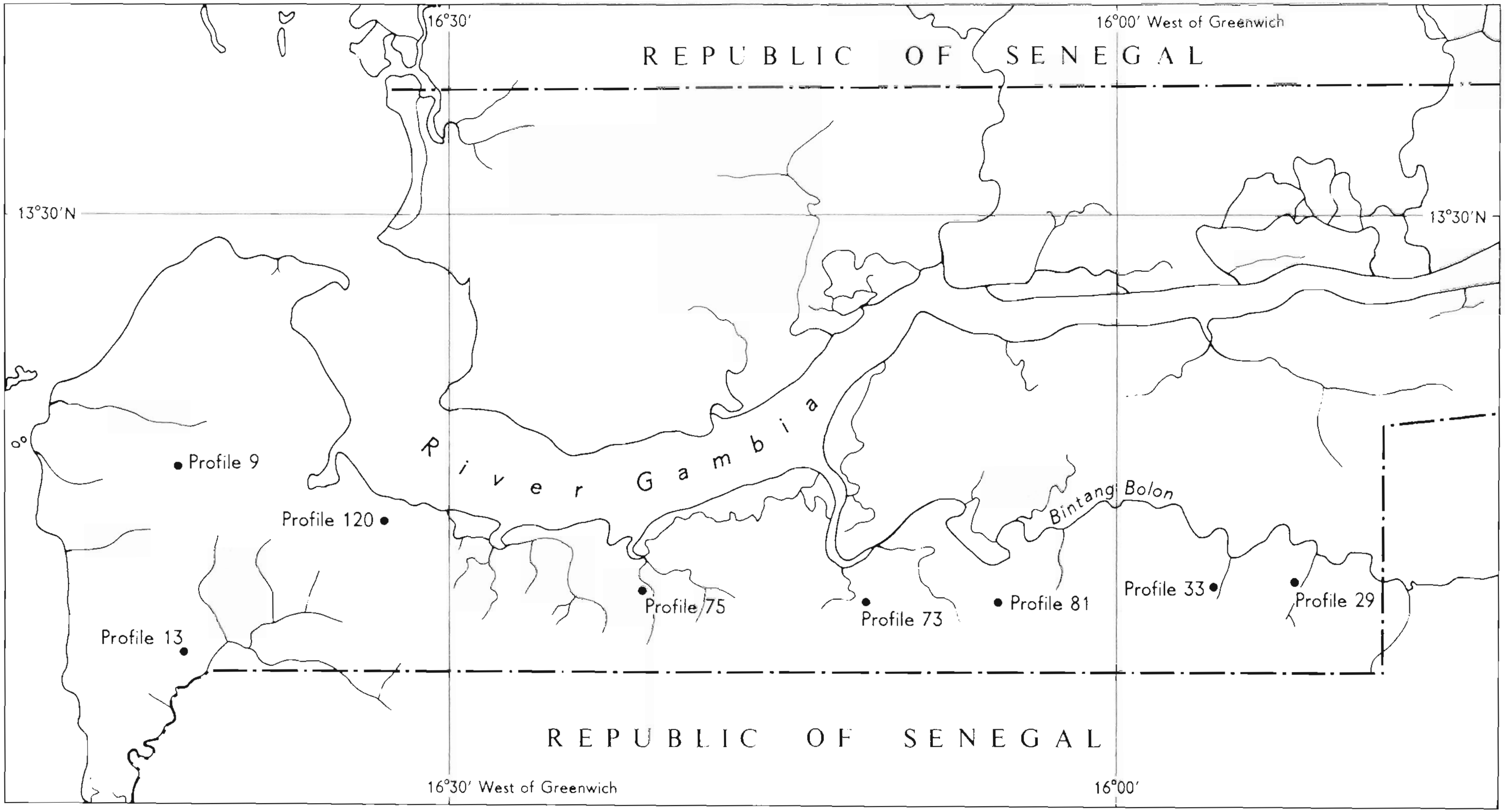


PLATE 1 Dense grove of wild palms on Sifoe soils (Map Unit 32) forming a narrow belt on the margin of a temporary swamp

## SOIL MOISTURE

In order to assess the moisture available in the soil to plants, samples were taken at intervals from the end of the 1966 rainy season until May 1967. Of the sites studied, those within the areas considered least unsuitable for oil palms, that is, on Sifoe Unit soils are discussed below. Their location is shown in Text Map 3. Further details of all the sites are given by Hill (1969).

The moisture content of 100 g of soil was determined for samples taken at the surface, and at depth of 25, 50, 75, 100, 150 and 200 cm at each site. Wilting point was measured in the laboratory at a pressure of 15 atmospheres and the results are summarised in Appendix 2. Field capacity was measured in the field but unfortunately gave widely variable results, probably because excess moisture from the previous rainfall had not drained from the site at the time of sampling. As laboratory measurement of field capacity on disturbed soil samples may not give meaningful results, available water capacity was assessed on the basis of texture (Williams 1967). This gives a figure of 167 mm available water per metre (2 in per ft) for the Sifoe Unit soils which compares with a figure of 140 mm per metre (1.7 in per ft) given by Ochs and Olivin (1965) for a sandy ferrallitic soil. Rees and Chapas (1963) give a figure of 83 mm per metre (1 in per ft) for soil near Benin, containing 30% clay in the lower part of the profile. Williams' method was developed for English soils, but it has been assumed to apply to the Gambian soils; the textures are sandy loams or lighter with low organic matter content and consequently anomalies due to the type of clay mineral or organic matter will be minimal.




**TEXT MAP 3** Sites of soil moisture recordings on Sifoe soils (Map Unit 32)

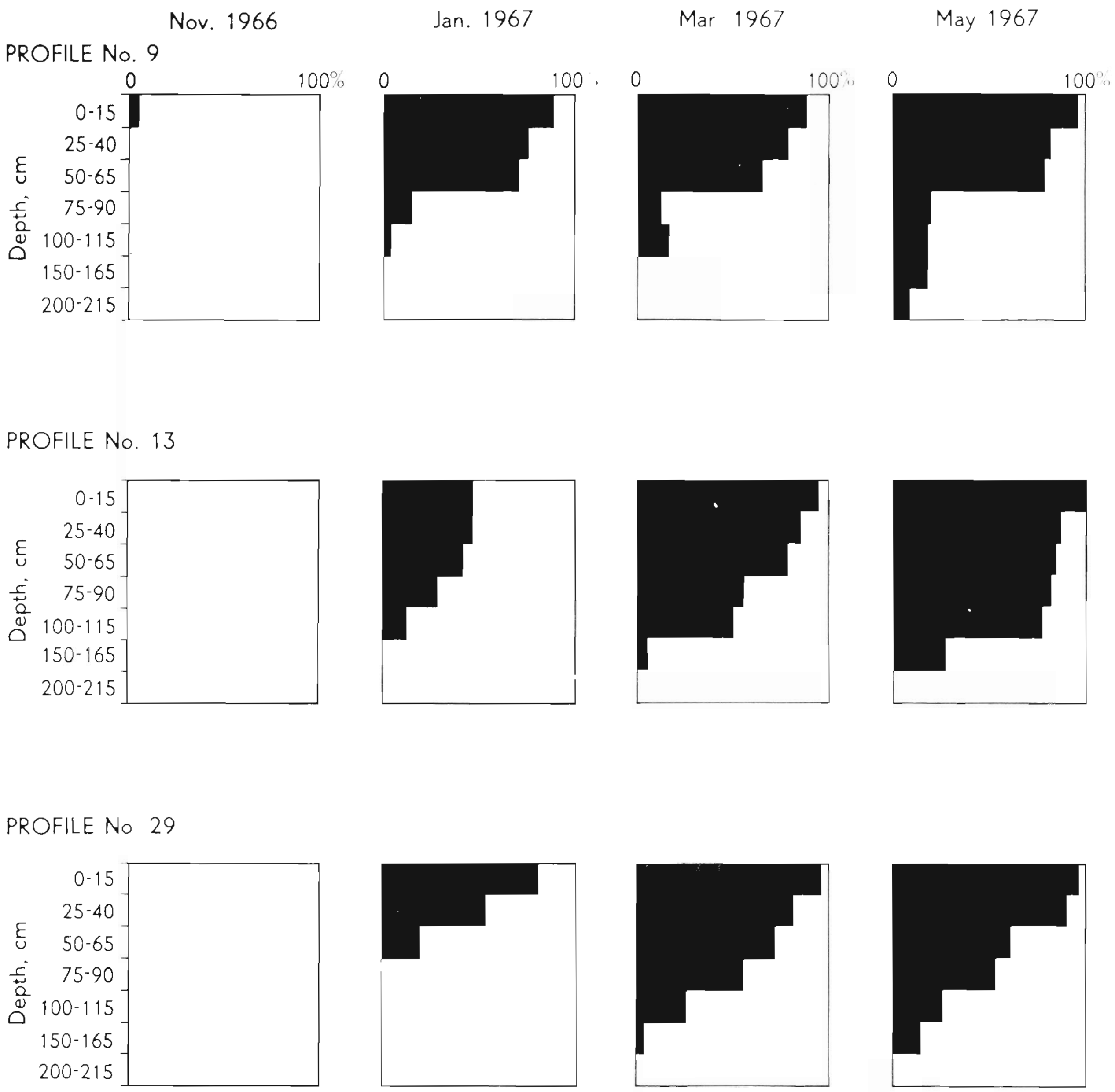



FIGURE 4 Soil moisture deficit as a percentage of available water capacity for selected profiles in Sifoe soils (Map Unit 32) (100 cm = 39.4 in)

(113389)



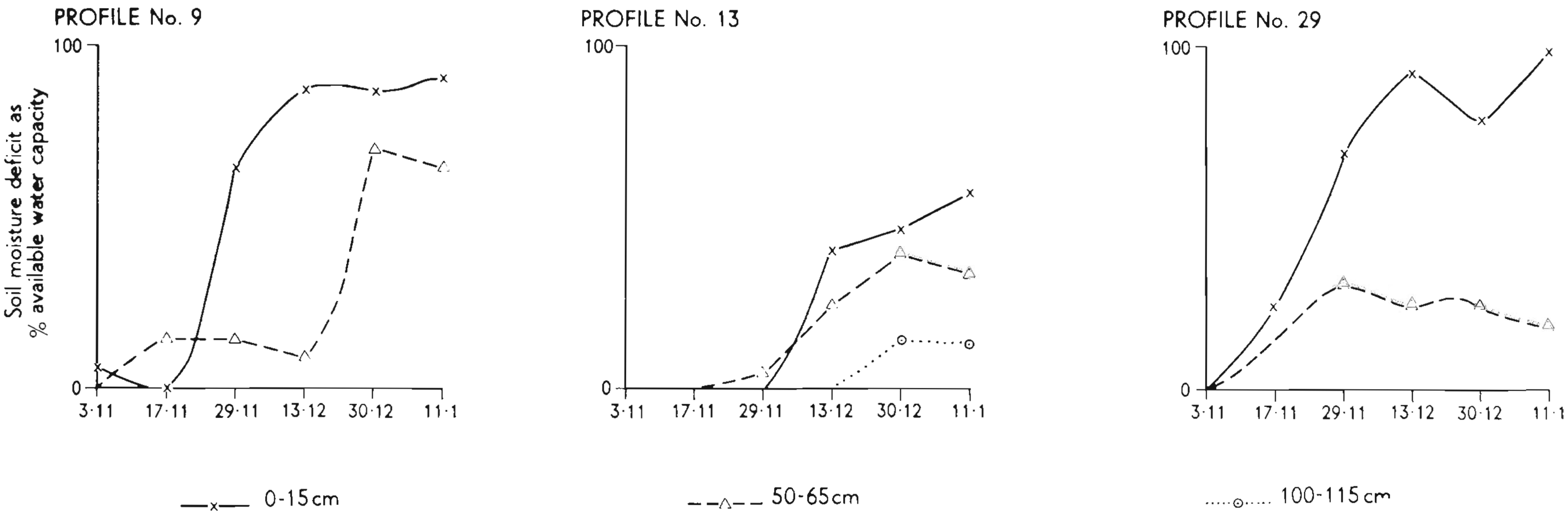



FIGURE 5 The increase in soil moisture deficit as a percentage of available water capacity, in the surface 115 cm (45 in) of selected profiles in Sifoe soils (Map Unit 32), over the period November 1966 to January 1967

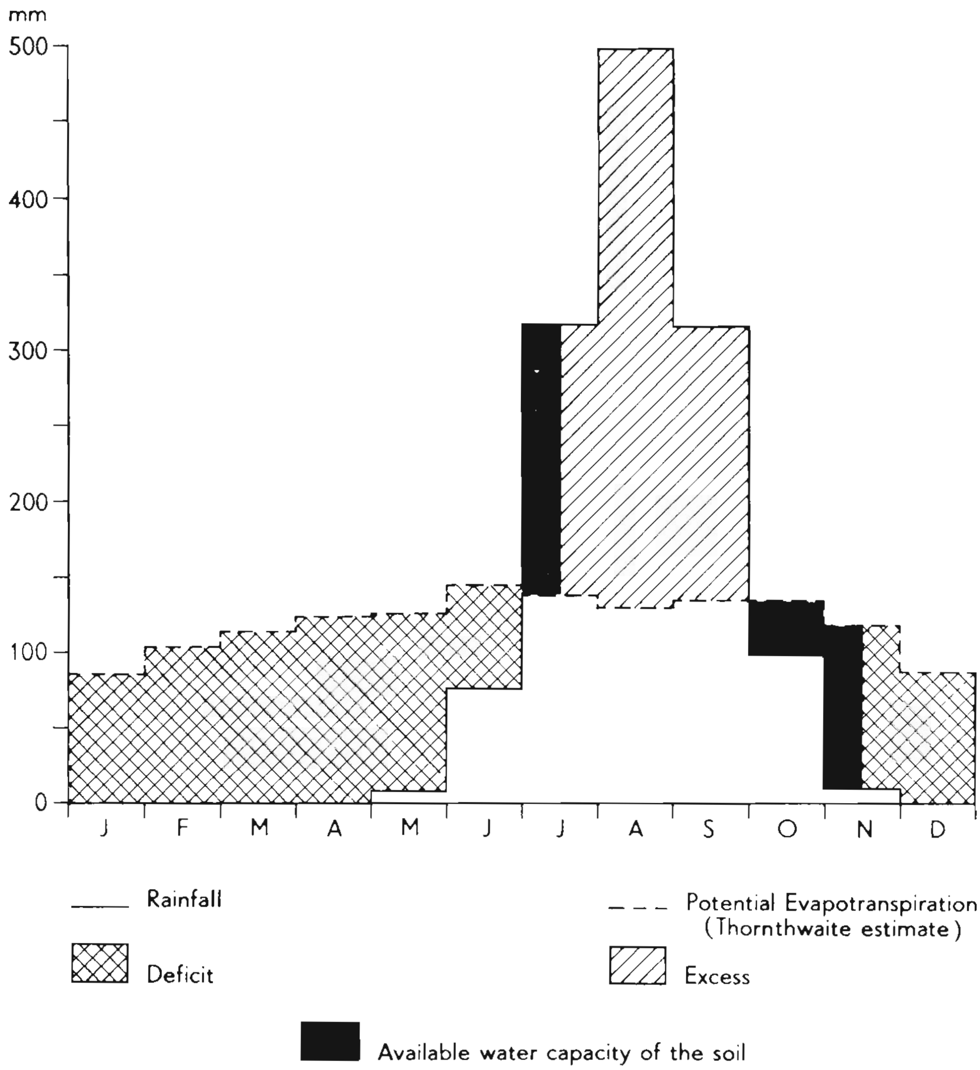



FIGURE 6 Theoretical water balance for the surface 50 cm (19.7 in) of a Sifoe soil (Map Unit 32) in the Yundum area

However, Salter and Williams (1965) have shown that the percentage moisture at field capacity is approximately three times the percentage moisture at the permanent wilting point. At the permanent wilting point the mean percentage moisture of the surface 50 cm (2 ft) of Sifoe Unit soils is 2.5%, rather lower than the values given by Salter and Williams for soils of similar texture. Thus, the values for available water capacity calculated on a textural basis may be too high for these soils, but in the absence of other data they have been used below for estimating soil moisture deficit.

The results are summarised in Appendix 3 and some are shown in Figures 4 and 5. Total soil moisture deficit figures are not given as the profiles were not sampled continuously with depth. Soil moisture deficit is thus given as a percentage of available water capacity for each 15 cm (5.9 in) depth sampled. More usually moisture deficit is based on the field capacity but this was not possible with the available data. Moisture deficit based on the available water capacity is a slight overestimate, but nonetheless shows the rapid drying of the surface horizons of the soil, and the increasing drying out of the lower horizons as the dry season proceeds. This is of considerable significance, as most oil palm roots occur in the surface 50 cm (2 ft) of soil. Thus for much of the year the main rooting zone has the least available moisture.

The soil moisture data can also be related to the optimum conditions for planting of palms. Seedling palms should only be planted when the soil is at or near field capacity. Figure 4 shows that at the end of the dry season the surface 50 cm (2 ft) of the soil is almost completely dry, and will need approximately 80 mm (4 in) of water to bring it to field capacity, assuming the available water capacity to be 167 mm per metre (2 in per ft). This is illustrated by the histogram in Figure 6 showing theoretical water balance, based on mean monthly figures for the Yundum area. The figure shows that there is a moisture deficit of 69 mm (2.72 in) in June due to the high potential evapotranspiration in the dry season, and that there is insufficient rainfall to bring the soil to field capacity until almost mid-July. Rainfall probability figures for June, given in Table 2, show that there is little or no chance of rainfall exceeding the potential evapotranspiration in that month, and consequently it will be exceptional to find adequate soil moisture for planting oil palms in June. During August and September, rainfall exceeds potential evapotranspiration, but in October rainfall is again less than potential evapotranspiration, soil moisture is reduced and by early November the surface layers of soil are again almost at the wilting point.

Not enough data are available to make assessments of the water balance at deeper levels for each site, as soil moisture differences may be due to differences in the position of the watertable. As there is little information on watertable fluctuations in The Gambia, an attempt was made to measure the level of the watertable in village wells, but records were not kept consistently. However, it was observed that during the rainy season the watertable was closer to the surface in all topographic positions, giving flooding and waterlogged conditions in the valley bottoms, though on the crests of ridges it was 15 m (50 ft) or more below the surface. The soil moisture records indicate that during the dry season the watertable falls 2 to 3 m (6 to 10 ft) so that even the valley swamps dry out.

These results strongly support Sly's (1965) recommendation that seedling palms should be planted early in July There is insufficient soil moisture for earlier planting and later planting reduces the period of abundant soil moisture when the palms can be expected to flourish. During the period when there is a moisture deficit, that is, from November to the following June, Forde (1967) has estimated that 50 mm (2 in) of water should be applied weekly over a six foot radius round each palm, amounting to about 80 gallons of water.

## THE RELATIONSHIP BETWEEN THE ENVIRONMENT AND OPTIMUM CONDITIONS FOR OIL PALM GROWTH

The highest yields are obtained from oil palms growing in a humid climate, with a well distributed rainfall and little temperature variation, and on deep, friable, porous soils with a good nutrient status. Surre and Ziller (1963) described ideal conditions for oil palm growth which are compared to Gambian conditions in Table 8. It will be seen that every climatic factor in The Gambia, except sunshine, is outside the optimum range. It is true that temperatures are favourable, but the minimum temperature is well below the optimum. In these circumstances where climatic conditions are not ideal, soil factors become increasingly limiting, so that minor divergences from the optimum may have an adverse effect on yield.

TABLE 8 Comparison of environmental conditions in The Gambia with optimum conditions for oil palm growth

| Factor | Optimum (Surre and Ziller, 1963) | The Gambia, Western Division |
|---|---|---|
| Rainfall mm<br>in | 1 800-2 200<br>71-87 | 1 327<br>52 |
| Relative humidity % | More than 75 | More than 75<br>June to Oct. only |
| Length of dry season in months | Not more than 3 | 7 |
| Temperature mean °C<br>mean °F<br>min. °C<br>min. °F | 25.0-28.0<br>77.0-82.4<br>18.0<br>64.4 | 25.6<br>78.0<br>7.8<br>46.0 |
| Bright sunshine h/a | More than 1500 | 2000 |
| Soil (a) depth | Not less than 1 m (3 ft) | Seldom less than 1 m (3 ft) |
| (b) texture | 25-30% clay; less than 10% clay is unsuitable | Many surface horizons with less than 10% clay |
| (c) K content | 0.15-0.20 meq% | Generally 0.05 meq% |
| (d) Mg/K and Ca/K | Greater than 2 | Greater than 2 |
| Moisture balance (1) | R + P>E | R + P<E |
| Distance from surface to watertable | Not more than 3 m (10 ft) | More than 3 m (10 ft) for all except hydromorphic soils |
| Waterlogging | No standing water | No standing water except in some hydromorphic soils |

(1) R = soil moisture reserve P = rainfall E = evapotranspiration

# PART 4. THE OIL PALM IN THE GAMBIA

## WILD OIL PALMS AND THEIR DISTRIBUTION

There is little information on the wild palms occurring in The Gambia. Virtually all are of the *dura* variety, yielding fruit with a thin mesocarp or flesh and a thick endocarp or shell, though a few *tenera* palms are also present. The wild palms generally have small crowns with many dead leaves probably due to water shortage; thin stems of uneven thickness also reflect the unfavourable conditions.

The distribution of wild palms is shown on the map 'Oil Palm Areas' accompanying this report. The density of palms is shown in three classes (Table 9), the division having been made subjectively in the field.

TABLE 9 Classes of oil palm density shown on the map 'Oil Palm Areas'.

| Class | Approximate density, trees per acre |
|---|---|
| 1. Few scattered palms | < 5 |
| 2. Commonly occurring palms | 5 - 15 |
| 3. Many palms | > 15 |

As the palms often occur in clumps there may be small areas with a high density of palms within any of the three divisions. The map shows a decrease in the number of palms from west to east. In the west the greatest density of palms is almost always found on the slopes immediately above the swamps, with a gradual decrease upslope. In the east palms are again found just above the swamps, but they form only a narrow band, with few palms, if any, on the slopes (Figure 7). To the east of Western Division there are fewer palms, and even on the margins of swamps dense groves are uncommon. Palms are found in a narrow strip near the coast and in some valleys on the north bank of the Gambia river west of Kerewan, but are rarely found in upland areas.

It is probable that this pattern reflects the original distribution of the palms, as it is similar in relatively undisturbed woodland. It is also important to note that human influence on the distribution pattern of wild palms is greatest in upland areas near the sites of intensive cultivation surrounding villages where there are few wild palms. Here the palms if present eventually die out, probably because they are easily accessible, and their fruit is collected regularly, so that natural regeneration stops. Regular grass fires will also accelerate the loss of oil palms from these areas. In the valleys where there are most palms, there is little cultivation, fewer fires and the human influence is slight.

The distribution of wild palms is important because in the absence of experimental evidence the environmental data have been interpreted partly in terms of the growth of wild palms. Thus, it has been assumed that the areas where wild palms do not occur are least favourable for oil palm growth, and areas with dense groves of wild palms are least unsuitable. Comparison of the environment, and the known requirements of the oil palm support this assumption; for example, it is known that oil palms require a high rainfall, and the greatest numbers of wild palms in The Gambia occur in the wetter coastal areas of Western Division.

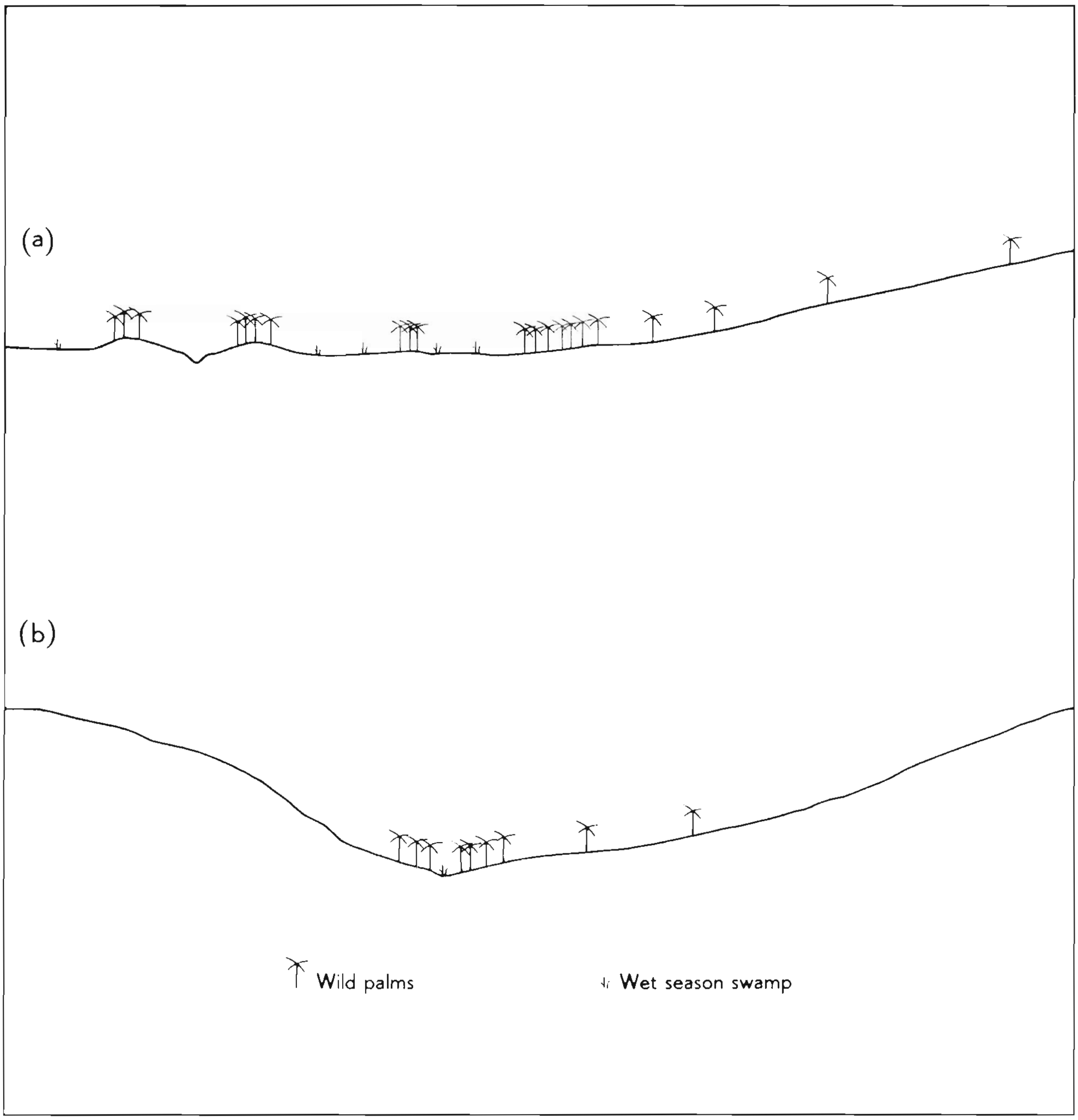



FIGURE 7 Idealised sections across valleys showing the distribution of wild oil palms in (a) the west and (b) the east of Western Division, The Gambia

## WILD OIL PALM PRODUCTION

As records are not available for the total yield of bunches from wild palms, or of the quantity of oil produced in The Gambia, an estimate is made below using figures for the export of palm kernels, and bunch and fruit composition data from other parts of West Africa.

Percival (1962) produced a short note on the export of wild palm kernels since the early part of the century. Fluctuations in the export figures probably do not reflect the actual availability of palm kernels as they are dependent on variations in the demand for palm oil and palm wine, variations in quantities of kernel crossing the frontier from Casamance, and variations in the allowances to buying agents. Export tonnages for more recent years are summarised in Table 10.

TABLE 10 Exports of wild oil palm kernels from The Gambia, 1955-67, in long tons

| | |
|---|---|
| 1955-59 | 1 674 (average) |
| 1960-64 | 1 597 (average) |
| 1965 | 1 518 |
| 1966 | 2 188 |
| 1967 | 2 260 |
| Mean | 1 847 |

TABLE 11 Bunch and fruit composition of wild oil palms in Nigeria as percentages by weight

| Relationship | Abak | Benin | Igala |
|---|---|---|---|
| Fruit as % of bunch | 69.3 | 58.5 | 60.0 |
| Kernel as % of bunch | 9.7 | 8.1 | 8.4 |
| Mesocarp as % of bunch | 31.2 | 14.6 | 27.0 |
| Oil as % of bunch (1) | 15.6 | 12.3 | 13.5 |

(1) Figures for oil as a percentage of bunch were calculated assuming Zeven's (1965) figures of 50% oil in the mesocarp.

TABLE 12 Fruit composition of wild oil palms as percentages by weight

| Relationship | Nigeria (Zeven, 1965) | | Senegal (Rousseau, 1950) |
|---|---|---|---|
| | Abak | Benin | |
| Kernel as % of fruit | 14 | 14 | 30 |
| Mesocarp as % of fruit | 45 | 42 | 20 |

Zeven (1965) found that in Nigeria wild palms had a bunch composition as shown in Table 11.

West of Nigeria the percentage fruit per bunch shown in Table 11 decreases, but the percentage kernel in the fruit increases (Table 12).

Using Sly's (1965) estimate that in Gambian conditions the kernel is likely to form 12% by weight of the bunch and Rousseau's (1950) figures for kernel and mesocarp as a percentage of fruit given in Table 12, it can be calculated that in The Gambia mesocarp will form 8% and oil 4% of the bunch. As the fruit is processed by primitive methods, the oil extraction efficiency is probably no more than 50%. The export of an average of 1 847 tons of kernel per year therefore suggests that approximately 15 400 tons of bunches are harvested, yielding at most 300 tons of oil.

## ROOTING DEPTH

In view of the importance of adequate supplies of water to oil palms in The Gambia, the rooting system of an improved palm (NIFOR EWS) in Abuko plantation was studied in detail. The results are shown in Figure 8. During this study the percentage of roots from bulk and auger samples was compared. Although there was no close correlation between the percentage weight of roots as determined by the auger and by actual excavation, the auger samples did show the presence of very low percentages of roots. This method was therefore used for studies of wild oil palm root systems in an attempt to determine the maximum rooting depth of oil palms in The Gambia. Auger samples were taken around twenty wild oil palms in a variety of positions. The results are summarised in Table 13 and Figure 9.

TABLE 13 The average weight of wild oil palm roots per 2 000 g (1) of soil at various depths in The Gambia

| Depth | | Distance from base of palm | | | |
|---|---|---|---|---|---|
| | | 1 m (3 ft) | | 2 m (6 ft) | |
| cm | ft | Av. wt. of roots g (1) | No. of samples | Av. wt. of roots g | No. of samples |
| 25 | 0.8 | 1.08 | 27 | 0.88 | 25 |
| 50 | 1.6 | 1.36 | 27 | 1.04 | 25 |
| 100 | 3.3 | 0.74 | 26 | 0.65 | 25 |
| 150 | 4.9 | 0.68 | 26 | 0.23 | 25 |
| 200 | 6.6 | 0.20 | 24 | 0.07 | 25 |
| 250 | 8.2 | 0.13 | 24 | 0.10 | 25 |
| 300 | 9.8 | 0.19 | 22 | 0.15 | 24 |
| 350 | 11.4 | 0.06 | 22 | 0.04 | 22 |
| 400 | 13.1 | 0.04 | 20 | 0.01 | 20 |
| 450 | 14.7 | 0.12 | 10 | 0.01 | 10 |
| 500 | 16.4 | 0.08 | 4 | 0.00 | 4 |
| 550 | 18.0 | 0.02 | 2 | 0.00 | 2 |
| 600(2) | 19.7 | 0.00 | 2 | 0.00 | 2 |

(1) 1 g = 0.035 oz; 1 000 g = 2.2 lb.

(2) Few samples were taken below 600 cm (19.7 ft) because beyond this depth either the watertable or a concretionary layer preventing further augering was encountered.

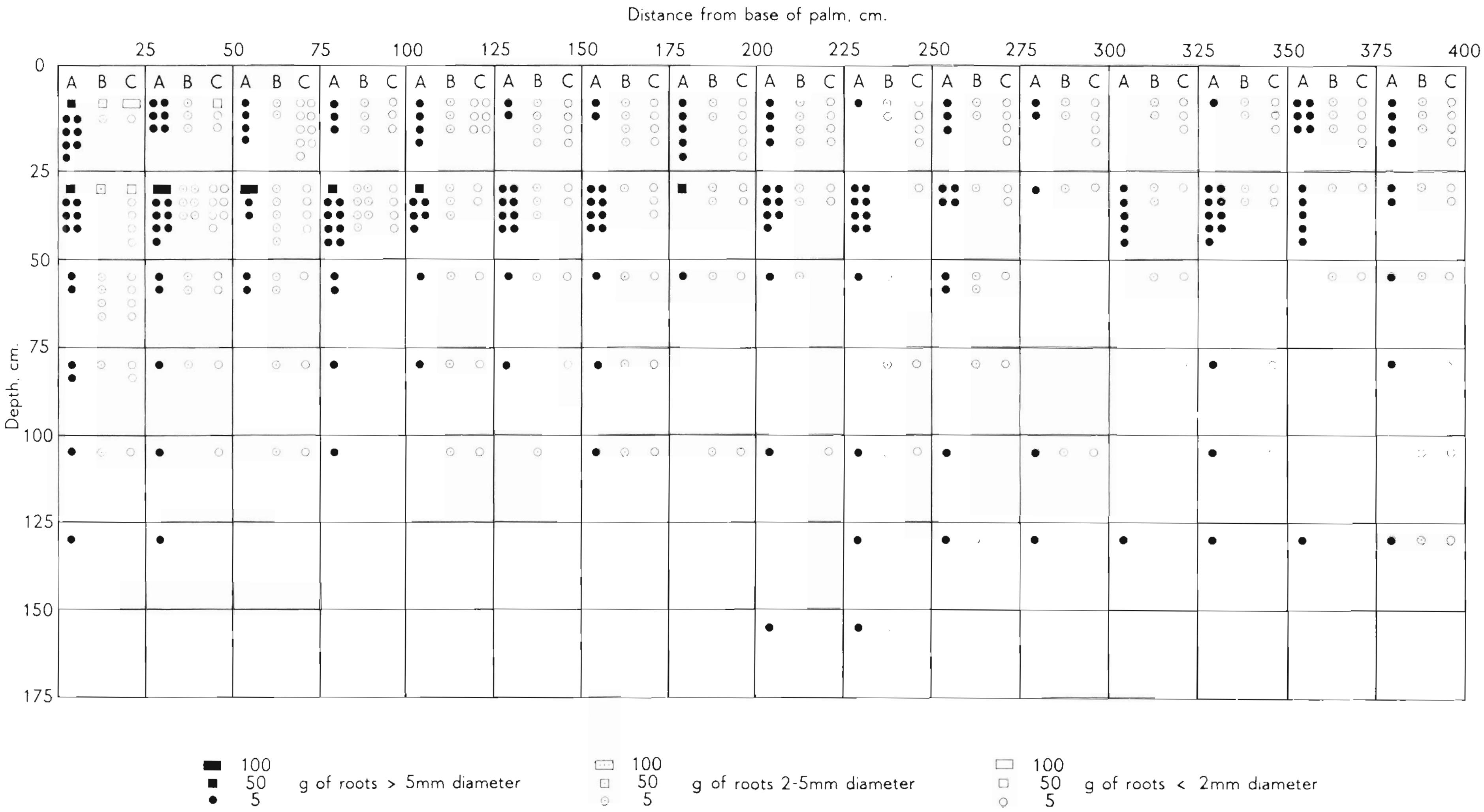



FIGURE 8 Root distribution of an eighteen-year-old improved oil palm (NIFOR EWS) at Abuko (100 cm = 39.4 in)

These studies show that the pattern of root development for both the improved palm and the wild palms is broadly similar to that described by Purvis (1956). The greatest density of roots occurs in the top 50 cm (19.7 in) of soil, with a rapid decrease in the number of roots with depth. This is particularly significant in The Gambia as the very sandy surface soil dries out rapidly at the end of the rains, and there is then little available soil moisture where there are most roots.

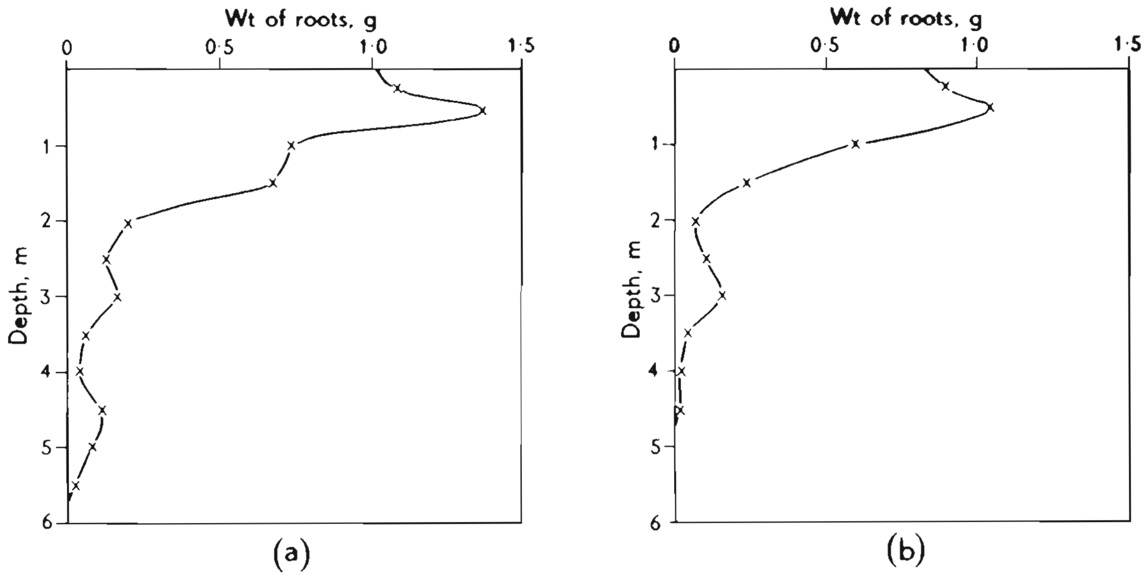
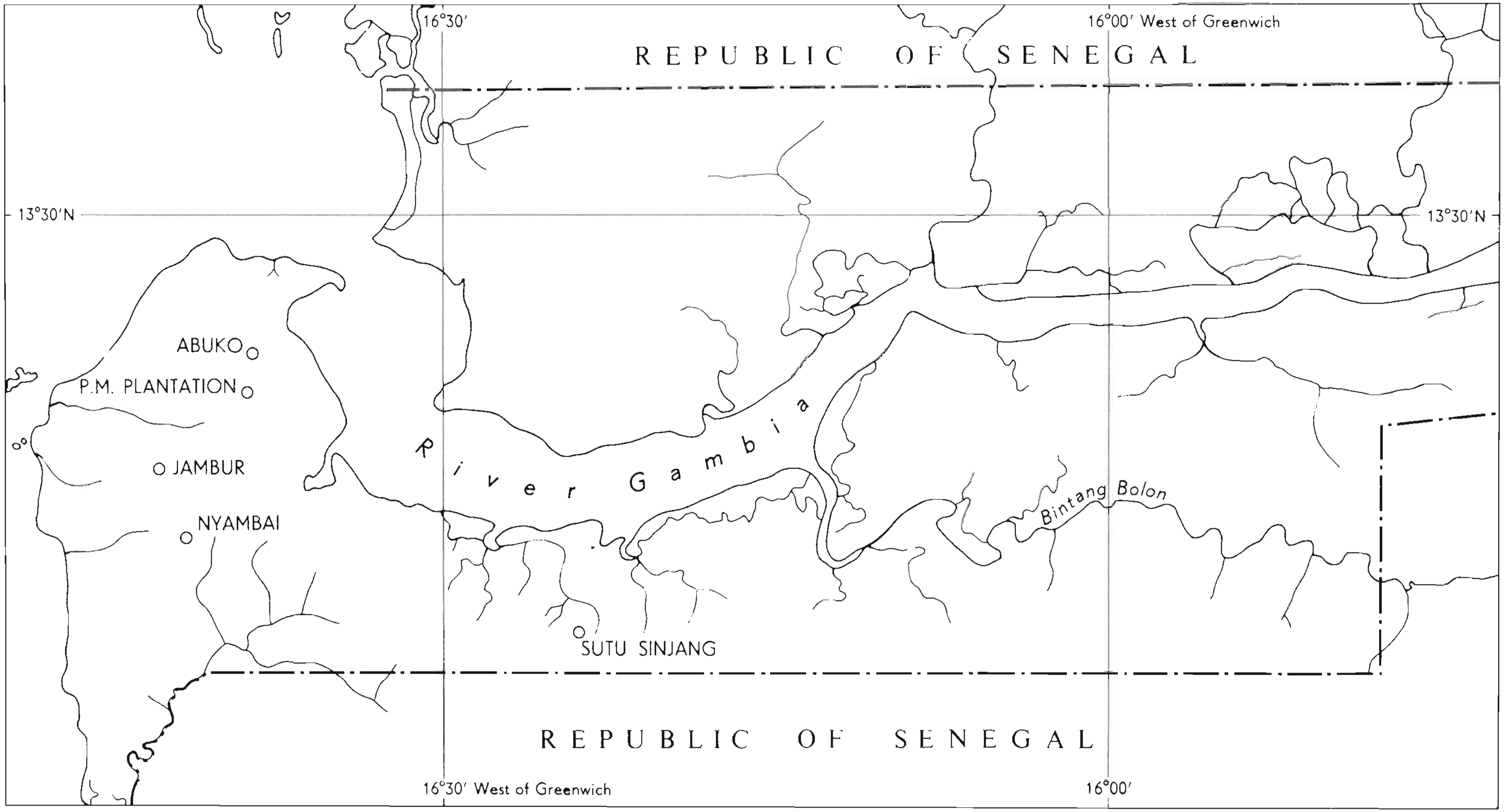



FIGURE 9 The weight of wild oil palm roots per 2 000 g of soil at various depths in The Gambia: (a) 1 m (3 ft) from base of palm; (b) 2 m (6 ft) from base of palm (1 g = 0.035 oz; 1 000 g = 2.2 lb)

## GROWTH MEASUREMENTS

Improved palms (NIFOR EWS) in The Gambia were studied in an attempt to assess the vigour of growth. The palms are all in small fenced plantations and their location is shown in Text Map 4. Abuko, Jambur and Nyambai plantations are cared for by the Department of Agriculture and are sited on or very close to Sifoe Unit soils; those at Jambur and Nyambai are watered daily by hand. The Prime Minister's plantation is on Jambanjeli Unit soils and is not favourably sited but the palms are watered with a hose. Sutu Sinjang, the most successful of the village plantations, is sited upslope from the least unsuitable area and is watered by hand.

Crown diameter, the length of leaf three and the number of leaves per tree from a variety of plantations in The Gambia are given in Table 14 and compared with Nigerian trees of similar age.




TEXT MAP 4 Fenced plantations in which oil palms were measured to assess vigour of growth

TABLE 14 Growth measurements of improved palms (NIFOR EWS), in The Gambia and Nigeria

| Plantation in The Gambia | No. of palms measured | Age of palm in years | Crown diameter m(ft) | | Length of leaf m(ft) | |
|---|---|---|---|---|---|---|
| | | | Gambia | Nigeria (1) | Gambia Leaf 3 | Nigeria Leaf 1(1) |
| Abuko | 100 | 18 | 8.23(27.0) | 11.68(38.3) | - | - |
| P.M.plantation | 5 | 5 | 6.55(21.5) | 7.25(23.8) | 3.35(11.0) | - |
| P.M.plantation | 50 | 4 | 4.06(13.4) | 6.25(20.5) | 2.40( 7.9) | - |
| Abuko | 50 | 3 | 1.83( 6.0) | 3.15(10.3) | 1.25( 4.1) | - |
| Jambur | 100 | 2 | 2.80( 9.2) | - | 1.52( 5.0) | 2.28(7.5) |
| Nyambai | 100 | 2 | 3.08(10.1) | - | 1.83( 6.0) | 2.28(7.5) |
| Sutu Sinjang | 100 | 2 | 1.86( 6.1) | - | 1.25( 4.1) | 2.28(7.5) |
| P.M.plantation | 25 | 1 | 2.05( 6.7) | - | 1.37( 4.5) | 1.22(4.0) |

(1) Data from N.I.F.O.R. experimental records. Leaf 1 and leaf 3 are comparable

PLATE 2 One-year-old improved (NIFOR EWS) oil palm at Benin, Nigeria

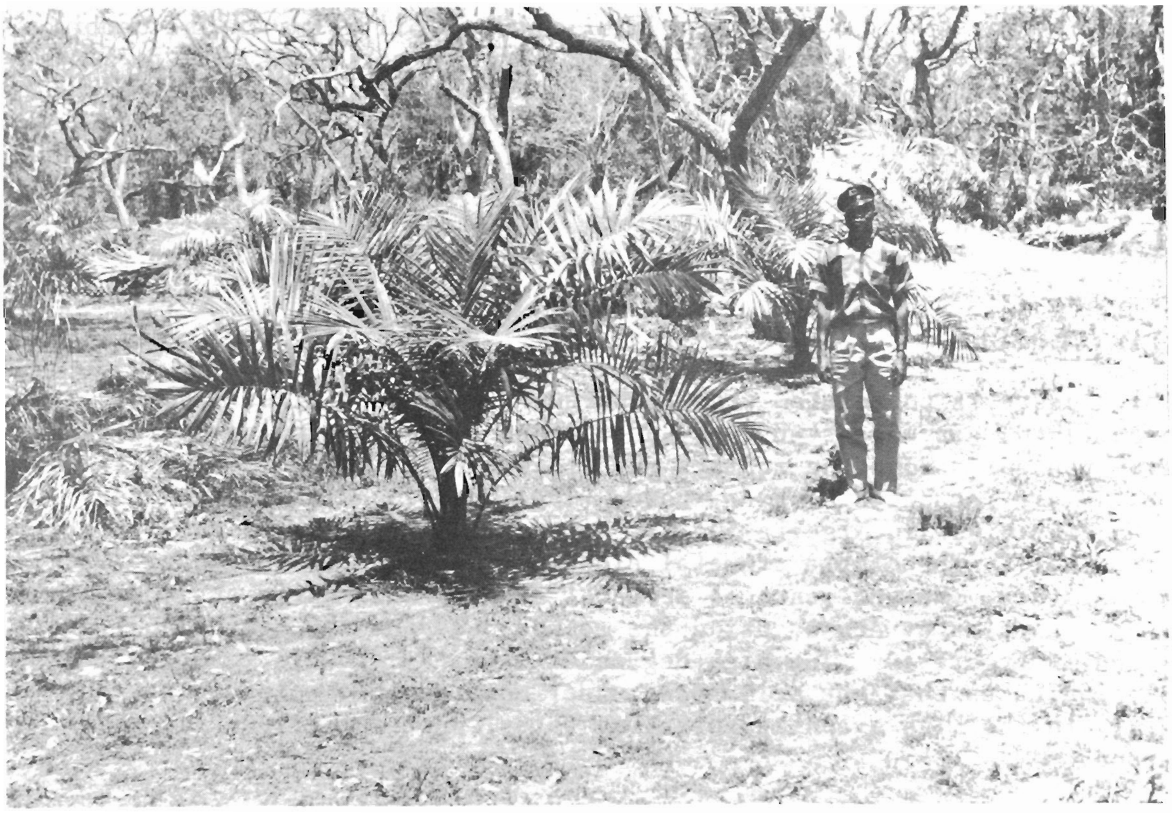


PLATE 3 Three-year-old improved (NIFOR EWS) watered oil palm in the Department of Agriculture plantation, Jambur, The Gambia

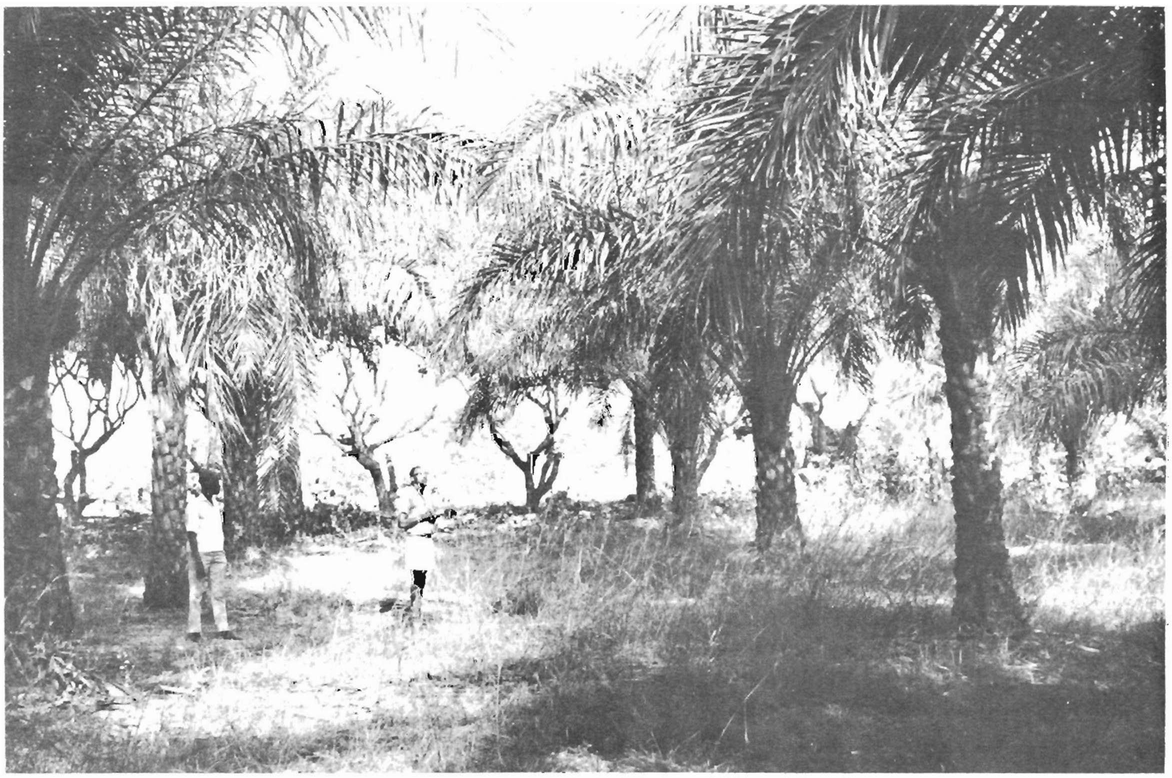


PLATE 4 Eighteen-year-old improved (NIFOR EWS) oil palms in the Department of Agriculture plantation, Abuko, The Gambia, planted on the square at intervals of 9 m (30 ft), showing the open canopy due to the small size of the crowns

These figures show that at all stages the growth of oil palms in The Gambia is less than that of trees of similar age near Benin, Nigeria, and this is further shown by Plates 2, 3 and 4. This is particularly significant as the measurements were only made on palms in the least unfavourable areas, or on watered palms. Although poor planting techniques may have had an adverse effect on growth, the maintenance that these palms have received is at least as good as that to be expected in village plantations. Consequently it is likely that these figures fairly reflect the growth potential of oil palms in The Gambia.

## STOMATAL CLOSURE

Stomatal closure is correlated with temperature and water stress, and Milthorpe (1960) has suggested that under conditions of very low humidity and high evapotranspiration, the stomata may close even if the soil is at field capacity. More recently, however, Forde (1967) has found that even under harmattan conditions in Nigeria 50% of the stomata stay open if the soil is moist, so that in The Gambia stomatal closure probably does indicate a lack of soil moisture. Measurements of stomatal closure made daily at 1400 h on four-year-old palms at Abuko, using the method described by Rees (1961) are summarised in Figure 10. The high degree of stomatal closure recorded probably indicates that the palms were under considerable moisture stress, due mainly to the high evapotranspiration rates, particularly during the dry season.

Stomatal closure was also measured on two-, five- and six-year-old palms in the Prime Minister's plantation, and is summarised in Table 15. These palms are watered twice weekly with a hose for about five minutes, the normal routine for the plantation.

TABLE 15 Mean % stomatal closure from 25.4.67 to 12.5.67 in improved oil palms (NIFOR EWS) in the Prime Minister's plantation

| Age of palm in years | 6 | | 5 | | 2 | |
|---|---|---|---|---|---|---|
| Time | a.m. | p.m. | a.m. | p.m. | a.m. | p.m. |
| Stomatal closure % | 35.56 | 44.31 | 44.31 | 78 | 53.5 | 85.56 |

These results suggest that the largest six-year-old palms suffer little moisture stress when watered, though there is a slight increase in stomatal closure during the afternoon. This probably reflects moisture stress, a factor that will hinder establishment for at least the first four or five years of the life of the palms.

## LEAF ANALYSES

Samples were collected from Leaf 17 of oil palms from the fertiliser trials on improved oil palms (NIFOR EWS) at Abuko, Kanefing and Cape St. Mary plantations. Leaf samples were also collected from wild oil palms on each of the major soil types; three sites were selected on each soil, and 30 oil palms, approximately 6m (20 ft) in height were sampled at each site. These samples were analysed at N.I.F.O.R. and the results summarised in Table 16.

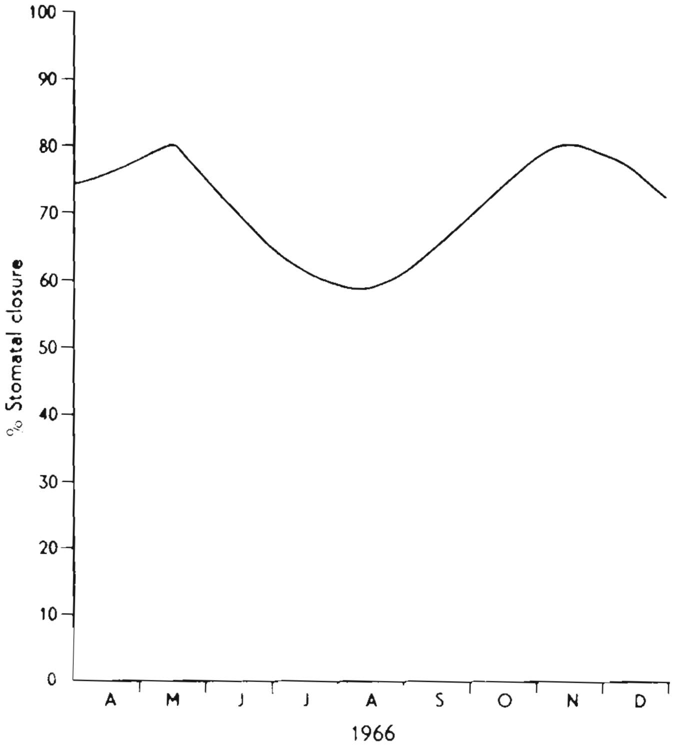



FIGURE 10 Mean monthly percentage stomatal closure at 1400 h of four-year-old improved (NIFOR EWS) palms at Abuko, The Gambia

The fertiliser trials at Abuko (two replicates) Kanefing and Cape St. Mary are observation trials designed by N.I.F.O.R. with treatments of 3 kg (7 lb) sulphate of ammonia per tree annually, 3.6 kg (8 lb) superphosphate per tree every three years, 3 kg (7 lb) sulphate of potash per tree every three years, 4.1 kg (9 lb) of magnesium sulphate per tree every three years, and a control. Fertiliser was applied in 1963, three years before the date of sampling. No record was found of annual application of nitrogen and no other fertiliser had been applied before sampling.

The low level of nitrogen in the leaf samples is thus probably due to non-application of fertiliser, rather than a lack of response to nitrogen. There is a good response to phosphorus at Kanefing and Cape St. Mary, an important response to potassium at Kanefing whilst magnesium has greatly increased magnesium leaf levels at Abuko and Kanefing. All other responses are slight, which is surprising in view of the extremely low nutrient status of the soils. Some other factor may thus be limiting the response, either lack of water or lack of nitrogen, as nitrogen fertiliser was only applied in the first year. The wild palms all show a marked deficiency of nitrogen, phosphorus and potassium, which is to be expected from the very low levels present in the soils.

TABLE 16 Results of analyses of Leaf 17 from oil palms in The Gambia

| Location | Treatment | Nutrient level % oven dry matter | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | | P | | K | | Ca | | Mg | |
| | | R1 | R2 | R1 | R2 | R1 | R2 | R1 | R2 | R1 | R2 |
| Abuko (2 replicates) | Control | 2.13 | 2.10 | 0.143 | 0.134 | 0.60 | 0.52 | 0.96 | 0.98 | 0.30 | 0.38 |
| | N | 2.14 | 2.29 | 0.139 | 0.151 | 0.59 | 0.48 | 0.94 | 0.87 | 0.38 | 0.39 |
| | P | 2.14 | 1.61 | 0.145 | 0.126 | 0.63 | 0.43 | 0.76 | 1.03 | 0.38 | 0.46 |
| | K | 2.09 | 2.07 | 0.144 | 0.136 | 0.63 | 0.46 | 0.80 | 0.78 | 0.30 | 0.41 |
| | Mg | 2.01 | 2.02 | 0.137 | 0.130 | 0.58 | 0.46 | 0.88 | 0.90 | 0.50 | 0.71 |
| Cape St. Mary | Control | 2.08 | | 0.142 | | 0.51 | | 1.11 | | 0.64 | |
| | N | 1.91 | | 0.118 | | 0.43 | | 1.04 | | 0.58 | |
| | P | 2.46 | | 0.158 | | 0.44 | | 0.97 | | 0.55 | |
| | K | 1.79 | | 0.133 | | 0.57 | | 1.06 | | 0.53 | |
| | Mg | 1.83 | | 0.131 | | 0.47 | | 1.05 | | 0.51 | |
| Kanefing | Control | 1.68 | | 0.107 | | 0.38 | | 1.08 | | 0.72 | |
| | N | 1.64 | | 0.107 | | 0.44 | | 0.98 | | 0.66 | |
| | P | 2.01 | | 0.134 | | 0.51 | | 1.10 | | 0.66 | |
| | K | 1.94 | | 0.116 | | 0.81 | | 1.08 | | 0.50 | |
| | Mg | 1.60 | | 0.106 | | 0.35 | | 1.20 | | 0.90 | |
| Tubakuta Unit | Wild | 2.48 | | 0.139 | | 0.54 | | 0.86 | | 0.50 | |
| Jambanjeli Unit | Wild | 2.15 | | 0.134 | | 0.56 | | 0.90 | | 0.63 | |
| Nyambai Unit | Wild | 2.28 | | 0.137 | | 0.58 | | 0.84 | | 0.61 | |
| Sifoe Unit | Wild | 2.17 | | 0.131 | | 0.52 | | 0.79 | | 0.47 | |
| Jabang Unit | Wild | 2.14 | | 0.135 | | 0.46 | | 0.77 | | 0.43 | |
| Optimum levels for oil palms in W. Africa (Bachy, 1964) | | 2.50 | | 0.15 | | 1.0-1.2(1) | | 0.60-0.70 | | 0.30-0.35 | |

(1) Ruer (1966) suggests that in areas with a pronounced dry season, the level of potassium in the leaf should be 0.8%.

## SEX RATIO

The ratio of the number of female flowers to the number of male flowers is known as the sex ratio. This ratio in an adult palm is normally 0.5, and in a five-year-old palm it is 1.5 (Surre and Ziller 1963). Sex ratio may also be given as the ratio of the number of female flowers to the total number of inflorescences. As the number of bunches produced depends on the number of female flowers, a low sex ratio indicates a low potential yield. Sex ratios were determined for various plantations in The Gambia, and are summarised in Table 17.

TABLE 17 Sex ratios of improved oil palms (NIFOR EWS) in The Gambia

| Plantation | No. of palms | Age of palms, years | Sex ratio female/male | Sex ratio female/total |
|---|---|---|---|---|
| Abuko | 100 | 18 | 0.40 | 0.29 |
| P.M. plantation | 5 | 5 | 0.46 | 0.33 |
| P.M. plantation | 50 | 4 | 0.14 | 0.13 |

All the sex ratios are low, probably due to the dry conditions. Plate 5 shows the preponderance of male inflorescences. Actual yields will be even lower than the sex ratios suggest, because under dry conditions many of the female flowers will abort and thus will not produce fruit.

PLATE 5 Six-year-old improved (NIFOR EWS) watered oil palm in the Prime Minister's plantation, The Gambia, showing the preponderance of male inflorescences

## BUNCH PRODUCTION

The monthly production of bunches at Abuko is summarised in Table 18, but the evidence is not sufficient to make correlation with climatic factors as Sparnaaij (1963) has done in Nigeria.

TABLE 18 Total of monthly bunch production over the period 1963-66 from an area of mature improved oil palms (NIFOR EWS) planted in 1948 at Abuko

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of bunches | 18 | 58 | 121 | 123 | 177 | 108 | 88 | 80 | 178 | 108 | 56 | 2 |

The production of bunches per tree from mature improved palms growing in The Gambia is summarised in Table 19, and shows an average production of two or three small bunches per tree per year. Both the number and size of bunches compare unfavourably with Nigerian palms of the same age.

TABLE 19 Comparison of bunch production from mature improved oil palms (NIFOR EWS) planted in 1948 at Abuko, The Gambia, with production in Nigeria

| | Year | Av. no. of bunches/tree | Av. no. of bunches/ bearing tree | Av. bunch weight | |
|---|---|---|---|---|---|
| | | | | kg | lb |
| The Gambia | 1963<br>1964<br>1965<br>1966<br>Mean | 1.5<br>2.5<br>2.5<br>2.2<br>2.18 | 2.5<br>3.2<br>3.2<br>3.1<br>3.0 | 9.50<br>9.90<br>6.47<br>7.61<br>8.32 | 20.9<br>21.7<br>14.2<br>16.9<br>18.42 |
| Nigeria | (N.I.F.O.R. estimate) | 3 - 4 | 3 - 4 | 13.6-18.1 | 30 - 40 |

Bunch production in wild palms from a variety of sites in the Western Division, The Gambia, is summarised in Table 20. The figures are based on counts of 50 palms at three different sites within each map unit and show an even lower rate of production than the improved palms. No conclusions can be drawn from these figures as to the most favourable soils or sites.

TABLE 20 Bunch production from wild palms in Western Division, The Gambia

| Soil map unit number and name | 40 Tubakuta | 41 Jambanjeli | 30 Nyambai | 32 Sifoe | 22 Jabang |
|---|---|---|---|---|---|
| Topographic position | Crest of ridge | Middle of long slope | Lower slope and valleys | Above swamp | Temporary swamp |
| Av. no. of bunches per bearing tree | 1.9 | 1.7 | 1.8 | 2.0 | 1.4 |

## YIELD

Yield data were compiled for the Department of Agriculture plantation at Abuko, a site of 1.07 ha (2.64 ac) with favourable conditions, supporting 128 mature trees and receiving at least average maintenance. Fertiliser was applied in 1963 according to N.I.F.O.R. recommendations. Levels of application and the response to the fertilisers have been noted in the section on foliar analysis. Yields are summarised in Table 21. The average yield is slightly over 2 200 kg per ha (2 000 lb per ac). Allowing for improved planting techniques and fertiliser application the estimate of 3 400 kg of bunches per ha (3 000 lb per ac) made by Sly (1965) is realistic. No evidence was found for Mocarski's (1962) estimate that a mature improved palm should give a return of £3 0s. 0d. per year in The Gambia, equivalent to a yield of about 17 000 kg of bunches per ha (15 000 lb per ac).

TABLE 21 Yield of bunches from improved palms (NIFOR EWS) planted in 1948 at Abuko

| Year | No. of bearing trees | Total yield | | Yield per bearing tree | | Yield | |
|---|---|---|---|---|---|---|---|
| | | kg | lb | kg | lb | kg/ha | lb/acre |
| 1963 | 75 | 1 789.0 | 3 944 | 23.8 | 52.6 | 1 674.5 | 1 494 |
| 1964 | 105 | 3 163.4 | 6 974 | 30.1 | 66.4 | 1 840.4 | 1 642 |
| 1965 | 100 | 2 565.5 | 5 656 | 25.7 | 56.6 | 2 400.8 | 2 142 |
| 1966 | 91 | 2 188.6 | 4 825 | 24.0 | 53.0 | 2 048.9 | 1 828 |
| Mean | 92.75 | 2 426.9 | 5 350 | 25.9 | 57.15 | 2 271.9 | 2 027 |

Source: Department of Agriculture records.

In Table 22 the average yield per acre at Abuko is compared with a 1948 planting of improved palms at Benin. The figures show that mature palms in The Gambia yield very much less than palms of equivalent age in Nigeria, though lack of fertiliser has undoubtedly had an adverse effect on the yields of Gambian palms. Sheldrick (1967) has estimated that unfertilised palms near Benin yield approximately 7 800 kg of bunches per ha (7 000 lb per ac).

TABLE 22 Comparison of yield per acre of oil palms planted in 1948 in The Gambia and in Nigeria

| Locality | Mean of years | kg bunches/ha | lb bunches/ac |
|---|---|---|---|
| Gambia: Abuko | 1963-1966 | 2 271.9 | 2 027 |
| Nigeria: Benin | 1953-1956 | 5 249.9 | 4 684 |
| | 1957-1960 | 11 837.0 | 10 561 |
| | 1961-1963 | | 9 058 |

Source: Gambia Department of Agriculture records and N.I.F.O.R. experimental records.

In Table 23, yields from palms in The Gambia are compared with palms at Kabba and Acharu, areas of N. Nigeria with rainfall similar to The Gambia, and to palms at Abak in the oil palm belt of Nigeria. These comparisons show that even with the best management as in the N.I.F.O.R. variety trials, at Kabba and Acharu, yields in dry areas are only one-tenth of yields in the oil palm belt, whilst in The Gambia five-year-old watered palms are just coming into bearing.

TABLE 23 Yield per acre of improved palms (NIFOR EWS) in dry areas of The Gambia and Nigeria compared with yields in the moist oil-palm belt of Nigeria

| Locality | Age of palms years | Annual rainfall mm (2) | No. of months with less than 100 mm of rain (2) | Yield kg bunches/ha | Yield lb bunches/ac |
|---|---|---|---|---|---|
| Gambia: P.M. plantation | 5 | 1 327 | 8 | 1 or 2 bunches (3) | |
| Nigeria: Kabba | 6 | 1 272 | 7 | 665.7 | 594 |
| Acharu | 6 | 1 328 | 7 | 1 578.1 | 1 408 |
| Abak (1) | 6 | 2 500 | 3 | 9 770.2 | 8 717 |

Source: N.I.F.O.R. experimental records.

(1) In the oil palm belt. (2) 100 mm = 3.937 in. (3) Weight not recorded.

## TIME TO COME TO BEARING

Little accurate information is available on the time taken for a palm to bear fruit in dry areas. Available observations are summarised in Table 24.

TABLE 24 Observations on the time taken for an improved oil palm to bear fruit in dry areas

| Area | Age of palms, years | Comment |
|---|---|---|
| N. Nigeria | | |
| Kabba | 5 | Departmental demonstration plot; not yielding |
| Kabba | 6 | N.I.F.O.R. variety trial; see Table 23 for yields |
| Kabba | 7 | Farmers' planting; small palms; not yielding |
| Lokoja | 7 | Departmental demonstration plot; first bunches forming |
| Kabba | 9 | Departmental demonstration plot; first bunches forming |
| Gambia | | |
| Village plantations | 1 | Small palms; not yielding |
| Sutu Sinjang | 2 | Small palms; not yielding |
| Abuko | 3 | Small palms; not yielding |
| P.M. plantation | 4 | Watered palms; not yielding |
| P.M. plantation | 5 | First bunches forming on watered palms |

These observations indicate that even with good management techniques, as in the N.I.F.O.R. variety trial or in the Prime Minister's plantation which is watered twice weekly, the palms do not give an appreciable yield five years after planting out. With less intensive management the palms may take from seven to ten years to come to bearing.

## SUITABILITY OF AREAS OF WESTERN DIVISION FOR OIL PALMS

The most suitable areas for growing oil palms will be those in which the factors limiting growth are at a minimum. These factors are summarised in Table 25 for the various soil types and discussed below. Generalised west to east trends of decreasing rainfall, increasing watertable fluctuation, increasing drying out of the soil and decreasing number of wild palms (which are common to all the soil map units and adversely affect their suitability for oil palm growing) are also indicated in Table 25.

### Map Units 40 and 41. Tubakuta and Jambanjeli

These soils occur in upland sites with a deep watertable. Freely draining, they dry out rapidly at the end of the rains. They are widely cultivated with annual crops and rarely support wild palms. These soils are not recommended for oil palms.

### Map Unit 43. Mayo

These soils occur on the margins of the interfluves in the east of the area where the watertable is at depth. Wild palms are seldom found on these soils which are generally cultivated. They are not recommended for oil palm cultivation.

### Map Units 33 and 34. Kalaji and Bwiam

These soils occur in depressions, but although there may be water present during the rainy season, the dry season watertable is at depth. The dry season desiccation, the presence of a concretionary layer and the absence of wild palms suggests that these soils are not suitable for palms.

### Map Unit 30. Nyambai

This complex occurs in depressions in the eastern part of the area. The watertable fluctuates considerably, and the surface horizons dry out rapidly. The presence of a concretionary layer in many parts of this complex will hinder rooting. Although these soils commonly support wild palms, they should only be used if no more favourable sites are available.

### Map Unit 22. Jabang

This soil occurs on wide flats in the bottom of many valleys, which are waterlogged during the rains, while the watertable falls to about 1 m (3 ft) in the dry season. Low in nutrients, the soil supports a few isolated clumps of wild oil palms. These soils are too wet for the cultivation of oil palms.

(11389)

TABLE 25 The suitability of the soils of Western Division, The Gambia, for oil palm cultivation, with an indication of general west to east trends of rainfall, watertable fluctuation, and number of wild palms

| Map unit number and name | Topographic position | Estimated depth to watertable | | Soil fertility | Rooting | Presence of wild palms | Present land use |
|---|---|---|---|---|---|---|---|
| | | Rainy season | Dry season | | | | |
| 40. Tubakuta | Upland | > 20 ft | > 20 ft | Low | No barrier | Few | Cultivation |
| 41. Jambanjeli | Upland | > 20 ft | > 20 fg | Low | No barrier | Few or common | Cultivation |
| 43. Mayo | Margin of interfluve | > 20 ft | > 20 ft | Low | No barrier | Few | Cultivation |
| 33. Kalaji | Depression on broad interfluve | Possibly perched < 6 ft | > 20 ft | Low | Fossil cuirasse at 3 ft | None | Woodland |
| 34. Bwiam | Depression | " | > 20 ft | Low | Concretionary layer at 6 ft | None or few | Woodland |
| 30. Nyambai | Depression | " | > 15 ft | Low | " | Common to many | Woodland and shifting cult. of upland rice |
| 32. Sifoe | Swamp margins | < 6 ft | < 20 ft | Low | No barrier | " | Woodland and rough grazing |
| 22. Jabang | Valley bottom | Surface | < 20 ft | Low | Watertable during rains | Common | Rice |

West ⟶ East

Decreasing rainfall. Increasing watertable fluctuation. Decreasing number of wild palms

## Map Unit 32. Sifoe

This soil is found towards the bottom of many valleys, surrounding swamps. Generally the watertable is within 2 m (6 ft) of the surface during the dry season, but in some sites particularly in the east, it may drop below that level. The surface horizons of this soil remain moist longer than any other, and although the nutrient status is low there is no barrier to root penetration. Furthermore, this soil consistently supports fairly dense groves of wild palms and it is considered to be the least unsuitable of the soils in Western Division on which to plant improved oil palms.

These least unsuitable areas are shown on the map 'Oil Palm Areas' accompanying this report. Their total area is 11 408 ha (28 190 ac). Individual sites vary in size from less than 1 ha to 1 467 ha (1 to 3 625 ac). The number of sites of various sizes is shown in Figure 11. Almost 60% of the sites are less than 40 ha (100 ac) in size and almost 40% are less than 20 ha (50 ac). In addition, most of the sites form narrow strips less than about 90 m (100 yd) wide, and are of irregular shape.

The greatest acreage of the least unsuitable land for oil palm development is in the west, as can be seen from Table 26.

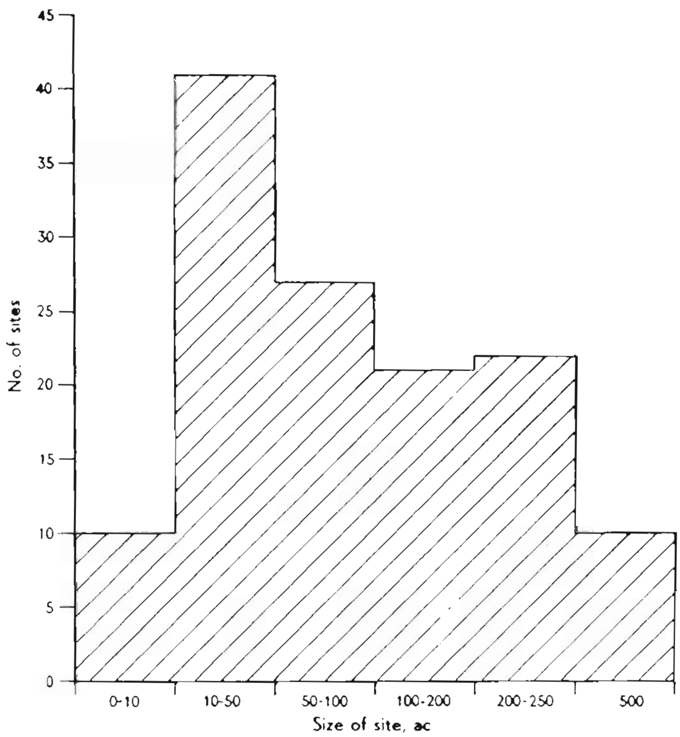



FIGURE 11 Size distribution of the least unfavourable sites for oil palm cultivation in Western Division (1 ac = 0.4 ha)

TABLE 26 Area of least unsuitable land for oil palm development in Western Division, in ha and (ac)

| | Sheets of the Map 'Oil Palm Areas' | | | |
|---|---|---|---|---|
| | 1 ; 2 | 3 | 4 | 5 |
| Total area | 5 796<br>(14 323) | 3 042<br>(7 517) | 1 612<br>(3 983) | 958<br>(2 367) |
| Mean size of each area | 114<br>(281) | 87<br>(214) | 64<br>(159) | 48<br>(118) |
| Size of largest area | 1 467<br>(3 625) | 238<br>(589) | 359<br>(887) | 192<br>(474) |
| Size of smallest area | 4<br>(10) | 0.8<br>(2) | 0.4<br>(1) | 0.4<br>(1) |

It should be noted that there are areas in the south-west forming a complex where it is impossible to map Sifoe and Jabang units separately at a scale of 1: 50 000. Approximately 25% of the complex can be considered as forming part of the Sifoe Unit and this adds approximately a further 809 ha (2 000 ac) to the total of land least unsuitable for oil palm development.

These data show that the greatest area of least unsuitable land and the largest individual units occur in the west. Because of their smaller size and lower rainfall, areas in the east of Western Division and eastwards into Lower River Division must be considered even less favourable for oil palm cultivation. Similarly low rainfall and a limited distribution of wild palms suggest that there is little potential for oil palm cultivation on the north bank of the Gambia River.

## PLANTATIONS OF IMPROVED PALMS (NIFOR EWS VARIETY) IN THE GAMBIA

In 1948 a trial planting of improved palms was made at Abuko. Little further development was undertaken until 1961 when a few palms were planted in the Prime Minister's plantation. Small numbers of palms were planted in the following year, and in 1963 a demonstration plot was planted by the Department of Agriculture at Abuko, followed by other plots at Jambur and Nyambai. More recently, plots of improved palms have been established on a co-operative basis near many villages and the location of these is shown on the map of oil-palm areas. Figures for the number of seedlings and acreages planted over the past three years are summarised in Table 27.

TABLE 27 Plots of improved palms (NIFOR EWS) in The Gambia

| Year | Western Division | | | Other areas | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of seedlings | Area ha | ac | No. of seedlings | Area ha | ac | No. of seedlings | Area ha | ac |
| 1964 | 950 | 6.47 | 15 | 120 | 0.80 | 2 | 1 080 | 7.27 | 18 |
| 1965 | 1 764 | 11.73 | 29 | 480 | 3.25 | 8 | 2 244 | 14.97 | 37 |
| 1966 | 2 095 | 14.16 | 35 | 2 226 | 14.97 | 37 | 4 321 | 29.14 | 72 |
| Total | 4 819 | 32.38 | 80 | 2 826 | 19.02 | 47 | 7 645 | 51.40 | 127 |

Source: Department of Agriculture records.

Of the total of 127 acres planted only 38 acres have been fenced. Plate 6 indicates the extensive damage caused by animals to unfenced palms, resulting in more than 50 per cent mortality during the first year. Fire damage may also be severe. Establishment even in fenced plantations is often hindered by insufficient watering. Most fenced plantations are intercropped with cassava or groundnuts and are thus kept free of grass; unfenced palms are seldom ring weeded. Sly (1965) and Forde (1967) have modified the N.I.F.O.R. recommendations on fertilisers and spacing of palms, specifically for Gambian conditions, and these recommendations should be implemented immediately. Many of the present plantings are located upslope from the area least unsuitable for oil palm development. Location of new plantations within these areas will involve felling existing groves of wild palms.

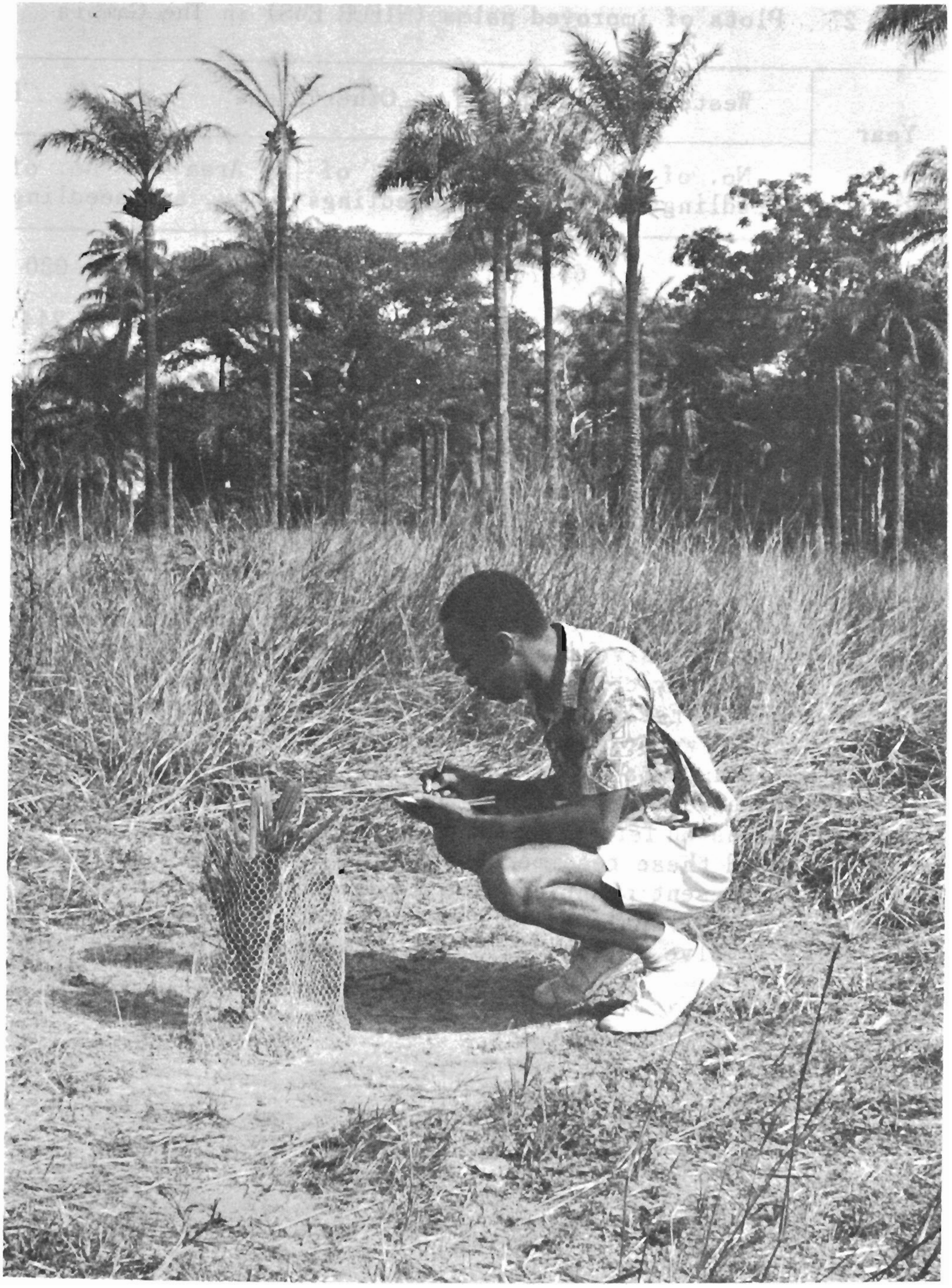


PLATE 6 Two-year-old improved (NIFOR EWS) oil palm near Bulok village, The Gambia, showing animal damage due to lack of adequate fencing

# PART 5. DISCUSSION

## SUMMARY OF FINDINGS

The environment in The Gambia is not favourable for successful oil palm cultivation as will be seen from Table 8 in which the optimum oil palm environment described by Surre and Ziller (1963) is compared with that in The Gambia.

The rainfall, 1 327 mm (52 in) per year at Yundum, is badly distributed, falling entirely between June and October, while high relative humidity is associated only with the rainy season. Calculated values for potential evapotranspiration show that there is a total annual water deficit of 26 in, and that only during July, August and September does rainfall exceed the monthly potential evapotranspiration. In addition, minimum temperatures fall below 18°C (65°F) from December to March. In fact every climatic factor except sunshine is outside the optimum range. Thus oil palms in The Gambia are growing in climatic conditions very different from the optimum, and in particular they are short of water for at least six months of the year.

It is possible that in areas with a watertable within 2 m (6 ft) of the surface the adverse effects of the long dry season will be reduced. Although there is little accurate information on watertable fluctuations in The Gambia, observations made during the survey showed that on the margins of swamps in the valley bottoms, for example sites similar to Abuko, the watertable is generally less than 1 m (3 ft) from the surface during the rains, and in the dry season it usually falls to about two metres (6 ft), though it may drop to a greater depth. Upslope from the valley bottoms, the depth to the watertable increases rapidly and in many upland sites the watertable is at 20 m (65 ft) or more. If climatic conditions are not ideal, soil factors become increasingly limiting, and soil nutrient status or soil depth that differs from the optimum will have an adverse effect on yield. The sandy surface horizons of most of the soils in Western Division provide a good rooting medium for oil palms. However, the surface horizons dry out rapidly at the end of the rains and fossil cuirasse or ironstone is frequently present, forming a barrier to deep root penetration. Thus potential oil palm sites are restricted to the sandy, light coloured soils occurring on the margins of valley swamps. These soils usually have a high watertable during the dry season but are low in nutrients and the addition of fertiliser would be essential before they could support oil palm plantations.

The unfavourable environment is reflected in the poor establishment and growth of the existing planted oil palms, although poor planting techniques may have had an adverse effect on the growth of some of these palms. In The Gambia both young and mature trees are smaller than palms of the same age growing in favourable conditions in Nigeria. The average number of bunches per tree also compares unfavourably with Nigerian production, probably due to the preponderance of male flowers, and the high abortion rate of female inflorescences of oil palms growing in dry conditions. A further important reflection of the adverse conditions is the long time taken for a palm to come into bearing: at least five years with watered palms, and probably seven to ten years for palms in village plantations.

Yields from the Department of Agriculture plantation at Abuko are only slightly in excess of 2 200 kg of bunches per hectare or 2 000 lb per acre. Allowing for improved varieties and improved planting techniques, Sly's (1965) estimate of one and a half tons of bunches per acre is realistic, and must represent the maximum expected yield in The Gambia under natural conditions. Although it has been appreciated for some time that yields in The Gambia would be lower than Nigerian yields, it must be stressed that they are only one fifth as high.

## COSTS OF ESTABLISHMENT

The cost to Government of providing seedlings and preparing and planting one acre of oil palms in The Gambia is about £55 as shown in Table 28.

TABLE 28 Costs of planting one acre of oil palm in The Gambia: (A) provision of seedlings; (B) field expenses

| A. Seedling Expenses (1) | Cost £ |
|---|---|
| 1. Cost of seed, 100 per acre at 9d. per seed allowing 60% survival | 3 15 0 |
| 2. Germination 100 days, labour and electricity | 4 2 |
| 3. Pre-nursery 120 days, labour, fertiliser, watering, wooden boxes, shading, insecticide, soil sterilisation | 5 0 |
| 4. Nursery 1 year, labour, fertiliser, water, fungicide, land preparation, lifting, transport and field expenses | 1 12 9 |
| Total | 5 16 11 |
| **B. Field Expenses (2)** | |
| 1. Demarcation and clearing | 10 0 0 |
| 2. Digging and transplanting | 18 0 |
| 3. Fencing material | 30 0 0 |
| 4. Wells: 4 at £2 each | 8 0 0 |
| Total | 48 18 0 |

(1) Source: Yundum Agricultural Station Records.

(2) Source: Department of Agriculture Estimates.

Under the present scheme all these costs are borne by Government. Seedlings are grown by the Department of Agriculture. The establishment of the plantation in the field is also supervised by the Department. Clearing and well-digging would normally be done by contractors. The high cost of fencing is due to the small size of the present plantations. Fencing of larger plantations may prove cheaper, and the fencing may be re-used on other plantations in the future which would also reduce the cost, but the feasibility of this has yet to be demonstrated. Without fencing, oil palms cannot be successfully established in The Gambia, as in 1965 over 50% of the 2 000 seedlings planted in unfenced plantations were destroyed by livestock, and many of the remaining plants were merely leafless stumps.

Some 70 000 seedlings have been prepared for the 1967 planting season (July to September) which would be sufficient to plant 1 000 acres, allowing for a considerable mortality rate. Planting this number of seedlings will cost the Government a minimum of £50 000, providing establishment costs do not increase. It has already been noted that the total area of land in The Gambia that is at all suitable for oil palm development is about 28 000 acres. If 1 000 acres of this land were to be planted annually, an investment of at least £1 500 000 would be called for over the next 30 years. In addition, harvesting, processing and marketing will require further investment.

## CONCLUSIONS

Almost all the environmental factors in The Gambia are unfavourable for optimum oil palm growth, in particular the low rainfall and long dry season of seven months. Measurements of the establishment, growth and yield of improved palms planted in the least unfavourable sites reflect the adverse conditions. Without fencing and irrigation, establishment of the young palms is extremely difficult, if not impossible, and the difficulties are increased if the palms are planted upslope from the least unfavourable sites.

It is difficult to assess the profitability of growing oil palms in The Gambia, as the methods of processing, the international market for palm products and not least, the level of crop management, will affect returns. Nevertheless, the adverse environment, the poor yield, and the difficulty and high cost of establishment suggest that the profitability of oil palm development in The Gambia is very doubtful. However, most of the least unsuitable land for oil palms is not used for other crops, and is occupied only by wild palm groves; there is an established marketing system for vegetable oil and it is important to find an alternative crop to groundnuts. If these or social considerations make the development of oil palm plantations desirable, then every possible care must be taken to ensure good management of the least unsuitable sites.

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# APPENDIXES 1 - 3

# APPENDIX 1. PROFILE DESCRIPTIONS AND ANALYSES OF SIFOE SOILS, MAP UNIT 32

A guide to the interpretation of the analytical results in terms of high, medium and low ratings is quoted below from Metson (1956).

**1. Total N%**

| Rating | Range |
|---|---|
| Very high | >1.0 |
| High | 0.5 - 1.0 |
| Medium | 0.2 - 0.5 |
| Low | 0.1 - 0.2 |
| Very low | <0.1 |

**2. pH**

| Rating | Range |
|---|---|
| Extremely alkaline | >9 |
| Slightly alkaline | 7.1 - 7.5 |
| Nearly neutral | 6.6 - 7.0 |
| Slightly acid | 6.0 - 6.5 |
| Moderately acid | 5.3 - 5.9 |
| Strongly acid | 4.5 - 5.2 |
| Extremely acid | <4.5 |

**3. Exchangeable cations**

| Rating | Range meq % | | | |
|---|---|---|---|---|
| | Exch. Ca. | Exch. Mg. | Exch. K. | Exch. Na |
| Very high | >20 | >8 | >1 - 2 | >2 |
| High | 10 - 20 | 3 - 8 | 0.6 - 1.2 | 0.1 - 2 |
| Medium | 5 - 10 | 1 - 3 | 0.3 - 0.6 | 0.3 - 0.7 |
| Low | 2 - 5 | 0.3 - 1 | 0.2 - 0.3 | 0.1 - 0.3 |
| Very low | <2 | <0.3 | <0.2 | <0.1 |

## 4. Total exchangeable bases

| Rating | Range meq % |
|---|---|
| Very high | 25 |
| High | 15 - 25 |
| Medium | 7 - 15 |
| Low | 3 - 7 |
| Very low | 3 |

## 5. Cation exchange capacity

| Rating | Range meq % |
|---|---|
| Very high | 40 |
| High | 25 - 40 |
| Medium | 12 - 25 |
| Low | 6 - 12 |
| Very low | 6 |

## 6. Percentage base saturation

| Rating | Range % |
|---|---|
| Very high | 50 - 100 |
| High | 60 - 80 |
| Medium | 40 - 60 |
| Low | 20 - 40 |
| Very low | 0 - 20 |

**PROFILE 13** **MAP UNIT 32**

| | |
|---|---|
| **Location** | Sifoe to Gunjur Road, ½ mile west of Sifoe, 50 yards south of road |
| **Site** | Lower slopes of valley, just above temporary swamp, concave slope about 2° |
| **Parent material** | Colluvium |
| **Vegetation/Land use** | Shrub woodland with many oil palms, partly cleared |
| **Soil drainage** | Poor |

| Horizon | Depth, cm (in) | Description |
|---|---|---|
| 1 | 0-13 (0-5) | Very dark grey (10 YR 3/1); loamy sand; weak medium sub-angular blocky structure; moist friable consistence; few fine pores; common fine and medium roots; clear wavy boundary |
| 2 | 13-34 (5-13) | Light grey (10 YR 7/2); few medium faint mottles of strong brown (7.5 YR 5/8); loamy sand; weak medium sub-angular blocky structure; dry loose consistence; common fine pores; few fine and medium roots; gradual smooth boundary |
| 3 | 34-53 (13-21) | Pinkish white (7.5 YR 8/2); few fine faint mottles of strong brown (7.5 YR 5/8); sand; massive structure, breaking to moderate medium sub-angular blocky structure; slightly moist slightly firm consistence; common fine pores; few fine roots and common medium roots; clear smooth boundary |
| 4 | 53-70 (21-28) | Brownish yellow (10 YR 6/8) patches of very pale brown (10 YR 7/4); common fine and medium distinct mottles of reddish yellow (7.5 YR 5/8); sand; massive structure, breaking to moderate medium sub-angular blocky structure; slightly moist slightly firm consistence; common fine pores; few fine roots; clear very irregular boundary |

## PROFILE 13. (CONTINUED)

| Horizon | Depth, cm (in) | Description |
|---|---|---|
| 5 | 70-152 (28-59) | Light grey (10 YR 7/2); abundant very fine distinct mottles of reddish yellow (7.5 YR 6/8); sand; massive structure breaking to moderate medium sub-angular blocky structure; slightly moist slightly firm consistence; many fine pores; very few medium roots; clear smooth boundary |
| 6 | 152-215 (59-85) | Pinkish grey (7.5 YR 7/2); abundant coarse prominent mottles of red (2.5 YR 4/8) merging into strong brown (7.5 YR 5/8); sand; strong coarse angular blocky structure; slightly moist firm consistence; common fine pores; very few medium roots; few rounded concretions |

PROFILE 13 (CONTINUED)

## ANALYSIS

| Characteristic | Horizon (sample depth in cm) | | | | | |
|---|---|---|---|---|---|---|
| | 1 (0-10) | 2 (20-30) | 3 (40-50) | 4 (60-70) | 5 (110-120) | 6 (170-180) |
| Mechanical analysis | | | | | | |
| 200µ - 2 mm % | 31 | 39 | 43 | 42 | 39 | 42 |
| 50µ - 200µ% | 45 | 35 | 40 | 39 | 35 | 39 |
| 20µ - 50µ% | 10 | 17 | 8 | 10 | 12 | 5 |
| 2µ - 20µ% | 8 | 3 | 5 | 5 | 7 | 8 |
| <2µ% | 4 | 5 | 3 | 3 | 6 | 6 |
| pH in water 1:2.5 | 5.4 | 5.5 | 5.2 | 5.3 | 4.8 | 5.1 |
| pH in KCl | 3.9 | 4.3 | 4.3 | 4.3 | 4.2 | 4.2 |
| Loss on ignition % | 2.2 | 1.1 | 0.9 | 0.8 | 1.1 | 1.0 |
| | (0-13) | (13-34) | (34-53) | (53-70) | (70-152) | (152-215) |
| Exch. bases meq % | | | | | | |
| Exch. K | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Exch. Na | 0.04 | 0.01 | 0.04 | 0.00 | 0.00 | 0.01 |
| Exch. Mg | 0.27 | 0.07 | 0.33 | 0.02 | 0.04 | 0.00 |
| Exch. Ca | 0.73 | 0.23 | 0.27 | 0.15 | 0.23 | 0.08 |
| Total | 1.08 | 0.32 | 0.65 | 0.18 | 0.28 | 0.09 |
| Cation exchange capacity meq % | 3.54 | 1.97 | 3.14 | 1.40 | 1.74 | 1.17 |
| Base saturation % | 31 | 16 | 21 | 13 | 17 | 8 |
| Total N% | 0.06 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 |
| Total P ppm | 46 | 32 | 33 | 26 | 19 | 13 |
| Total K ppm | 415 | 170 | 225 | 155 | 140 | 205 |
| Total Mg ppm | 215 | 165 | 270 | 123 | 128 | 128 |

PROFILE 33 MAP UNIT 32

**Location** Bondali

**Site** Just above swamp, concave slope about $3^{o}$

**Parent material** Colluvium

**Vegetation/Land use** Shrub woodland with oil palms

**Soil drainage** Poor

| Horizon | Depth, cm (in) | Description |
|---|---|---|
| 1 | 0-16 (0-6) | Light brownish grey, (10 YR 6/2); loamy sand; massive structure, breaking to weak medium sub-angular blocky structure; dry hard consistence; many coarse medium and fine pores; few fine roots; clear smooth boundary |
| 2 | 16-30 (6-12) | Light grey (10 YR 7/2); loamy sand; massive structure, breaking to weak medium sub-angular blocky structure; dry hard consistence; common medium and fine pores; few fine and medium roots; gradual smooth boundary |
| 3 | 30-62 (12-24) | Pale brown (10 YR 6/3); loamy sand; massive structure, breaking to weak coarse sub-angular blocky structure; moist, firm consistence; common medium and fine pores; few medium and coarse roots; gradual smooth boundary |
| 4 | 62-110 (24-43) | Light brownish grey (10 YR 6/2), patches of light grey (10 YR 7/2); few coarse faint mottles of yellowish brown (10 YR 5/8), and many fine faint mottles of yellowish brown (10 YR 5/6) associated with root pores; sandy loam; massive structure breaking to weak coarse sub-angular blocky structure; moist firm consistence; common medium roots; gradual smooth boundary |

## PROFILE 33 (CONTINUED)

| Horizon | Depth, cm (in) | Description |
|---|---|---|
| 5 | 110-155 (43-60) | Light grey (10 YR 7/2), patches of light brownish grey, (10 YR 6/2); common coarse distinct mottles of strong brown (7.5 YR 5/8) merging to brownish yellow (10 YR 6/6); sandy loam; massive structure, breaking to weak coarse sub-angular blocky structure; moist loose consistence; few fine pores; few fine roots; gradual smooth boundary |
| 6 | 155-200 + (60-79+) | Light grey (10 YR 7/2), with patches of light browny grey (10 YR 6/2); few coarse distinct mottles of strong brown (7.5 YR 5/8) merging to brownish yellow (10 YR 6/6); sandy loam; massive structure, breaking to weak coarse sub-angular blocky structure; moist loose consistence; few fine roots |

# PROFILE 33 (CONTINUED)

## ANALYSIS

| Characteristic | Horizon (sample depth in cm) | | | | | |
|---|---|---|---|---|---|---|
| | 1 (0-10) | 2 (20-30) | 3 (40-50) | 4 (70-80) | 5 (130-140) | 6 (170-180) |
| Mechanical analysis | 29 | 26 | 21 | 21 | 20 | 28 |
| 200µ - 2 mm % | 29 | 26 | 21 | 21 | 20 | 28 |
| 50µ - 200µ% | 32 | 42 | 41 | 35 | 36 | 36 |
| 20µ - 50µ% | 18 | 16 | 16 | 16 | 12 | |
| 2µ - 20µ% | 13 | 11 | 13 | 12 | 9 | 8 |
| <2µ% | 6 | 4 | 8 | 15 | 18 | 16 |
| pH in water 1:2.5 | 6.1 | 5.8 | 5.6 | 5.1 | 5.1 | 5.1 |
| pH in KCl | 5.5 | 4.9 | 4.6 | 4.0 | 4.0 | 4.0 |
| Loss on ignition % | 2.6 | 1.7 | 2.0 | 2.1 | 2.4 | 2.0 |
| | (0-16) | (16-30) | (30-62) | (62-110) | (110-155) | (155-200) |
| Exch. bases meq % | | | | | | |
| Exch. K | 0.03 | 0.02 | 0.02 | 0.03 | 0.00 | 0.02 |
| Exch. Na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Exch. Mg | 0.52 | 0.31 | 0.46 | 0.37 | 0.15 | 0.04 |
| Exch. Ca | 1.38 | 1.13 | 1.13 | 0.50 | 0.75 | 0.25 |
| Total | 1.93 | 1.46 | 1.61 | 0.90 | 0.90 | 0.38 |
| Cation exchange capacity meq % | 2.50 | 2.28 | 2.21 | 2.28 | 2.50 | 1.79 |
| Base saturation % | 77 | 64 | 73 | 36 | 21 | |
| Total N% | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
| Total P ppm | 50 | 40 | 37 | 38 | 34 | 27 |
| Total K ppm | 265 | 285 | 405 | 925 | 985 | 435 |
| Total Mg ppm | 208 | 200 | 245 | 280 | 263 | 203 |

# APPENDIX 2. PERMANENT WILTING POINT

The permanent wilting point of eight profiles of Sifoe Unit soils measured as percentage moisture at 15 atmospheres pressure is given below.

| Site | Depth cm | Moisture % | Site | Depth cm | Moisture % |
|---|---|---|---|---|---|
| Sifoe, Profile 13 | 0-13 | 2.22 | Killing, Profile 73 | 0-18 | 1.81 |
| | 13-34 | 1.80 | | 18-48 | 3.16 |
| | 34-53 | 4.33 | | 48-76 | 4.60 |
| | 53-70 | 1.75 | | 76-155 | 5.63 |
| | 70-152 | 2.34 | N'Demban, Profile 75 | 0-11 | 2.20 |
| | 152-215 | 2.56 | | 11-45 | 2.80 |
| Kambalayba, Profile 29 | 0-24 | 3.00 | | 49-95 | 4.69 |
| | 24-38 | 2.96 | | 95-200 | 8.38 |
| | 38-65 | 1.33 | Bwiam, Profile 81 | 0-10 | 2.31 |
| | 65-130 | 0.89 | | 10-34 | 1.88 |
| Bondali, Profile 33 | 0-16 | 2.34 | | 34-56 | 2.11 |
| | 16-30 | 2.33 | | 56-120 | 1.93 |
| | 30-62 | 3.60 | Pirang, Profile 120 | 0-16 | 1.57 |
| | 62-110 | 4.90 | | 16-78 | 2.87 |
| | 110-155 | 5.80 | | 78-166 | 3.37 |
| | 155-200 | 3.80 | | 166-200 | 5.97 |

# APPENDIX 3. SOIL MOISTURE DEFICIT

TABLE 1 Soil moisture deficit as a percentage of available water capacity for some Sifoe Unit soils

(Anomalous results are in brackets. 'H' indicates that the soil was too hard to be sampled in the time available.)

| | Depth | Available water capacity cm | 1966 | | | | | 1967 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3.11 | 17.11 | 29.11 | 13.12 | 20.12 | 11.1 | 20.2 | 7.3 | 20.3 | 5.4 | 18.4 | 2.5 |
| Profile No. 9 | 0-15 | 2.5 | 6 | 0 | 64 | 87 | 86 | 90 | 95 | 85 | 81 | 86 | 92 | 94 |
| | 25-40 | 2.5 | 0 | 46 | 73 | 68 | 76 | 76 | 78 | 75 | 71 | (14) | 78 | 77 |
| | 50-65 | 2.5 | 0 | 15 | 16 | 9 | 70 | 64 | 76 | 64 | 85 | 66 | 72 | 72 |
| | 75-90 | 2.29 | 0 | 0 | 0 | 0 | 18 | 8 | (54) | 14 | 6 | 8 | 7 | 23 |
| | 100-115 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 6 | 14 | 18 | 21 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 21 |
| | 200-215 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| Profile No. 13 | 0-15 | 2.41 | 0 | 0 | 0 | 40 | 46 | 57 | 82 | 94 | 92 | 100 | 92 | 100 |
| | 25-40 | 2.5 | 0 | 6 | 0 | 30 | 47 | 42 | 72 | 81 | 81 | 86 | (28) | 89 |
| | 50-65 | 2.5 | 0 | 0 | 4 | 24 | 39 | 33 | 65 | 75 | 80 | 78 | 80 | 83 |
| | 75-90 | 2.5 | 0 | 0 | 0 | 6 | 35 | 29 | 50 | 56 | 69 | 70 | 82 | 79 |
| | 100-115 | 2.5 | 0 | 0 | 0 | 0 | 14 | 13 | 22 | 49 | 47 | 55 | 80 | 72 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 21 | 21 | 25 | 34 |
| | 200-215 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 |
| Profile No. 29 | 0-15 | 2.5 | 0 | 24 | 69 | 92 | 79 | 99 | 90 | 96 | 94 | 96 | 94 | 96 |
| | 25-40 | 2.5 | 0 | 8 | 33 | 51 | 54 | 76 | 68 | 77 | 79 | 82 | 80 | 88 |
| | 50-65 | 2.5 | 0 | 0 | 30 | 24 | 24 | 18 | 48 | 66 | 60 | 61 | 72 | 65 |
| | 75-90 | 2.5 | 0 | 0 | 39 | 30 | 0 | 31 | 24 | 56 | 57 | 49 | (24) | 54 |
| | 100-115 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 31 | 45 | 31 | 40 | 30 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 17 | 20 | 21 | 19 |
| | 200-215 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

TABLE 1 (continued) Soil moisture deficit as a percentage of available water capicity for some Sifoe Unit soils (Anomalous results are in brackets. 'H' indicates that the soil was too hard to be sampled in the time available.)

| | Depth | Available water capacity cm | 1966 | | | | | 1967 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3.11 | 17.11 | 29.11 | 13.12 | 30.12 | 11.1 | 20.2 | 7.3 | 20.3 | 5.4 | 18.4 | 2.5 |
| Profile No. 33 | 0-15 | 2.5 | 0 | 31 | 66 | 99 | 90 | 96 | 89 | 95 | 93 | - | - | 92 |
| | 25-40 | 2.5 | 6 | 0 | 48 | 0 | 70 | 78 | 65 | 75 | 77 | - | - | 77 |
| | 50-65 | 2.5 | 0 | 0 | 12 | 60 | 55 | 57 | 47 | 66 | 59 | - | - | 60 |
| | 75-90 | 2.5 | 0 | 0 | 0 | 6 | 14 | 22 | 14 | 50 | 51 | - | - | 58 |
| | 100-115 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 38 | - | - | 53 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 41 |
| | 200-215 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | | | 25 |
| Profile No. 73 | 0-15 | 2.5 | 9 | 84 | 88 | 88 | 79 | 86 | - | 88 | 98 | 70 | 96 | 95 |
| | 25-40 | 2.5 | 7 | 50 | 62 | 63 | 60 | 73 | 77 | 76 | 80 | 26 | 71 | 80 |
| | 50-65 | 2.5 | 0 | 0 | 23 | - | 0 | 63 | 54 | 58 | 71 | 8 | 73 | 77 |
| | 75-90 | 2.5 | 0 | 0 | 0 | 0 | - | 59 | 47 | 70 | 64 | 0 | 83 | 61 |
| | 100-115 | 2.5 | 0 | 0 | 0 | 0 | - | 0 | 4 | 0 | 5 | 0 | 54 | 44 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 200-215 | 2.5 | | | | | | | | | | | | |
| Profile No. 75 | 0-15 | 2.5 | 54 | 67 | (19) | 80 | 82 | 85 | 96 | 91 | 91 | 86 | 91 | 89 |
| | 25-40 | 2.5 | 0 | 31 | 38 | 52 | 61 | 74 | 74 | (49) | 70 | 68 | 80 | 82 |
| | 50-65 | 2.5 | 0 | 9 | 18 | 30 | 42 | 64 | 62 | 68 | 57 | 61 | 80 | 64 |
| | 75-90 | 2.5 | 0 | 0 | 0 | 23 | (10) | 31 | 58 | 58 | 58 | 60 | 62 | 58 |
| | 100-115 | 2.5 | 0 | 0 | 0 | 0 | 0 | 18 | 45 | 49 | 52 | 61 | 67 | 50 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 19 | H |
| | 200-215 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 1 (continued) Soil moisture deficit as a percentage of available water capacity for some Sifoe Unit soils (Anomalous resuts are in brackets. 'H' indicates that the soil was too hard to be sampled in the time available.)

| | Depth | Available water capacity cm | 1966 | | | | | 1967 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3.11 | 17.11 | 29.11 | 13.12 | 30.12 | 11.1 | 20.2 | 7.3 | 20.3 | 5.4 | 18.4 | 2.5 |
| Profile No. 81 | 0-15 | 2.5 | 0 | 0 | 0 | (64) | 0 | 40 | 42 | 77 | 80 | - | 91 | 87 |
| | 25-40 | 2.5 | 0 | 0 | 0 | 0 | 0 | 12 | 19 | 76 | 50 | - | 63 | 40 |
| | 50-65 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 30 | 15 | - | 18 | 25 |
| | 75-90 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | - | 0 | 0 |
| | 100-115 | 2.5 | | | | | | | | | | | | |
| | 150-165 | 2.5 | | | | | | | | | | | | |
| Profile No. 120 | 0-15 | 2.5 | 54 | 89 | 96 | 97 | (0) | 99 | 98 | 73 | 96 | 94 | 96 | 92 |
| | 25-40 | 2.5 | 27 | 80 | 83 | 79 | 84 | 100 | 86 | 75 | 85 | 85 | 82 | 85 |
| | 50-65 | 2.5 | 13 | 36 | 60 | 66 | (28) | 84 | 68 | 63 | 61 | 67 | 63 | 58 |
| | 75-90 | 2.5 | 0 | 32 | 52 | 50 | 26 | 62 | 64 | 64 | 65 | 60 | 60 | 46 |
| | 100-165 | 2.5 | (23) | (41) | 27 | 46 | 16 | 57 | 64 | 60 | 53 | 71 | 59 | 52 |
| | 150-165 | 2.5 | 0 | 0 | 0 | 0 | 0 | 52 | 36 | 64 | 17 | 34 | 50 | 38 |
| | 200-215 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | - | 31 | 0 | 0 | 0 | 0 |

# PUBLICATIONS OF THE LAND RESOURCES DIVISION

The Division makes a report on each completed project. The report is published as a *Land Resource Study* or *Technical Bulletin* only with the consent of the government concerned. The abbreviated titles of the reports in the style of the 'World List of Scientific Periodicals' are *Land Resour. Stud.* and *Tech. Bull. Land Resour. Div. Dir. Overseas Surv.*

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| BAWDEN, M. G. and LANGDALE-BROWN, I. | 1961 | An aerial photographic reconnaissance of the present and possible land use in the Bamenda Area, Southern Cameroons.* |
| BAWDEN, M. G. and STOBBS, A. R. | 1963 | The land resources of Eastern Bechuanaland. |
| LANGDALE-BROWN, I. and SPOONER, R. J. | 1963 | The land use prospects of Northern Bechuanaland. |
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| HILL, I. D. | 1969 | An assessment of the possibilities of oil palm cultivation in Western Division, The Gambia. *Land Resource Study* No. 6. |

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| PIGGOTT, C. J. | 1968 | A soil survey of Seychelles. *Technical Bulletin* No. 2. |

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