Savanna Afforestation in Africa

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FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME

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lecture notes for

the fao/danida training course on forest nursery and establishment techniques for african savannas

and papers from

the symposium on savanna afforestation

with the support of

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1976

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PREFACE

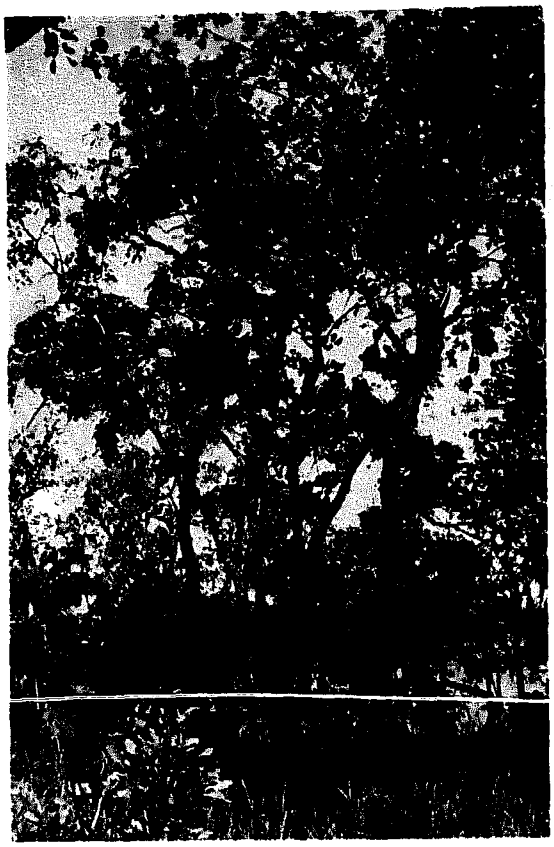
This compilation is the result of a Training Course on Forest Nursery and Establishment Techniques for African Savannas which was to have been held in Kaduna, Nigeria, from 16 February to 21 March 1976 at the invitation of the Government of Nigeria with funds made available from both the Danish International Development Agency (DANIDA) and the Forest Research Institute of Nigeria[1/]. The course was planned in collaboration with the Forest Research Institute and the Food and Agriculture Organization of the United Nations (FAO) and was to have been held in conjuction with the Symposium on Savanna Afforestation organized by the Forest Research Institute, with part of the training course running jointly with the symposium. Regrettably, the closing of Nigeria's international borders in response to political disturbances in the country forced cancellation of the training course. The symposium was held as scheduled but with reduced participation.

The training course was to have been the latest in a series financed by DANIDA on aspects of forest plantation establishment with emphasis on tree improvement and seed handling. Previous courses in the series were held in Denmark (1966) and Kenya (1973) on forest tree improvement and in Thailand (1975) on forest seed collection and handling.

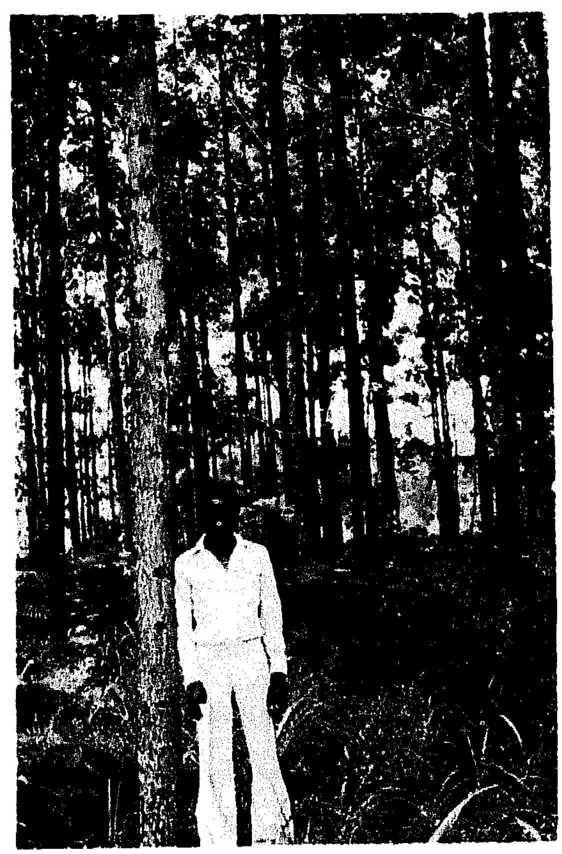
Although it was not possible to realize at least two of the main purposes of the training course - to provide demonstration of good nursery and plantation establishment techniques in savanna Africa and to facilitate the interchange of ideas and experience between francophone and anglophone participants - it was thought that reproduction and distribution of the lecture notes and papers prepared for the training course and symposium would be useful. This report (printed both in English and French) therefore, contains a set of lecture notes prepared in advance of the training course, the principal symposium papers and the country statements contributed by "would-be" course participants. As lecture notes were planned to complement, but not duplicate, material in Tree Planting Practices in African Savannas (FAO Forestry Development Paper No. 19 by M.V. Laurie, 1974), readers may wish to refer to that FAO book for further information on a given subject. One part of the symposium was devoted to the presentation of a number of short case studies on aspects of planting pine, neem and eucalypts in the Nigerian savanna. Only the summaries of these case studies are reproduced here; the full texts are available from the Forest Research Institute in Ibadan. A few lectures and papers have been shortened for inclusion in this report, especially in cases where duplication occurred. The order of presentation here departs from that planned for the symposium and training course, in that all papers on a given subject are together.

Permission from the Forest Research Institute of Nigeria to publish papers prepared for the Symposium on Savanna Afforestation is gratefully acknowledged. Thanks are also due to that organization, and especially its staff at the Savanna Forestry Research Station in Samaru, for the many local arrangements and preparations made for the training course and to the forest departments of Kaduna, Kano and North East states for similar assistance in providing for the planned study tours. The support of the FAO/UNDP forestry project in Samaru, the UNDP offices in Kaduna and Lagos and the FAO Senior Agricultural Adviser was invaluable and is most gratefully recognized. Appreciation is also extended to the many authors of symposium papers and training course lecture notes for their efforts. Finally, regrets are offered to the training course participants who were inconvenienced and disappointed by the unavoidable cancellation of the course.

1/ then the Federal Department of Forest Research.



The natural savanna woodlands are sparsely stocked, low yielding and made up of species of poor stem form, illustrated here by Uapaca togoensis and Isoberlinia doka in the northern Guinea savanna.



By the judicious selection of exotic species for the planting sites available and the application of intensive cultural techniques, savannas can be converted to fast-growing forest plantations, such as this 8-year old stand of Eucalyptus cloeziana at Afaka, Nigeria.

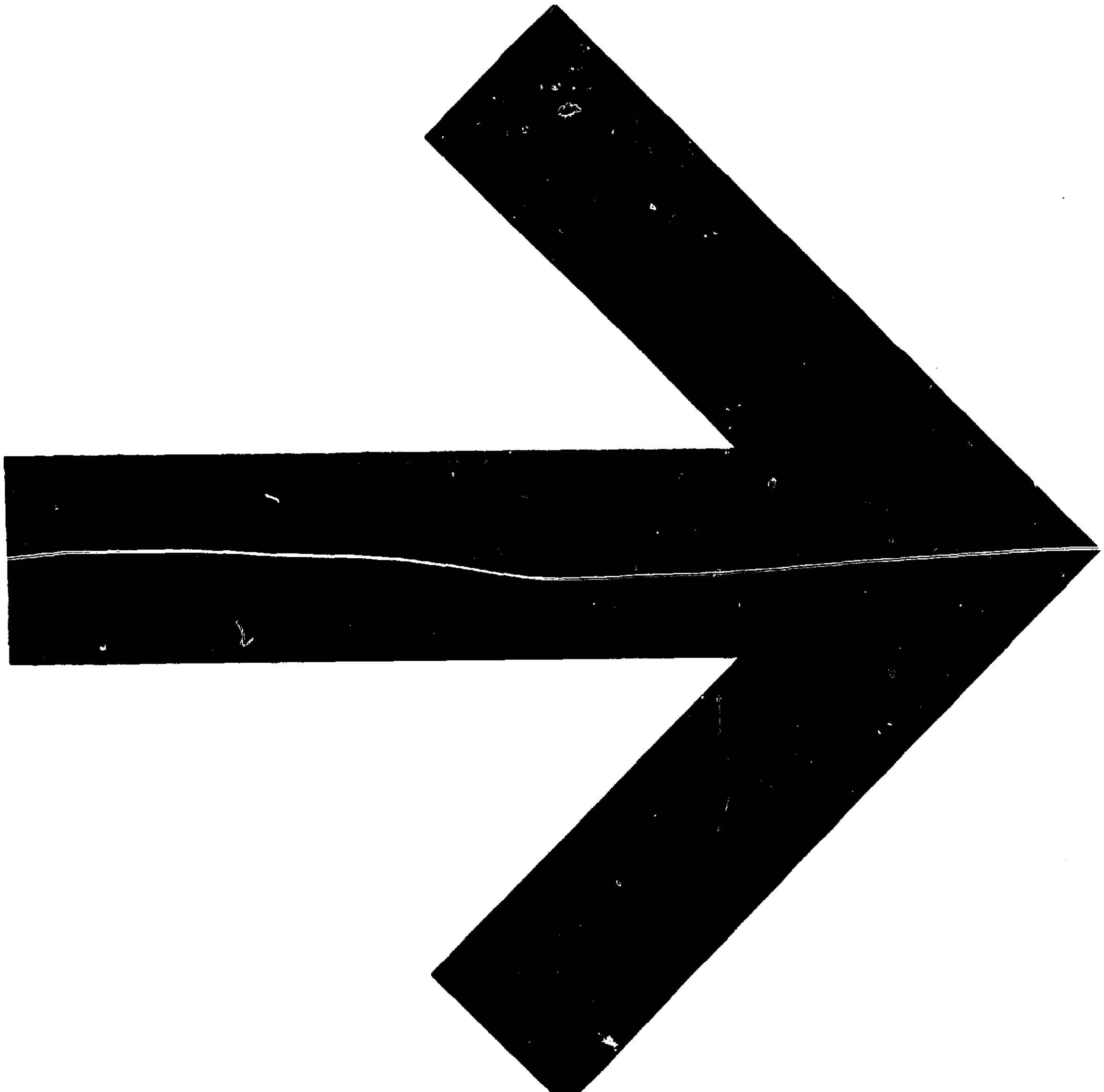


TABLE OF CONTENTS

DEFINITION, CLASSIFICATION AND EXTENT OF AFRICAN SAVANNA [1/]

C.F.A. Onochie
Onitsha, Nigeria

CONTENTS

DEFINITION

The word 'savanna' is from the Spanish zavana or cavana and is thought to have Carib origin. It means a grassy plain with scattered trees and in particular refers to such plains in tropical and subtropical regions. The term is used also for a tract of level land covered with low vegetation or any large area of tropical or subtropical grassland covered in part with trees and spiny shrubs.

Richards (1952) gives the following definition, and remarks on the probable ecological status of savannas.

> "Savanna is a name applied to plant communities of varied physiognomy and status found over a wide range of climatic conditions; some are seral stages, others are certainly stable climaxes. Savanna on which trees are dominant (with or without a continuous ground-cover of grasses) may be a climatic climax, but many types of savanna should be regarded as fire-climaxes ..... Open savannas with trees growing scattered or in occasional clumps, and treeless grasslands may arise by the degradation of the forest or savanna woodland by excessive cultivation or burning but in some cases they are probably edaphic climaxes due to local soil conditions unfavourable to the growth of trees. The nature of the factors responsible is uncertain but one which probably operates in some cases is seasonal waterlogging alternating with dry conditions during the rest of the year. There is little support for the view that lowland tropical grasslands are ever a climatic climax in equilibrium with a 'tropical grassland climate'; grassland therefore should not be regarded as occupying a place in the natural climatic ecotone from tropical rain forest to desert."

Schimper (1903) gives the following definitions:

> "Savanna forest is more or less leafless during the dry season, rarely evergreen, is xerophilous in character, usually, often much less than 20 m high,

[1/] Paper for Symposium on Savanna Afforestation park-like, very poor in underwood, lianes and epiphytes, rich in terrestrial herbs, especially grasses."

"Thorn forest, as regards foliage and average height, resembles savanna forest, but is more xerophilous, is very rich in underwood and in slender-stemmed lianes, poor in terrestrial herbs, especially in grasses, and usually has no epiphytes. Thorn plants are always plentiful."

Used loosely and in the African context the term may cover an array of types of tropical vegetation, ranging from the relatively dry to the semi-arid, which lie between the tropical rain forests of the equatorial region and the deserts to the north and to the south. These consist of a wide variety of transition types ranging from woodland savanna, including the so-called derived savanna (Keay 1959), to the semi-arid steppe with scattered trees, consisting mostly of species of Acacia. This belt extends from near the equator to latitude 25 to 30 degrees north and south.

A distinguishing climatic feature of the savanna is the distinct dry season. The rainfall cycle results from the poleward shift of the global wind belts in the summer and their equatorward shift in the winter. A savanna climate has one or more months with less than 60 mm (2.4 ins) of rainfall. The climate is warm with a short summer rainy season and a dry winter. In areas of heavy rainfall there is a season of up to 1 000 to 1 500 mm (40 to 60 inches) of rainfall interrupted by a distinct dry season.

The general appearance of the savanna is one of rolling plains, and the vegetation is tall grass with scattered trees. The tree cover ranges between the one extreme of a closed canopy near the border with the rain forest and where there has been little human interference, and the other extreme of very open grassland with dwarf trees (or even with very few trees) dotted all over the landscape. The latter occurs at the edge of the desert and where excessive cultivation or extensive burning or heavy grazing has resulted in the disappearance of the original tree cover.

The grass grows to a great height, 1.5 to 4.5 metres (5 to 15 ft) in some places, particularly where the giant elephant grass (Pennisetum purpureum) grows in the wet season. At the other extreme the grass is very short reaching up to a height of 30 cm (12 inches).

In order to combat the effects of the long hot dry season, savanna vegetation has developed a number of adaptations: the deciduous habit, leathery leaves, thick or corky barks, the thorn habit, small leaves, cactus nature and the development of storage systems, long and extensive root systems, and so on.

Several florisitic types are easily recognised, such as the Daniellia - Parkia, the Daniellia - Hymenocardia - Lophira and Combretum woodlands which are characteristic of certain areas in Central Africa, the stretches of Acacia woodlands covering vast areas in West, East and Central Africa; also the Hyphaene palm savannas, and the Borassus savanna which is associated with seasonally flooded sites.

CLASSIFICATION

While it may not be true to say that there are as many classifications as there are workers in the field, the literature on African vegetation is replete with systems of classification and of names used by individual workers for the various types of vegetation encountered (Kuchler 1970). Most often different names are applied to the same type. This is, of course, inevitable in view of the vast area involved in the study, the general lack of communication and consultation between workers, the large number of habitats and life forms encountered in the field and the determination of each worker to map what he considers are clearly distinct and discrete types in his area of operation, even though this may be a very small and irrelevant type in the context of the whole continent. The situation is also bedevilled by the lack of a generally accepted criterion for classification.

Individual authors have used the climate, the soil, the general geographical location, the physiognomy of the vegetation and the phyto-chorological divisions (Phillips 1959, Monod 1957, Keay 1956).

In Nigeria, this problem has for some time been resolved by the acceptance by most workers of the classification proposed by A.P.D. Jones and R.W.J. Keay (Jones 1945, Jones and Keay 1946, Keay 1953). In this classification, the Nigerian savanna is arranged as follows (from south to north) (see Figure 1):

Derived Savanna

Southern Guinea Savanna

Northern Guinea Savanna

Sudan Savanna

Sahel Savanna

This is in line with the classification adopted by French workers in the neighbouring countries of West Africa.

Recent workers in Nigeria have rightly questioned the validity of the basis of this classification, and consequently a new classification based on the recommendations of the Scientific Council for Africa South of the Sahara (C.S.A.) Specialist Meeting on Phytogeography in Yangambi (C.S.A. 1956, Boughey 1957) and on the Association pur l'Etude taxonomique de la Flore d'Afrique tropicale (A.E.T.F.A.T.) Vegetation Map of Africa (Keay et al 1958) has been adopted by Charter (1970) for the new Vegetation Map of Nigeria, which is included in the National Atlas of Nigeria.

The aims of the Yangambi meeting were:

1. "to establish a common terminology for all African phytogeographers";
2. "to limit this terminology to African vegetation only", and
3. "to exclude from African nomenclature some of the terms used in other countries of the world which illustrate various types of vegetation the homology of which is not proven".

The meeting accepted the proposal "to illustrate, particularly by profile diagrams, the description of the various types of vegetation or plant communities". It concluded that in the interests of a co-ordination which was highly desirable, there was a need for essentially physiognomic definitions of the various types of vegetation. It therefore recommended the adoption of a broad system of classification based on this principle, but left the use of intermediary physiognomic terms corresponding to the various recognisable transitions in the field and the designation of certain very particular formations to the initiative of the phytogeographers, according to local conditions.

Two main groups of vegetation formations were recognised, namely:

1. Closed Forest Formations, including "Thickets", the latter being described as "Shrubby vegetation, evergreen or deciduous, usually more or less impenetrable often in clumps, with grass stratum absent or discontinuous" (Some thickets, like the *Combretum micranthum* thicket, come within our definition of savanna).

2. Mixed Forest-Grassland Formations and Grassland Formations.

The latter is the subject of this Symposium. There are four primary subdivisions:

1. "Woodland", defined as open forest; tree stratum deciduous consisting of small or medium-sized trees with the crowns more or less touching, the canopy remaining light; grass stratum sometimes sparse or mixed with other herbaceous and suffrutescent vegetation.

2. "Savanna", defined as formations of grasses at least 80 cm high, forming a continuous layer dominating a lower stratum; usually burnt annually, leaves of grasses flat, basal and cauline; woody plants usually present. This is sub-divided into:

   (a) Savanna woodland, having trees and shrubs with light canopy;

   (b) Tree savanna with scattered trees and shrubs;

   (c) Shrub savanna;

   (d) Grass savanna, in which trees and shrubs are generally absent.

3. "Steppe", defined as open herbaceous vegetation sometimes with woody plants, usually not burnt, perennial grasses usually less than 80 cm high, widely spaced; leaves of grasses narrow, rolled or folded, mainly basal, annual plants very often abundant between the perennials. This is also subdivided into:

   (a) Tree and/or shrub steppe with trees (mostly small) present;

   (b) Dwarf shrub steppe;

   (c) Succulent steppe;

   (d) Grass and/or herb steppe in which trees and shrubs are virtually absent.

4. "Grassland", sub-divided into:

   (a) Aquatic grassland;

   (b) Herb swamp;

   (c) High montane grassland.

Following this meeting, Keay and other authors (1958) published "Vegetation Map of Africa South of the Tropic of Cancer" on behalf of L'Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale (A.E.T.F.A.T.) with the assistance of Unesco, which is the basis of the vegetation map given in Tree Planting Practices in African Savannas (Laurie, 1974). Altogether 35 types in 19 broad groups are recognised of which the following come within our definition of savanna:

A. 8. Forest - savanna mosaic

   9. Coastal forest - savanna mosaic

B. 10. Dry deciduous forest (with savanna): with
   abundant Baikiaea plurijuga

   11. Dry deciduous forest (with savanna):
   Madagascar types

C. 12. Thickets: Itigi types

   13. Thickets: Madagascar types

   14. Thickets: Ethiopian evergreen types

D. 16. Undifferentiated: relatively moist types

   17. Northern areas: with abundant Isoberlinia doka and I. tomentosa

   18. South-eastern areas: with abundant Brachystegia and
   Julbernardia

   19. South - western areas (principally on Kalahari sand): with
   abundant Brachystegia, Julbernardia, Cryptosepalum psuedotaxus, Guibourtia coleosperma and areas of steppe (type No. 24).

E. 20. Undifferentiated: relatively dry types

21. Ethiopian types

22. With abundant Colophospermum mopane

F. 23. Madagascar grass savanna and grass steppe

24. Grass steppe on Kalahari sand

G. 25. Wooded steppe with abundant Acacia and Commiphora

26. Grass steppe with thick clumps: western Uganda type

27. Grass steppe: Luanda type

I. 28. Karoo succulent steppe

J. 29. Subdesert steppe: Karoo shrub and grass

30. Subdesert steppe: transitional and mixed Karoo

31. Subdesert steppe: tropical types

To these may be added the following:

Montane grassland, Sub-tropical grassland and Oxytenanthera bamboo thickets.

A second edition of the A.E.T.F.A.T. map designed to incorporate the criticisms and revisions of the first edition is in preparation (White, in press). An interim report (White 1974) indicates that there are now 60 mapping units (as against 35 in the earlier edition). These have been reduced to 14 in the report, of which the following represent the savanna types:

6. Broadleaved woodland and wooded grassland;
7. Thorn (Acacia) woodland, wooded grassland and semidesert vegetation;
8. Karoo-Namib semidesert shrubland;
9. Grassland.

To this may be added:

Deciduous thicket.

EXTENT

Savanna vegetation occupies a vast area in Africa. According to Shantz and Marbut (1923), the comparative areas occupied by the three main types of vegetation are:

	Area (Square miles)	Area (Square kilometres)	Percentage
Forest	2 056 700	5 326 853	18.4
Grassland	4 736 400	12 267 276	42.3
Desert	4 406 900	11 413 871	39.3
Total land surface (without lakes and excluding Madagascar)	11 200 000	29 008 000	100.0

In West Africa, the savanna belt sweeps from Mauritania, Senegal and Gambia in the west through Mali, parts of northern Guinea, Ivory Coast, Ghana, Togo and Benin, Upper Volta, Niger, the northern four-fifths of Nigeria[1/], Chad and northern Cameroon, continues into the Sudan and through the greater part of the Eastern Horn (Ethiopia, Afars and Issas, Somalia and Socotra). It then wheels south to the three East African countries of Kenya, Uganda and Tanzania and thereafter turns to the west to Rwanda, Burundi, Zaire (surrounding the central forest block) and Gabon (15% of the surface area). Further south it fans out to Angola, Zambia, Malawi, Mozambique, Rhodesia, Botswana, Namibia and northern parts of South Africa. It occurs too in the territories of Lesotho and Swaziland as grassland, thorn savanna and mixed tree savanna. Much of the island of Madagascar is covered with grass savanna and grass, and thickets, perhaps as a result of severe degradation of the forest by cultivation and burning.

It is not possible, nor indeed is it desirable, in a paper of this length to describe in any detail all the savanna types in all countries in which they occur. But, perhaps as a suitable conclusion to this paper, the new classification adopted by Charter (1970) for Nigeria's savanna vegetation is shown in the table below against the well-established classification by Keay and other authors.

Table 1

Charter	Keay and Jones	Rosevear (1953) and other authors
Forest-savanna mosaic	Derived savanna	-
Mixed Leguminous wooded savanna		
a. with Afzelia africana	Southern Guinea savanna	Guinea savanna
b. with Isoberlinia doka and I. tomentosa	Northern Guinea savanna	Guinea savanna
c. with Burkea africana	-ditto-	-ditto-
d. with all the species above	-ditto-	-ditto-
Mixed Combretaceous woodlands with Combretum nigricans or Anogeisus leiocarpus	Sudan savanna	Sudan savanna
Mixed Acacia woodland with Acacia senegal	—	—
Undifferentiated wooded savanna	Sudan savanna	Sub-Sudan savanna of Clayton (1957) and other authors
Wooded tropical steppe	Sahel savanna	Sahel savanna
Plateau grass savanna (sub-montane grass savanna)	Montane vegetation	-

1/ The actual extent of the savanna in Nigeria is 86.4% of the land surface (Anon. 1974)

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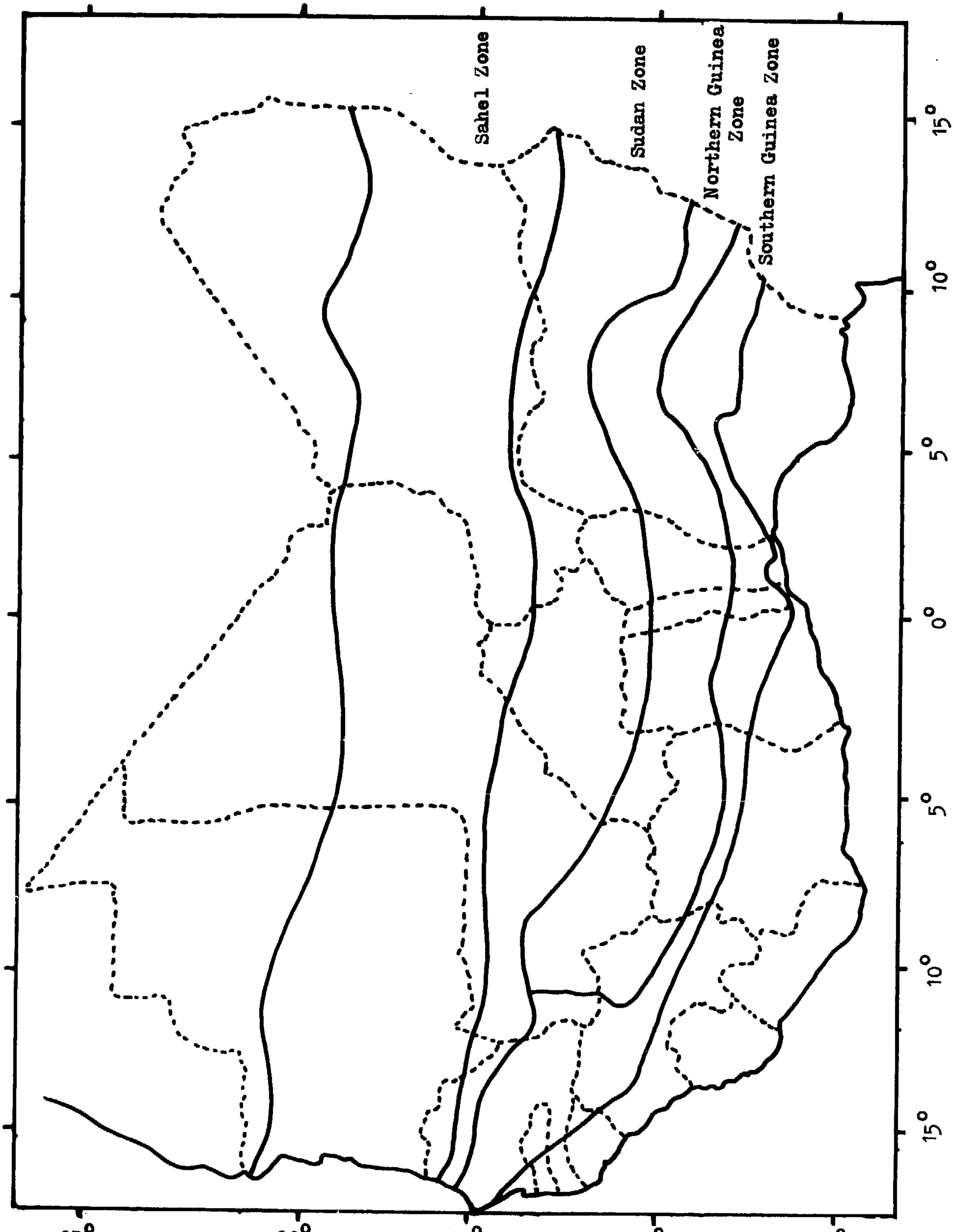
Figure 1 - MAP OF WEST AFRICAN VEGETATION ZONES [1/]



1/ For A.E.T.F.A.T. map, see Laurie (1974).

CLIMATE OF THE GUINEA AND SUDAN SAVANNAS OF WEST AFRICA[1/]

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

INTRODUCTION

The interaction of climatic, edaphic and biotic influences largely results in the distribution and characteristics of various vegetation types in West Africa as in other parts of the world. As a result of this, broad vegetation zones more or less coincide with climatic zones. Localized variation, often due to corresponding localized physical features, however, are sometimes found to occur within these broad zones.

As West Africa lies almost entirely within the tropics, the climate is often classified as tropical. In the tropics, climatic changes throughout the year are much more dependent on rainfall than on radiation, which shows only minor variations during the year; thus the year is divided into rainy and dry seasons.

GENERAL CAUSES OF THE WEST AFRICAN CLIMATE

Climate changes from place to place in West Africa as a result of the seasonal effect of three main factors: air masses, ocean currents and altitude. The most widespread features are the tropical continental and tropical (or equatorial) maritime air masses which alternate seasonally over the West African land mass.

The effect of the tropical continental air mass is more predominant from September to February. It spreads southwards from the Sahara to about 5°N latitude, causing the hot, dry weather which characterises most of West Africa during this time of year. It is often accompanied by the dry north-easterly wind known as harmattan.

The tropical maritime air mass is predominantly active over much of West Africa from March to August extending northwards to about 21°N latitude. Associated with it are the rain-bearing southwesterly winds.

These two air masses are separated by a zone known as the intertropical front (sometimes referred to as intertropical discontinuity or intertropical convergence zone). From March onwards, the position of the intertropical front moves northwards allowing tropical maritime air to penetrate far inland. From about September it moves southwards toward the equator and the drier continental air spreads southwards across the West African land mass.

This alternating northward and southward movement of the intertropical front is largely responsible for the orientation of the climatic and vegetation zones in an almost latitudinal pattern in West Africa.

Ocean currents largely contribute toward the dry weather conditions which partly result in the coastal savanna of eastern Ghana, Togo and the Republic of Benin (formerly Dahomey). Cool ocean currents of uncertain origin occur in the middle of the year off these coasts thereby cooling sea and air temperatures and restricting convection. In addition to the effects of the ocean currents, the relief features of the Guinea Highlands, Cape Three Points, the Mampong Scarp and the Akwapim-Togo Mountains cause the rain-bearing southwesterlies to lose their moisture on the highlands, so becoming dry westerlies.

Similarly, the occurrence of monsoonal and mountain grassland along the latitudinal belts of Guinea and Sudan savanna in Senegal and Guinea are due to the effects of the Fouta Djallon Mountains. The Jos Plateau has a similar effect on the occurrence of derived savanna vegetation on its southwestern slopes.

GENERAL CHARACTERISTICS OF WEST AFRICAN CLIMATE

Rainfall

In the tropics rainfall is the most vital element in the climate as the natural vegetation largely depends upon its quantity (and especially its effectiveness), its degree of certainty, its length and how it falls. Figures 1 and 2 show the general picture of the annual rainfall. The very heavy rainfall of the southwestern coast and the Cameroon Highlands is evident. The low rainfall of central Ivory Coast, eastern Ghana and Togo are also clear. Apart from these contrasting features along the West African coast, annual rainfall decreases regularly northwards from the coast, both in amount and duration. There is a south to north spread in the beginning of the rainy season and a corresponding north to south retreat at the end. For this reason the rainy season gets progressively shorter further north in the area.

The rainfall is extremely variable in amount, in time of onset and cessation as well as regime. This variability is greatest in the interior.

Temperature

Because of its situation in the tropics, there is the general belief, especially among non-Africans, that temperatures in West Africa are exceedingly high throughout the year. This is more often an exaggeration. The very high temperatures characteristic of many months in the lowland parts of similar latitudes in East Africa and India are attained in West Africa only in or near the desert for short periods of the year.

On the whole, average temperatures in West Africa are lower than the world average for similar latitudes in the northern hemisphere during winter, during the rains in the south and almost all year round in Senegal, the coastline of eastern Ghana and Togo, and in highland areas. On the other hand, temperatures are higher than the world average for similar latitudes in April, July and October.

A very common feature of the temperature conditions in West Africa is the diurnal and seasonal range of variation. There is a gradually increasing range from the Guinea coast northward and a sharper increase from the Senegal coast inland. The greatest ranges occur during the change of seasons.

Sunshine

Because West Africa is situated in the tropics, night and day lengths are almost always equal. For this reason sunshine seldom exceeds twelve hours. During the wet season, clouds and early morning mist often obscure the sunshine, while during the dry season, the sun is often obscured by dust - haze. As a result of this, the recorded sunshine is often reduced. Table 1 shows representative figures of mean daily sunshine in hours for Freetown (Sierra Leone) and Kumasi (Ghana).

Relative Humidity

High relative humidity is common in rainy areas and during the rainy seasons. During the dry season, relative humidity drops considerably. Table 2 shows mean percentage relative humidity in January and July for some places on the coast and in the interior.

CLIMATE OF THE GUINEA SAVANNA

The map on page 8 shows the vegetation zones of West Africa. The Guinea savanna lies roughly between latitudes 7° and 9°30'N and occurs to the north of the lowland rain forest except for the southern portions of Ghana, Togo and the Republic of Benin where it extends southward to the Atlantic coast. The southern and northern portions of this vegetation zone show some differences in structure and floristic composition which are consistent enough to subdivide it into southern and northern Guinea savanna. The climatic differences between the southern and northern portions of the Guinea savanna, however, are more a degree of severity of conditions rather than of kind.

Accra - Togo Dry Coastal Savanna

Some of the reasons for the occurrence of this type of vegetation in this area have already been mentioned.

The rainfall pattern for this southward extension of the Guinea savanna is similar to that of the lowland rain forest, but the monthly and yearly totals are low. The coastal fringe between Elmina and Grand Popo has an average annual rainfall of below 35 inches (875 mm). The number of rain days are few and there are only two or three months in the year with more than 4 inches (100 mm) of rainfall.

Relative humidity is only a little lower than in the rain forest zone. Temperatures are generally a little higher than in the rain forest zone except from July to September when they are much cooler for reasons already mentioned above.

Table 3 shows average monthly maximum and minimum temperatures and rainfall for Accra (Ghana) and Lomé (Togo).

Southern Guinea Savanna

This zone lies roughly between latitudes 7°30' and 9°N and extends from Nigeria to Guinea.

Temperatures are moderately high with a wide diurnal variation in the dry season which lasts about four to five months. Then follows a rainy season of about seven to eight months with lower temperatures and less variation.

Relative humidity varies between 50 and 80% but is generally below 70% at 9.00 a.m. during the dry season. Table 3 shows mean monthly maximum and minimum temperatures and rainfall for some principal towns within the zone.

In Nigeria, total annual rainfall in this belt ranges from about 40 to 50 inches (1 050-1 250 mm), with two peaks. The rainy season begins in early March and reaches its first peak in May. Rainfall then declines till July and increases again at about August to reach a second peak in September before declining sharply to an end in October/November. Because their timing varies from year to year, the peaks are often not evident from average figures (e.g. Table 3).

In Lokoja (Nigeria), mean maximum temperatures range from about 96°F (36°C) in February/March to about 85°F (29°C) during July to September, while mean minimum temperatures range from about 76°F (24°C) in February/March to about 66°F (19°C) in November to January. Corresponding figures for Mokwa (Nigeria) are: mean maximum temperatures 100°F (38°C) in February/March to 86°F (30°C) in July to September, while mean minimum temperatures vary from about 76°F (24°C) in March to about 60°F (16°C) in December and January.

At Mokwa, although mean daily relative humidity during the dry season ranges between 70 and 30%, humidity often drops sharply during the day to below 20% by early afternoon.

Northern Guinea Savanna

The northern Guinea savanna extends from about 9°30'N to about 11°N latitude in Nigeria, 12°N in Upper Volta and 13°N further west.

Maximum diurnal variation in temperature occurs in the dry season, with less variation during the wet season (see Table 3). At Afaka (near Kaduna, Nigeria), mean maximum temperatures range from about 100°F (38°C) during February to April to about 78°F (26°C) in July to August. Mean minimum temperatures range from about 74°F (23°C) in April to about 58°F (14°C) during November to January.

The rainfall pattern in this zone is generally of a single peak. Annual total rainfall in this zone ranges from about 40 to 55 inches (1 000 - 1 375 mm). The dry season lasts about 5 to 6 months (October/November to March) with a rainy season of six to seven months (April to October). The rains increase in frequency and amount from April, reaching a peak in August/September and then decline sharply to an end in October.

Mean relative humidity is in the range of 45 - 35% during the dry season months. Humidity figures of below 20% are common in early afternoon from November to January.

Jos Plateau

The Jos Plateau within the Guinea savanna is regarded as a highland varient of the northern Guinea savanna (Harrison Church, 1968) and, because of its altitude, temperatures are generally lower. Table 3 shows mean monthly maximum and minimum temperatures as well as rainfall for Jos (Nigeria).

The rainfall pattern on the plateau is similar to that of the northern Guinea, but at the southwestern edge of the plateau, annual rainfall is generally higher. Average annual rainfall for Miango (Jos Plateau) and Nimbia (southwest of the plateau) are about 55 inches (1 375 mm) and 70 inches (1 750 mm) respectively.

At Miango, diurnal variation of temperature is small compared to typical northern Guinea savanna. Mean maximum temperatures vary from about 94°F (33°C) during February to April to about 78°F (25°C) in July to September. Mean minimum temperatures are generally about 66°F (19°C) from March to May, dropping to about 56°F (13°C) during December and January.

Mean relative humidity is generally above 80% during the height of the rains from July to September and drops to below 30% during December to February.

CLIMATE OF THE SUDAN SAVANNA

This vegetation zone lies north of the northern Guinea savanna and extends between approximately 11° and 13°N latitude in its southern limit and between 12° and 14°N in its northern limit. It includes the southern interior of Senegal, interior Gambia, central Mali, most of Upper Volta and most of the extreme northern parts of Nigeria.

In comparison with the northern Guinea savanna, rainfall is less - about 22-40 inches (550 - 1 000 mm) annually. The rains fall for five to six months followed by a dry season of six to seven months. The rainfall is much more variable than in the northern Guinea savanna. Table 3 shows mean monthly temperatures and rainfall for some principal towns in the Sudan savanna.

Sokoto and Katsina in Nigeria have an average annual rainfall of about 29 inches (725 mm) each; Kano receives about 34 inches (850 mm). The rainy season starts in May, with the amount and frequency of the rains increasing steadily to a peak in August or September before declining rapidly to an end in October.

Mean maximum temperatures in both localities are about 102°F (39°C) in April and May. During this period, temperatures of 106°F (41°C) are often attained during the day. At the height of the rains during July to September, maximum temperatures average about 88°F (31°C). Mean maximum temperatures are lowest during the months of December and January averaging about 54°F (12°C) but often dropping below 50°F (10°C). Minimum temperatures rise to about 75°F (24°C) in April and May just before the onset of the rainy season and drop to about 70°F (21°C) at the peak of the rains.

SOME IMPLICATIONS OF CLIMATIC CONDITIONS FOR SAVANNA AFFORESTATION

The rains begin first in the southern portion and progress northward, while their cessation begins first in the north and progresses southward, resulting in the relative shortness of the rainy season in the north compared to the south.

North of about latitude 7°30'N, total annual precipitation becomes progressively less than annual evapotranspiration. This means that all areas above this latitude are deficient in moisture on an annual basis. This deficit increases with latitude. The difference between the commencement of the rains around Lokoja and Katsina is about three months and the length of the rainy season about 200 and 100 days respectively (Kowal and Knabe, 1972).

Forest plantation establishment in the northern savanna zones would therefore require more drought hardy species which can sufficiently establish themselves during the comparatively short rainy season to be able to survive the long dry season. It appears that the southern Guinea and possibly the southernmost parts of the northern Guinea savanna zones could support a greater number of plantation species than the Sudan and Sahel zones because of the comparatively less critical moisture conditions.

Irrespective of how favourable moisture and light conditions may be, plant growth ceases when the temperature of the environment either exceeds a certain maximum or falls below a certain minimum value. Between these maximum and minimum values, there is usually an optimum range. It is important to distinguish between air and soil temperatures in considering the effect of temperature on plant growth. Equally important is the fact that plants differ in their adaptation to ranges of temperature regimes.

While many annual and biennial agricultural crops have been classified into cold season and hot season crops on the basis of their adaptability to different temperatures (Kowal and Knabe, 1972), there has not been any such classification for forest trees.

Unsuitability of air or soil temperatures during the whole or part of the growing season may be a decisive factor in the success or failure of exotic or indigenous species as plantation candidates in the savanna zones of West Africa. Air temperature conditions have never been found too drastic to limit plant growth in the savanna areas.

Table 4 shows mean monthly soil temperatures at three principal towns in the savanna zones of Nigeria. Too high soil temperatures may inhibit proper root development and growth. Consistently high soil temperatures at places such as Mokwa may militate against successful development of mycorrhizae for good growth of pines in spite of its low latitude and annual rainfall compared to places like Afaka.

Other factors of the environment such as daylength and sunshine and values of potential photosynthesis computed from them have been estimated to be adequate for plant growth in the savanna zones. Successful afforestation in the savanna zones of West Africa, therefore, will depend on the proper selection of plantation species which are sufficiently adapted to utilize the very limited soil moisture (and sometimes the very low levels of nutrients) for maximum dry matter production under the prevailing environmental conditions.

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Figure 1: GENERAL CHARACTERISTICS OF THE CLIMATE OF WEST AFRICA

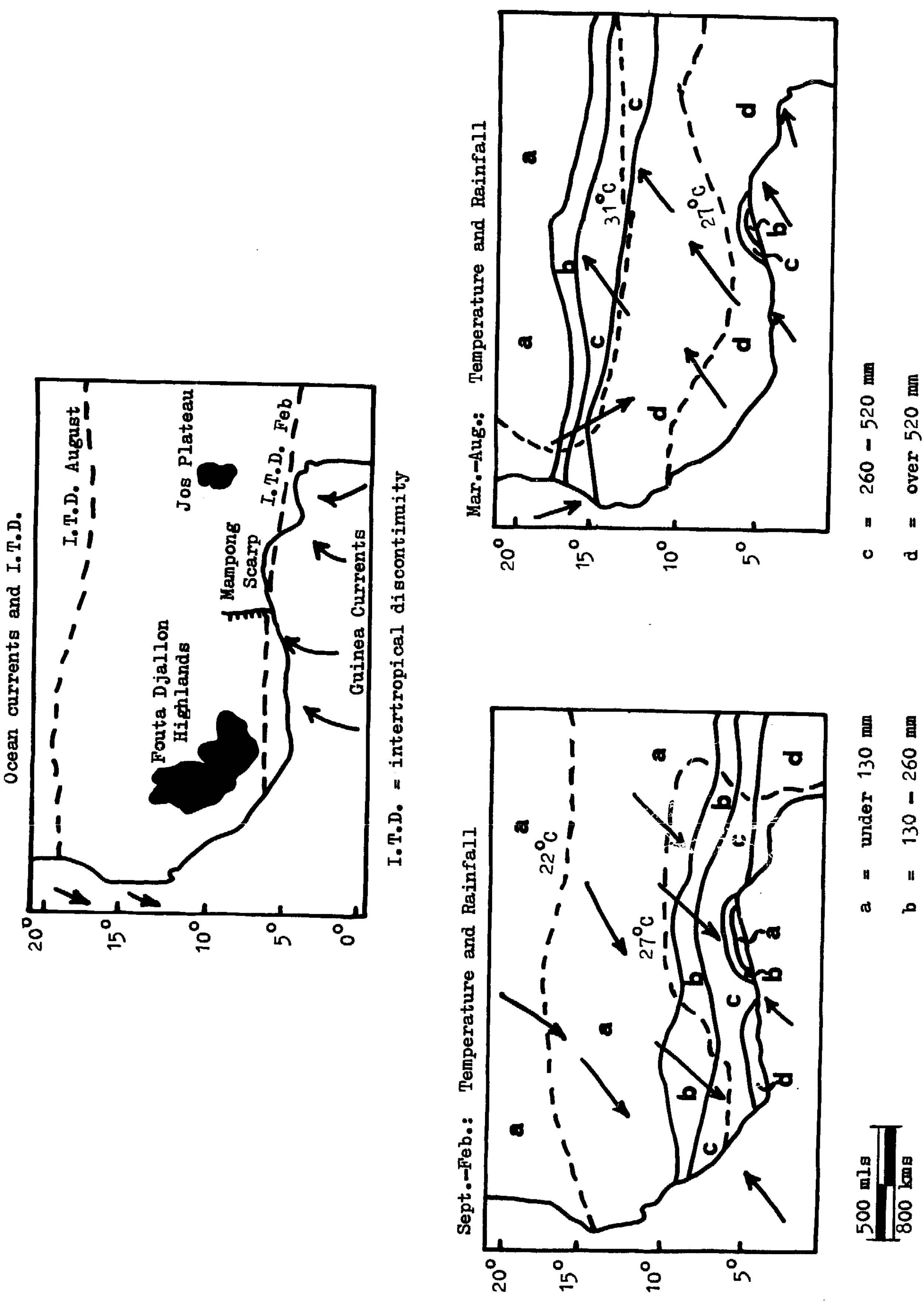
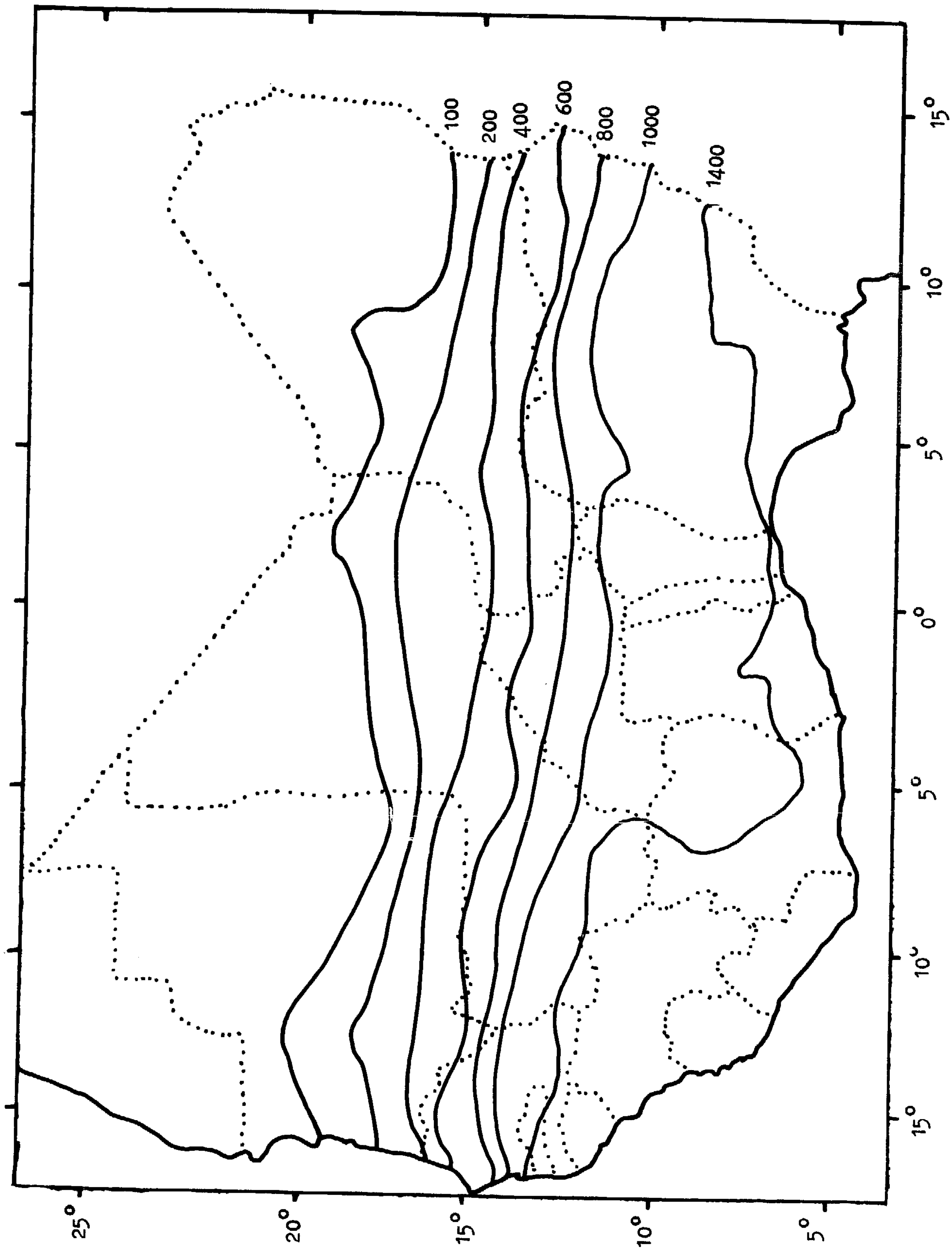


Figure 2 - MAP OF ANNUAL RAINFALL (MILLIMETRES) IN WEST AFRICA 1/



1/ For greater detail and other regions, see map in Laurie (1974).

TABLE 1

MEAN DAILY SUNSHINE (HOURS) FOR FREETOWN (SIERRA LEONE) AND KUMASI (GHANA)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Mean
Freetown (Average 1941-50)												
8.1	8.2	7.7	7.0	6.3	5.3	2.8	2.2	4.0	6.2	6.6	7.0	5.9
% maximum possible												
69	69	64	57	50	42	22	16	33	52	56	60	49
Kumasi (6° 43'N, 1° 37'W) Average of 9 years												
3.9	4.3	4.8	5.0	3.7	2.0	1.1	0.9	2.3	3.9	4.6	3.9	3.4

TABLE 2

MEAN RELATIVE HUMIDITY (%) IN JANUARY AND JULY IN WEST AFRICA

	January		July	
	a.m.	p.m.	a.m.	p.m.
Monsoon and Guinea Coasts				
Conakry (9° 31'N, 13° 43'W)	85	71	92	85
Accra (5°31'N, 0° 12'W)	82	84	85	85
Port-Novo (6° 30'N, 2° 37'W)	90	77	89	85
Interior				
Timbuktu (16° 47'N, 3° W)	39	29	68	46
Bamako (12° 39'N, 7° 58'W)	50	27	89	71
Beyla (8° 41'N, 8° 39'W)	68	31	94	84
Natitingou (10° 16'N, 1° 23'E)	43	22	81	75

TABLE 3

MAXIMUM AND MINIMUM TEMPERATURES AND RAINFALL IN WEST AFRICAN SAVANNA

Location	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Mean Max & Min Temp (°F)	Tot. Ann. Rain (inches)
Accra-Togo Dry Coastal Savanna														
Accra (Ghana): 20 ft 5°31'N, 0°12'W														
T 39 max	87.9	87.9	88.3	88.0	86.7	84.1	82.7	80.8	82.4	84.9	87.1	87.5	85.6	
T 29 min	73.6	74.9	75.6	75.6	74.6	73.5	72.5	71.4	72.3	73.3	74.2	74.2	73.8	
R 47 avg	0.7	1.5	2.2	3.0	5.0	7.5	2.0	0.6	1.5	2.3	1.4	1.0		28.6
Lomé (Togo): 34 ft 6°08'N, 1°13'E														
T 5 max	85.1	86.7	87.9	86.2	85.5	82.8	79.7	78.8	80.2	83.3	85.5	85.3	83.8	
T 5 min	72.2	73.9	74.3	73.9	73.9	72.7	71.4	70.9	71.6	72.1	72.5	71.8	72.5	
R 15 avg	0.6	0.9	1.8	4.6	5.7	8.8	2.8	0.3	1.4	2.4	1.1	0.4		30.8
Southern Guinea Savanna														
Tamale (Ghana): 637 ft 9°24'N, 0°53'W														
T 34 max	96.3	100.3	101.1	98.3	94.2	90.2	87.1	86.1	87.5	91.8	95.3	93.2	93.5	
T 34 min	66.4	70.4	74.0	73.8	72.7	70.8	70.9	69.8	69.7	70.5	69.6	69.5	70.7	
R 38 avg	0.1	0.3	2.2	3.2	4.7	5.5	5.5	8.1	8.9	3.7	0.7	0.2		42.9
Bida (Nigeria): 605 ft 9°04'N, 5°59'E														
T 5 max	93.8	97.0	98.3	98.1	93.3	88.0	85.7	84.3	86.1	89.8	94.6	94.0	92.0	
T 5 min	70.0	73.4	76.0	77.3	74.2	72.7	72.1	71.8	71.5	71.6	71.1	68.5	72.5	
R 25 avg	0.1	0.3	1.0	3.0	6.0	7.7	7.6	8.4	10.2	3.8	0.3	0		48.5
Northern Guinea Savanna														
Kouroussa (Guinea): 1 247 ft 10°39'N, 9°53'W														
T 5 max	92.4	96.5	99.0	98.8	94.3	89.1	86.2	85.1	86.8	89.5	91.2	90.8	91.6	
T 5 min	56.8	62.8	71.0	73.4	73.1	70.8	69.6	69.6	69.5	69.1	66.0	58.0	67.3	
R 10 avg	0.4	0.3	0.9	2.8	5.3	9.7	11.7	13.6	13.4	6.6	1.3	0.4		66.3
Bobo Dioulasso (Upper-Volta): 1 421 ft 11°12'N, 4°17'W														
T 5 max	93.6	98.0	100.8	100.8	96.3	91.2	87.0	85.5	87.8	93.0	95.2	94.6	93.6	
T 5 min	60.3	62.1	69.5	72.2	70.6	71.0	69.6	69.3	68.8	69.3	66.8	62.0	67.6	
R 10 avg	0.1	0.2	1.1	2.1	4.0	4.8	9.8	12.0	8.5	2.5	0.7	0		46.4
Jos Plateau														
Jos (Nigeria): 4 230 ft 9°52'N, 8°54'E														
T 5 max	82	85.6	87.2	88.5	85.0	80.9	76.4	74.9	78.6	82.2	83.4	82.4	82.2	
T 5 min	57.0	59.3	64.1	66.3	65.4	63.4	62.7	62.3	62.2	62.2	60.3	57.2	61.9	
R 31 avg	0.1	0.1	1.1	3.4	8.0	8.9	13.0	11.5	8.4	1.6	0.1	0.1		56.3
Sudan Savanna														
Tambacounda (Senegal): 187 ft 13°46'N, 13°11'W														
T 5 max	94.8	99.0	102.8	105.8	103.3	97.0	90.0	87.3	88.8	90.0	95.2	93.0	95.7	
T 5 min	58.8	61.0	67.1	70.2	75.6	73.6	71.5	71.5	72.2	71.5	63.4	59.4	67.9	
R 10 avg	0	0	0	0.1	1.1	6.9	7.6	12.0	8.5	3.2	0.1	0		39.6
Bamako (Mali): 1 076 ft 12°39'N, 7°58'W														
T 5 max	92.0	96.8	101.4	103.8	100.8	94.3	87.6	85.6	88.2	92.0	94.0	91.0	94.0	
T 5 min	63.0	67.0	73.6	76.6	77.8	74.2	72.0	71.1	71.3	71.6	67.0	63.8	70.8	
R 10 avg	0	0	0.1	0.6	2.9	5.3	11.0	13.7	8.1	1.7	0.6	0		44.0
Ouagadougou (Upper-Volta): 991 ft 12°22'N, 1°31'W														
T 5 max	97.0	101.6	106.0	107.0	102.6	97.4	92.6	89.3	92.4	100.1	101.8	97.6	98.7	
T 5 min	57.6	61.0	69.6	75.8	76.8	73.6	71.8	70.4	70.0	71.6	66.2	59.6	68.7	
R 10 avg	0	0	0.1	0.3	2.7	4.5	8.0	12.4	5.1	0.5	0	0		33.6
Kano (Nigeria): 1 549 ft 12°02'N, 8°32'E														
T 5 max	85.6	89.9	95.7	100.8	99.3	94.5	87.2	85.1	88.0	93.5	92.5	87.1	91.6	
T 5 min	56.1	59.5	65.9	72.4	74.6	73.9	71.1	69.6	69.4	68.1	61.6	56.9	66.6	
R 48 avg	0	0	0.1	0.3	2.7	4.5	8.0	12.4	5.1	0.5	0	0		33.6

Note: The numbers after T and R indicate the number of years from which temperature (T) and rainfall (R) values were calculated.

TABLE 4

MEAN MONTHLY SOIL TEMPERATURE (^{o}F)
IN THE SAVANNA ZONES OF NIGERIA

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Monthly mean earth temperature at 1 ft												
Mokwa	83.4	88.2	94.0	93.5	90.5	86.3	83.9	82.7	82.9	84.5	85.9	84.3
Samaru	74.7	78.3	84.2	86.8	85.5	81.9	79.6	78.1	79.2	80.2	77.4	75.1
Gusau	76.1	81.8	86.9	89.6	89.4	85.1	81.2	80.3	81.5	82.4	80.7	78.4
Monthly mean earth temperature at 4 ft												
Mokwa	84.7	86.5	90.7	92.6	91.0	88.6	86.2	84.6	84.2	84.7	85.7	85.4
Samaru	77.9	78.8	82.0	84.9	85.4	83.6	81.8	80.2	80.3	81.2	80.4	78.6
Gusau	81.0	82.6	85.5	88.6	89.5	88.4	85.1	83.2	83.1	83.7	83.8	82.8

SOILS OF THE GUINEA AND SUDAN SAVANNAS OF WEST AFRICA[1/]

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

INTRODUCTION

The term West Africa is commonly used in referring to countries laying east of and along the Atlantic coast of continental Africa. In this paper West Africa will include (Pugh and Perry, 1960) Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Mali, Niger, Upper Volta and Nigeria. These countries lie between the latitude 5°N and the Tropic of Cancer and cover about 2 200 miles from east to west and 1 200 miles from north to south with a total area of 2 333 041 square miles. The 10-inch isohyet where the density of population is about 2 persons per square mile is more or less the northern boundary of the Sudan zone and of West Africa.

CLIMATE1/

Climate is a very strong and active factor affecting soil formation as well as plant growth in West Africa. Its effect on the soil is shown directly in rock weathering, leaching of bases, soil development and indirectly by its influence on the nature of vegetation.

Rainfall distribution in West Africa is fairly constant. Rains are caused by two main movements of air masses - a dry continental air mass to the north and a moist body of tropical maritime air to the south.

The latter brings rain which produces the wet and dry seasons, whilst the former brings in the cold, dry air from the north which is called harmattan. North of latitude 8° or 9°N there is only a single wet season with a single peak and followed by a long dry season. South of this latitude there are two distinct rainy seasons with double peaks, namely April-July and October-November.

In the savanna areas, average annual rainfall is generally less than 1 150 mm; the range would be from 510 mm to 1 150 mm. Potential evapotranspiration ranges from 1 270 mm to 1 520 mm (50 to 60 inches) a year (Ahn, 1970). This creates a general deficit of soil moisture throughout the zone. The findings at Afaka Forest Reserve (Samie, 1973) showed that the 1 360 mm (54 inches) of rainfall in 1969 provided an ample supply of available soil moisture to grow plantation trees in this area. It was also reported that regions with less than 380 mm of rainfall are unlikely to support natural forests (USDA, 1938) and areas with less than 760 mm do not readily allow economic production of timber. Heavy and concentrated rainfall effects leaching of weathered materials in the profile. The amount of rain infiltrating into the soil depends upon its intensity, vegetation cover, slope of land, soil moisture content, soil texture and compactness and time of day. Less rainfall and sparse vegetation with warm temperatures allow less percolation in the soils of the northern parts of the savannas than in the high rainfall, high forest belt of the southern parts of West Africa. Slow and even rainfall permits the water to penetrate into the soil, whereas a sudden downpour creates runoff and also causes soil erosion. Due to this difference in amount of rainfall between the northern and the southern parts of West Africa, (see Rainfall map, page 16). leaching also varies, being great where the rainfall is heavy so that the tendency of the soil reaction would be slightly alkaline to neutral in the northern part and acidic toward the southern part (Ahn, 1970).

GEOLOGY

West African geology consists mainly of three known classes of rock formations. The first two are crystalline rocks, or igneous (granite) and metamorphic (gneiss and quartzites), which are the oldest (pre-Cambrian) (see Map 1) and together these are commonly called rocks of the Basement Complex. Less extensive are the younger sedimentary rocks which cover most

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1/ A more detailed discussion on climate is presented in the preceding paper by M.A. Ogigirigi.

of the Niger River valley and western parts of Senegal and Guinea. The very much older sedimentary rocks (sandstones) are found mainly in the Northern areas of the Ivory Coast and Guinea. Most of these sedimentary rocks also rest on the Basement Complex sometimes at very great depths. Some of the old rocks weathered very slowly or were resistant to erosion with the result that they form the upland features of the Guinea Highlands, the Atakora Ranges, the Jos Plateau, the Fouta Djallon and the Adamawa Highlands. Most rocks on the Basement Complex are less resistant to erosion and subsequently levelled the lands almost to wide plains, known by some authors as peneplains. Widely scattered over the peneplains are isolated hills in the form of domes made up mainly of granite. They are commonly bare or covered by very thin soils or gravels and stones and are known as insolbergs. Rocks of the Basement Complex produce poor soils as the minerals composing them are very resistant to weathering and contain very low reserves of weatherable minerals. Upon cropping, the soil fertility is soon depleted. Through traditional experience the farmers have learned that in order to produce good crops it is better to abandon the farms for a while and settle in another virgin area. Five or more years later when native vegetation has been re-established in the abandoned area, farmers will clear and farm again. This is the basis of what is known as "shifting cultivation".

Volcanic rocks are located in the area around Mambilla, south of Potiskum, on the Jos Plateau and to a small extent in Senegal. Soils formed from this rock are generally much more fertile than those from the Basement Complex, as the content of weatherable minerals is high.

SOILS, GENERAL

The depth of soil that can be formed depends upon the factors affecting soil formation. The texture as well as the fertility of a soil depends principally upon the factors affecting rock weathering.

The breaking of rocks into fine particles is accomplished by either a mechanical or chemical process, or by both. Where temperature is high and rainfall is low as in the northern parts of West Africa, rock weathering is mainly by mechanical means and thus produces coarse textured soils which are usually of low fertility. But towards the southern parts, rainfall becomes progressively greater and rock weathering gradually changes to chemical means producing fine textured soils. The rock minerals change into more soluble forms thus producing more fertile soils. In the drier areas, the savanna vegetation (grass and trees) dominates, but in the much wetter areas, high forest becomes dominant. In general, the volume of vegetation in savanna areas is less than that in the forest areas (Ahn, 1970). Trees tend to extract nutrients from the soils at much greater depths than grasses. Due to seasonal burning in the savannas, large amounts of organic matter and soil nutrients are lost. Burning is not frequent in high forest areas and the nutrients in the top soils are greater than in savanna soils. From 15 cm and deeper the amount of nutrients in the horizons is practically the same for both savanna and high forest soils.

SOIL CHEMICAL PROPERTIES

The chemical aspects of West African savanna soils were discussed in detail by Nye and Greenland (1960), Ahn (1970) and Jones (1973). The following discussions will be limited to the chemical characteristics of the soil that were found to influence the establishment and growth of exotic tree species.

Organic Matter and Nitrogen

Many West African savanna soils are low in organic matter and nitrogen. This is caused primarily by the effects of environmental factors and human interference on vegetative growth. Usually in undisturbed soils, the level of organic matter builds up to a limit governed by the type and production of vegetative materials.

Table 1 shows amounts of soil carbon and nitrogen for some sites in the savanna areas of West Africa. At Yambawa in Sudan savanna, for example, the average contents of carbon and nitrogen were 0.22 and 0.022 percent, respectively; whereas corresponding mean values of 0.98 and 0.058 percent were recorded at Afaka in the northern Guinea savanna. A striking feature of organic matter and nitrogen in savanna soils is the similarity in their distribution to vegetation patterns. This is basically so, as the vegetation serves as a medium through which other factors that influence organic matter level express themselves.

TABLE 1

CARBON AND NITROGEN CONTENTS OF SOME SURFACE WEST AFRICAN SAVANNA SOILS

Site	Rainfall (mm)	No. Samples	pH	%C	%N	C/N
Ghana 1/	1 143	9	6.0	0.44	0.034	12.9
Ivory Coast 1/	1 780	5	4.6	1.15	0.063	18.3
Upper Niger	381	10	6.2	0.23	0.022	10.5
Afaka, Nigeria	1 245	24	5.9	0.98	0.58	16.8
Mokwa, Nigeria	1 118	19	6.3	0.88	0.060	14.6
Yambawa, Nigeria	762	5	5.9	0.22	0.022	10.0
Hadejia, Nigeria	610	3	6.0	0.23	0.021	10.9

1/ Data quoted by Nye and Greenland (1960).

Jones (1973) has shown that the two major factors governing the amount of carbon and nitrogen in well drained West African savanna soils are clay content and a moisture factor measured by the length of the wet season. Recently, Kadeba (1975) showed strong significant correlation between organic matter and mean annual rainfall for some sites in the savanna zone for Nigeria. The effect of latitudinal position on organic matter level was also demonstrated. There was a decrease of 0.40 and 0.03 percent, respectively, in soil carbon and nitrogen contents per degree latitude to the north. Not only does quantity of organic matter in the soil vary with environmental conditions, but also the quality. Work done on savanna soils showed the C/N ratio decreases with decreasing rainfall, in keeping with the findings that the degree of humification of organic matter increases with dryness of climate (Duchaufour and Dommergues, 1963; Jones, 1973).

Burning, cultivation and grazing are common features of peasant agriculture in West Africa. The degrading effects of these practices on soil organic matter and nitrogen have been demonstrated (Jenkins, 1964; Moore, 1960; Nye and Greenland, 1960; Jones, 1971; Jones 1973). The suppression of nitrogen mineralization by annual early burning was documented in a study at Afaka in northern Guinea savanna (Kadeba, 1973).

Available data provide evidence of the influence of soil parent material on soil organic matter. This is expected, in as much as parent material determines soil texture. In a region of predominantly sandy soils, the influence of clay on soil fertility and hence on vegetative growth could be considerable.

Phosphorus

Phosphorus is one of the primary elements limiting the growth of forest trees in savanna areas of West Africa. Most savanna soils have less than 100 ppm total P. Little concentration of phosphorus occurs through vegetative cycling and spectacular responses to applied P have been observed in several areas (Nye and Greenland, 1960).

The data of Ipinmidun (1973) shown below provide information on the levels of total and organic P that could be met on some sites in the Nigerian savanna region.

Location	Soil Category	Organic P (ppm)	Total P (ppm)
Azare	Juvenile soil on aeolian sand	10.6	37.6
Mokwa	Undifferentiated ferrisol and lithosol	25.3	73.6
Ochanja	Ferrallitic	39.8	82.2

Many West African studies have shown that values of organic P constitutes a significant propotion of total P (Omotosho, 1971; Acquaye, 1963; Friend and Birch, 1960). It has also been suggested that input from organic P through mineralization to available P could be comparatively large in these highly weathered soils.

The deficiency of P in savanna soils is often attributed to the occurrence of relatively large amounts of free Fe and Al oxides that lead to strong P adsorption. This may be true in certain instances as in volcanic soils. Most tropical soils possess oxides that are highly crystalline, of low surface area and hence they fix small amounts of applied P. Low addition of P fertilizers will maintain satisfactory P concentration in the soil solution. Residual effects of phosphate gave significant correlation with crop yield on such soils in a field experiment in Samaru (Ipinmidun, 1973).

In ferruginous and other soils of West Africa, the amounts of 'active' oxides and their participation in phosphate sorption may depend on the organic matter content of the soil and hence the depth of sampling. Juo and Maduakor (1974) found that a surface and subsurface Funtua soil in the Guinea savanna, required 96 and 456 kg/ha of P respectively to maintain an equilibrium soil solution of 0.2 ppm P.

Exchangeable Nutrients and CEC

The most important parameter determining the cation exchange capacity (CEC) of savanna surface soils is the soil organic matter content. In the Guinea savanna, it has been estimated that between 60 and 85 percent of the cation exchange surface is provided by the organic matter (Kadeba and Benjaminsen, 1975); the CEC of organic matter was calculated as lying between 282 to 322 mE_q/100g. In the subsoil it is the mineral fraction of the soil that makes significant contribution to the CEC. In keeping with the kaolinitic nature of the clay as well as the low organic matter level, the CEC of the soils are generally low, often less than 10 mE_q/100g.

The levels of the exchangeable cations are determined primarily by the kind of soil parent material. Soils derived from Basement Complex contained between 0.35 and 3.99 percent total K compared with 0.06 and 0.11 percent total K for soils derived from sandstone (Wild, 1971). Except in sandy soils, cation deficiency is not a serious problem under the non-intensive farming conditions which prevail over most of the savanna region of West Africa. Moreover, because of the low CEC, the percentage saturation of the exchange complex by the individual cations is relatively high and this might be a favourable factor in their availability.

Micronutrients

There is limited evidence of the effects of micronutrients on growth of exotic tree species in the savanna zone of West Africa. In Nigeria, the die-back of eucalypts has been associated with boron deficiency. At Samaru, hot-water-soluble boron, which is used as an index of availability, ranges from 0.03 to 0.13 ppm with a mean value of 0.076 ppm. There is evidence that sulphur and molybdenum levels are often marginal for groundnuts.

SOIL CLASSIFICATION

As a consequence of the different factors of weathering and soil formation, a large number of different types of soil were produced. To study these different kinds of soil individually is impossible and it is, therefore, necessary to classify them into units - each unit with soils of similar characteristics. A system of broad classification of soils was developed by Pugh and Perry (1960) in which the soils in West Africa were classed into four groups as follows:

Northern sandy soils. These generally cover the Sahel and part of the Sudan zones. Vegetation is mainly grass with a few low trees. The area is used mainly for pasture. The sandy materials are usually blown by wind during the dry season.

Zone of lateritic soils. The soils in most of this area are poor and clearing of new lands often exposes the soil to laterite formations thus extending the areas of poor soil. Soil erosion is also common and fertilizers are needed to produce economical crops.

Equatorial forest soils. High forests are found in this zone of high rainfall and humidity. Soil is less eroded and is highly desirable for agriculture. This formation is found in the lower parts of the Guinea zone.

Coastal swamp soils. The soils in this class are mostly mud and sand mixed with organic matter and are usually saturated with brackish water. Vegetation is mostly mangrove. When properly washed and drained, the soil can be used for farming.

Another more precise and technical classification was prepared by D'Hoore (1964). A similar soil classification was also prepared by Unesco and FAO, but in as much as the soil map published in FAO Forestry Development Paper No. 19 (FAO, 1974) is the one based on D'Hoore, the authors decided to use this and to describe the soil units based on D'Hoore's report on the Explanatory Monograph No. 93 dated 1964. In this system, the different soil units were classified into main groups according to their developing genetic criteria.

The soil map presented in this paper is a reproduction of that published in FAO Forestry Development Paper No. 19. Only soil units covering the Sudan and Guinea zones of West Africa are included in the following discussions. The soil units numbered in figures, correspond to those in the legend on the soil map.

Raw Mineral Soils

The term "soil" may scarcely be applied under this group. The environmental conditions encountered here are so unfavourable to biological activities that living processes and the pedogenesis they promote are lacking almost completely. These are "pre-soils", or soils near zero time in soil formation. The raw mineral "soils" are of particular importance because of the enormous surface they cover, specially in the northern parts of West Africa.

1. Desert Soils, Undifferentiated

Definition. This includes all loose materials, mostly sandy and submitted to desert conditions. Associated with this are also desert pavements that are transported and some halomorphic soils, which are not differentiated.

Distribution. Found mainly in the Sahel or north of the Sudan zone of West Africa.

Value for forestry. At present these soils do not have much value for forestry. However, with irrigation they can be made to support some species of trees intended for fuel or posts. The soil needs application of abundant organic matter to increase water holding capacity.

Weakly Developed Soils

Soils in this group are classified with the order entisols (USDA 7th Approximation, except for the sub-desert soils that belong to aridisols). These soils have a low level of profile development reflected in a very weak differentiation of horizons. Factors contributing to their poor development are:

a) Parent materials low in alterable or transferable minerals and

b) Erosion processes that remove loose superficial layers as soon as they are formed, either due to strong relief, intense winds or rainfall, or by all of the these factors.

6. Skeletal Soils, Mostly Rock Debris with Pockets of Soils

Definition. Soils with very weak differentiation of genetic horizon, containing coarse elements and having solid rock within a depth of 30 cm.

Distribution. Found mainly in the high-lands as well as widely distributed among other soil units, especially within the ferruginous tropical soils.

Value for forestry. Generally low. This soil requires erosion control measures, such as **contour trenching,** planting on the contour and application of fertilizers, to raise the level of fertility. This soil can be used for reforestation of shallow rooted trees or trees whose roots can penetrate the plinthite layer.

7. Weakly Developed Soils on Young Allevium, Often Halomorphic or Hydromorphic

Definition. Deposition is still proceeding intermittently in these soils and they are characterized by a great heterogeneity. They differ not only from one spot to another but also after a flood, as reflected by the stratifications in the profile. Moreover, the age of the deposits is not the same throughout. It is mapped as complexes.

In the most recently deposited soils, humic horizons are often lacking whereas the gley horizon is barely discernible, but on older formations covered by vegetation there are humic horizons, showing structural development and a gley horizon becomes perceptible.

Distribution. This soil unit although not very extensive, is well distributed. It may be found under every climate near bodies of water which fluctuate periodically.

Value for forestry. The forestry potential is influenced largely by the composition of the sediments and the type of climate. Alluvial plains often comprise the soils with the highest potential for planting. It is seldom that these favoured soils make up all of the alluvial deposits. Hence detailed soil mapping prior to reclamation is always useful. Areas with deep and moderate textured soils, however, will support good growth of trees - provided there is sufficient moisture available.

13. Lithomorphic Soils with Dark Non-Kaolinitic Clays, Developed on Calcareous and Basic Igneous Rocks, but as a Rule not in the Humid Areas

Definition. These lithosols on a calcareous crust may still be forming and are a product of present day soil formation. They are found on loose sediments, generally in association with brown soils of arid and semi-arid tropical regions and in areas with flat or slightly undulating relief. A thin layer of brown to red aeolian sand overlays a calcareous crust of variable thickness. The pH is neutral to slightly alkaline. In the clay fraction illite and montmorillonite are the dominant minerals. Of course, these soils may be considered lithosols only in so far as the loose overlying layer is sufficiently thin (30 cm).

Distribution. This formation is limited to the relatively arid regions situated near the border of the desert or in the northern part of Senegal. In North Africa its presence seems linked to calcareous bedrock.

Value for forestry. These soils have a certain potential for forestry. In North Africa they often carry vineyards and also may be used for extensive grazing. Their use for forestry may be a problem due to insufficient rainfall in the area. Irrigation may help.

Brown and Reddish-Brown Soils of Arid and Semi-Arid Regions

The brown or reddish soils are darkened by organic matter in the greater part of the profile under steppe vegetation, are without an A_2 horizon, but have a textural structural or colour B horizon. The reserve of weatherable minerals in the soils is often considerable but this depends on the composition of the parent material. Ordinarily they contain appreciable quantities of clay minerals with 2:1 lattice. The cation exchange capacity of the mineral complex, which is medium to high, is more than 50 percent saturated in horizons B and C and often contains free carbonates. These soils are situated between the desert areas and the equatorial region.

12. Brown Soils of the Arid and Semi-arid Tropical Regions, Generally with Highly Saturated Non-Kaolinitic Clay Complex

Definition. These soils are formed under a hot dry climate where annual rainfall rarely exceeds 500 mm. They are often formed on aeolian deposits where the climate is rather more humid and the parent rock rich in bases. Impeded external drainage seems to favour their development.

Although the total organic matter content is low (less than 1%) it is well distributed throughout the profile. The French classification subdivides the group "sols bruns subairdes" into two subgroups: the brown soils proper and the red brown soils. The latter differ from the former in that they are generally developed on sandy parent materials, have a greater thickness, generally do not contain any free carbonate, are lower in organic matter and are neutral to weakly acid. It is necessary to bring in climatic variations and chronological successions to explain their present co-existence.

Distribution. Parent materials are not only of aeolian sand deposits that border the desert regions but also weathered sandstones or paleopedological mantle material as well.

Value for forestry. Generally, these soils are not suitable for forestry due to low rainfall, but under irrigation they may be able to produce early maturing trees. Cultivation tends to deteriorate the good structure and permeability of the soil. Addition of organic matter should be maintained but excessive irrigation should be avoided as this could induce more destruction of the structure and cause the soil to become compacted.

Vertisols and Similar Soils

Vertisols are important in view of the possibilities for agriculture. African vertisols have all of the morphological characteristics of true vertisols but the clay fraction is rather lower in expandable minerals and consists more of amorphous gels, than those defined under the U.S.D.A. 7th Approximation.

Vertisols are subdivided into (1) lithomorphic vertisols and (2) vertisols of topographic depressions. Each subdivision is related to distinct geomorphological features that can be mapped readily and correspond respectively to the usterts and aquerts of the USDA 7th Approximation.

14. Soils with Dark Non-Kaolinitic Clays Confined to Topographic Depressions: Occurring in Semi-Arid Areas with a Marked Seasonal Distribution of Rainfall

Definition. These soils are found in topographic depressions with poor external and internal drainage. They seem to develop under climates where potential evaporation is high during part of the year and on parent materials (often sediments) of enriched insoluble constituents derived directly or indirectly from surrounding higher land. Accordingly, they are more commonly associated with soils having sodic, calcic or gypsic horizons than are the vertisols of lithomorphic origin. The reserve of weatherable minerals is often high. The clay fraction usually consists mainly of 2:1 lattice clays, especially the montmorillonite and mixed layer clay minerals. The cation exchange capacity of the complex is high and is generally more than 50 percent saturated, mostly with bivalent cations (normal ammonium acetate at pH 7).

Distribution. These soils are found only in areas under conditions of relatively well marked seasonal drought: three months of dry season and a mean annual rainfall of 1 000 mm or less. The Sudan depressions are probably the largest expanse of these soils in the world.

Value of forestry. Their topographic situation frequently associates them with calcimorphic or halomorphic formations and impedes drainage and desalinization. After drainage, these soils may be used to grow trees with high water requirements like *Eucalyptus robusta*. In the Sudan zone trees like *Acacia nilotica*, *A. seyal*, *A. albida* and *A. Senegal* may be tried.

Ferruginous Tropical Soils (Fersiallitic Soils)

These are soils with an ABC profile; some have an A2 horizon and a textural B horizon showing uniform or a weakly prismatic structure. There is a frequently observed marked separation of free iron oxides, which may either be leached out of the profile or precipitated within the profile in the form of nodules or concretions. The reserve of weatherable minerals is appreciable. The silt/clay ratio is generally above 0.15. The clay is mostly kaolinitic but often contains small amounts of 2:1 lattice clays. Gibbsite is generally absent. The SiO_2/Al_2O_3 ratio is near 2 or slightly higher, while the SiO_2/R_2O_3 ratio is always below 2. The cation exchange capacity of the mineral complex is low but higher than that of ferrisols and ferrallitic soils having comparable (granulometric) clay contents. The cation saturation of the B horizon generally exceeds 40 percent (normal ammonium acetate at pH7).

As compared to the ferrallitic soils that often overlay weathered layers several metres thick, the ferruginous tropical soil profiles are seldom thicker than 250 cm. The thickness of the altered layers that separate them from the fresh rock is always less than 100 cm over crystalline acid rocks.

Colours are duller than those of ferrallitic soils and fall in the 100 YR and 7.5 YR range, exceptionally in the 5YR range. There is generally a difference of 2 to 3 points in value and chroma between colour of wet and dry soil. Most ferruginous tropical soils would fall under the ultustalf.

Their high content of alterable ferruginous minerals may give rise to important liberations of iron and frequently to formation of iron crusts at slight depth. Moreover, like all but the most permeable of the ferruginous tropical soils, they are very vulnerable to erosion.

15. Ferruginous (Fersiallitic) Tropical Soils: on Sandy Parent Material Clay Complex Dominantly Kaolinitic, More Than 40% Saturated. Often Appreciable Mineral Reserve. Confined to Semi-Humid Areas

Definition. Unlike other ferruginous tropical soils, the one on sandy parent material does not have a textural B horizon. In other words, leaching is not a dominant factor. Rainfall usually ranges from 500 to 1 200 mm. The reserve of weatherable minerals is often appreciable and clay is mostly the kaolinitic type. Soil drainage and depth to the plinthite layer are the principal characteristics of this soil unit.

Distribution. The distribution of this soil is zonal, generally covering the Sudan zone and the northern parts of the Guinea zone.

Value for forestry. This soil is generally used for planting of many species of Eucalyptus and some species of pines. Although relatively poor, the land is suitable for mechanized farming and gives good response to fertilizers. Better response to fertilizers is achieved by increasing the organic matter content of the soil. In spite of the low rainfall in the area, soil erosion needs attention.

16. Ferruginous (Fersiallitic) Tropical Soils: on Miscellaneous Rocks.

Definition. Because of the high quartz content of their parent materials, these soils are generally lighter than those of the other units. Since they contain less iron they are less frequently iron crusted, but their leaching may be important and often leads to a textural B horizon.

Distribution. On the map this unit reflects the frequent outcrops of more or less basic veins that traverse the pre-Cambrian Basement Complex and the post-Cambrian sediments that cover it locally. In climatic zones more humid than those favourable to the formation of ferruginous tropical soils, such outcrops give rise to ferrisols or ferrallitic soils, where the dominant colour is red, on rocks rich in ferromagnesian minerals. These soils are specially dominant in the Guinea zones.

Value for forestry. Low to average. These very erodible soils should be used with care. The little rainfall limits the species of trees that can be planted. Eucalypts and neem were found to be doing well.

Ferrisols

Like the eutrophic brown soils of tropical regions, the ferrisols are a transitional group which are evolving under a hot and humid climate and whose normal development is retarded compared with that of neighbouring soils. In the case of the ferrisols, this is effected mainly by surface erosion which forces the profile to develop in depth at the expense of less weathered parent material. The ferrisols, just as the eutrophic brown soils of tropical regions, are distinguished from neighbouring soils by their better structure, their higher biological activity and, therefore, by their higher fertility. More widespread than the eutrophic brown soils of tropical regions, they also developed under more humid climates.

17. **Ferrisols: Clay Complex Almost Entirely Kaolinite and Oxides, Less than 50% Saturated. Low Mineral Reserve. Confined to Humid and Semi-Humid Areas**

Definition. Ferrisols have a profile closely resembling that of ferrallitic soils, often having a structural B horizon with aggregates having glossy surfaces. These coatings are not always evident when a profile has become dry. They are not necessarily coatings of clay but may be due to the presence of mixed alumino-silica gels. The reserves of weatherable minerals are generally low but may exceed 10 percent of the 50-250 micron fraction.

The clay fraction consists almost entirely of kaolinite, free iron oxides and amorphous gels, sometimes with small quantities of 2:1 lattice clays and gibbsite. The SiO_2/Al_2O_3 ratio is near 2, mostly slightly below 2. The cation exchange capacity of the (granulometric) clay fraction of the B horizon generally exceeds 15 mE_q per 100g and is intermediate between that of ferruginous tropical soils and that of ferrallitic soils *sensu stricto*. The saturation of the B and C horizons is less than 50 percent (normal ammonium acetate at pH7).

As for their place in the USDA 7th Approximation, the absence of oxic horizons requires that they be classified provisionally among the ultisols, although certain objections might be raised to the truly argillic nature of their B horizon.

Distribution. In the equatorial zone these soils are generally found at altitudes higher than 1 600 m, such as on the Jos Plateau, and in Sierra Leone and Liberia.

Value for forestry. Although these soils are higher in plant nutrients than ferrallitic soils (*sensu stricto*), they appear to be relatively poor soils as compared to the eutrophic brown soils of tropical regions which have developed on similar parent materials. When climate, landform and altitude permit, they are suitable for most trees like teak, *Gmelina* and pines.

Ferrallitic Soils (Sensu Stricto)

On the African continent ferrallitic soils cover approximately 5 338 000 km^2 or more than 18 percent of the total surface. Consequently, the ferrallitic soils are the most extensive group of soil units in Africa. (Less homogeneous desert detritus, with 5 913 000 km^2, can hardly be considered soil.) Ferrallitic soils reflect the final stages of weathering and leaching, wherein only the least mobile and least weatherable constituents remain and where even kaolinite may become altered.

Notwithstanding their apparently zonal distribution, a major part of these soils is not exclusively the result of present day soil formation. Many are polygenetic, i.e. recent soils developed in old weathered layers that have undergone ferrallitic pedogenesis and which have remained in place or have been reworked and redistributed according to the new relief of the rejuvenated landscapes. Such ferrallitic mantles are most frequent in intertropical Africa, where they persisted due to the flatness of the major part of the continental massif.

The subdivision that has been maintained is a compromise among the different systems of classification that were in use in Africa at the time when the partial maps were established. It is based on criteria that at first glance may appear somewhat ill-assorted and where colour occupies a paramount place.

20. **Ferrallitic Soils: on Miscellaneous Rocks**

Definition. These are soils that are often deep, whose horizons are only slightly differentiated with diffuse or gradual transitions, but sometimes having an A_2 or textural B horizon. This B horizon may have slight structure in the more clayey profiles but the aggregates do not show clearly developed glossy surfaces as are described for the ferrisols. The structural elements are often very fine subangular blocky peds, more or less coherent and forming a very friable, porous mass. There is little or no reserve of weatherable minerals.

The silt/clay ratio (20/2 microns) is generally less than 0.25 in horizons B and C. Clay minerals are predominantly of the 1:1 lattice type and are mostly associated with large quantities of iron oxides. Although they are generally associated with hydrated oxides of aluminum, gibbsite, one of the crystalline forms, is not an essential constituent, though it is frequently present. The SiO_2/Al_2O_3 ratio is sometimes near 2 but usually below. The cation exchange capacity of the (granulometric) clay fraction is generally below 20 mEq per 100g and the level of saturation in horizons A and B is generally below 40 percent (normal ammonium acetate at pH7). It must be noted that this definition is slightly more restrictive than that of the French classification. In the USDA classification, 7th Approximation, certain ferrallitic soils could be ranged among the oxisols, but the absence of oxic horizons excludes many others which tend toward the ultisols.

Distribution. This element is as equally well distributed to the north as to the south of the equator but the total surface occupied is much less than that under yellowish-brown ferrallitic sandy soils, even though both units cover similar geological formation.

Value for forestry. The low fertility level of these soils varies with their clay content (20 - 60%), with the nature of the rock from which they are directly or indirectly derived, with the present-day climate that ranges from per-humid to sub-humid and with the vegetation the climate has induced.

Due to their low base saturation, the quantity of bases that must be added to increase yields significantly often is rather high and under current circumstances, often prohibitive.

Their value for forestry is comparable to that of yellowish-brown ferrallitic soils on loose sandy sediments. Trial planting of species of trees which have very low nutrient requirements is recommended. Casual observations showed Gmelina as a promising species.

Hydromorphic Soils

22. Hydromorphic Soils, Temporarily or Permanently Waterlogged

Definition. These are soils, other than vertisols and similar soils, whose development and characteristics (presence of gley and/or pseudo-gley in at least one of their horizons) are influenced by permanent or seasonal waterlogging. Some of these soils have a relatively high level of cation saturation.

Distribution. From the climatic point of view, distribution of these soils is not as extensive as that of the juvenile soils on riverine and lacustrine alluvium with which they are most frequently associated. In more arid regions, hydromorphy is replaced by halomorphy.

Value for forestry. Several of these soils have relatively little value for forestry especially those that are waterlogged either temporarily or seasonally. Their reclamation may necessitate control of the water level. However, some species of trees like Eucalyptus robusta may be tried.

SUMMARY AND CONCLUSIONS

Two main problems confronting afforestation in West Africa are (1) climate and (2) soils. The effect of climate is shown both by its influence on the growth of trees and by its influence on soil formation.

The different kinds of parent materials and living organisms acted upon by the different elements of climate resulted in the formation of different kinds of soils. To be able to study diligently all these kinds of soils would first require a systematic classification so that similar soils needing similar treatments or management could be grouped together.

The ferruginous tropical soils are the most widely encountered soils in the Sudan and Guinea zones of West Africa as the rainfall (500 to 1 200 mm per year) and a well separated dry and wet season seemed to favour their formation. Many pilot plantation trials of different species of eucalypts and pines (P. caribaea and P. oocarpa) have given very good results when grown in the Guinea zones.

The soils north of the ferrugineous tropical soils are the largest in extent in West Africa but, having very little rainfall (less than 500 mm per year), produce scanty vegetation. They also have very little value for forestry. Trees like Azadirachta indica seemed to be favoured north of the 500 mm isoyeth, but lately, Acacia senegal, A. albida, A. seyal and A. nilotica are becoming important trees in this area; A. senegal for its gum arabic and A. nilotica for its tanning material.

South of the ferruginous tropical soils, rainfall becomes much heavier, vegetation much thicker and both crops and tree production much higher. In this area, teak and Gmelina are more adaptable, and in the much elevated areas, pines are promising.

The best soils in West Africa are those developed from volcanic rocks (newer basalt) but are of very limited extent. Teak, Gmelina and pines have shown very good results.

In relation to chemical properties the soils most suited to plantation development are those in which there is a) sufficient depth of soil above the parent rock and b) a sufficient amount, and in proper proportions, of mineral nutrient elements. Few sites meet these criteria. Quite a good number of the various species of eucalypts being tried in the afforestation programme will thrive well on sites with marginal fertility if the problem of die-back caused by boron deficiency is rectified. Pinus species need an adequate level of phosphate for successful establishment in the field. Because of the acute phosphorus deficiency of most savanna soils, application of phosphate fertilizer to pines has become a standard practice both in the nursery and in the field. Significant responses to nitrogen are obtained if P deficiency is first corrected. Apart from N, P and B, incidence of other deficiencies have not been detected or described for the various tree species being tried.

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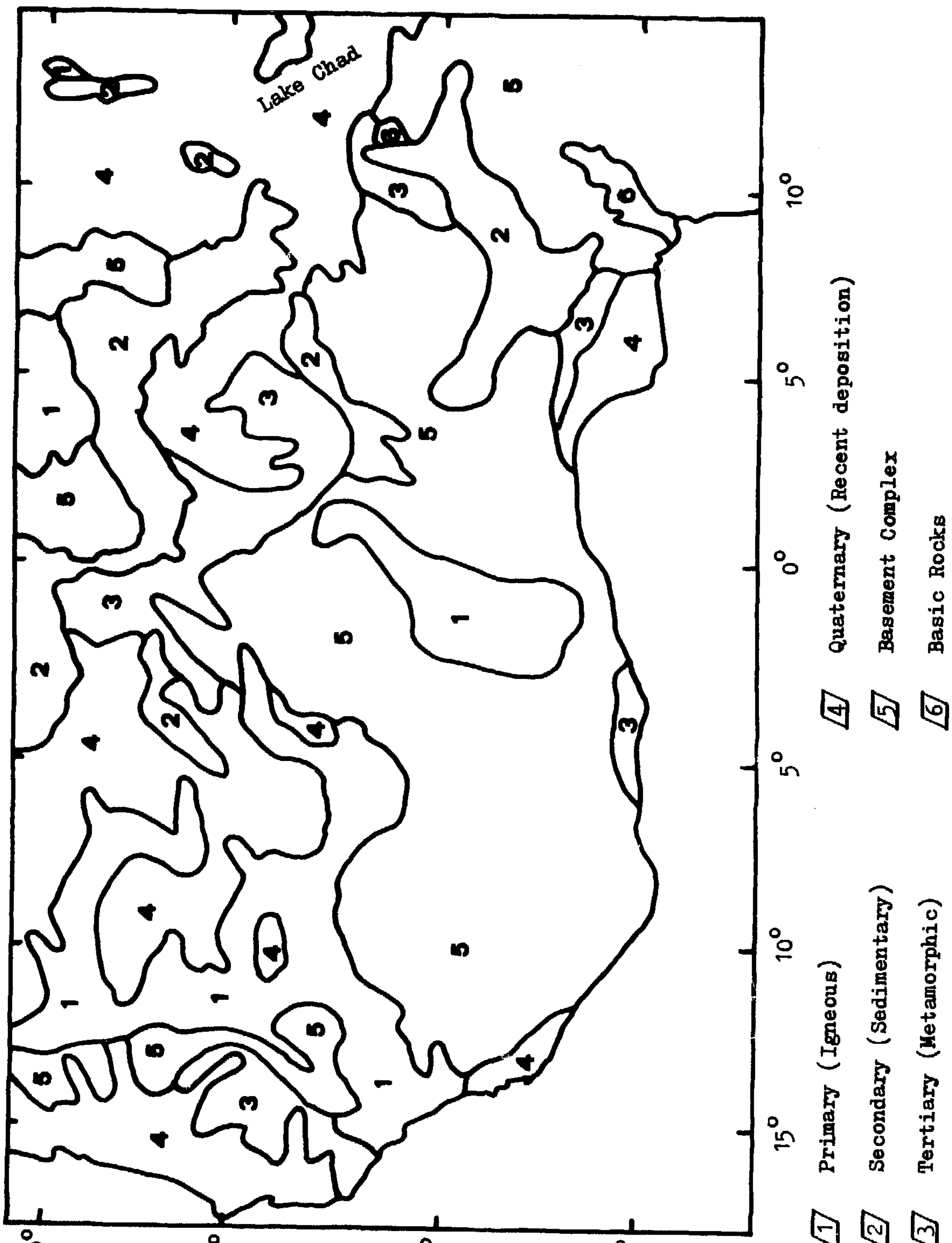
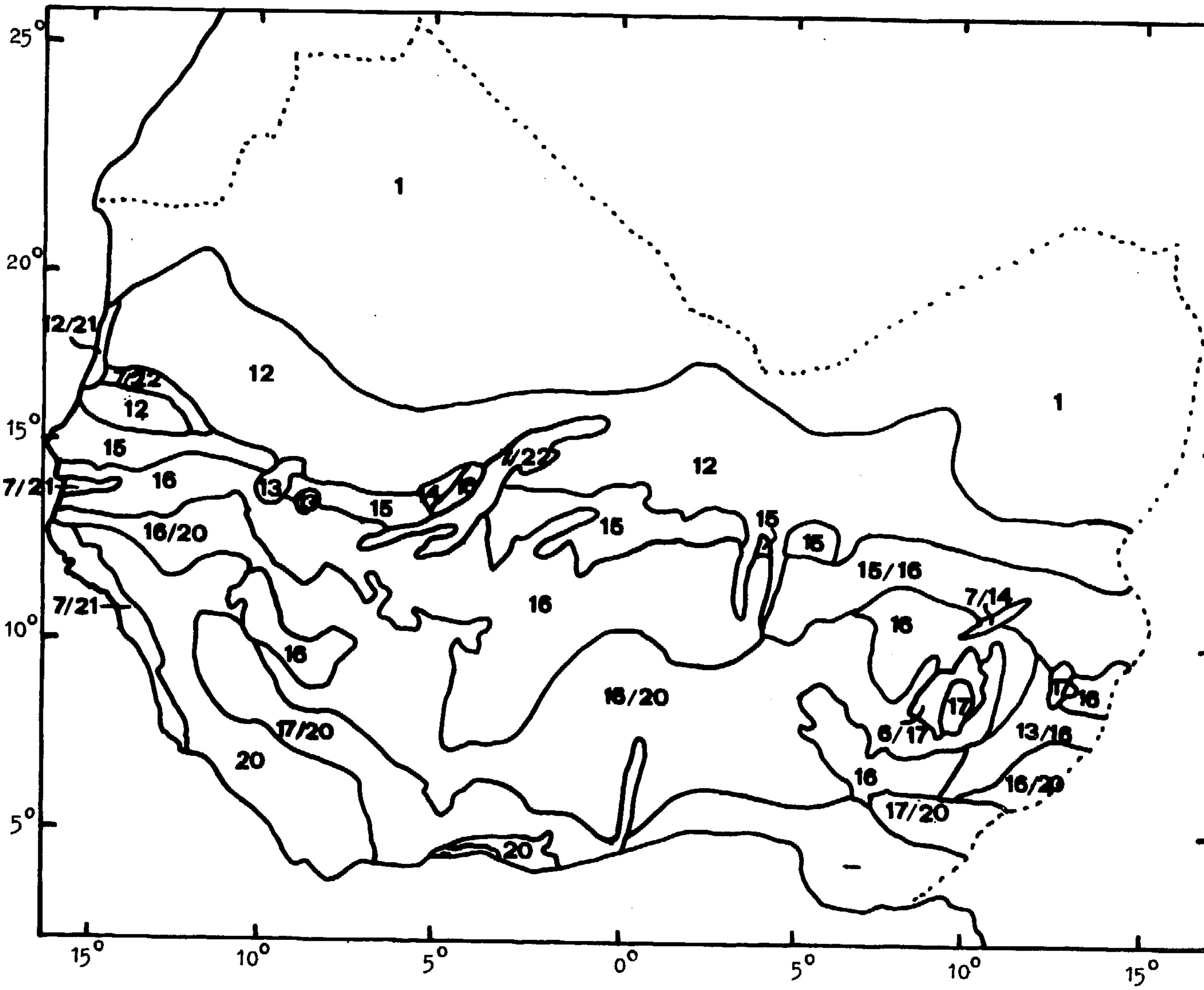
Map 1 - GEOLOGICAL MAP OF WEST AFRICA



Map 2 - MAP OF SOIL GROUPS IN WEST AFRICA 1/



/1/ Desert, undifferentiated.
/6/ Skeletal soils mostly debris with pockets of soils.
/7/ Weakly developed soils on young alluvium often halomorphic or hydromorphic.
/12/ Brown soils of the arid and semi-arid tropical regions.
/13/ Lithomorphic soils with dark non-kaolinitic clays.
/14/ Soils of dark non-kaolinitic clays confined to topographic depressions in semi-arid areas.
/15/ Ferruginous (fersiallitic) tropical soils on sandy parent material.
/16/ Ferruginous (fersiallitic) tropical soils on miscellaneous rocks.
/17/ Ferrisols: clay complex almost entirely kaolinitic and oxides less than 50% saturated.
/20/ Ferrallitic soils: on miscellaneous rocks.
/22/ Hydromorphic soils, temporarily or permanently water logged.

1/ For greater detail and other regions, see Laurie (1974).

CLIMATES AND SOILS OF THE ARID AND SEMI-ARID SAVANNAS OF WEST AFRICA [1]

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CONTENTS

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[1] Paper for Symposium on Savanna Afforestation

CLIMATES

Background

The climate classification most commonly used in French-speaking Africa is the one established by Aubréville and discussed by him in particular in the texts Climates, Forêts et Désertification de l'Afrique Tropical (Aubréville, 1949) and Flore Forestière Soudano-Guinéenne (Aubréville, 1950). These climates are described only schematically in Tree Planting Practices in African Savannas (FAO, 1974).

The principal biological factor is rainfall and, in particular, the duration of the dry season and of the true rainy season. This factor is represented by an "index of rainy seasons" or rainfall index which covers three sets of figures:

a) the first gives the number of very rainy months (>100 mm);

b) the third gives the number of ecologically dry months (<30 mm);

c) the second, usually the smallest, is that for the intermediary months, neither dry nor wet.

This rainfall index supplements the information on rainfall, i.e. the average annual rainfall expressed in mm.

The next most important factor after rainfall is the saturation deficit and its fluctuation over the year. Unfortunately only very few weather stations record atmospheric hygrometric measurements.

Finally, average temperatures, whether annual or monthly, are of only secondary significance in making climatic divisions within the geographic area in question.

Five main types of climate have been defined for tropical Africa:

- the humid tropics;
- the semi-humid tropics, of which the Sudan-Guinea zone is typical;
- the Sahel-Sudan;
- the Sahel-Sahara;
- the Sahara.

It is only the last three types of climate that are of interest to us here.

Sahel-Sudan Climate

This is a characteristic type of climate in Africa. It occurs in a long strip roughly paralleling the equator from Senegal to the mountains of Ethiopia. It is definitely continental and does not reach the seas. On the west, the Sahel-Sudan gives way to maritime climates that may be considered as variants (e.g. the Sahel climate of Senegal and the lower Casamance climate).

The area stretches 3 to 4°, its limits being slightly inclined on the parallels with its northern limit in Senegal at 16° N latitude and at the Nile, 12° or 13° N latitude.

Temperature

Average annual temperature: 26° to 31.5°
Average maximum monthly temperature: 30.5° to 36.5°
Average minimum monthly temperature: 24° to 28.2°

Minima: in January and August
Absolute maximum: in April/May
Relative maximum: in October

Rainfall

Rainfall index: 400 to 1 200 mm, almost always less than 1 000 mm
Rainy season: short to very short with 2 to 4 very rainy months; maximum in August
Dry season: severe with 6 to 8 dry months, more rarely 5
Rainy season index:

2 - 2 - 8	3 - 2 - 7	3 - 3 - 6
3 - 1 - 8	4 - 1 - 7	4 - 2 - 6
2 - 3 - 7	2 - 4 - 6	4 - 3 - 5

Sahel-Senegal Climate

This is a transition climate between the marine trade winds climate of the coast of Senegal and the Sahel-Sudan continental climate.

Temperature

The temperature regime is similar to the Sahel-Sudan.

Average annual temperature: 26.5° to 28.3°
Average maximum monthly temperature: 29° to 32°
Average minimum monthly temperature: 23° to 23.8°

Rainfall

Rainfall index: 500 to 900 mm
Rainy season: short, running June to October with three very rainy months
Rainy season index: 3 - 2 - 7

Guinea-Lower Casamance Climate

This is a maritime subzone climate of the Sahel-Sudan occurring in Gambia, lower Casamance, Guinea-Bissau.

Temperature

Average annual tempertaure: 25.2° to 26.3°
Average maximum monthly temperature: 26.5° to 27.8°
Average minimum monthly temperature: 23.2° to 24.6°

Absolute minimum: in January
Relative minimum: in August (contrary to the maritime Guinea climate)

Rainfall

Rainfall index: 1 200 to 1 750 mm
Rainy season index: 4 - 1 - 7 or 5 - 0 - 7

Sahel-Senegal Coastal Climate

This is an exceptional climate due to two influences: the fresh North Atlantic trade winds during much of the year, and the Guinean monsoons for a short part of the year. This climate prevails only on a narrow coastal strip of Senegal.

Temperature

This climate is much cooler than the Sahel-Sudan at the same latitudes.

Average annual temperature: 23.7° to 25°
Average maximum monthly temperature: 28.4°
Average minimum monthly temperature: 20° to 21.6°

Rainfall

Rainfall index: 400 to 550 mm
Rainy season index: 2 - 1 - 9; 2 - 2 - 8; 2 - 3 - 7

Sahel-Sahara Climate

This is a subdesert climate, transitional between the Sahel-Sudan and Sahara climates. It occurs across a broad strip of Africa running from Mauritania to the Red Sea along the southern fringes of the Sahara.

Temperature

Average annual temperature: 24.5° to 28.5°
Average maximum monthly temperature: 29.5° to 33°
Average minimum monthly temperature: 18.5° to 21°

Absolute minimum: in January, sometimes a second minimum in August
Absolute maximum: in May/June

Rainfall

Rainfall index: 200 to 400 mm, maximum in August
Rainy season index:

0 - 1 - 11	1 - 0 - 11	1 - 1 - 10
0 - 3 - 9	1 - 2 - 9	2 - 1 - 9
0 - 4 - 8	1 - 3 - 8	

Sahara Climate

The 200 mm isohyet is conventionally considered the limit of the Sahara.

Temperature

Average annual temperature: 27.5° to 29°
Average maximum monthly temperature: 32.5° to 36.5°
Average minimum monthly temperature: 16° to 22.2°

Excessive maximum: in June
Absolute minimum: in January
Relative minimum: sometimes, in August
Relative maximum: in September and October

Rainfall

Rainfall index: 200 mm
Rainy season index: 0 - 0 - 12; 0 - 1 - 11; 0 - 2 - 10; 0 - 3 - 9

CLIMATIC CHANGES

Geological-Scale Fluctuations in Climate

During the Quaternary period and, especially the Pleistocene epoch, the whole world underwent extremely severe changes in climate and in Africa, as it has been possible to demonstrate, there were three major rainy ages: the Kaguérien, Kamasien and Gamblien. These wet ages lasted far longer than the arid ones between.

In the Gamblien age, between the VIII and III millennium B.C., the Sahara was particularly wet. Between 8000 and 6000 B.C., it sheltered an equatorial type fauna that attracted many hunters. From 6000 to 3000 B.C., a Neolithic civilization flourished in the Sahara (Adrar des Iforas, Aïr, Tibesti) while Ténére, Niger, this "desert in the desert", was then a large lake that became a vast marsh toward 3000 B.C.

Between 3000 and 2500 B.C., there was a brusque change of climate in which it turned dry, so that the population moved toward the south along the valleys (in particular the Azawak wadi).

A considerable mass of humanity, therefore, migrated between the 12th and the 15th parallels from 2500 to 500 B.C.

The discoveries of geologists and students of prehistory are corroborated by the presence of plant species that were able to survive locally although their ecological environment is now much further south. Although these species also went along with the general withdrawal, it was possible for them to retain a hold on certain sites. Aubréville mentions several of these species, namely:

- Anogeissus schimperii, found in an area extending from north of Tahoua, Niger, along certain marshes and streams although with some difficulty there; regeneration is not easy;
- Celtis integrifolia;
- Daniellia oliveri; and
- the tamarind, the regeneration of which is becoming more and more rare.

Other species that can be included perhaps are: Diospyros mespiliformis, Mitragyna intermis.

From these observations, it might be concluded that what happened was an encroachment of the desert during geological ages, leaving behind a few islands of vegetation to the south, but can it also be concluded that at present the desert is still encroaching on other land? Certainly not because, inversely, there are vestiges of an advance of the desert further southward. For instance, throughout the Sahel one finds traces of many sand dunes that once were moving and are now fixed; the most notable examples are in the Ferlo, in Senegal, but there are also some in Mali, Upper Volta and Niger, if even only in the immediate vicinity of Niamey. It is often surprising, too, to find in the Sudan species of definitely Sahel affinity, such as the numerous acacia (Acacia gourmensis down to the border of Ghana and Upper Volta) and Balanites aegyptiaca, that is found as far south as Parakou in Benin. It is possible to attribute this to transport of the seed by livestock, but it is also not impossible that these may constitute vestiges of a more pronounced thrust of the Sahara than at the present time.

The above analysis, therefore, does not explain the current desertification in Africa so it is necessary to consider present-day changes in its climate.

Present-Day Changes in Climate

Studying such changes of climate means essentially considering fluctuation in annual rainfall over several years. In certain localities marked fluctuations occur from one year to another. For instance, following are the fluctuations recorded at Niamey between 1948 and 1952:

1948	657.5 mm
1949	357.5 mm
1950	596.5 mm
1951	566.0 mm
1952	900.5 mm

Under these circumstances, it is understandable that it is hazardous to draw conclusions from fluctuations over only a few years. For instance, in the period 1961-1970 the average rainfall from 1961 to 1965 at Niamey was 657.3 mm as compared with only 589.6 mm from 1966 to 1970, because of which the "prophets of doom" scream about "rapid conversion of the land into desert".

Investigating whether a change in rainfall pattern could be proven, meteorological data were consulted from stations set up in Niger since 1932, or before that, 13 stations in all, and the average rainfall for the n/2 first years and the n/2 last years were established. (When the number of data is uneven, the middle year was counted as belonging half in the first and half in the second halves). Following are the results, cut off as of 1970.

Place	Number of Readings	Average Rainfall (mm)		Maximum Recorded (mm)	Minimum Recorded (mm)
		1st half	2nd half		
Agadès	48	157.3	168.6	288.2	39.7
Bilma	48	19.1	18.1	63.5	0
Dogon-Doutchi	46	647.3	586.7	1 011.6	358.6
Dosso	36	701.2	658.8	1 048.0	433.1
Filingué	39	483.0	670.5	878.3	284.4
Gaya	36	831.5	887.5	1 108.1	655.7
Maradi	39	617.5	623.0	928.1	362.3
Nguigmi	47	186.6	242.5	472.4	40.9
Niamey Ville	50	594.2	603.9	900.5	308.8
Say	46	674.5	660.8	957.1	341.9
Tahoua	47	366.2	446.5	611.1	208.6
Tillabéry	47	483.8	506.8	746.1	265.9
Zinder	49	528.8	511.7	800.3	230.3

Great caution must be used in handling these figures as it is certain that not all these readings were made with all the necessary care. Furthermore, annual fluctuations are such, and the amplitude of the fluctuation is so great, that we would be deluding ourselves in the thinking that it is possible to draw conclusions based on a maximum of fifty years of observations.

From these figures one might be led to conclude that there is a trend toward rehumidification (8 stations out of 13 give figures showing that rainfall is on the increase). We would not, however, go as far as to say that and merely conclude that the meteorological statistics now available to us are not reliable enough and above all that they cover too short a period for us to be able to make any pronouncement on the present evolution of the climate.

In any case the above figures show at least that, if there is any change, it is extremely slow and definitely does not explain the rapid desertification that is occurring at present. So other reasons for this conversion into desert than a change in climate have to be sought.

Finally, certain periods seem to be definitely drier than others, although the periodicity of the change is far from clear.

Our conclusions are, therefore, identical to those of Aubréville in 1936: to date there is nothing to prove any trend toward a permanent change in climate. It would, however, be extremely valuable to pursue such research in depth because rainfall is far from being the most important factor: rainfall distribution and the duration of the rainy season are equally useful factors for both agronomists and foresters.

CHOICE OF FOREST TREE SPECIES IN RELATION TO CLIMATE AND DIFFERENT SOIL TYPES

The Climate

Laurie (FAO, 1974) identifies various species now in use for reforestation in the various climatic zones in the savanna.

Soil Types

It is not the intention here to go into the details of soil science, but as far as is known to the author, no serious statistical survey has been made which would enable us to answer the following question accurately and objectively: "What soil type is particularly suited to a certain species?" Or conversely, "What species will give the best results on a certain type of soil?"

In order to conduct trials along these lines, it is necessary to have several different kinds of terrain (often difficult to find) and to do replicated planting all during the same season and with the same techniques, with the risk that rainfall may vary. Such a trial is to be conducted in Upper Volta in 1976.

What foresters know in this field is therefore somewhat subjective, though nonetheless valuable.

Production stands

The goal of the Upper Volta project is to obtain the maximum yield of timber per unit area, essentially to supply the town of Ouagadougou with fuelwood and poles, it being understood that this should be done in the context of maximum profitability. If the production goal is taken to be the prime one, obviously the best yields will be obtained on fertile farmland. For this, the land capability maps drawn up in the past cannot be accepted. In fact, usually after a soil science/morphology survey the land is classified as follows:

- the most fertile soils are defined as suited for farming;
- bottomlands, generally flooded during the crop-growing season, are defined as suited for grazing (i.e., as grasslands);
- soils which from a glance are seen to be unfertile (definitely granite or lateritic hardpan) are classified as land unsuited for growing anything - whether agricultural crops, forest trees or grass;
- whatever land remains is divided up somewhat arbitrarily between land suited for growing of forest trees, grassland or as suited only for forest trees.

Such a classification is useless because as far as concerns foresters the most fertile, rich soils should be those suited for growing crops—whether they be agricultural, forest or forage and fodder crops. On the other hand, soils defined in the past as suited for growing grass or forest trees are not generally, with some exceptions, really cropland.

Proper management would consist of intensive utilization of fertile land for all three purposes - agricultural, forest, and forage or fodder crops - entailing a dividing up of the land for these various purposes. As for the rest of the land it could be managed on an extensive basis, natural forests being put under management with regular felling cycles.

Choice of Species in Relation to Soils (Below the 800 mm Isohyet)

The species mentioned here are all capable of producing a great deal of wood. The better the soil is, the more they will produce, and the poorer the soil, the less.

Eucalyptus camaldulensis. From the site comparisons, it appears that it is possible to grow *Eucalyptus camaldulensis* almost everywhere. As a matter of fact this is an astonishingly "plastic" or adaptable species and is the one that will certainly be used for most plantations.

It must nevertheless be stated that this species is here at the ecological limit of its range and in this sense can be said not to be a suitable species, even though its use is still recommended.

It actually has a very short life span and begins to die when it reaches six or seven years of age so, in fact, the plantations are cut only shortly before they would naturally disappear.

Gmelina arborea. This species has been imported from the East Indies, the specimens of foreign provenance being adapted to a rainfall on the order of from 1 000 to 1 300 mm. Its use under the 800 mm isohyet, therefore, takes it beyond its normal range, but it is still a good, usable species. Still, soils that conserve water best should be reserved for it, whereas muddy bottom-lands where it does not flourish should be avoided.

Azadirachta indica. Neem is an astonishingly adaptable species that flourishes down to the 400 mm isohyet. Probably its preferred area is around 800 mm. Sometimes neem will regenerate underneath its own stands in this zone, this being an excellent sign of good adaptation.

From the standpoint of soils, best conditions are achieved with a light soil, with the water table at a depth of 1.5 - 2.5 m, although these are rather exceptional conditions. The plasticity of the species is however such that no soil is excluded except those that are extremely heavy which are to be avoided.

Cassia siamea. This species, like neem, gives good results within a rainfall range as extreme as from 500 mm to 1 500 mm.

However the parallel stops there because, contrary to what is true of neem, it is more demanding as regards soils, requiring for good growth a rich, deep and neither too light or too heavy soil. Consequently, both poorly and excessively drained soils should be avoided for this species and hydromorphic brown soils sought.

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SPECIES AND PROVENANCE TRIALS IN NIGERIAN SAVANNA [1]

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CONTENTS

[1] Paper for Symposium on Savanna Afforestation

INTRODUCTION

Species trials started in the savanna areas of Nigeria about 60 years ago in response to the peculiar circumstances of the area. The natural savanna woodlands are sparsely stocked and low yielding (Jackson and Ojo, 1970) and, more often than not, have suffered from overcutting in the past. Near the larger towns and centres of population tree growth has virtually disappeared leading to acute local shortages of wood. The result of this was the introduction of a few species such as Azadirachta indica A. Juss (neem), Dalbergia sissoo, Gmelina arborea L. and Tectona grandis L.f. (teak). The fuel plantations around such towns as Sokoto, Katsina, Nguru, Hadeija, Maiduguri etc. are a testimony to the efforts of the early foresters.

It was not, however, until 1959 that a comprehensive programme of species trials was started; provenance trials are even more recent, the first having been established in 1964. About 130 species have been tried so far including a few indigenous species, about 20 "tropical" pines and 60 eucalypts.

METHODOLOGY

The primary objective of the species trial is to test plants of identical seed origin and nursery treatment simultaneously on sites covering a range of different climatic conditions under identical cultivation and maintenance regimes.

Savanna vegetation occurs in 17 of the 19 states of Nigeria and covers about 85 percent of the land area - about 800 000 square kilometres (300 000 square miles). Ecologists recognize four different zones, namely the Southern Guinea, Northern Guinea, Sudan and the Sahel (Keay, 1955). In addition to these four true savanna zones, a transition zone along the border with the rain forests, the derived savanna, is distinguished. These zones correspond well with climate - increasing length of the dry season from south to north, and decreasing mean annual rainfall from south to north.

It was, therefore, recognised from the start that all the forest reserves could not be covered at the same time and that representative sites would have to be chosen. It was also understood that the trials should be on the best sites available for afforestation. Initially only one or two sites in each vegetation zone were selected and all the seedlings were raised in a central nursery under close supervision. Later planting was expanded to about 50 other sites. This necessitated the raising of plants in several widely scattered nurseries with consequent poorer supervision. The value of the extra information obtained from these sites was diminished because the planting stock was not uniform. In addition, care and maintenance also varied because supervision was inadequate. It became obvious that the number of sites had to be limited to one or two within each vegetation belt. This led to the development of the present experimental areas in Yambawa, Afaka, Mokwa, Miango and Nimbia.

PROCEDURE

The procedure used, which has been fully described by Kemp (1969), consists of three stages, namely: (a) elimination trials; (b) growth trials and (c) plantation trials.

Species Elimination Trials

These started as nine tree plots with a randomised block design and four replications but with a provision to include one large plot, of 36 trees, of each species in each trial. The idea was to maintain the larger plots as arboreta after the final assessment of the trials at the end of the second dry season. High mortality of most species led to the plot size being increased to 25 trees and the discontinuation of the larger arboreta plots.

Normal plantation espacement of 1.8 m x 1.8 m (6ft x 6ft) was used initially but this was changed to 0.9 m (3ft x 3ft) in 1962 to reduce maintenance costs and the possibility of site variation within each trial.

Certain criticisms have been levelled against this stage of the species trials.

(a) The degree of replication is said to be unnecessary to distinguish such gross differences in survival and growth as the experiments were designed to reveal; in fact, statistical analysis of the results was never made.

While it is true that statistical analysis was not necessary to distinguish gross differences in survival and growth, the soil conditions of the savanna, which vary greatly over short distances, make replication very important.

(b) Two years were found to be insufficient to assess potentialities, even of survival in some cases.

This is a justified criticism, and in practice the length of trial was increased to four years because some species are slow starters while others may show early promise. This caused other difficulties as very vigorously growing species tended to suppress those growing in adjacent plots. The answer to this may be to increase the espacement to between 5ft - 6ft (1.5 m - 1.7 m).

(c) The trees were not planted under normal field conditions e.g. large espacements with mechanised weedings.

This criticism is unjustified as there was no plantation technique in use when the trials began and equipment for cultivation was not available to forestry personnel. The plantation technique, including mechanisation, was developed using some of the species chosen at the beginning of the species elimination trials. In any case, species that were chosen grow better under mechanical cultivation than under hand cultivation (Iyamabo and Ojo, 1971). Moreover, Nigerian results agree very closely with those from other parts of the world in that no species that failed here has succeeded in any similar area of the world. One can, therefore, conclude that no species was lost through this method of maintenance.

(d) That the plots were virtually useless for other work after their original purpose had been fulfilled; i.e. whether this stage is in fact necessary if it is to be followed by a second stage of replicated trials with individual 100 tree plots.

The elimination trials were not designed to do more than eliminate useless species. The second stage is meant to yield all the other information that may be required of the chosen species. The time lag in obtaining these data (2-4 years) if the species elimination trials had been larger is more than compensated for by the reduction in costs and space. It must be remembered that only about a quarter to half of the species reach the second stage and if the trials are repeated for two or three years in succession, management of the experimental areas will be difficult because of the "empty" plots.

The authors, therefore, recommend that (1) this stage be retained in species introduction, with replication or without depending on soil variability on the sites on on which afforestation is envisaged and (2) that spacing be determined by existing technology and facilities of the country making the introduction. For example, if Nigeria were to try new species in the savanna areas, they would probably be planted at 2.8 m x 2.8 m (9ft x 9ft), about 0.4 ha (1 acre) in size at a corner of the yearly plantations.

Species Growth Trials

These are usually of randomised block or latin square design with four replications, and were originally spaced 1.8 m x 1.8 m (6ft x 6ft). When mechanical cultivation was introduced, spacing was increased to 2.7 m x 2.7 m (9ft x 9ft) or 2.7 m x 1.8 m (9ft x 6ft) depending on whether cultivation was to be in one or two directions. The trials are assessed throughout the entire rotation of the species.

Plantation Trials

This, the third stage, consists of unreplicated plots at normal spacing comprising an area of 0.4 to 2 ha or more. Ideally this stage should be reserved for species that have passed through the growth trial stage; in practice species that perform satisfactorily in growth trials for five years are considered qualified.

The objective is to obtain quantitative data on crop performance under plantation conditions, in addition to supplying information on problems encountered in planting on a larger scale than small trial plots. They also provide material for further experimental work, such as thinning and pruning trials. Assessments follow usual "sample plot" procedure.

RESULTS

Some species emerged through the three stages and today form the basis for the reforestation in the savanna areas. To this extent, the procedure adopted could be said to have fulfilled its purpose. Although some species tried and rejected might be found to be more promising if certain improved techniques were used (e.g. mechanical cultivation, application of boron to eucalypts, and of phosphates to pines), it is believed that no species of improtance has been missed.

Detailed results were published by Kemp (1969); Appendix 1 shows a list of species that were used in the trials. The results may be summarised as follows.

Sudan Zone

More than 40 species have been tested but results have been almost entirely negative and no species has yet proved equal to the performance of neem (*Azadirachta indica*) on sites favourable to it. *Eucalyptus microtheca* has consistently showed high survival and satisfactory growth; its main defect being poor stem form. *E. camaldulensis*, Katherine provenance, shows promise. *E. tesselaris* has shown high survival, but its rate of height and diameter growth is poor. An interesting feature of this zone is the success of indigenous species. Such species include *Acacia albida*, *A. senegal* and *A. nilotica* which are planted for specialised products such as fodder and shade during the dry season, gum arabic and tannin materials, respectively.

Northern Guinea Zone

The most encouraging progress has been achieved here. Thirty six species, of which 20 were eucalypts, reached the species growth trial stage and about 15 of these qualified for the plantation trial stage. Among these are *Pinus caribaea*, *P. oocarpa*, *P. merkusii*, *P. kesiya*, *Eucalyptus camaldulensis*, *E. tereticornis*, *E. citriodora*, *E. "saligna"* (hybrid), *E. cloeziana*, *E. punctata*, *E. propinqua*.

Of importance here is tha lesson learnt from the early success of some species which later failed. These "early starters" include Acrocarpus fraxinifolius, Eucalyptus pilularis, E. robusta, Albizia lebbek and Callitris intratropica. If the various stages of trials had not been gone through before a choice was made for plantation work in this zone, any of these species could have qualified but would have resulted in a collosal waste of funds some years later.

Southern Guinea Zone and Derived Savanna

Generally the results of these zones correspond with those of the Northern Guinea Zone with the exception of the pines for which a successful establishement technique has not been found. It is probable that pine plantations will not be possible here until a suitable mycorrhiza (that can survive high temperatures) has been introduced 1/. In this zone, however, teak and Gmelina are the current plantation species.

On the Jos Plateau, 1 300 m (4 000 ft), species which have shown promise include Pinus caribaea, P. kesiya, P. oocarpa and P. merkusii. The list of eucalypts is as for the Northern Guinea Zone.

At the still higher altitude of the Mambilla Plateau, 2 000 m (over 6 000 ft), Pinus patula and P. merkusii show promise. Cupressus lusitanica grows well in this area. Eucalyptus grandis (probably a hybrid, but not the same as the hybrid grown on the lowlands) which was introduced about 30 years ago from Bamenda, Cameroons, gives the best growth of the Eucalyptus species tried so far. Growth of a few scattered trees of Eucalyptus globulus suggests that trials of this and other eucalypts which prefer cooler climates would be worth-while.

PROVENANCE TRIALS

Some of the earlier species trials included more than one provenance of a species and from these and other trials it was clear that provenance was very important in some species, especially those with wide geographical natural distribution. Provenance trials are, therefore, a logical stage after the species trials. Systematic provenance trials of Eucalyptus camaldulensis began in 1967, and of pines in 1968. They have since been extended to Eucalyptus tereticornis, E. citriodora, E. grandis, E. saligna, E. decaisneana, E. alba, E. cloeziana, Pinus caribaea, P. oocarpa, P. kesiya, P. merkusii and Tectona grandis.

Most of these are replications of international trials with seed supplied by the Commonwealth Forestry Institute, Oxford (Pinus caribaea and P. oocarpa), Forestry Research Institute, Canberra, Australia (P. kesiya), Comité de la Recherche Forestière Méditerranéene (E. camaldulensis).

A full account of the results of the E. camaldulensis provenance trials has been given (Jackson and Ojo, 1973). The important results are:

1. The markedly superior growth of the Petford provenance in the Guinea Zone.
2. Good survival of the Katherine provenance in the Sudan Zone and its generally good performance in the other zones, except in the Sahel Zone.

1/ See also the article by Momoh, Odeyinde and Gbadegesin entitled "The role of mycorrhiza in afforestation - the Nigerian experience, page 100.

3. General superiority of provenances from the northern summer rainfall areas of Australia, again with the exception of the Sahel Zone, and the Lake Albacutya provenance.

4. The very great improvement in volume production which can be obtained by using the best provenance. At Afaka the ratio of the volumes of the best and worst provenances is 3.4 to 1.

Preliminary results of the pine provenance trials have been published (Ojo and Shado, 1973). The results were summarised as follows:

(i) That Pinus caribaea var. hondurensis is to be preferred to the other varieties and that Belize (formerly British Honduras) and Guatemala are likely the best seed sources.

(ii) That Pinus oocarpa gives better growth than P. caribaea and that the only source of seed that should be ruled out at the moment is the Mexican provenance because of its poor stem form (on the Jos Plateau) and low yield on the lowland.

(iii) That Pinus kesiya and Pinus merkusii are likely to remain "second string" species in Nigerian forestry.

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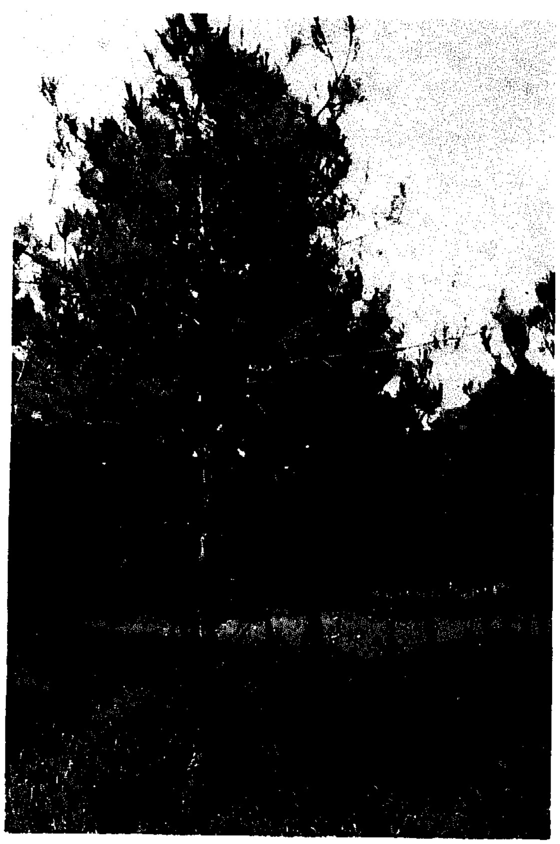
APPENDIX 1

List of Species Used in the Species Trials

Acacia cyanophylla
Acrocarpus fraxinifolius
Albizia falcataria
A. lebbek
Araucaria cunninghamii
Astronium urundeuva
Azadirachta indica
Baikiaea plurijuga
Callitris endlicheri
C. huegelii
C. intratropica
C. robusta
Cassia siamea
Cedrela odorata
Ceratonia siliqua
Chlorophora regia
Cryptomeria japonica
Cupressus arizonica
C. lindleyi
C. lusitanica
Dalbergia latifolia
D. sissoo
Eucalyptus alba
E. albens
E. astringens
E. bicolor
E. blakelyi
E. bleeseri
E. bridgesiana
E. calophylla
E. camaldulensis
E. campanulata
E. citriodora
E. citriodora x E. torelliana
Eucalyptus cladocalyx
E. cloeziana
E. corymbosa
E. crebra
E. deglupta
E. fastigata
E. gomphocephala
E. grandis
E. hemiphloia
E. intertexta
E. kirtoniana (hyb.)
E. laevopinea
E. leucoxylon
E. maculata
E. marginata
E. melliodora
E. micrantha
E. microcorys
E. microtheca
E. obliqua
E. occidentalis
E. oleosa
E. paniculata
E. patens
E. pilularis
E. polycarpa
E. propinqua
E. punctata
E. robusta
E. rudis
E. saligna
E. salmonophloia
E. sideroxylon
E. tereticornis

Eucalyptus tereticornis (Mysore)
E. tereticornis (Zanzibar)
E. tessellaris
E. tetrodonta
E. torelliana
E. transcontinentalis
E. viminalis
E. wandoo
E. woollsiana
Melaleuca leucadendron
Pinus ayacahuite
P. canariensis
P. caribaea
P. douglasiana
P. elliottii
P. engelmannii
P. halepensis
P. kesiya
P. leiophylla
P. luchuensis
P. massoniana
P. michoacana
P. montezumae
P. oocarpa
P. palustris
P. patula
P. pseudostrobus
P. radiata
P. sabiniana
P. taiwanensis
P. teocote
Widdringtonia cupressoides
W. schwartzii



Although early trials with Pinus kesiya were promising, with the Philippine provenance shown here giving best results, the species as a whole has not performed well in Nigeria below 1 200 m elevation where development is apparently hindered by high temperature. Even at higher elevations, growth has not been as good as P. oocarpa or P. caribaea.

PROVENANCE TRIALS

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CONTENTS

INTRODUCTION

Provenance trials are the logical continuation of the process of selection that began with the species elimination trials, and the methodology involved is essentially similar. However, one fundamental difference exists that affects all stages of provenance research from exploration and seed collection to field trials and evaluation. Whereas in species trials we try to determine accurately the comparative values of populations which we know to be genetically different, provenance research is concerned with differences which at the outset can only be surmised. One of its functions is therefore to establish whether real differences exist between the populations, as well as to determine their comparative value for particular uses in various environments.

Definition of the Term "Provenance"

There have been several published definitions of provenance (see Jones and Burley, 1973, for a review) but in this lecture the word means the place in which any stand of tree is growing or refers to the seed derived from those trees. For an indigenous stand the provenance is also the origin but for a non-indigenous stand the origin is the place from which the seed or plants were originally introduced. These usages are in accordance with the OECD[1] definitions and are now widely accepted.

PLANNING PROVENANCE TRIALS

Well designed comparative experiments are needed to determine genetic differences between populations. The principles governing the location, design, replication and management are the same as in species trials but the need for careful control at all stages is even greater. Therefore, the need for written control plans must be emphasised, showing clearly the objectives, the expected duration, the methods and the resources to be employed in the experiment. Since representative seed collections for provenance research are more difficult to obtain than single samples of a species, and may necessitate special collecting expeditions, planning of provenance trials must start several years in advance of their actual establishment in the field.

Phasing of Trials

Three successive phases of provenance trials are commonly recommended (e.g. Burley, 1969; Kleinschmit, 1974). The first range-wide phase is intended to investigate the extent and pattern of inherent variation between populations (provenances) and may reveal broad regions which are either suitable or unsuitable as seed sources for a given area of introduction. This phase is analagous to the species elimination trial, but the number of provenances may be large or small depending on the extent of the natural range and the variability of the species and its environments within the range. The number included should not be less than five and 10 to 30 widely separated sources are recommended (Lines, 1967). Large plots are not needed as the duration of the trial is normally not more than half rotation age. These trials may be located on two or three of the major site types.

In the second phase a restricted number of provenances are tested for a longer period, usually up to a full rotation, on all the important site types. These trials must be designed to reveal relatively small differences between provenances. Larger plots are needed, to provide sufficient trees for reliable estimation of population differences throughout the life of the trial, and to minimise the effect of tree to tree differences.

Finally, the provenance proving phase, often with only one or two provenances, requires large replicated plots, capable of accommodating mensuration studies, management trials and wood quality evaluation.

Design of Trials

Even in the first stage of provenance trials, it is essential to use valid statistical designs that will reveal significant differences between populations at a given level of precision (e.g. for height measurements, a difference of 5% of the mean). It is also important to estimate the variability within each provenance, particularly for stem form and branching habit. In savanna conditions, it is desirable to maintain the trials long enough to test the security of different populations against severe drought, particularly if the moisture storage capacity of the soil, or effective rooting depth, are limited.

1/ OECD = Organization for Economic Co-operation and Development

In such cases, important differences between provenances may only become apparent after several years. For all these purposes, it is preferable to use square plots of several trees, in replicated, randomised designs. When the number of provenances in a trial is very large, single-tree plots may sometimes be considered. However, they are complicated to lay out and the risk of confusion is very great if accidental errors occur in plot labelling. They also hinder the assessment of intra-provenance variability.

The most widely used design is the Randomised Complete Block (RCB). This has the advantage over fully randomised designs that it does not demand such uniform site conditions throughout the trial and can accommodate differences of treatment between blocks. However, if very large numbers of provenances (e.g. 16 or more) are included, the large size of the blocks increases the danger of site differences within blocks. In such cases, the use of an incomplete block design may be indicated, in which each block contains fewer than the total number of plots. These designs are complex and the analyses are best undertaken on an electronic computer. The lattice designs have the advantage that they can be analysed as an RCB if necessary, although with some loss of information. For further details and examples see Cochran and Cox (1966) or Burley (1976).

Choice of Provenances

Attempts to match environmental conditions (e.g. latitude, altitude, rainfall distribution, temperature, soil type) between the source area and the site of introduction, by homoclimal comparisons, are not always successful. The necessary information may be lacking or unreliable. Moreover, natural distribution may reflect past climatic, geological or historical occurrences rather than present conditons. Special attention may be given to marginal sites, near the edge of the ecological or geographical range. For savanna afforestation the security of the crop against infrequent years of very severe drought may be important and marginal populations which have been subjected to such conditions are likely to be more resistant as a result of past selection pressures.

Very rarely is the seed user able to collect the seed personally. He must, therefore, ensure that his objectives are clearly understood and if necessary detail the desired method of sampling and the provision of all information (climate, soil, vegetation, history, methods of collection, etc.) needed to interpret the results of studies and experiments based on the material collected.

For provenance research, it is desirable to sample as fully as possible the range of potentially valuable genetic variation within the population. In the absence of any estimate of population variances, this means collecting from relatively large numbers of trees - Callaham (1964) suggested 25-50 trees in heterogeneous populations - well spaced to avoid closely related neighbours (half-sibs). It is best to collect only in a year of abundant seed production. The selection of better than average phenotypes is not recommended. For some purposes, it is preferable to keep seed of each tree separate and to preserve the identity of each parent tree, but for most provenance trials this is not essential and often not possible.

For further information on seed collection see e.g. Kemp (1976) and Turnbull (1975).

CONDUCTING PROVENANCE TRIALS

Nursery Practices

The primary concerns are (i) to maintain the identity and integrity of each provenance at all stages and (ii) to ensure uniform treatment so that results are truly comparable. Differences in nursery stock resulting from different treatments can persist into the field and may be detectable several years later. To some extent these two aims conflict, since it is easier to avoid accidental mixing or wrong labelling of provenances if each is kept in one discrete block with physical barriers between. On the other hand to guard against unknown nursery effects it is preferable to use the same replicated, randomised designs that will later be employed in the field trial. Conditions within each replication should be as uniform as possible and sowing should be done one replication at a time. Pricking-out and transplating are two operations during which the danger of mixing different provenances is high. This danger can be lessened by careful attention to labelling and by moving only the seedlings of one provenance, in each replication, at one time. The position of the provenances within each replication should be re-randomised when pricking-out or transplanting.

Culling of poor or deformed plants is permissible in accordance with normal nursery practice, but the number of plants culled of each provenance should be recorded. Edge effects in transplant beds or in blocks of pot plants are common and if possible, the outer one or two rows should be regarded as guard rows and not used in the inner assessment plots of the field trials. If, due to shortage of stock, it is necessary to use such plants, or those that would normally be culled, their field positions should be recorded.

Nursery records of germination, survival and growth at successive stages in the nursery must be meticulously maintained. Additional assessments to reveal differences between provenances should also be made whenever possible, such as the number, length and colour of cotyledons, length of hypocotyl and phenological observations, e.g. production of secondary needles in pines or mature leaves in eucalypts. It is sufficient to make such observations and measurements on random samples of perhaps 20 seedlings in each plot. Where facilities are readily available, comparative studies of different provenances in controlled environments (growth cabinets or phytotrons) may reveal differences in physiological response to drought, for example, which could be significant for savanna afforestation. Biochemical studies may also be helpful in revealing differences between populations, based on characters which are under more direct genetic control than such production variables as height and diameter (Lever and Burley, 1974). The value of such studies lies not only in their contribution to biosystematics, but also in the possible indications they may give of later performance in the field. They also help to prevent or reveal errors in identification, if consistent differences between provenances at this stage are established.

Field Trials

The main principles involved in selection of representative sites for trials, collection of site data, the use of valid experimental designs and careful labelling and recording, are the same as those applied to species trials. However, because all species included in provenance trials have already been shown to be sufficiently well adapted to the local environment to make them potential plantation species, we are concerned not with gross differences, such as very high mortality, but with subtler differences of growth and form. For this reason even greater care is needed in all aspects of design and execution. This applies particularly to plot labelling and recording, since it is usually much more difficult to recognise different provenances than different species.

To minimise possible errors due to differential effects of weed growth on different parts of the experimental site, complete removal of competing vegetation prior to planting is recommended, followed by a very high standard of subsequent weedings and cultivations. The use of insecticides, or fertilisers, may also be recommended in certain circumstances, if uniform treatment throughout the experiment can be assured. Generally larger plots are used in provenance trials than in the equivalent stage of species trials, to minimise the effects of tree to tree differences, and to provide sufficient trees for reliable estimation of population differences throughout the life of the trial. The recommended size of the inner assessment plot is 25 trees, with a surround of one or two guard rows. Recommended spacing between trees is 3 x 3 m as a general rule.

Information from species trials may be available that can be used to calculate the desirable number of replications, in order to achieve a certain probability of obtaining a significant result (see Cochran and Cox, 1966). In practice some compromise is usually reached between the degree of precision desired in detecting differences and the practical limitations imposed by the site, the availability of planting stock and so forth. However, it may sometimes be preferable to reduce the plot size, or to use a complex design such as a lattice, to maintain the required precision.

Field Assessment and Records

The principles in regard to method and frequency of measurement of survival, height, diameter and volume production are the same as in species trials, although the degree of precision demanded may be greater. In addition to these basic data, very often considerations of tree form assume greater importance at the provenance trial stage. The problem of ensuring uniform standards of assessment of such characters is usually met by a standard scoring system, such as is employed in tree breeding. (See e.g. Hans, 1972). For assessment of branch characters a standard assessment point for all trees is needed (e.g. half total height). Number of branches per whorl, and mean branch angle may be measured directly and branch size may be related to the diameter of the bole at that point. Burley, et al, (1975) give further information on uniform standards of assessment.

When provenances are grown in different environments not only the comparative rates of growth may vary, but the patterns of growth and wood formation may also change, as a result of genotype/environment interactions. It is important when comparing provenances to take into account possible differences in wood quality, such as might arise from different patterns of latewood formation, or overall density, since these might materially affect the value of the product for certain end uses. Studies to detect differences between populations may include detailed examination of leaf or needle-morphology, cytological characteristics or biochemical products (see Lever and Burley, 1974).

The use of standard forms to record measurements and observations is strongly recommended. For design and analysis of experiments and specimen forms for records and calculations, see Burley (1976).

INTERNATIONAL COOPERATION

Provenance research requires well documented seed of known origin and for this special collecting expeditions are usually required. The same expedition can collect seed for use in a number of trials in different countries and this can have advantages not only in reducing the cost that would otherwise be involved in several separate expeditions, but also in making seed for provenance research available to countries that could not otherwise obtain it. Where the country of origin has the staff and other resources to undertake exploration and collection, it may extend the activities as a form of aid overseas, as in the case of Australia, where substantial quantities of seed of many eucalypts are stored and tested at the Australian Government's seed bank in Canberra and samples are made freely available for research in other countries. Elsewhere, where local resources are inadequate, bilateral aid programmes of countries outside the region concerned have financed similar seed collections, such as the work of the Danish/FAO Forest Tree Seed Centre in S.E. Asia, or of the Commonwealth Forestry Institute, in Central America (Kemp et al, 1972). These activities are coordinated through FAO (1974a) which has prepared proposals for an integrated Global Programme (FAO, 1974b).

These international programmes have the further advantage that it is possible to compare the performance of the same provenance on a wide range of sites in many different countries and thereby to gain a better understanding of the plasticity of the population and its site requirements. This may help in predicting performance on other sites where trials have not been established. In order to make such comparisons possible, centralised systems of data storage and retrieval are needed (Burley, et al, 1973). By this means also results of trials, or of more detailed laboratory studies, may be made more widely and readily available, to assist the interpretation of local experiments and the choice of provenances for plantation establishment, or for further trials. The greatest amount of information possible is needed in order to identify precisely the pattern of phenotypic and genetic variation. International programmes may also provide the basis for effective conservation of genetic resources and for future tree improvement through selection and breeding.

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SEED COLLECTION AND CERTIFICATION

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CONTENTS

FEATURES OF SEED PROCUREMENT FOR SAVANNA REGIONS

Tree Planting Practices in African Savannas (FAO, 1974a) discusses the present and future requirements for forest products in the savanna region of Africa. Certain trends relevant to seed procurement emerge in spite of the difficulties in making such forecasts. Due to expected increases in population and living standards and in the development of wood-based industries, wood consumption is estimated to increase from 29% for fuelwood to 185% for paper and paperboard in the period 1960-1975. Such a rise in consumption cannot be met from the existing low productive savanna woodland; the establishment of plantations, therefore, becomes a necessity.

The next questions that arise are what species may be the most suitable under varying conditions and purposes and what areas are required for fulfilling the stipulated demand. A number of species and provenances have already been tested and those most widely planted are listed and described in the above mentioned FAO publication on African savannas (see, for instance, Chapter 7). A good deal of testing, however, still remains. In most circumstances, experience from species testing has shown that exotics are superior to indigenous species with respect to ease of establishment, growth and utilization. This results in the problem of having to import seed, or the long term process of developing seed production locally.

Documentation, General

The importance of tracing promising plantings back to their origins, irrespective of their status as small-scale or large-scale plantings, has been recognized for quite a long time in forestry and has led to the formation of control systems for seed and plant transfer. Where more deliberate action has been taken to establish improved seed sources, including selective breeding and the formation of seed orchards, the control system has developed into certification schemes.

In the savanna region, the problems in these respects do not differ from those of temperate regions, but they may be more pronounced as the procurement of seed for some time to come will be largely dependent on import. One characteristic of seed import is that it involves cooperation between countries; it is, therefore, of great importance that international agreements be reached on the terms and documentation of collections. Such an international system presupposes the development of national or local control systems, and in order to discuss the coordination of these we shall need to look briefly at the principal aspects of seed collection and documentation.

Seed Procurement, General

The considerable role that seed import may play, as indicated above, has certain implications which may decisively affect the procurement and production of seed. Problems connected with the importation of tree seed may comprise:

1. Inadequate resources in funds, manpower and organization for seed collection in the host countries;

2. Lack of accessible seed stands and seed production areas, especially of desired origins;

3. Lack of reliable data about the seed origin and the collection method;

4. Risks of reduction in quality of seed, i.e. reduced germination capacity due to transport; and

5. Restrictions on the export of seed in bulk quantities imposed in several countries.

In addition to these problems there are those which are specific to individual species. They may comprise periodicity in seed production, short viability, low seed production, difficulty of access to specified stands or ecotypes, etc.

In general it is easier to obtain small quantities of seed for experimental purposes either through international seed centres or by exchange of seed. However, because of the difficulties and restrictions in getting bulk imports of desired species and provenances, it is necessary to seriously contemplate how to produce seed locally as soon as a seed source has shown promise.

SEED COLLECTION

Two things make it relevant to discuss seed collection in connection with tree planting practices in African savannas. The first is the general trend for countries in the savanna region to build up their own seed production and thus free themselves of the dependency on import; the second is that a better understanding of the various operations applied in other regions with tradition and knowledge of seed collection may help to make one's own collections more efficient in a shorter time. Therefore, we shall briefly consider the more important and principal aspects of seed collection. The subject is extensive, as is evident from the report of a recent training course on seed collection and handling in Thailand (FAO, 1975a). It is recommended to consult the report of that training course for details on the principles and techniques of seed collection and handling, especially as concerns tropical tree species.

When discussing seed collection in general terms, it is convenient to ask "where", "when" and "how" to collect.

Where to collect locally will mainly depend on the extent of trials with exotic species and the length of time they have been conducted. Indigenous species in the savanna regions are so far only used on a very limited scale. Looking at table 9, page 78-79 of Tree Planting Practices in African Savannas, it appears that out of 35 species only 6 may be considered indigenous to parts of the savanna region. It is natural to start collection of a species as soon as it has shown itself promising. This has been done in many instances, sometimes with remarkably good results (e.g. teak, gmelina, southern U.S.A. pines, Cupressus sp.), but sometimes also with disappointing effects perhaps showing up only a fairly long time later.

A common case is collection from an early introduction of a species with very vague or inaccurate information about origin and which often was planted at only one or two places in small plots (½ acre or 0.2 ha) without replications. Here the problem is that the seed to be used is from a single, very small population of trees, which perhaps has shown promise in only a limited number of the varied environments in which it is to be planted. The uncertainty concerns the genetic effect of using a small population, perhaps from a restricted location, for improvement purposes and the adaptability of the offspring to conditions differing from the test site. Although good results have been obtained by using seed from such small introductions, it is advisable to carefully select seed sources or to collect seed from stands which have a broader basis for selection and more precision in testing. From a technical point of view, seed collection in excessively small units, say below 2-3 ha, is generally less satisfactory. Cost of collection is relatively high and the seed may be of lower quality due to insufficient interpollination. See Keiding (1975a) for details on seed stands and Jones and Burley (1973) for information about the genetic implication.

To improve seed collection possibilities within the shortest possible time in areas relying on exotics, it has been recommended, and I believe also practised, to establish larger blocks of certain provenances beside the actual provenance trials. The purpose of this is to have larger units ready as seed sources, as soon as the results from provenance testing become available. Such blocks of provenances may also serve the purpose of conservation ex situ if the sources of origin are threatened in one way or another. A valuable reference material for this very important aspect of seed collection is "The Methodology of Conservation of Forest Genetic Resources" (FAO, 1975b).

Concerning "where" to collect, circumstances vary considerably within the savanna region, from having very little choice of sources locally to having selected seed stands and seed orchards. Procurement of seed is very often an act of balance between getting sufficient quantities of seed and getting seed of satisfactory genetic quality. Thus, which sources to use and how to utilize them should be closely coordinated with tree improvement programmes. This applies to all stages of seed procurement from importation to selection of seed stands and establishment of seed orchards. As it is not possible to cover the broad subject of the relation between seed procurement and tree improvement in the present paper, reference is made to more thorough treatments of the various aspects involved as given in the Report on the FAO/DANIDA Training Course on Forest Seed Collection and Handling (FAO, 1975a) and by Guldager (1974).

"When" to collect is a matter of timing in respect of age and season. When planning seed collections it is essential to know at what age the individual tree species can be expected to reach sexual maturity, their possible periodicity in flowering and fruiting, and at what time of the year the seed collection is best carried out. For the more important economic species such as pines, teak, Gmelina arborea and eucalypts, plus a number of other species, a fair amount of knowledge about flowering biology has been accumulated. Still, fairly large variations may occur within a species depending on origin (provenance) and the environments to which it may have been introduced. In some cases flowering and fruiting starts at a younger age in exotic environments than in the natural habitat, e.g. teak in Trinidad and certain areas of West Africa, while other exotic stands hardly produce any viable seeds at all, e.g. some tropical pines in Malaysia. Still other species may change their mode of flowering from being distributed more or less evenly throughout the year to becoming seasonal, e.g. Pinus merkusii on Java. It is, therefore, important to observe and register the flowering and fruiting habit of species, especially exotics, under local conditions. Such studies of the reproductive biology are also necessary to build-up and improve seed production, as they may help to determine the size and scope of seed production units, treatment of seed stands, seed handling and storage, etc. Even individual trees show variation in seed production which may be of some concern for the composition of seed orchards (see Keiding, 1975b).

Closely related to flowering and fruiting habits is the physiological quality of the seed which, among several factors, is also influenced by the right time and method of collection. Within the collection period of a certain species there is usually an optimum period in which the quality of the seed is best. Teak seed in Thailand, for example, may be collected over 3 months: February-April, but the month of March is normally the best, while the first and early fall in February often has a certain portion of immature seeds. Similarly, it can be of great importance to collect pine cones when they have reached just the right stage of maturity, indicated usually by the colour of the cone scales. Pinus merkusii is particularly sensitive to the timing of seed collection which is further complicated by the variation in ripening of cones between localities, between trees and even within trees.

Although the majority of species being used in the savanna region have more or less seasonal fruitbearing correlated with the change between wet and dry seasons, there may be fluctuations between years. It is often advantageous to make a survey and an assessment of the coming seed harvest well ahead of the actual collection in order to determine the best time for collecting and the size of the crop to expect. Again, for further information, reference is made to the report on the FAO/DANIDA Training Course on Forest Seed Collection and Handling (FAO, 1975a).

Finally in respect of "how", the subject of collection techniques has been reported on and described for many different situations. Naturally, the techniques vary according to the scale of collection, tree species and their economic importance, funds available, organization, etc. and they represent all stages from highly mechanized equipment requiring very little manpower, such as tree shakers, to climbing with or without ladders and to picking of seed from the ground with many collectors involved. It is not possible here to discuss the merit of the different methods and how to apply them under different circumstances, but it may be useful to briefly consider some of the more general aspects. Technically speaking, seed collection should aim at getting the largest possible quantity of seed in the best conditions, i.e. the highest possible physiological quality as efficiently and economically as possible. For the majority of species, the fruits have to be taken on the trees, which usually implies climbing. This requires a certain skill and training and may become fairly technical, involving ladders of different kinds, safety and other equipment. In highly developed seed production areas such as special seed stands and seed orchards of easy access, tractors with elevating platforms or tree shakers may be considered. As in nearly all circumstances it is important to utilize selected seed sources continuously, the fruitbearing portion of the tree should not be damaged. The practice of collecting fruits or cones from felled trees or by lopping large branches should generally be avoided unless the stand(s) are due for felling anyhow or it is the only possibility left because of lack of climbers. The handling of fruits and seed in the field and their transport also influence the quality of seed. If cones are packed tight in big bags they make "take heat", especially if they are picked a little too early. Similarly, fruits of Gmelina may be difficult to store if the pulp is allowed to ferment for too long a time.

To get a seed collection programme to function properly a certain amount of specialized knowledge and technical skill is required, combined with good coordination of the various operations involved. In many countries, therefore, it may be advantageous to establish seed centres or seed handling stations where all seed collection and seed handling are concentrated. Such seed centres may contain seed extraction machines, such as drying kilns for coniferous species, and equipment for cleaning, dewinging and grading the seed. Further facilities for seed testing, i.e. tests of germination capacity and moisture content, plus adequate store rooms should be available. It is also necessary to properly register all operations connected with seed handling and seed distribution. Depending on the magnitude of seed collection and the funds available, equipment may be more or less refined, but a fairly great flexibility can be exercised; often rather simple arrangements may work satisfactorily. For consultation regarding the establishment of seed centres see, for instance, Guldager (1974) and the previously mentioned FAO/DANIDA training course report (FAO, 1975a).

CERTIFICATION

The importance of obtaining seed from the right sources and of good quality has been stressed several times already. Another question which needs to be discussed is how the consumer can be assured of receiving the seed he wants or, if he does not know exactly what to request, how he may be provided with intelligible information to help him in his selection. For this purpose, certification schemes have been introduced in several countries and regions. Certification in relation to forest trees is defined as follows (Matthews, 1964, ex Barner, 1974a):

> "The object of certification of tree seed and plants is to maintain and make available to the practising forester sources of seed, plants and other propagating materials of superior provenances and cultivars so grown and distributed as to ensure the genetic identity and high quality of the seeds and plants."

"Genetic identity" is a key-word in connection with certification and the reasons why so much attention is given to this concept are very aptly summarized by Barber (1969, ex Barner, 1974a):

> "Exact control of genetic identity of reproductive material is necessary if success is to be achieved in tree breeding and in forestation programs. We should seek the goal of using only reproductive material with known genetic identity. However, the precision with which we identify material will vary according to the species, location, and final use.
>
> "The tree breeder must have complete knowledge of the source of the germ plasm with which he works. It is particularly important that the identity of each tree be maintained so that the breeder can consider the risks of any adverse traits associated with the mating of related individuals. As progenies are produced and grown, the breeder must be able to trace the pedigree record of each individual in order to locate parents contributing certain characteristics, either desirable or undesirable, and he must be able to duplicate all of his crosses as needed. The breeder has the responsibility to catalogue his material and to identify accurately all material exchanged or released for use.
>
> "The forester should know what source or strain will best meet his needs, and he must know the exact source of material used in establishing plantations and in regenerating stands if he is to provide optimum management, as knowledge of the genetic identity of the material used is necessary for planning proper spacing and culture. For example, since the use of a disease-resistant strain will result in less mortality and fewer defects, the manager may either use wider spacing or undertake more frequent thinning. Reports of substantial genotype environment interaction indicate that tree breeders can develop cultivars that will respond favourably to differences in site quality and culture. Where seed or seedlings of the proper source are not immediately available it may be economically feasible to delay planting for a year or more."

If a certification scheme is to be successfully established, it is necessary to consider all parties involved in the procurement of seed and reproductive material, including commercial seed dealers and nurserymen, state agencies for seed collection and plant production, research institutes and consumers. In addition, the scheme must be backed by legislation. National certification schemes are operating in many countries, but a few regional ones have also been established(e.g. North America). As seed and, to some extent, plants or parts of plants are moving across state boundaries, the need for internationally applicable rules has been felt for some time. As a consequence of this and on the recommendation of the World Consultation on Forest Tree Improvement in 1963, work was initiated by the Organization for Economic Cooperation and Development (OECD) that year. Four years later, in 1967, the OECD certification scheme was finally implemented. Amendments were made in 1970 and 1974 (OECD, 1974).

This scheme is based on voluntary participation by members of the organization, but is open to other states which are members of the United Nations. Thus the OECD scheme is the first of its kind which aims at world-wide application. For a detailed description of the scheme, its background and definitions of terms, see Barner (1974a). There are, of course, many problems involved in getting such a scheme to function for so many different conditions. However, a very useful framework is available from which a better control of genetic identities may be obtained and thereby some safeguard against gross mistakes.

A few main points of the scheme are outlined in the following:

If a certification scheme is contemplated, the necessary funds must be allocated and, therefore, authorities controlling the finance have to be convinced about the justification of the scheme. To quote Barner (1974a) the best approach is "to furnish estimates of the real losses caused by sustained carelessness rather than those of costs and benefits of initiating long-term breeding programmes".

To implement a comprehensive scheme the following elements should be considered (Barner, 1974a):

"Planning

1. Preparation of maps showing distribution of important species,
2. Delimitation of regions of provenance of these species,
3. Delimitation of major regions of afforestation and reforestation and
4. Estimation of supply and demand of seed and plants;

Implementation

5. Organization and management,
6. Classification and approval of sources,
7. Recommendations for choice of provenances and transfer of reproductive material,
8. Production and control procedure,
9. Data recording and documentation and
10. Marketing of reproductive material."

Items 1 and 2 have special reference to countries or regions with extensive areas of species covering different ecological conditions. The direction and distance of seed transfer may be of considerable importance.

"Organization and management" (item 5) concerns the appointment of various groups of responsible authorities such as: 1) a designated authority or management committee, 2) an advisory group, 3) a working group on approval of sources and 4) inspectors.

Item 6 is a broad and fundamental subject in connection with the development of the scheme (Barner, 1974b). Basically the sources may be classified according to an increasing degree of selection:

a) regions of provenance
b) stands
c) seed production areas
d) individual trees
e) seed orchards.

Approval of the sources according to some minimum requirements should be the responsibility of the working group on approval of sources, mentioned above. A national list of these sources must be made in which the most necessary information is recorded, such as: Latin name, identification (reference no. or letter), location, origin, ecological conditions and test results. Definition of classes and prescriptions for the recording of information are given by Barner (1974b). It should be emphasized that the national list does not necessarily comprise all the types of sources stated above, as they simply may not be present, but allowance should be made for extending the list as new sources become productive. Another important aspect of setting up a national list is its applicability in an international context.

A further development of the approval of sources is the "recommendations" (item 7) of them for either general or specific utilization. Very often seed sources are approved on the basis of the performance or phenotypic appearance of the seed trees without, or with very limited, testing of the offspring. Recommendations must be based on tests, but as these take time and seed has to be produced, it is necessary to make use of seed sources which are not yet tested. Certification schemes, therefore, distinguish between tested or untested material within each class of approved sources. For species which have a wide geographic distribution, it may be appropriate to give directives for the transfer of seed both in respect of altitude and in latitude and to delineate planting zones and regions. The establishment and the development of a certification scheme, therefore, should take place in close co-operation with research, especially in the field of tree improvement.

A certification scheme should furthermore contain rules for "production and control procedures" (item 8). Barner (1974a) has given the rules and minimum requirements applied by the OECD-scheme which ensure that the material produced from the approved sources of different categories is of the right identity and has been treated correctly, when it reaches its destination. The rules prescribe how inspections should be carried out in forests, plantations and nurseries and how the material should be labelled and packed. "Data recording and documentation" (item 9) are of course necessary elements of the control measures. Each seed lot, for instance, will have to be furnished with a standard set of records comprising detailed identification, year of collection, quantities of fruit/cones collected and seed extracted, storage and quality of seed. In addition, records should be kept of handling in nurseries, and reference made to institutes (organizations) and persons responsible for the execution of the different operations (see Barner, 1974a). When the designated authority is satisfied that all operations have been made in strict accordance with the directives, certification will be issued.

Although the description above is just a brief outline of a certification scheme in operation, it may give the impression of a fairly cumbersome system with a heavy load of bureaucracy or papers. True, a scheme which has to cater to so many interests will require a good deal of checking and registration. But it has also provided a clarification of the many concepts and terms which are used in connection with collection, handling and testing of seed, and thus given an international basis for the procurement and control of seed. It should be stressed that the OECD scheme has been developed with particular consideration given to circumstances in temperate regions of the Northern Hemisphere. Therefore, before implementing the rules and directives to tropical conditions the scheme should be critically examined and altered where rules do not apply, which may mean simplification. Referring to the purpose of certification as defined by Matthews (1964), the scheme should make available seed from the best sources, properly identified genetically, and of the highest possible physiological quality. As explained above, this necessitates control and registration, but it may be appropriate to warn against a too elaborate control system if the result becomes either a hindrance to the provision of seed or a temptation to evade the system.

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SEED HANDLING AND STORAGE

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CONTENTS

INTRODUCTION

The importance of seed in any forest plantation programme cannot be over-emphasized as seed is a key element in plant production. A prerequisite in any planting programme is an assured supply of seed (FAO, 1955). Usually, the ideal thing would be to sow seed in the field or nursery as soon as it is collected. However, in view of the great demands for seed by large-scale plantation programmes, this is not always possible so seed must be collected in advance and stored. The aim, however, should be to store seed for as short a time and as perfectly as possible in order to ensure minimum loss of germinative energy.

Baldwin (1942) defined storage as the preservation of seed from the time of collection or extraction until it is desired that it shall germinate. From a physiological point of view, however, the storage period also includes the time on the plant between maturity and harvest, where weathering is often a serious factor. Detailed aspects of physiological considerations involved in storage will be given less treatment in this lecture; emphasis instead will be on the practical aspects of seed preservation from the time of collecting to sowing.

PREPARATION OF SEEDS FOR STORAGE

Transportation of Fruits

Seeds require transportation from their sources of collection to their destination for extraction and cleaning before storage. When fruits or cones are collected they should not be delivered to the processing centres in such air-tight containers that air circulation is prevented. On the other hand, cloth bags should not be of such open weave that seeds can escape during transportation. To prevent "heating" and mould in warm weather, the collected seed should not be piled closely in a confined space, and they should be delivered for extraction as soon as possible. It is advisable to move bags about daily to provide sufficient aeration.

Seed Extraction

After collecting cones or other fruits, a very important stage in seed handling is the extraction and cleaning of seed. Generally, cones and several other types of fruits require pre-drying to facilitate extraction of the seeds. On the other hand, some fruits require a period of soaking in water before seeds can be released for easy extraction. Whether drying or soaking in water is required, great care is needed during the operation in order to ensure minimum injury to the seeds.

Mechanical devices have been developed for the extraction of seed, but in Nigeria and many other developing countries, seed extraction is still done by hand. In either case, be it manual or mechanical extraction, the techniques vary with the species.

Seed Cleaning

There is usually the practical problem of inadvertently collecting immature fruits during harvesting. This is because not all the fruits of a given crop mature at the same time, and since it is not usually economical to harvest each seed or fruit as it matures by repeatedly going over the crop, immature seeds are often harvested along with mature ones. Since immature seeds are low in viability and have a shorter longevity than mature seeds, they are less desirable for storage and should therefore be removed during cleaning.

When a seed lot is harvested, it contains trash, broken seeds and light seeds which should be separated from the sound seed before storage. However for some species, such as most eucalypts, it is not practical to separate sound seed from the smallest impurities (e.g. unfertilized or aborted ovules called "chaff"). Also, as more and more evidence indicates that the seeds of greatest longevity in a given seed lot are those with the greatest density, it is desirable that only seeds of high density should be kept for long storage (Harrington, 1972). Proper cleaning procedures for seeds are well covered in the handbook by Harmond et al (1968).

Effects of Extraction and Cleaning Treatments

Haack (1909) states that the first pre-requisite for successful storage is good extraction and cleaning. Seed cleaning can be damaging to seeds, especially dry seeds. Damaged or weakened seeds will not keep well in storage; therefore, it is of vital importance to exercise maximum care during extraction and cleaning to avoid injury to the seeds. Seeds which have been injured by abrasive dewinging and scarification, or weakened by wetting, fluctuating temperatures, or other influences never regain their original vigour.

Methods of Seed Drying

When seed moisture content after harvesting and cleaning is too high for storage, the seeds must be dried. Harrington (1972) describes the following three ways of drying seed.

Sun-Drying

Seeds can be dried by spreading them on to the ground, on a paved surface or on a canvas for sun-drying. This method, however, fails during rainy or highly humid periods. Also, seed germination capacity can be decreased if the days are extremely hot.

Use of Ambient Air

Seeds can be placed in a bin or other container through which ambient air is blown. Such drying is inexpensive, but is effective only as long as the relative humidity of the air is lower than the equilibrium moisture content of the seeds. If the relative humidity of the air exceeds equilibrium moisture, the seeds will gain moisture. Also, if the seeds are not dried fast enough, storage fungi will invade the seeds, thereby reducing longevity.

Use of Heated Air

This method is most commonly used. The temperature of the drying air is heated to increase the moisture gradient between the moist seeds and the hot air, thus drying the seeds faster. However, excessively high temperatures and rapid drying can be harmful and may seriously diminish seed vigour or even kill the seeds outright. The maximum safe drying temperatures will vary depending on the species.

PRINCIPLES OF SEED STORAGE

Reasons for Storage

The main reasons for storage of tree seeds can be summarised as follows (FAO, 1955):

(i) to preserve seeds under conditions that best retain germinative energy during the interval between collection and time of sowing;

(ii) to protect seeds from damage by rodents, birds, insects and other enemies; and

(iii) to preserve quantities of seed collected during years of heavy seed to furnish a supply during years of little or no crop.

Techniques of Storing Seed

Tree seeds are commonly stored under one of the following conditions as described by Baldwin (1942):

(1) Dry and cold storage, simulating conditions in the cone or dry fruit on the tree; or

(2) Moist and cold storage, simulating conditions in the forest litter and humus.

Dry and Cold Storage

All seeds can be kept longer at low temperatures than at high temperatures, since respiration and chemical processes are retarded. Cold dry storage involves the control of temperature, moisture, and to some extent light, atmospheric conditions (pressure, gases) and other environmental factors (Baldwin, 1942). Generally, it has been established that fluctuation of factors, especially temperature and/or moisture, has adverse effects on seed under storage.

Moist and Cold Storage

Large heavy seeds are best preserved in cold moist storage. Prevention of mould and maintenance of moisture may be obtained by mixing the seeds thoroughly with clean, moist sphagnum moss. Damp sand, peat, sawdust, cork, or ground charcoal have also been used successfully (FAO, 1955).

Factors Influencing Storage

Although species differ markedly in their storage requirements, the same factors are involved for all. Many of the factors which influence the longevity of seed in storage include:

(a) type of seed; each species differs from every other in its capacity for retaining viability;

(b) stage of maturity at collection;

(c) prestorage treatment including extraction and cleaning operation;

(d) viability and moisture content when stored;

(e) air temperature, humidity and oxygen pressure during storage;

(f) degree of infection by fungi and bacteria before and during storage;

(g) light; since light may occasionally act as a stimulant of vital activity, if not germination, it is generally believed that seed retain their viability better in darkness (Baldwin, 1942); and

(h) pressure. Low atmospheric pressure is apparently favourable for retention of viability. Most of the effectiveness is probably due to reduction in the partial pressure of oxygen (Baldwin, 1942).

The complexities of the interrelationships among these various factors notwithstanding, a few generalizations provide guidelines in sustaining seed viability (Holmes and Buszewicz, 1958 and Roberts, 1972 as given by Stein et al, 1974):

"(i) Fully ripened seeds will retain viability longer than seeds collected when immature.

(ii) Seeds of high initial viability will store better than those with low initial viability.

(iii) Seeds with hard, impermeable seed coats will retain viability longer than those with soft permeable seed coats.

(iv) Undamaged seeds will retain viability better in storage than seeds physically damaged during collection or processing.

(v) At low moisture content or low temperature, the adverse activities of insects and diseases are effectively slowed or stopped.

(vi) Fluctuations in temperature or moisture are less favourable than constant conditions.

(vii) For many species, the lower the temperature and the lower the seed moisture content, the longer the period of viability."

Proper storage should, in fact, begin with sound seed. Given seed that is mature, highly viable, and undamaged, its life span will hinge primarily on species characteristics and the temperature and humidity conditions prevailing during storage. Obviously, seedlots known to contain damaged, immature or low viability seed should be scheduled for earliest use and the best seed should be retained for long-term storage (Stein et al, 1974).

Temperature and Storage

One of the major environmental factors affecting seed longevity is storage temperature. Generally speaking, all seeds keep better at relatively low temperatures than at high. In other words, the cooler the temperature the more slowly seed vitality declines. This rule continues to apply even at temperatures below freezing.

It is a known fact that temperature fluctuations are more unfavourable to keeping qualities than an even temperature.

Just as with high relative humidity, high temperatures are conducive to the activity of micro-organisms, especially insects. At 5°C and below, insects become inactive. Therefore, besides retaining seed viability, low temperature storage automatically prevents or controls insect damage.

The role of high temperature in speeding seed deterioration is not fully known. It is generally assumed that the high seed respiration at high temperatures is related in some way to rapid loss in germination. In spite of this assumption, it is quite obvious that the cause of death is not depletion of stored foods (Harrington, 1972). The effect of temperature on seed longevity still remains a fertile field for future research.

Seed Moisture Content

Seed moisture content is one of the two main factors influencing seed longevity. Generally, the higher the seed moisture content the more rapid is the decrease in germination capacity. But, at extremely low moisture contents of seeds, a slight increase in the rate of loss in germination occurs.

Low moisture content is favourable for keeping seed viability since it operates to suspend vital processes. This applies particularly to seeds which can be dried safely.

Seed moisture content is probably more important than temperature in its influence on keeping qualities and rather more difficult to control. It is hard to measure or determine accurately without laboratory tests. Standard methods of determining moisture contents of seed are described in the ISTA Rules and Regulations (ISTA, 1966 and 1974).

Problems of storing seed of high moisture content. The problems of maintaining viability increase with seed moisture content. Harrington (1972) came to the following conclusions:

(a) When seed moisture is above 40-60 percent, germination will occur;

(b) When it is 18-20 percent, heating may occur;

(c) When it is 12-14 percent, multiplication of micro-organisms will result; and

(d) When it is 8-9 percent, insects become active and reproduce.

Thus the problems of high seed moisture content include germination during storage, fungal attack and insect attack. In addition, there is a serious longevity - halving effect with each one percent increase in seed moisture.

Critical moisture content levels. It is important to note that critical moisture content levels for seeds of most genera have not been worked out, but a range between 5-12 percent has been recommended for most species which can be dried. It is also important to note that even though low moisture increases longevity, over-drying can also be harmful, often leading to complete death of the seed.

Normally, seeds are stored with a moisture content low enough so that germination, with resulting death of seed, will not occur during storage.

Methods of controlling moisture content. Moisture content in seeds can be controlled in many ways; these include:

(i) Air-drying in the sun, or in a warm room, or in a seed extraction shed. This is the safest and the most simple.

(ii) Oven-drying. This is often not economical, and great care is required to avoid over-drying.

(iii) Use of desicants, e.g. calcium oxide, charcoal, and silica gel beads. These are very effective and harmless to seeds if used in the right proportions.

(iv) Other chemical solutions have also been effectively used. However, great care is needed in using any chemical for regulating humidity and seed moisture content since the chemical may directly affect the seed or cause excessive reduction in moisture content.

Moisture content and control of insect and microflora. Insects and fungi are usually held in check by dry, near-freezing or sub-freezing storage of seed, but in moist storage at cool temperatures, pre-storage fumigation may be necessary (Holmes and Buszewicz, 1958).

At seed moisture contents of 12-20 percent, the activity of micro-organisms, particularly fungi, can be great. The higher the moisture content in this range the more rapid is the growth of organisms and the greater is the danger that they will destroy the capacity of seeds for germination. Storage fungi are mostly species of Aspergillus and Penicillium, which are ubiquitous on decaying organic matter.

Since it is almost impossible to keep seeds free of storage fungi, the easiest and best alternative is to keep seeds dry - in equilibrium with a relative humidity of 65% or drier. Under such conditions, these organisms cannot damage seeds (Harrington, 1972).

At seed moisture contents below 8-9%, little or no insect activity occurs and insect reproduction will not take place. If seed moisture content is maintained below 8%, and the storage is completely sealed so that respiration reduces the oxygen content below 14%, insects cannot survive in the seed (Harrington, 1972).

CONSTRUCTION OF SEED STORAGE FACILITIES

Certainly, the longevity of seed in storage is intimately related to its storage facility. There must be protection against theft, rodents, birds, insects, and fungi that might enter the storage and destroy the seed from outside. There must also be adequate control of temperature and relative humidity to minimize biochemical destruction of the seed.

Protection Against Theft, Rodents, Birds and Insects

A good seed storage unit should have no windows and only one door, thus minimizing the chances of theft. The door should be sealed properly against rodents and insects, and locked when the storage is not in use. Care must be taken not to let in rodents through the door when loads of seed are being brought in or taken out.

Wooden construction is less desirable than brick, stone, concrete or metal. When wooden constructions are used, the foundation should be of stone or concrete and should extend three feet (1 m) above the ground. There should be a lip around the building at a height of 3 feet (1 m) extending out 6 inches (15 cm). Such a construction makes entrance by rodents through the walls virtually impossible as long as the foundation remains uncracked.

Storage insects can even be more damaging than rodents and usually constitute a greater problem in the tropics than in temperate countries. Construction of the floor, walls and ceiling of the storage should be such that no cracks exist which can harbour insects. Plaster, insulation and plywood, properly applied, can minimize cracks. Ventilation openings should be screene against insects. All openings, such as electric conduits, ventilation openings and doors, should be thoroughly sealed. A yearly painting of the interior with a residual insecticide will further minimize the possibility of insect infestation.

Sanitation

Sanitation, both inside and outside the building,is very important. Discarded seed and cleanings should be hauled away and not dumped just outside the door and left to harbour storage insects.

Fumigation

Once the seed storage is completely free of insects, the most serious source of reinfestation is infested seed which is brought in. Seed may be brought in from the field already infested or it may be transferred from an infested storage. Such infestation is controlled by fumigation.

Rather than fumigate the whole storage, it is advisable to have a fumigation room, with its own door on the outside, or to fumigate the seed on a concrete slab under a tarpaulin. It is only after fumigation that the seed should be brought into the storage area.

It is important to note that fumigation (particularly repeated fumigation) may seriously reduce vigour and even germinative capacity of seeds. This is particularly true of seeds with high moisture contents. Seeds with moisture content greater than 14% should be dried to below this value before fumigation.

High temperatures also increase damage to seeds by fumigants. Therefore, fumigation is only used with entering seed. However, when a storage unit containing much seed does become infested, then fumigation is necessary.

Temperature Control

Temperature is one of the two most important factors influencing seed longevity. The lower the temperature the longer seeds maintain their germinative capacity. Temperature control may be achieved by ventilation, insulation and refrigeration. These methods are not mutually exclusive and are normally used to supplement each other.

In tropical countries,refrigeration is necessary to keep storage temperatures below the usual ambient tempe:atures for long-term storage of seed.

Moisture Control

Experience has shown that refrigeration alone is not sufficient for seed storage. Hence,refrigeration storage is used in combination with dehumidification or with sealing the dried seeds in moisture-proof containers before they are placed in refrigerated storage. This is the technique principally adopted in Nigeria.

If seeds are dried to safe moisture levels and then stored scaled in moisture-vapourproof containers, the low moisture content of the seed will be maintained even under storage conditions of high relative humidity. Seeds sealed in such containers and stored in cold storage can keep their germinative capacity for long periods.

Use of Desiccants

Since moisture-proof containers are difficult to open and reseal, they are not useful for plant breeders and seed control officials, who must store many small samples that must be readily accessible. Such samples could be stored in a dehumidified,refrigerated room. Such rooms sre in use though they are very expensive. Also in many areas of the world, electricity is often unreliable, so refrigeration and dehumidification may not always work. An alternative is to store seed samples in metal boxes with gasketted snap-on lids, with desiccants (e.g. silica gel) enclosed with the seed samples.

Silica gel is available with all or some of the granules treated with cobalt chloride, which makes the silica gel turn from blue to pink at about 45% relative humidity. A quantity of silica gel is enclosed with the seed in the metal box in the ratio of 1:10. When the indicator granules turn pink, the silica gel is removed, reactivated by drying in an oven at 175°C, cooled in a sealed container, and returned to the metal box. Thus, the seeds are kept below equilibrium with 45% relative humidity, a moisture content desirable for several years of storage in a temperature range of 20 to 25°C.

In addition to easy accessibility, the metal box or such other container has other advantages:

(i) It is rodent and insect-proof as well as moisture-proof;

(ii) The boxes which are not very expensive are easily stacked on shelves in a small area,

(iii) Also, seeds in equilibrium with 45% RH will not be damaged by stored fungi;

(iv) The only care required is periodic inspection to make sure the indicator silica gel remains blue.

Effects of Airtight/Sealed Storage

Haack (1909), by carefully controlled experiments, showed that while airtight containers cannot wholly prevent deterioration of seed with storage, they help prolong life considerably.

It is now believed that the main virtue of sealed storage is not only to preserve the moisture content, but also to prevent contamination by fungi and possibly other enemies (Baldwin, 1942). It is of vital importance to ensure that seed is dried to optimal moisture content level before being sealed, otherwise, sealing will serve only to prolong an unfavourable condition, resulting in deterioration.

Choice of Containers

Several types of storage containers have already been mentioned. The important factor in the choice of containers is primarily the degree of sealing required.

Most large-scale storage of seeds is done in tightly-closed containers. Such containers slow down but do not entirely stop gas exchange between the contents of the container and the air within the storage facility. Obviously, the more contrast there is between inside and outside, the greater the need for minimising exchange. Other factors to consider in the choice of the best container for a given use were listed by Stein et al (1974) as follows:

"(i) When seed requires further drying in storage, do not use a tight-closing container because enclosing excess moisture is harmful to the seed (Barton, 1961).

(ii) Use a tight-closing container if gain in mositure content can be damaging and relative humidity in the storage facility is high.

(iii) Containers and seed can quickly gather unwanted condensation when brought out of cold or subfreezing storage. Warming to room temperature is recommended before opening a container brought out of such storage.

(iv) Four to 10 mil polythylene bags will exclude or retain moisture but still allow exchange of oxygen and carbon dioxide with air outside. Such exchange may be beneficial or harmful depending on the species.

(v) A container that is easy to open and close is desirable when quantities of seed are likely to be added or removed repeatedly. Open only when necessary to minimize temperature and relative humidity fluctuations. Alternatively, store seeds in small containers, so that the entire content can be stored or emptied at once.

(vi) Fill containers completely to ensure minimum exchange of moisture between the seed and the entrapped air.

(vii) When seed moisture content or relative humidity is high, the container must be made of moisture resistant material.

(viii) When seeds are fragile and easily damaged, a rigid-walled container should be used. Moisture-proof plastic bags are often used as liners for rigid containers.

(ix) Choose a container shape and stacking arrangement which facilitates uniform temperature and aeration throughout the storage facility.

(x) Some containers may be of substances that are harmful to tree and shrub seeds (Barton, 1954). Unproven containers should be tested for toxity."

TESTING SEED QUALITY

Any seed storage programme, whether for commercial seed or germ-plasm seed, needs to have a seed testing programme as well. The storer of commercial seed needs to know which lots will begin to deteriorate most rapidly so he can sell them first. Also, the director of a germ-plasm storage must be able to ascertain when to "grow out" a seed lot before it is seriously reduced in germination capacity or even completely lost (Harrington, 1972).

The various kinds of seed testing and the procedures are described in the International Seed Testing Association (ISTA) rules and regulations (1966 and 1974). Among other tests, it is important that every seedlot should be germination-tested when it is received for storage, so that the seed quality is recorded. Subsequent periodic tests should be made to detect deterioration. If deterioration occurs, storage conditions should be checked to discover the reason and corrective measures taken (Harrington, 1972).

PACKING AND TRANSPORT OF SEED

Packing for Shipment

Experience has shown that loss of viability has been traced to exposure to high temperatures and varying humidity in transit. Some seeds require preservation in dry conditions, others moist.

The type of packaging selected for a seed shipment will depend on the nature of the seed, quantity to be shipped, time in transit, mode of transport, and expected weather conditions. The following helpful practices are recommended by Stein et al (1974):

(i) Double-wrap the seed. Enclose the seed container in a sturdy, preferably rigid, outer container.

(ii) Small or moderate size containers generally withstand shipment better than large containers.

(iii) Fill containers completely to minimize air content and jostling of seeds during shipment.

(iv) Seal in plastic, foil, or moisture-resistant kraft bags or in rigid containers such as vials, plastic bottles or tins.

(v) Seeds requiring high moisture should be mixed in moistened fine sphagnum moss, peat or sawdust and placed in water-resistant containers.

(vi) For some species, a chemical germination inhibitor may be added to the moistened medium (Barton 1961).

(vii) Large, moist seeds can be sealed individually with paraffin or latex.

(viii) All packages should bear a good identifying label on the innermost covering and another one within the container.

(ix) For long distances, shipment of sensitive seeds by air is desirable. Hermetically sealed containers may explode at high altitudes.

(x) Seed packages should permit ready opening and reclosing if destined for export to a country requiring fumigation.

Transportation of Seed

In addition to transportation from field to storage, seeds also undergo transportation between storages, as well as from storage to the planting site. All these involve periods of storage during which deterioration can be serious. It is important to note that at all stages of transportation, the principles of good storage apply equally. Steps must be taken to avoid high and fluctuating temperatures and adverse humidity which are the major causes of loss of viability.

With adequate packing and carefully planned shipment, most lots should arrive at their destinations in good condition. It is wise to send adequate instructions on post-shipment care with each lot.

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TREE IMPROVEMENT, SEED STANDS AND SEED ORCHARDS

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CONTENTS

TREE IMPROVEMENT

Tree improvement implies, generally speaking, all the activities based on utilizing the genetic potential of the species. This means that between and within species there is variation that we can use to our advantage. Variation is the result of interaction between the environment and inherited qualities of tree populations and individuals. In other words, it matters a good deal how we treat a particular population silviculturally and what kind of site it is planted on. Tree improvement may be applied in different circumstances and at varying degrees of intensity ranging from the conservation of gene resources and species and provenance trials to seed orchard establishment, controlled crossings and progeny trials.

A prerequisite for a tree improvement programme is plantation forestry. As soon as seed is collected and plants are raised and artificially cultivated, there is a chance to select and improve. Thus, it is convenient to consider tree improvement in relation to afforestation and reforestation programmes. It is obvious that tree improvement is particularly relevant to savanna conditions as all forest establishments will have to rely on planting, and to a large extent with introduced species.

Tree improvement, and in a more narrow sense tree breeding, or selective breeding, involves various stages of selection, beginning at the species and population level and ending with individuals, if we use the logical sequence. Species and provenance selection have already been discussed; we shall therefore turn to selection of superior single trees.

Phenotypic Selection and Environment

Any selection of individual trees is a phenotypic selection as we cannot separate the influence of the environment and the genotype without progeny trials. At more advanced stages of tree breeding, where single trees are selected in replicated experiments, the selection becomes increasingly "genotypic", but the most common situation is probably the selection of plus trees or superior phenotypes in natural stands or plantations in order to initiate an improvement programme.

The relationship between the three concepts, phenotype, genotype and environment, is expressed in the well-known equation:

$$\text{Phenotype} = \text{genotype} + \text{environment}$$

The breeder's interest lies in securing the good genotypes, i.e. the trees that irrespective of environmental influences perform well or better than average. Such trees will possess a favourable genetic constitution, and they will, when grouped together, change the gene frequencies in a positive direction.

The phenotypes are selected on the basis of a number of characters whose superiority should usually be equal to or better than a certain, fixed percentage above the population mean. Instead of the population mean, a representative portion of the population is often used for comparison. This may be the four or five nearest dominant trees.

Which selection procedure to follow will have to be decided for the individual breeding programme, as each species and local market will have different requirements. Some guidelines on which method to follow may be attained by examining the relative importance of the individual characters in utilization or economic return. If a grading system (characters weighted) is employed, as for instance in the Texas Forest Service, U.S.A., the composite evaluation of the individual tree may be expressed as: total score = height score + diameter score + form score. In the allocation of a point score for a given characteristic, three factors have to be taken into account: (1) the amount of superiority of the trait, (2) the strength of inheritance of the trait, and (3) the economic worth of this superiority.

The number and type of characters used for selection vary of course, but some of the most common are listed below:

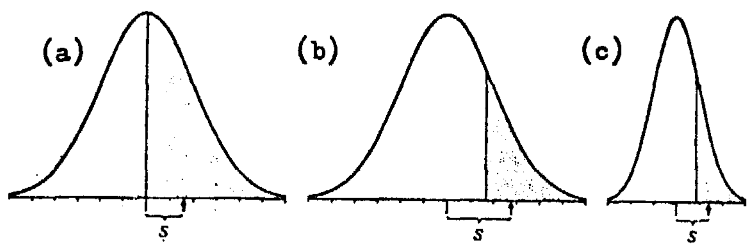
1. Superior height growth
2. Superior diameter growth
3. Good pruning ability
4. Straight, no crook or spiral bole
5. Flat (= wide) branch angle
6. Narrow, compact, well-formed crown
7. Disease resistance
8. Insect resistance
9. Drought resistance
10. Wood characteristics

Of the three factors to be considered before employing a grading system, the first can be measured, but the other two may be much more difficult to estimate. The strength of inheritance of the trait (2) for instance is only possible to assess after progeny testing i.e. in the course of the breeding work for which we have to select material.

Therefore in the initial phases of a breeding programme it may be advisable to use a selection procedure for individual trees which only registers the necessary information without weighting. What is actually "necessary" may be difficult to foresee so there is an understandable tendency to work out more elaborate plus tree record forms than is really justifiable. A measure of how much is reasonable to register can be obtained from breeding programmes which have been in operation for some time and from actual usage in the field. From the former it may be seen how much and to what purpose the data have been used and from the latter whether the forms and descriptions are practical to handle.

A measure of the intensity of selection is the selection differential, which is the difference between the mean of the selected trees and the mean of the population from which they are selected (see Fig. 1). As mentioned above, the mean of the whole population may be replaced by the mean of the four to five nearest, dominant trees. The reason for doing this is partly the difficulty or impossibility of measuring the whole stand, especially in natural mixed forests, and partly that a better basis for comparison is probably obtained as the nearest trees are more likely to have been exposed to the same environmental influences as the potential plus-tree. The comparison trees should be found within a radius of 25 to 50 m from the plus-tree.

Selection Intensity



Diagrams show how the selection differential, S, depends on the proportion of the population selected, and on the variability of the character. All the individuals in the stippled areas, beyond the points of truncation, are selected. The axes are marked in hypothetical units of measurement.

(a) 50% selected; standard deviation 2 units: S=1.6 units
(b) 20% selected; standard deviation 2 units: S=2.8 units
(c) 20% selected; standard deviation 1 unit: S=1.4 units

Fig. 1 From D.S. Falconer (1960)

The "effect" of selection is termed response (R) or genetic gain (Δ G), and it will be seen that in addition to the selection intensity the response is also affected by heritability. If the same selection intensity is applied to two characters with different heritabilities, the one with the lowest heritability will give the smallest response.

Vegetative Propagation

A technical problem which by no means should be ignored is the ease with which the different species may be propagated vegetatively. In several cases the development of a suitable method of grafting, budding or cutting has been decisive for the progress of breeding. The patch-budding method, for instance, gave rise to the intensive breeding of rubber (*Hevea brasiliensis*) and was later used for large-scale establishment of clonal plantations. The same method with certain modification has made breeding of teak feasible, and it seems suitable for some other tropical hardwoods as well. Thus the development of techniques for vegetative propagation is an indispensable part of individual tree selection.

Progeny Testing

The purpose of progeny testing in the traditional sense is "to assess the genotype of an individual or the performance of a parent by a study of its progeny under controlled conditions". Progeny testing was first introduced by Gregor Mendel about 100 years ago, so it is an old story.

Testing of progenies is also a means of estimating genetic parameters such as variances of different kinds (phenotypic, genotypic, additive and interaction between them), breeding value, combining ability, heritability etc. The latter, which may be termed "strength of inheritance", is of great importance for our selection work, as indicated above under selection of individuals.

Types of Progeny

The type of the progenies, among other things, determines how much information may be retrieved from the trials. Distinction is made between two main groups: half-sibs and full-sibs.

Half-sibs

Half-sibs comprise individuals deriving from one mother tree or one mother clone pollinated by the surrounding trees. Thus only the female parent is known. Many progeny trials are composed of half-sib families, a family being the group of trees with a common mother.

Full-sibs

In full-sib families both parents are known, as in the case with controlled crosses. More information can be obtained from such trials than from trials with half-sibs because an estimate of genetic variance can be made for both the female and male partners.

SEED STANDS

The following definitions are adopted in accordance with the OECD[1/] scheme:

Stand: "A population of trees possessing sufficient uniformity in composition, constitution and arrangement to be distinguished from adjacent populations".

A stand may be classified as plus, almost plus, normal or minus.

Seed stand, seed production area: "A plus stand that is generally up-graded and and opened by removal of undesirable trees and then cultured for early and abundant seed production" (Snyder, 1972 and Barner, 1974).

1/ OECD = Organization for Economic Co-operation and Development

The objectives of forming seed production areas, or seed stands, are, according to Matthews (1964) to:

1. produce seed of improved inherent quality by selecting and favouring seed trees which are vigorous, straight stemmed and healthy and produce wood of good quality;

2. concentrate seed collection into a few specially treated parts of the forest, thus making seed collection easier to organize and control;

3. improve the germinative energy and germinative capacity of the seed collected.

Age, Area and Development of Stand

The stand must be old enough to have proved its value in various respects and it should be in a good stage of flowering and seed production, and not too old to allow seed to be collected for a reasonable number of years ahead.

In special cases, however, it is justifiable to select younger stands, if they are showing great promise. It is recommended to register such stands as canditate seed stands for later inspections. See Barner (1974).

Seed stands should be of sufficient area, which normally means not less than 5 ha, in order to produce enough seed to be worth collecting and also to avoid possible risks in collecting from very small populations.

Isolation

Isolation from inferior sources is very important. In wind-pollinated tree species such as most conifers, proper isolation can be quite difficult to obtain, while insect-pollinated species like teak and rubber are easier to handle. If the seed stand is surrounded by undesirable pollination sources, contamination may be avoided or at least reduced by using isolation belts or filters either of the same or other species.

Treatment of Seed Stands

According to the definitions used earlier, a seed stand or seed production area is distinguished from a seed source by the treatments given to it in order to promote seed production.

Such treatments may comprise:

1. Removal of inferior trees to improve the genetic quality of the seed.
2. Thinnings to give the seed trees better spacing in order to improve conditions for flowering and seed production.
3. Removal of undergrowth to facilitate seed collection.
4. Application of fertilizers to improve seed production and seed quality (technical).
5. Proper demarcation of the seed stand.
6. Various other treatments, such as pruning and application of insecticides to protect flowers and fruits.

SEED ORCHARDS

Seed Orchard Approach

Stated briefly, the seed orchard method involves selection of superior individuals (within a large, satisfactory population or one known to be of superior provenance) and transference of their genes in the form of clones or seedling progeny into an area which is isolated from undesirable sources of pollen contamination, and where the object of management is efficient seed production. This procedure may or may not be taken further to include the development of new improved orchards.

Thus a tree seed orchard is a planted stand that is located, designed, established, composed, and managed to produce a reliable supply of genetically definable seed for purposes of forest management.

This description of the seed orchard breeding procedure and the above definition of a seed orchard do not imply a static strategy in which all worthwhile gains will accrue from the first orchard. In fact, a tree breeding programme should be dynamic, the objective being to continuously up-grade the genetic quality of the unit which produces the seed for reforestation (the seed orchard) by adding to the existing orchard or creating new orchards with improved clones of families.

Clonal vs. Seedling Orchards

Seed orchards may be established with clones (grafted ramets or rooted cuttings) or seedlings of selected trees. An entire double issue of the journal Silvae Genetica (1964) was devoted to discussions of seedling and clonal seed orchards (Toda, 1964); reference can be made to the several papers therein and a more recent and brief resumé of Kellison (1969) for details of arguments for and against each of these types of orchards. Suffice it to say that, as regards the breeding of tropical coniferous species, a recent survey by Nikles (1973) showed that only seven orchards of about eighty seed orchards established by countries surveyed were seedling seed orchards.

Benefits or Gains

A comparison of seed orchard offspring of *P. radiata* (30 clones) with that from commercial sources showed after 3½ years an improvement of 16 percent in height growth and 20 percent in diameter, both characters of fairly low heritability. The experiment was conducted in Australia and reported by Griffin (1969). Hybrid seed orchards for larch (*Larix decidua* x *leptolepis*) have constantly given offspring with a 10 - 30 percent increase in vigour plus improved form and resistance to canker when compared with the respective species in Denmark. In rubber (*Hevea brasiliensis*), where seed orchard development has reached an advanced stage, offspring are yielding 4-5 times as much latex as the base populations from which breeding started (Keiding, 1972).

Porterfield (1974), as quoted by Zobel (1974), had analysed the heritabilities of different qualities and worked out the gains that might be expected. In relation to the economic considerations of seed orchards his results were as follows:

"1. Total volume gains from seed orchard seed over unimproved plantations varied from 12 to 14 percent for unrogued seed orchards in the tree-improvement programmes assessed. Additionally, there was a gain of 5 percent for specific gravity, while bole straightness and crown improvement were in excess of 5 percent. Volume gains of more than 20 percent are quite possible by increasing roguing intensity and intensifying wild-stand selection intensities.

2. The profitability of a tree improvement programme is closely related to seed yields from the orchard. The best genetic stock is of no value until sufficient seeds are collected and planted - the more seeds, the more acres that can be planted with superior seedlings. Porterfield's study illustrates the extreme importance of maximizing seed yields from orchards by use of the best parent trees, fertilization, irrigation and pest control. Only 8 pounds of seed per acre per year in the seed orchard (after age 10) are necessary to break even for seed which produces seedlings 10 percent genetically superior in volume, at an eight percent rate of return; however, each pound of this kind of seed has a present value of $ 116 and every effort should be made to obtain maximum seed yields."

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NURSERY DESIGN AND IRRIGATION

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CONTENTS

INTRODUCTION

The production by the forest nursery of a sufficient number of plants of the right size and adequate quality at the right time is an important factor in successful plantation establishment. The first step towards the achievement of this is to have a properly-sited well-designed nursery with an efficient system of irrigation. Good nursery techniques, however skilfully applied, can rarely make up for a badly sited or badly designed nursery or one with an unsatisfactory system of irrigation. It must be remembered, however, that without a good nurseryman even the best-designed nursery is unlikely to produce good stock.

CHOOSING A NURSERY SITE

The decision must first be made whether the programme can best be met by having a large central nursery or several scattered small ones. Where communications are inadequate or transport facilities not available there is no alternative to a number of smaller nurseries. When there is a choice, one has to consider the relative economics of the two systems as well as several technical factors :

(a) The cost per plant of mass production in a large nursery is likely to be much lower but the cost of transport from such a nursery to the planting sites is bound to be higher. There may be a labour transport and subsistence cost to be considered in the case of remote smaller nurseries.

(b) The total capital cost of establishing several small nurseries has to be balanced against that of establishing the large central nursery. Equipment in the small nurseries will be simpler and the housing and related facilities of poorer quality but the total labour force will be higher and many items may have to be duplicated.

(c) In a large nursery you have the advantage of being able to concentrate your skilled supervisory staff, you can provide more sophisticated equipment and you can provide better facilities for your staff and labour. The supply of materials and the repair and maintenance of equipment are easier to organise.

(d) When you have a series of small nurseries, then you have the advantage of being able to isolate disease outbreaks and limit their effects on total production. The overall effect of equipment breakdowns will be less, and it will usually be easier to obtain the necessary quantities of soil and water.

(e) The effect on the nursery plants of transporting them long distances from a central nursery over rough roads must be taken into consideration. Plants can suffer from wind-burn if not protected, but even with adequate protection deaths can occur as the result of the breakage of fine roots by continual vibration.

Each nursery site should be on well-drained level ground. Where well-drained land is not available, then a slight slope is desirable but care is needed to see that erosion does not develop. A system of surface irrigation dependent on gravity flow may also demand the use of a sloping site. A mid-slope position to allow cold air to drain away is preferable and one has to avoid the temptation to choose a topographically unsuitable site such as a valley bottom or stream bank in order to facilitate the supply of water.

The nursery must of course be situated where an adequate and suitable supply of water can be provided (not forgetting domestic demands) and it must be situated as near as possible to a source of suitable soil or of the major constituents of whatever soil mix may be used (balancing the cost of transport of soil against the cost of transport of the planting stock).

Shelter is very important and unless the site is naturally sheltered a wind-break against the prevailing wind will have to be established. Hedges should also be established around the nursery, with gaps for cold air drainage, and in large nurseries internal hedges may be helpful provided they do not interfere with transport and work flow. In short-term nurseries artificial screens can take the place of hedges and wind-breaks and are likely to be needed in the early stages of a long-term nursery before the hedges and wind-breaks are fully established.

Air pollution has to be taken into account in the vicinity of industrial plants. Sulphur dioxide can have adverse effects at considerable distances under certain atmospheric conditions. This has already proved a serious problem in one nursery on the Zambian Copperbelt.

The presence of existing labour accommodation and related facilities and existing road access may be a further factor to be taken into consideration in the final choice of a site.

PLANNING THE NURSERY LAYOUT

It is convenient for both planning and operational purposes to divide a nursery into blocks, sections and beds:

(a) The bed is the basic unit, and the term 'bed' includes an area where boxes or plant containers are laid out when in use, in addition to the obvious structural formation used as a seed-bed or transplant bed.

(b) The section might consist of anything from two to eight beds and is the unit which will be subjected to the same treatment at the same time.

(c) The block is merely a group of a convenient number of sections which will vary according to the ground layout of the nursery. A block must always have space for a road through the centre, along the long axis preferably, so that truck off-loading or loading can take place from both sides.

A seed bed or transplant bed should be not more than 1 metre in internal width for comfortable working but standing-out beds in which containers or boxes are stacked may be up to 1.2 metres wide, the actual width preferably being arranged to take a round number of containers. Bed length is a matter of scale of operations and space available. The length of standing-out beds should be arranged to take a round number of containers, as this simplifies counting and organisation. It is usually not convenient to have any beds longer than 10 metres or lateral access is impeded. The orientation of seed beds should ideally be East-West to avoid sun-scorch.

Seed beds would normally be in separate blocks from the transplant and standing-out beds but should not be remote from them.

The total number of beds and sections required has to be calculated from the planned plantation programme taking account of culls, an allowance for blanking, and a safety margin. Allowance also has to be made for future expansion in the case of long-term nurseries. It must also be remembered that where plants have to remain in the nursery for over a year, additional bed space will be required.

Facilities for shading may have to be allowed for, but the precise form of these, as of the bed structures themselves, will depend on the types of bed, the techniques employed and the materials available locally. Where root pruning by means of a wire is standard practice, the design of the shade supports and other bed features must allow for this.

In the overall design and the layout of sections, blocks and beds, vehicle access and vehicle flow must receive considerable attention. A width of 5 metres should be allowed for a single track road. There must be adequate turning space, and there should be no necessity for reversing or other ground-churning manoeuvres. Any water draining from the beds over the surface should be led away from roads to avoid the development of soft patches.

The paths between the beds must be wide enough to take whatever hand-trucks, trolleys or barrows are used. One metre width is usually ample (see sketch 1).

The layout should be such as to enable a "flow" system of working to be employed (see example in sketch 2) and should enable the handling of soil, containers and other material to be kept to the minimum.

The type of irrigation system in use will also affect the specific layout. Examples of the layout of parts of actual nurseries in Zambia are given on the diagrams (sketches 1-3) to illustrate this.

In nurseries where soil has to be mixed with fertiliser or other ingredients, or where the soil is to be sterilised in 'clamps', then a section of the nursery has to be set aside for this. If the soil is to go into containers, then a further space immediately adjacent to the mixing/sterilising area will have to be set aside for the filling operation. In nurseries where soil is used without any admixture or where sterilisation is either not done at all or done in the pots <u>in situ</u>, then these special areas will not be required as the soil will be offloaded directly in the bed areas. Where such areas are required they must be located with work flow and minimum handling and within-nursery transport in mind (sketch 3).

In areas where mycorrhizal inoculation is expected to be necessary, it is useful in a long-term nursery to have a special mycorrhizal bed where pines are kept growing. The soil with which the bed is started should be brought from an established pine stand, but it can be kept topped up thereafter with ordinary woodland soil.

In long-term nurseries, it is always as well to allow extra space in any case, to allow not only for unforeseen expansion but also for changes in technique and experimentation with new techniques.

In addition to covered storage for barrows, containers and other equipment, special storage has to be provided for fertilisers, insecticides, fungicides and other chemicals. This latter should be conveniently located in the nursery where possible to minimise handling of dangerous materials.

Some provision should be made for the recording of meteorological data, in particular maximum and minimum temperatures and humidity.

WATER SUPPLY REQUIREMENTS

It is important to estimate the quantity of water which will be required. Where a domestic supply is also required the water source at its lowest level must be able to yield not only the peak requirement for the plants but also the peak domestic demand.

The nursery requirements obviously vary enormously according to local conditions and the type of stock being raised. Where there is no local experience on which to base an estimate then rough calculations can be made on the basis of evapotranspiration rates (see Appendix 6 of Laurie, 1974). Figures on which to base domestic demand estimates will usually be obtainable locally.

WATER QUALITY

The water should be relatively free from silt and other undissolved solids and the content of dissolved salts must also be low. pH should normally be not more than 7. It is not possible to be absolutely dogmatic about the limits of these factors, however, as different species and different soils react differently and the cultural practices employed will also affect the tolerance of the plants. Laurie (in Chapter 11 and Appendix 6) suggests limits which could be used as a guide until local knowledge has accumulated.

WATER SUPPLY INSTALLATIONS

Water may be delivered to the nursery by gravity feed, hydraulic rams or pumps. Details are given in Appendix 6 of Laurie.

When the irrigation is done by hand-held watering cans or knapsack sprayers or when it is a system of surface irrigation, then storage can be at ground level. It is, however, still essential to have storage, especially when the water source (a well, for example) cannot supply high peak flows over a short period although perfectly capable of supplying the required quantity per day. A common way of calculating the storage capacity required is to take the peak daily requirement, allowing for future expansion, and then to double it.

For hand watering by hose-pipe and spray rose and for all systems of overhead sprinkler irrigation, overhead storage is needed. A head of at least 10 metres when the tank is half full is needed in order to give the pressure required to produce small droplets. One should not rely upon continuous pumping against a closed valve to produce the required pressure.

Where domestic water is supplied from the same source, the domestic main must be separate from the nursery main so that varying domestic demands do not cause a fluctuation of pressure in the irrigation system. If a completely separate system can be provided then so much the better.

Wherever pumping is involved it is advisable to have a standby pump. If this is not feasible, the storage capacity should be further increased to cover breakdown periods.

Whatever irrigation system may be in use, the water has to be distributed to various points in the nursery by a series of either stationary or portable lines. Details of the various alternatives are described in Appendix 6 of Laurie.

Silt traps should be installed and a means of flushing out the system provided wherever sprinkler irrigation is in use.

IRRIGATION METHODS

Hand watering with cans fitted with a spray-rose or with knapsack mist sprayers is the obvious method for small nurseries (say, up to 10,000 plants). An adequate number of filling-points must be provided.

Hand watering with hose-fitted with a spray-rose can be used in small nurseries where the necessary head of water can be provided. This method can of course cope with larger nurseries but suffers from the same defect as the other hand methods in that uniformity of coverage is difficult to achieve. It is necessary to provide plenty of stand-pipes for this method, say one at each end of each block.

Surface irrigation can be applied to large nurseries but it is not a method very widely used. A good deal of skill is required in laying out such a system though it is comparatively inexpensive to operate. It is moreover difficult to control the amounts of water supplied and it is inefficient in water use. Fertilisers, insecticides and fungicides which cannot be used in sprinkler systems can be introduced with the water in surface systems but this also tends to be wasteful and difficult to control.

The ideal system for large nurseries is overhead sprinkler irrigation. A large number of systems are available but they can all be classed as either rotary sprinklers, nozzle lines, or perforated pipes. Rotary systems tend to produce larger droplets than the other two and owing to the shape of their spray pattern it is more difficult to arrange uniform coverage. They are however more tolerant of small particles in the water and so less liable to blockages. Nozzle lines are easier to maintain than perforated pipes. Both give a good uniform coverage.

No sprinkler system is perfect, however, and it is often found in practice that some supplementary hand watering is required, particularly in turbulent conditions.

Whenever a sprinkler system is being designed it is helpful to obtain expert advice before a final decision is made. Potential suppliers of equipment should be consulted and should be given very full information about the requirements. This should include:

(i) Area to be covered
(ii) Frequency, strength and direction of wind
(iii) Maximum permissible droplet size
(iv) Required rate of delivery per square metre of bed
(v) Pressure available
(vi) Size of main pipe from storage tank
(the last two where water supply already installed)

If you cannot get advice then at least get hold of the makers' manuals and study them before ordering the equipment.

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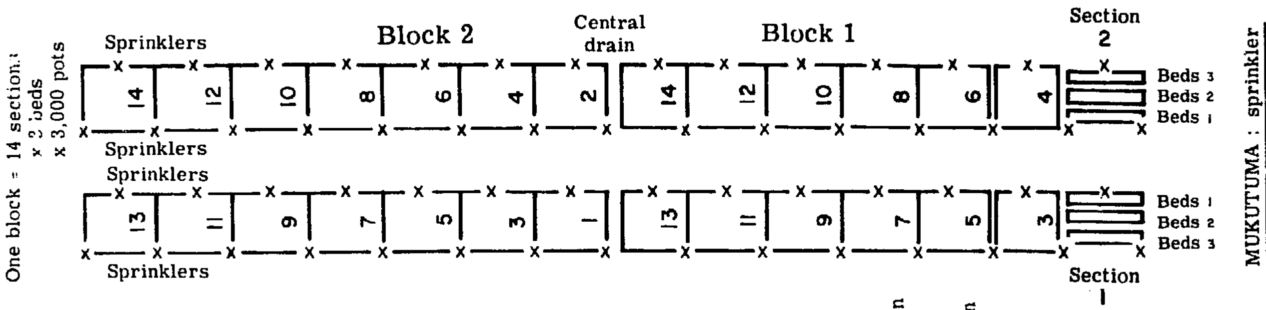
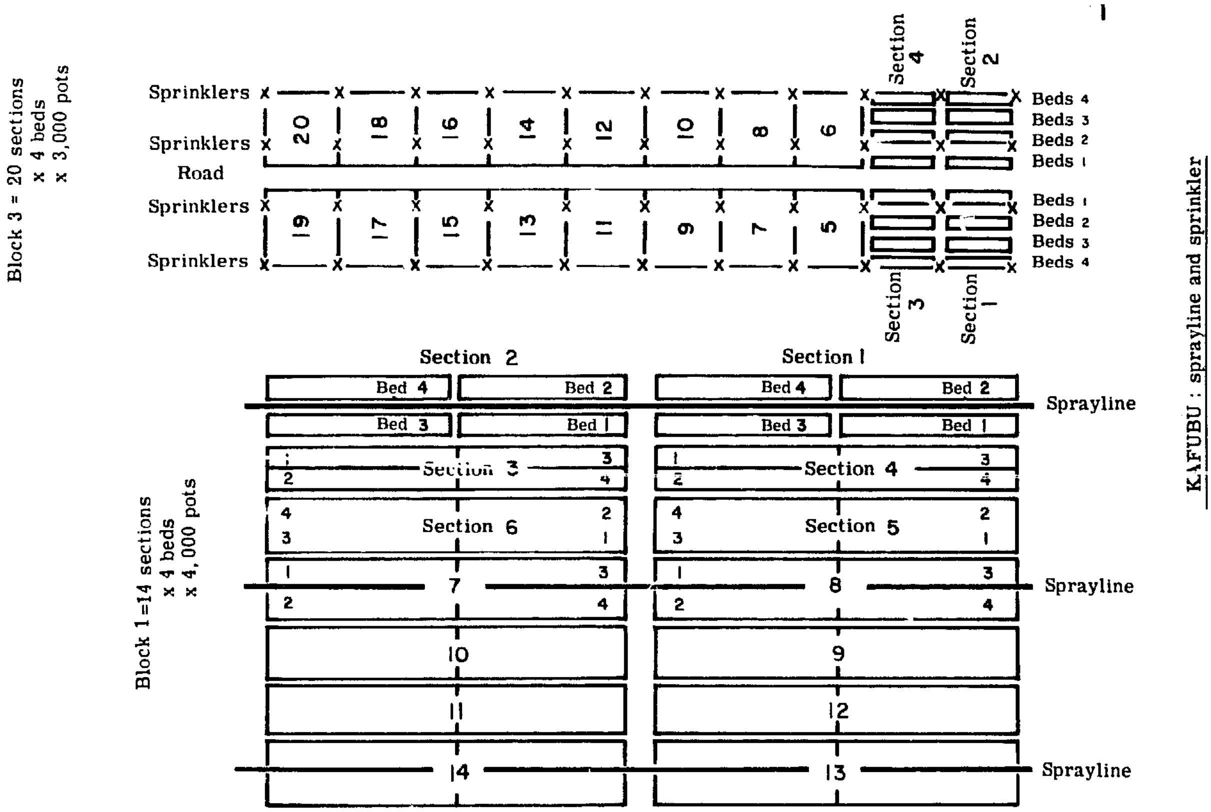
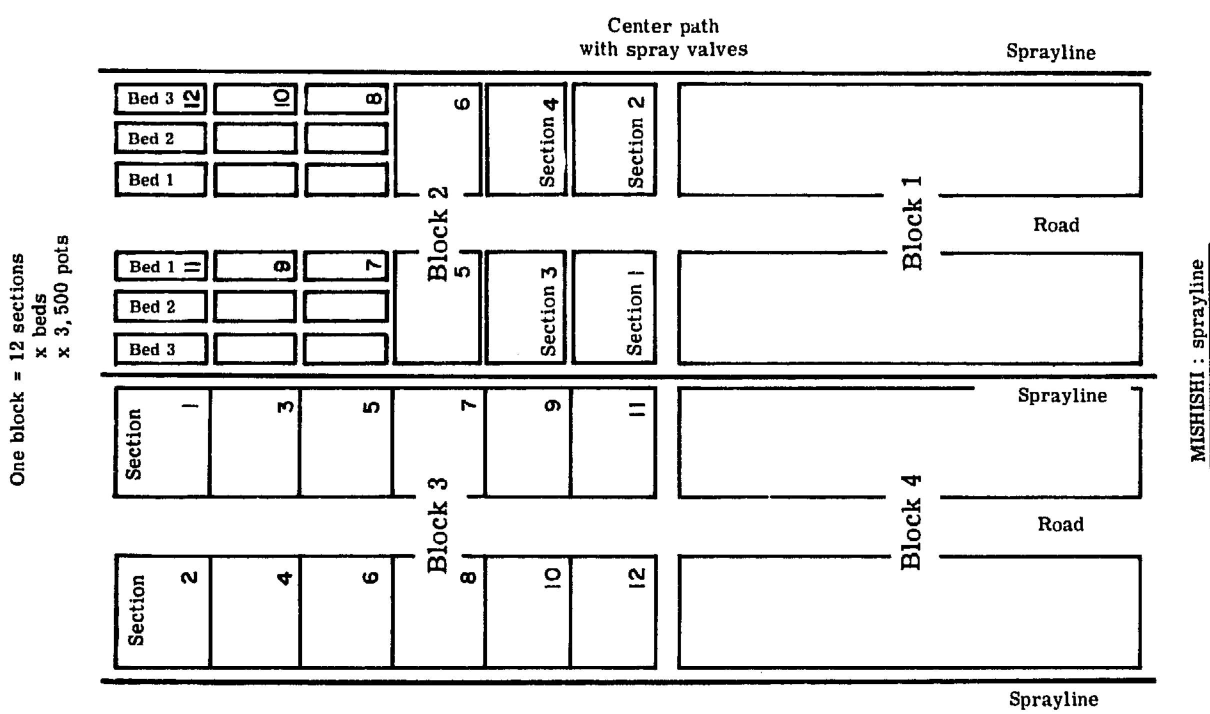
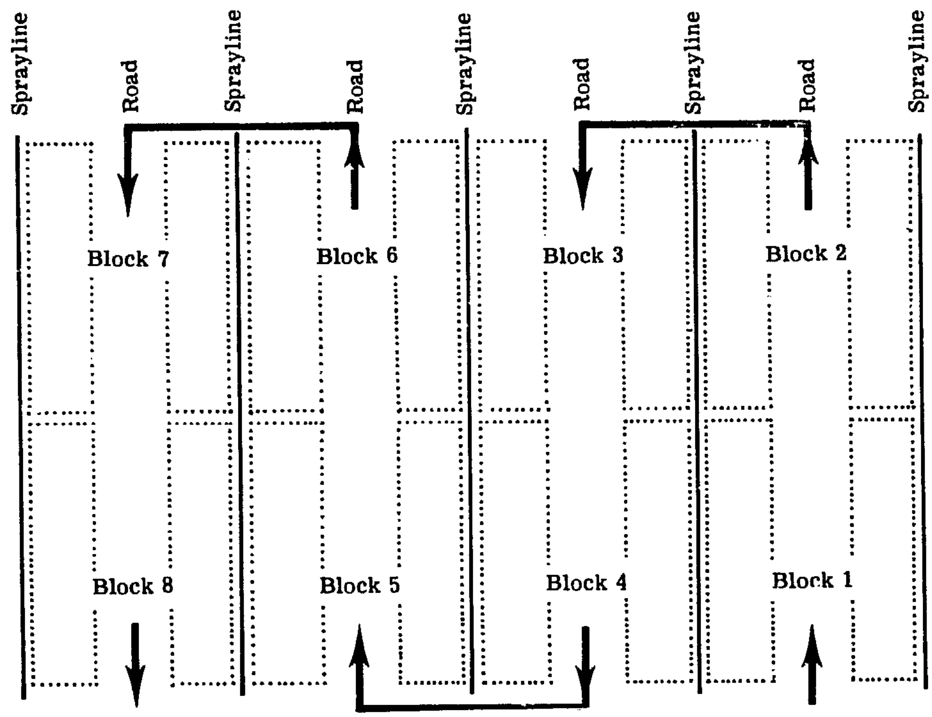

MUKUTUMA : sprinkler
One block = 14 sections
x 3 beds
x 3,000 pots
Block 2
Central drain
Block 1
Sprinklers
Section 2
Section 1
Beds 1
Beds 2
Beds 3

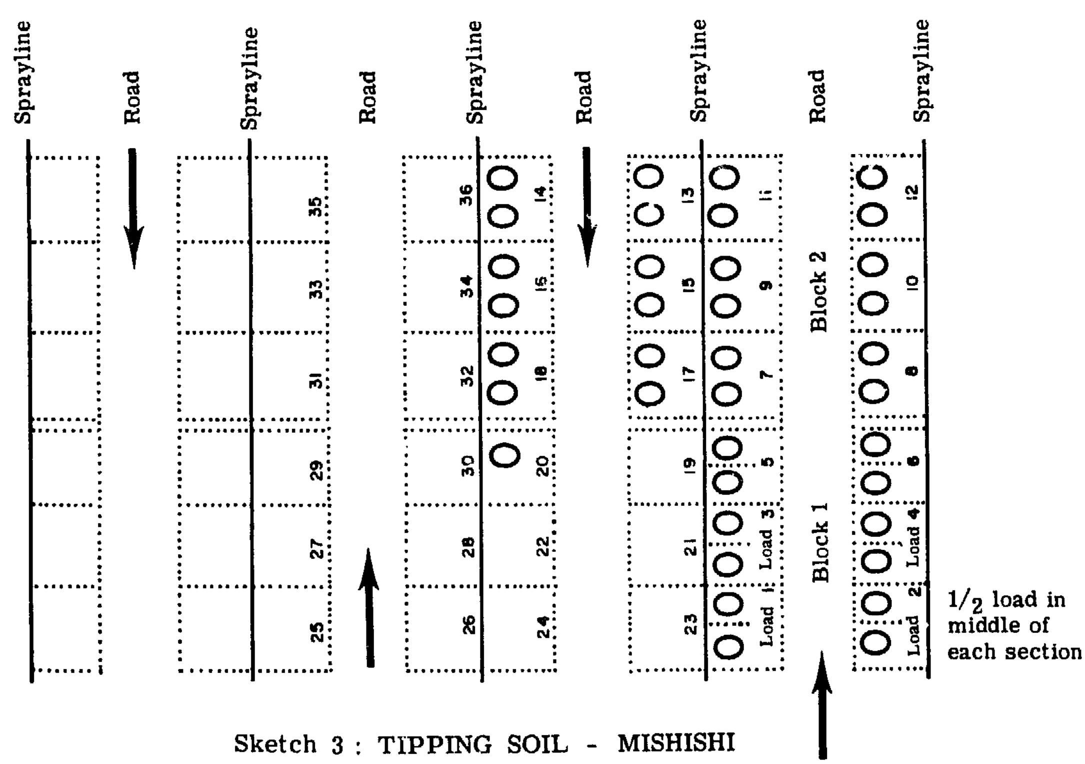

KAFUBU : sprayline and sprinkler
Block 3 = 20 sections
x 4 beds
x 3,000 pots
Sprinklers
Road
Section 1
Section 2
Section 3
Section 4
Beds 1
Beds 2
Beds 3
Beds 4
Block 1 =14 sections
x 4 beds
x 4,000 pots
Bed 1
Bed 2
Bed 3
Bed 4
Section 3
Section 4
Section 5
Section 6
Sprayline


MISHISHI : sprayline
One block = 12 sections
x beds
x 3,500 pots
Center path
with spray valves
Sprayline
Road
Block 1
Block 2
Block 3
Block 4
Bed 1
Bed 2
Bed 3
Section 1
Section 2
Section 3
Section 4
Section



Sketch 2 : " FLOW - WORKING " PRINCIPLE - MISHISHI

The same system is used at Mukutuma and Kafubu with slightly different spacing due to the existing sprinkler systems. See sketch 1



Sketch 3 : TIPPING SOIL - MISHISHI

SOIL MIXTURES, USE OF CONTAINERS AND OTHER METHODS OF PLANT RAISING

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CONTENTS

BASIC RESEARCH ON NURSERY SOIL MIXTURES

Two contrasting hypotheses have been put forward for plant-raising in the particularly difficult conditions of the Sahel:

1. Great care should be taken to raise vigorous plants in the best nursery conditions so that they can grow rapidly during the first rainy season and survive the following dry season.

2. Nursery plants should not be given special care in the nursery, in order that they become used to the difficult conditions which they will experience in the field and in order that only the most resistant individuals survive to be planted.

In order to settle this question, trials were conducted in Niamey (Niger) in 1971 involving the following nursery treatments:

Soil:

S1 - compost
S2 - black earth and sand
S3 - sand

Fertilizers:

F1 - no fertilizer application
F2 - 2 g fertilizer applied per pot
F3 - 4 g fertilizer applied per pot

Watering:

W1 - limited watering
W2 - average watering
W3 - heavy watering

Thus, by factorial combination, 27 different treatments were given. The test species selected was Eucalyptus camaldulensis 8298.

These plants were planted out in the field in July 1971 in a cubic lattice design (3^3 treatments), 25 plants per plot, spaced 3 x 3 m, with three replications.

Starting with the first season, important differences in rate of growth were distinguishable, depending on the types of soil - S1, S2 or S3 and on the amounts of fertilizer applied, F3, F2 or F1. No clear difference was revealed as regards results due to different rates of watering.

The conclusion was that good treatment of plants in the nursery is desirable because it helps the "take-off" of plants out in the field and guarantees better growth and better rate of take.

Another experiment of the same kind, but in which the plants were followed only through the nursery stage, was undertaken in 1975 at Ouagadougou (Upper Volta). The test species was Eucalyptus camaldulensis and the trial involved seven different treatments using mixtures of sand, earth, manure (cow-dung) and compost in different proportions as follows:

1. 1/4 manure, 1/4 sand, 1/2 earth
2. 1/10 manure, 3/10 sand, 6/10 earth
3. 1/4 compost, 1/4 sand, 1/2 earth
4. 1/10 compost, 3/10 sand, 6/10 earth
5. -, 1/2 sand, 1/2 earth
6. -, -, 1 earth
7. -, 1 sand, -

The results as of 14 July 1975 were as follows:

Treatment	% of live plants	height reached (m)	average height (cm)
1	70	0.927	66.2
2	85	1.044	61.4
3	100	1.604	80.2
4	95	1.433	75.4
5	100	1.213	60.65
6	100	1.250	62.5
7	100	1.162	58.1

The best results were obtained with the mixture: 1/4 compost, 1/4 sand and 1/2 earth. A definite depressive effect was noted when manure (cow-dung) was used, an effect which needs to be discussed, because there is "manure" and "manure".

Aside from the conclusion that it is worthwhile to provide good treatment of plants in the nursery, these results still refer to local sites and it would be necessary to determine the best mixtures for use on other sites, and to determine what are the possibilities of obtaining local supplies of potting media.

The points in the discussion of soil potting mixtures in Tree Planting Practices in African Savannas (FAO, 1974) are valid as broad principles; that is, the soil should be relatively light and cohesive, and have good water retention capacity and a high organic and mineral matter content. The practical forester must never forget, however, that these are only general principles and his skill consists entirely in working out which mixture of materials available to him is most appropriate for each site.

GROWING SEEDLINGS IN NURSERY BEDS VS. POTS

Plants traditionally used for forestation purposes in the Sahel - Sudan zone are usually grown in seed beds, viz: neem (*Azadirachta indica*), cassia (*Cassia siamea*), and gmelina (*Gmelina arborea*). Since this simple method has proved satisfactory, no further experimentation has been done. Still it should be noted that potted plants have better chances of good "take" than those set out with bare roots, this being all the more true the harsher conditions are. By way of illustration, following are the survival rates for neem 6 months after planting in a trial conducted in Niger in 1972 (total annual rainfall only 281 mm).

Plants grown in:	Date of planting in the field	Survival rate
pots	5/11/71	88
pots	4/10/71	81
pots	4/12/71	80
pots	5/1/72	77
beds	4/12/71	35
pots	19/2/72	34
beds	5/1/72	31
beds	16/11/71	29
beds	5/10/71	20
beds	5/11/71	17

The results are particularly clear. They were obtained during an extremely dry year. When rainfall is more abundant these differences diminish; and when rainfall is on the order of 500 mm, no sharp differences are found between the field survival rates of plants originally grown in pots and those grown in beds and planted bare-rooted. Below the 800 mm isohyet, it is therefore normal to plant neem, *Gmelina*, *Cassia*, and *Dalbergia* with bare roots. It is, however, not impossible - and this is a matter for discussion - that one would be quickly led to advise the planting of eucalypts bare-rooted.

USE OF POTS

The use of plastic (polythene) pots is now very common in the arid parts of Africa. The manual Tree Planting Practices in African Savannas (FAO, 1974) dwells a great deal on this point.

In some cases the use of small pots, which is often advised and certainly makes for appreciable savings in transportation costs, may lead to the production of sickly and generally too small plants. The pots which we feel combine maximum advantages for many species have the following specifications:

Height:	20 to 25 cm
Diameter:	10 cm
Thickness:	40 microns
Color:	preferably black
Holes:	approximately 10, the highest at 13 cm from the seam.

Particular emphasis should be laid on the need to cut away the bottom of the pot at planting time in order to eliminate curled roots at the bottom of the pot, which are a problem for many species. The plastic sheath obviously also has to be carefully removed; this point can stand repetition because all too often bad plantings are the result of careless methods used in removing the plastic pots.

OTHER METHODS OF RAISING PLANTS

As there has been previous discussion on the growing of plants in beds, coverage here will be confined to the use of cuttings and direct sowing.

Growing of Shoot Cuttings

It is necessary to stress the great hopes vested in the growing of genetically selected *Eucalyptus* clones, mist propagated from shoot cuttings. The People's Republic of Congo has accumulated valuable experience in this field and it was intended that its research programme would lead to industrial plantations of *Eucalyptus* clones (which have perhaps already been started).

Quite aside from the programme of genetic improvement of plants, which goes beyond the scope of this report, the multiplication phases comprise:

- selection of plus trees from among improved species;
- possible multiplication by grafting;
- felling the grafted trees (above the graft) or plus trees to produce coppice sprouts;
- taking cuttings from among the sprouts (with consideration of the position along the branch);
- determining what kind of soil is suitable for striking cuttings (very well-drained, inert soil like gravels);
- definition of mist;
- hormonal treatment;
- pricking out of rooted cuttings;
- possible establishment of clone banks for industrial-scale production of cuttings or for other research purposes (controlled hybridization, etc.)

As regards the using of *Eucalyptus* cuttings for planting, note that the techniques devised in the Congo are rather local in character; they are not suitable for use either in Tunisia, where other techniques have been worked out, or in Niger, where after 4 years of such trials the project was abandoned.

Direct Sowing

Mention should also be made of forestation by means of direct sowing in the field, but in the savanna this method is useful only in very special cases (e.g. *Anacardium* and *Acacia senegal*) as described by Laurie (FAO, 1974).

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FAO 1974 — Tree planting practices in African savannas, by M.V. Laurie. FAO Forestry Development Paper No. 19. Rome.

NURSERY CULTURAL PRACTICES

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CONTENTS

INTRODUCTION

Other lectures are dealing with sowing, soil mixtures, irrigation and protection, so the subjects to be considered now are shading, sheltering, weeding, root pruning, grading and packing.

The notes which follow refer mainly to plants raised in polypots as this is the most common practice in savanna regions.

SHADE AND SHELTER

The use of shade in forest nurseries is a matter of considerable difference of opinion among foresters. In Malaysia for pines, seedbeds are shaded with a dense shade made from palm leaves, and after the seedlings are pricked out, a high shade is used for another three weeks (Paul, 1972). However in northern Thailand, where conditions are more severe than in Malaysia, shading pines after pricking out is only recommended during March and April, the hottest time of the year, and then only for three days after pricking (Granhof, 1974). In Samaru, Nigeria, seedlings were usually unshaded though there was some mortality from overheating in the outside rows of blocks of polypots, and one experiment did show increased height growth of pine seedlings when these were grown under shade. Unfortunately the performance of the shaded and unshaded seedlings in the field was untested. Shading is needed for small seedlings sown in boxes or trays, but for pricked out seedlings, or seedlings raised by direct sowing into containers, shade, if needed at all, should be removed one to three weeks after sowing or pricking out.

A number of different materials can be used for shade. For seed trays a building with a translucent corrugated perplex roof such as is used in Samaru, Nigeria, is very suitable though expensive. A special type of shade cloth, known as "Sarlon" is used in Malaysia for transplant beds in the form of high shade about 2 m above the ground; the material used in Malaysia transmits about 50 per cent of the light falling on it, but this shade cloth can also be obtained in other shade intensities from 30% to 95%. White cotton cloth has been used in Thailand. Often only partial shade is needed; this can be made from laths, or bamboos, or corn stalks, separated so as to give about half shade. It is possible to fasten these together with wire or cord to form rolls. This enables the shade to be rolled up during the early morning and later afternoon, and also to be rolled up while the plants are being irrigated by spray lines or sprinklers.

In areas exposed to drying winds, such as the harmattan of northern Nigeria, provision of shelter in the form of screens of mats or coarse cloth round the nursery is desirable. A hedge or windbreak of closely planted trees would serve the same purpose. Such shelter not only reduces the desiccating effect of the wind, but also by reducing the effect of wind on spray irrigation, gives a more regular irrigation pattern.

Small seedlings sometimes need protection against heavy rains occurring at the beginning of the rainy season. Light cloth or polythene sheeting can be used for this.

Further information on nursery shade and shelter can be found in Laurie (1974).

WEEDING

Hand weeding is still the commonest method in African savanna nurseries, but in Zambia the weedkiller "Gramoxone" is used. This might well result in considerable savings in cost (see Laurie, 1974, pp. 126-127). Fumigation of the soil before the seed is sown can greatly reduce the number of weed seeds in the soil; a full description of the method, using methyl bromide, is given in Appendix 5 to Laurie's paper. Weeds on paths etc. can be controlled by the use of a flame gun.

ROOT PRUNING

If plants are grown in containers the roots will tend to emerge from the drainage holes into the soil beneath. The prupose of root pruning is to prevent this happening, as otherwise a long tap root is formed. The simplest method of root pruning is by lifting the pots and breaking off the roots; an improvement, when doing this, is to cut the roots with a sharp knife. Another method is to draw a piano wire between the bases of the pots and the soil. The method of air pruning, in which the plants are raised above the soil surface, so that when the roots emerge they are killed by exposure to the air, is described in Laurie, p. 98, where there are also descriptions of other pruning methods. Methods of root-pruning in boxes, and in undercut beds, are described on p. 94.

GRADING

About one month before the beginning of the planting season the plants should be graded and arranged in groups with the plants of approximately even size, while at the same time culls are discarded. Culls are plants which are excessively stunted, forked, or otherwise abnormal. They may also include oversized plants. If planting is to extend over two or three months the large plants should be planted first, and the rest as they successively attain a size large enough for planting. Otherwise an attempt may be made to attain more uniformity of size by reducing water to the larger plants, and increasing that to the smaller plants, and also possibly by application of fertilizers to the smaller plants.

Holding back smaller plants until they become big enough for planting has certain drawbacks, as these plants may be genetically inferior, or have been so checked in the nursery that subsequent growth in the field is poor. It is better to try to spread out sowing dates so that plants come to the right size at the time they should be planted out.

The question of the best size of plants to use is a matter of some controversy, and little experimental work appears to have been done on this. There is some discussion of this in Laurie, p. 99. It may be that a much greater range of sizes can be planted satisfactorily than is commonly thought. Certainly in Thailand excellent results have been obtained from one year old *Pinus kesiya* seedlings 30-40 cm high, though there the standard size is 15-20 cm. In India also *Eucalyptus* plants over 1 m tall are sometimes used.

Factors influencing the optimum size of plants include the size of the container, the severity of the climate, and the amount of competition by grass and weeds. Another factor which should be considered is that large plants will be more expensive to transport, and more likely to be damaged in the process.

PACKING AND TRANSPORT

Packing of container-raised seedlings presents few problems. They are merely put in trays, and are loaded into vehicles. Wooden trays are sometimes used, but these are heavy, and trays made of wire mesh are preferable. A simple tray of wire mesh has been designed in Thailand, capable of holding 20 to 25 seedlings. These are provided with a spacer, so two or three tiers can be carried. This type of tray was designed so that it could be used in conjunction with a carrying frame, so that a labourer can carry two full trays on his back. This is very useful in mountainous country, where plants often have to be carried fairly long distances by human transport.

It is important that the containers should be packed tightly, so that they cannot move. Lashing a rope over the containers is sometimes advisable, when carrying-distances are long. The vehicle carrying the plants should be provided with a tarpaulin shade, and should travel at a moderate speed.

Bare-rooted plants should have the roots puddled in mud, and be packed in bundles of 50 or so in a large polythene bag.

Teak stumps are very easy to transport. Trials in Thailand have shown that plants stumped to about 2 cm stem and 15 cm root, with all side-roots removed, can be stored in boxes or trenches filled with dry sand for several months without losing their viability. Stumps are thus prepared in March or April, for planting in June.

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THE ROLE OF MYCORRHIZA IN AFFORESTATION - THE NIGERIAN EXPERIENCE 1/

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

INTRODUCTION

There are several records in different parts of the world which show that exotic pines usually fail to establish unless suitable mycorrhizal fungi have been imported for inoculation purposes (Mikola, 1973). This statement is also true for Nigeria where it has been shown that pine plantations cannot be established unless the seedlings have been infected by mycorrhizal fungi.

According to Redhead (1974), the first record of introduction of pine into Nigeria was in 1925 when Pinus longifolia Roxb. was introduced into the country from India.

This and several other introductions in the following decade failed apparently because no mycorrhiza was supplied. According to Madu (1967), P. halepensis Mill. and P. canariensis Smith were tried in Naraguta nursery, Jos, in 1950 while P. oocarpa was also sown in the nursery in 1951. In 1952 they were inoculated with soils collected from pine stands in Oxford and flown to Nigeria. These seedlings were planted out in Vom in 1954 without any visible evidence of mycorrhizal infection. Also in 1954, P. patula Schiede & Deppe and P. radiata D. Don seed from South Africa was sown and inoculated with soil collected from P. patula stand in Bamenda, Cameroons. These seedlings were also planted in Vom in 1954. The set of 1954 plantings in Vom were the first successful pines raised in Nigeria.

Redhead (1974) quoting other unpublished records indicated that soil and fine root material was brought from Ndola Hill, Zambia, in 1959 and used to inoculate P. insularis and P. kesiya. These and other one year old seedlings of P. caribaea, P. patula, and P. radiata previously inoculated with mycorrhiza soil and root material collected from Vom and Naraguta were planted out in Miango in 1961.

Since the establishement of the Miango plots, infected soil collected from there has been the normal source of inoculum for pines raised for plantation establishments in other parts of Nigeria. It is not very clear which of the original sources of inoculum succeeded but it is probably either the one from Zambia or the Cameroons or both.

Attempts to study mycorrhizae, technically, in Nigeria were initiated by Olatoye (1966) who made some general observations on mycorrhizae of pines at Ibadan. He also noted that soil inoculum collected from under pines at Vom, Naraguta and Bamenda were suitable for inoculation purposes. Mikola (1968) visited Nigeria among other countries to study the importance of mycorrhiza in afforestation. He made a number of valuable recommendations for future work. Momoh (1970) noted that temperature and aeration probably played vital roles in mycorrhizal establishments. Later on he synthesized mycorrhiza of Pinus oocarpa, using pure culture of Rhizopogon luteolus. The seedlings so raised were successfully grown in the field (Momoh, 1975)

Redhead (1974) carried out a number of studies on mycorrhizae in Nigeria, including some ectotrophic associations. Ekwebelam (1973) as well as Odeyinde and Ekwebelam (1974) also made some attempts to study mycorrhizae in Nigeria. They worked with pure cultures of mycorrhizae forming fungi with limited degrees of success. They found that Genoriz (a mixture of different species of Boletus) and Coenococcum graniforme promoted better growth of P. caribaea than the other fungi they worked with.

Despite these various studies, the normal practice of raising pines in Nigeria is still by using soil inoculum collected from established pine plantations.

AREAS OF SUCCESSES AND FAILURES

With the current technique of using soil inoculum collected from under old pine plantations for the inoculation of seedlings, a reasonable degree of success has been achieved in the country. Pines have been successfully grown on the Jos Plateau (elevation 1 200 metres), Mambilla Plateau (average elevation of about 1 600 metres) and Obudu Cattle Ranch Plateau (about 1 600 - 1 700 metres). Pines have also been grown fairly successfully at lower elevations in Afaka (600 metres) and Ibadan (about 180 metres). In the case of Ibadan, there are only 3-4 rainless months while in some other localities such as the Jos Plateau or Afaka, the rainless period can be of 4-6 months duration.

In most places where pines grow well the best ones are Pinus caribaea and P. oocarpa.

In some localities such as Bida and Mokwa (elevation of about 140-160 metres and about 4-5 rainless months), pines have almost always failed to grow successfully even after a successful mycorrhizal infection of the seedlings in the nursery. The reasons for this are not yet completely known but it is suspected that certain soil factors and the soil temperatures in particular might be a major factor.

The sporocarps of Rhizopogon luteolus have been found in some plantations in the country (at elevations above 300 metres). Laboratory studies of cultures raised from such sporocarps showed the optimum growth of this fungus on Hagem agar as 23°C. In culture the fungus was incapable of growing above 34°C (Momoh, 1970). It is also known that the temperatures of the soil near the surface can sometimes be as high or even higher than 34°C. When the temperature remains high in the desiccated soil over a prolonged period in the dry season, it is not impossible that this might lead to the death of mycorrhizae and subsequent failure of the pines.

In nurseries situated in dry areas of the country such as Samaru, Zaria, it is common to see dead inactive mycorrhiza on the sides of polythene bags facing the sun (in a block of bags) while the mycorrhiza remains active on the opposite side of the same bag.

PROSPECTS OF PISOLITHUS TINCTORIUS

Redhead was the first to import Pisolithus tinctorius (Pers.) Coker & Couch into Nigeria. He got his cultures from Dr. Zak in Oregon, U.S.A. He tried to inoculate seedlings with this and other pure cultures of mycorrhizae fungi but did not get any infection. In his report, he (Redhead, 1974) noted that "None of the pines showed any sign of mycorrhizal development" after 4 months. Redhead however gave some cultures to Ekwebelam who indicated that he had some successful inoculations (Ekwebelam, 1973). Since Ekwebelam worked with many fungi under a closely packed situation, it was not clear if the reported success with some of the cultures was not due to contamination from others.

Nevertheless, P. tinctorius is known to be a very good mycorrhizal former in some hot zones of U.S.A., especially in Georgia. Both cultures and sporocarps of this fungus were therefore imported into Nigeria for further trials in the areas where other fungi like Rhizopogon luteolus initially introduced into Nigeria through soil inoculum had failed. Momoh and Gbadegesin (1975) have described the introduction of this fungus and the successful initial experiments carried out with it. Successfully inoculated seedlings of Pinus oocarpa were planted out in the field at Miango, Afaka, Mokwa, Bida and Ejidogari. So far, the inoculated seedlings have continued to grow quite well. The fungus is also being inoculated onto P. caribaea for similar and more extensive trials. Eventually, it is hoped that "mycorrhizal banks" of P. tinctorius will be available to all pine growers in the country.

It is clear that *P. tinctorius* has great prospects in Nigeria. In culture it has its optimum growth at 30°C and continues to grow at 42°C, while other known mycorrhizae fungi in Nigeria are incapable or growing at this high temperature. For example, *R. luteolus* has an optimum of 23°C and dies at 34°C. The rate of growth of seedlings inoculated with *P. tinctorius* is very much faster than what has been achieved with any other mycorrhizal fungi tried in Samaru. The fungus also forms sporocarps very readily (Momoh and Gbadegesin, 1975). Thus large quantities of pure forms of inoculum could be readily obtained through spore inoculation.

FUTURE LINES OF RESEARCH

In his studies Redhead (1968a & b) discovered that some indigenous Nigerian forest trees have ectotrophic mycorrhizae which is the type found in pines. These were *Afzelia bella*, *A. africana*, *Brachystegia eurycoma* and *Uapaca togoensis*. This fact suggests that there might be naturally existing fungi in Nigeria that might be capable of forming mycorrhiza with pines. Further studies in this respect are desirable. If suitable pine mycorrhiza fungi are found in natural savanna lands, a new dimension might be introduced into pine inoculation problems.

The current success of *Pisolithus tinctorius* will be pursued with vigour. The fungus will be introduced into various localities on a wider scale so that its inoculum can be available to all pine growers in Nigeria and probably elsewhere. The seedlings of pines already inoculated with *P. tinctorius* and planted out in the field will be assessed from time to time and more field trials will be set up.

TECHNIQUES OF COLLECTION AND INOCULATION

In the interest of pine growers, broad guide lines on mycorrhiza collection and inoculation will now be given. Further details can be found in earlier publications (Momoh, 1970, and Momoh, 1974).

Most foresters, tend to collect their inoculum from under old pine stands. This is very practical. However, in areas with pronounced dry season, as is normally the case in savanna areas, the mycorrhiza in the soil may not be active all the year round especially at lower elevations. The inactive phase is the dry season which is also the usual nursery season. It is, therefore, necessary to carefully inspect the proposed site of collection to ensure that the mycorrhiza collected for nursery inoculation is taken from an area where the mycorrhiza is in its active phase.

The mycorrhiza soil should be used as soon as possible after collection. The soil inoculum should not be allowed to dry out before use. Inoculation can be done by mixing mycorrhiza soil with the sowing mixture or by introducing a pinch of the inoculum into close proximity of the roots of the seedlings.

Since excessive temperature can be detrimental to many mycorrhizal fungi, light shading might be necessary in very hot areas. It must however be remembered that excessive shading can lead to etiolation of the seedlings.

Technically, pure culture inoculations are the best. They are however laborious and are normally limited to scientific research. Nevertheless, pure culture inoculations can be used to establish mycorrhizal banks of desirable fungi.

CONCLUSION

After some initial failures, pines were successfully introduced into Nigeria in 1954 after necessary mycorrhizal inoculations. There are now some promising stands of pines, especially P. caribaea and P. oocarpa, in different parts of Nigeria. Pisolithus tinctorius appears to be a very promising fungus for the areas where pine growth is still difficult as a result of mycorrhizal failures.

All pine growers in tropical savannas are advised to always ensure that their seedlings are well inoculated with suitable mycorrhizae before they are planted out in the field.

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RESULTS OF NURSERY RESEARCH 1/

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CONTENTS

INTRODUCTION

This lecture will deal mainly with results from experiments in nursery methods at the Savanna Forestry Research Station at Samaru, Nigeria. Nursery research formed a relatively small part of the programme, as satisfactory techniques for raising most of the important species had been found before the establishment of the station. These included the use of polythene bags for raising seedlings, the incorporation of dieldrin dust in the potting mixture to prevent termite attack on *Eucalyptus*, and the technique of pregerminating seeds, especially of pines, in a mixture of sand and vermiculite. However, this is not to say that more research into nursery methods would not be desirable. Although the methods used are successful in producing satisfactory planting stock, it is certainly possible that even better and cheaper methods could be found.

1/ Paper for Symposium on Savanna Afforestation

The main experiments undertaken were on container size, soil potting mixtures, and the effect of shading and different methods of inoculation by mycorrhizal fungi.

CONTAINER SIZE

The standard polythene bag used in northern Nigeria when full had a length of 25 cm and a circumference of the same length, and weighed, when full, about 1 800 g. Obviously, considerable savings in the amount of soil needed in the nursery, in nursery space, in road transport of seedlings, and in handling seedlings in the field could be obtained if smaller pots were used. Thus a number of experiments were undertaken to compare survival and growth in the field of plants raised in containers of different sizes. Results are given in Table 1; both survival and height were recorded nine months after planting.

In the *Eucalyptus* trials, the smaller bags had little effect on survival, but caused some reduction in growth, which could possibly be tolerated. In the pine trials the smallest bags caused lower survival and growth, but there were no significant differences between plants raised in the two other sizes.

Thus for pines 15 x 25 cm bags are satisfactory, but not the smaller ones, in the conditions of Afaka. This will save about 40 percent in weight. The smallest bags would give a much greater saving, as they are only 22 percent as heavy as the largest ones. Such bags are, in fact, used in Zambia but the conditions are not as severe there as in Nigeria. Under more severe conditions than those at Afaka, larger bags might be desirable.

POTTING MIXTURES

Different combinations of potting mixtures and fertilizers have been experimented with for *Eucalyptus camaldulensis*, *E. grandis* hybrid, and *Pinus caribaea*. A full account is given in Jackson *et al* (1971). Some of the more important results are given below.

For eucalypts three rooting media were tried: river sand, sand mixed with rotted cow dung, and sand mixed with loamy top soil from Mairabo Forest near Zaria, both of the last two in the proportion of three parts sand to two parts of the other constituent. For both *Eucalyptus* species, tested germination was best in the sand and cow dung mixture, though there were indications that the cow dung increased mortality in *E. grandis* hybrid seedlings, though not enough to offset the better germination. *E. camaldulensis* showed little difference in germination between the sand, and the sand and soil mixtures, but germination of *E. grandis* was slightly better in the sand.

Subsequent height growth of both species was best in the mixture of sand and cow dung, and worst in the sand only. In the sand, growth was very poor indeed unless, in addition to phosphate, at least 0.9 gm of nitrogen per seedling were added to the potting mixture.

The effect of phosphate was tested in only one experiment. At the rate of 3 kg of superphosphate per cubic metre of mixture, or 0.3 g of phosphorus per seedling, it increased the height growth of the seedlings from between two to four times, depending on what other nutrients were present. In other experiments this quantity of superphosphate was added as a standard procedure.

There was also a very pronounced response to nitrogen, whether in the form of urea, or of hoof and horn flakes. At a level of 0.3 gm of phosphate per plant, each additional gramme of nitrogen increased height growth of 96-day old *E. camaldulensis* seedlings by 17.8 cm.

The most rapid growth of eucalypt seedlings was obtained from a mixture of two parts of rotted cow dung, and three of sand, to which superphosphate at the rate of 3 kg/m^3 and fertilizer at the rate equivalent to 700 g of nitrogen per m^3 was added. However, in 90 days this produced seedlings 50 cm high, which are probably over the optimum size for planting. Indeed, if cow dung is used in the potting mixture, satisfactory growth of seedlings can be obtained without additional nitrogen fertilizer. In the soil and sand mixture used, about 500 g per m^3 of nitrogen equivalent would need to be added. Sand alone, even with the addition of fertilizers, gave generally poor results.

Pinus caribaea differed considerably from the eucalypts in its responses, especially to nitrogen. There were two experiments. The first compared different mixtures of sand and topsoil in proportions of 5:0, 4:1, 3:2 and 2:3 respectively, combined with the addition of urea, at 0, 1 and 2 kg/m^3 and superphosphate at 0, 1 and 2 kg/m^3. The topsoil had a clay content of 16 percent, a nitrogen content of 1.16 percent and a phosphorus content of 75 ppm. Survival was best in the 4:1 and 3:2 soil mixtures, but the mean height of survivors was much the same in all mixtures, except in the sand without soil, where it was markedly lower. Two kg of urea per m^3 significantly increased mortality from an average of 14 percent to an average of 32 percent but the slight increase by 1 kg/m^3 was not statistically significant. Urea had negligible effects on the height growth of the seedlings. Superphosphate increased the mean height of 6-month old seedlings from 10.2 to 17.7 cm, except in the pure sand, where effects were negligible: 1 kg of superphospate per m^3 was as effective as 2 kg. The superphosphate, except in the sand, increased the percentage of seedlings with mycorrhiza visible to the bare eye from 33 to 66 percent. There was also better mycorrhiza production in the 4:1 and 3:2 sand-soil mixtures, than in the pure sand or the 3:2 mixture. When no phosphate was added, over 60 percent of the seedlings were stunted and with yellowish needles, and even with the phosphate 35 percent of the seedlings grown in pure sand were of this type. In the other mixtures the number of these stunted seedlings was neglegible.

The second experiment compared the effects of using topsoil (as above), compost, and cow dung in the potting mixture, at the ratio of 3 parts of sand to 2 of the other constituent, together with addition of urea at 0, 0.25, 0.5 and 0.75 kg/m^3. In this experiment 1 kg of superphosphate per m^3 of mixture was used throughout. The only significant effect was that the use of cow dung increased seedling mortality, and reduced height growth and the numbers of seedlings with mycorrhiza. Urea had negligible effects at all levels tried.

Thus pines showed great benefits from phosphate, but 1 kg/m^3 was sufficient. Added nitrogen (at least in the form of urea) had negligible effects at lower levels, and was harmful at higher levels. Cow dung also contained some substance injurious to pines.

The harmful effects of urea on pines were also found in plantation experiments, where it greatly increased mortality. Thus a suitable mixture for pines would be sand and topsoil in the proportions of 4:1 or 3:2, and as sand is easier to obtain than forest topsoil the former proportions would be preferable. One kg of superphosphate (or its equivalent in phosphorus) should be added per m^3 of mixture, but no nitrogenous fertilizer is necessary or desirable.

SHADING AND MYCORRHIZA INOCULATION

In general it has been found at Samaru that satisfactory nursery seedlings can be raised without artificial shade, though some mortality of the outmost seedlings in a block has been caused by insolation and heating of the black polythene bags. However an experiment was designed to compare the effect of shade, and of different methods of inoculation with mycorrhizal fungi, on Pinus oocarpa seedlings in 1970.

Shade was provided by guinea corn (Sorghum) stalks tied in a roll, in two ways, one with the stalks as close together as possible, and the other with them separated to give half shade. No shade was the third treatment. Eight and a half months after pricking out percentage survival in full shade was 80, in half shade 82, and in the open 71. The differences were not significant statistically, but the test, based on only four degrees of freedom, was not very sensitive. Mean heights of surviving seedlings at the same age were 24.1, 24.0, 16.1 cm respectively, showing highly significant effects from shade.

Mycorrhizal inoculation was effected in the following ways: use of roots and soils from bags containing 1 year old seedlings of pine, chopped up and added to the potting mixture, at two months before the time the seedlings were pricked out, immediately before pricking out, and 45 days after pricking out (three treatments); use of topsoil from a Pinus caribaea plantation immediately before pricking out, and 45 days after pricking out (two treatments); and no inoculation. Use of the forest topsoil either before pricking out or 45 days after, produced the best height growth, but mycorrhizal development was slightly better when the topsoil was added before pricking out. It is also much simpler to mix the topsoil with the potting mixture, than to apply it to individual seedlings in bags, so this method would be preferred on economic grounds.

CONCLUSIONS

It is obvious that this research has only touched on a few aspects of nursery production, and even in the subject most studied, potting mixtures, considerably more could be done, in particular to find the cheapest satisfactory potting mixture. This might differ at different localities. Other important factors, at present little studied, include watering regimes; use of soil fumigants to control fungi and weeds, and herbicides to control the latter; and the optimum size of planting stock in relation to bag size, based on performance in plantations. Another aspect of nursery work needing study is how to organize and manage nurseries so that seedlings can be produced as economically as possible.

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TABLE 1

GROWTH IN PLANTATION OF SEEDLINGS RAISED IN DIFFERENT SIZES OF BAGS

Species	Year	Size of bags, cm 25 x 25		15 x 25		15 x 16		least significant difference
		Survival percent	Mean height cm	Survival percent	Mean height cm	Survival percent	Mean height cm	Mean height cm
Eucalyptus camaldulensis	1966	94	220	96	208	91	202	± 10.1
E. camaldulensis	1967	100	203	100	176	97	145	± 14.8
Pinus caribaea	1971	91	42	86	39	75	30	± 6.4
P. oocarpa	1971	85	47	86	49	78	42	± 6.7

In the size of bags, the first figure is the length, the second the circumference

TABLE 2

EFFECT OF POTTING MIXTURES AND FERTILIZERS ON GROWTH OF EUCALYPTUS CAMALDULENSIS SEEDLINGS

Potting Mixture	Added Fertilizer gm/seedling	Nutrients per plant, g N	Nutrients per plant, g P	Age when measured, days	Mean height cm
Sand	Nil	0	0	96	5.1
Sand	Urea 1.3	0.7	0	96	3.8
Sand	Super 2.9	0	0.3	90	3.2
Sand	Super 3.0	0	0.3	96	15.5
Sand	HF 1.3, Super 2.9	0.2	0.3	90	1.8
Sand	Urea 1.3, Super 2.9	0.7	0.3	90	6.0
Sand	Urea 1.3, Super 3.0	0.7	0.3	96	15.0
Sand	Urea 1.3, HF 1.3, Super 2.9	0.9	0.3	90	15.5
Sand: Soil 3:2	Super 2.9	0.7	0.3	90	10.1
Sand: Soil 3:2	HF 1.3, Super 2.9	0.9	0.3	90	33.4
Sand: Soil 3:2	Urea 1.3, Super 2.9	1.4	0.3	90	22.4
Sand: Soil 3:2	Urea 1.3, HF 1.3, Super 2.9	1.6	0.3	90	35.9
Sand: Cowdung 3:2	Super 2.9	2.1	0.4	90	37.3
Sand: Cowdung 3:2	HF 1.3, Super 2.9	2.3	0.4	90	37.8
Sand: Cowdung 3:2	Urea 1.3, Super 2.9	2.8	0.4	90	37.0
Sand: Cowdung 3:2	HF 1.3, Urea 1.3, Super 2.9	3.0	0.4	90	48.0
Sand: Cowdung 4:3	Nil	4.5	0.25	96	23.1
Sand: Cowdung 4:3	Urea 1.3	5.2	0.25	96	31.5
Sand: Cowdung 4:3	Super 3.0	4.5	0.55	96	50.3
Sand: Cowdung 4:3	Urea 1.3, Super 3.0	5.3	0.55	96	80.3

Combined results from two experiments.

HF = Hoof and hornflakes

Super = Single superphosphate

SOIL AND SITE SELECTION

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CONTENTS

INTRODUCTION

Afforestation in West Africa is confronted by two important problems involving (1) the soil and (2) the climate. In this paper only soil will be dealt with although climate, which is intricately associated, will be mentioned as it affects the soil.

Soil critically affects the growth of trees, and good growth requires that the soil be in such condition as to favor good root development. The seven important soil factors that affect development of tree root systems are: (1) depth, (2) texture, (3) structure and consistency, (4) moisture, (5) aeration, (6) soil fertility and (7) toxic substances. An ideal soil for the proper development of roots of trees, therefore, should:

- be deep enough to serve as anchorage for the trees and allow for the storage of sufficient soil moisture;

- have favourable texture, structure and consistency so that roots are able to absorb the needed moisture, nutrients and air;

- have moisture in an available form throughout the year;

- be well aerated (Aeration is correlated to soil texture, structure, consistency and depth of water table. Proper aeration is important in the metabolism of the plants and also prevents the formation of toxic substances in the soil.);

- be fertile (A fertile soil has the ability to provide the proper compounds in the required amounts and in the correct balance for the growth of plants when other environmental conditions are favourable); and

- low in toxic substances (Any layer of toxic substances will limit soil depth by preventing the roots from developing downwards through the toxic layer.).

In the Guinea zones of West Africa, the two principal limitations in soils affecting tree growth are: (1) soil depth and (2) soil drainage. In the Sudan zone, they are (1) availability of soil moisture and (2) soil texture.

Soil conditions, however, vary tremendously from one place to another due to differences in climate and living organisms acting on the different kinds of parent materials. Some soils are very shallow and others are very deep; some are very compact and hard, others are friable; some are high in fertility, others are low; some are very wet and others are dry, etc. Forest trees also vary in their soil requirements. One has either to choose the kinds of trees to suit the soil or to a certain extent, change soil conditions to suit the requirements of the trees.

The scope of this paper is to show the procedures used in determining soil conditions in the field that will serve as a guide in selecting sites for afforestation.

ESSENTIAL REQUIREMENTS

Site selection for afforestation purposes involves soil surveys, i.e. the study of soils in the field. Equipment both for the office and for the field is needed (see Appendix 1). Prior to field work, aerial photographs (stereoscopic pairs), maps and references covering the area under study for afforestation should be obtained. If aerial photographs are not available, the soil surveyor has to make the base map himself. Needless to say, the aerial photographs should be of very good quality. Geological, topographical, physical, climatic and vegetation maps covering the area for soil survey are important prerequisites. References involving the geology, climate, geography, agriculture and forestry of the area of study, or nearby areas are also needed.

PROCEDURE OF SOIL SURVEYS

Depending on the objectives, soil surveys can be classified as detailed, semi-detailed or reconnaissance. For site selection, a semi-detailed soil survey is required; this calls for mapping of soil units on a selected scale from 1:20,000 to 1:50,000 (see Appendix 2). The soil units used in mapping are series, types and phases.

The field work starts by examining the soils along the roads; later traverses are made from several points along the roads. The characteristics of the soil profiles are studied in as many places as required using, as much as possible, the hydraulic powered soil corer mounted at the rear of a Land Rover truck. When the Land Rover cannot be used due to lack of accessibility, the soils are examined with the use of an hand auger. Pits one metre square by 1.5 metres deep are dug for the detailed description of a representative profile of each soil unit. One side of the pit facing the light is cleaned to show the horizons or layers. The boundaries of the different horizons are marked and their depths measured. The FAO Guidelines for Soil Profile Description (FAO, 1968) are used as the basis for describing the colour, texture, structure, consistence, pores, inclusions, presence of roots and reaction of soil in each horizon of the profile. The Munsell Colour Chart is used to describe soil colours in wet and dry conditions. The finger feel method is used in the field to determine soil texture, plasticity and stickiness. The soil reaction is determined using colour indicators (Chlorophenol red for soils with reactions between pH 5.2 and pH 6.8 and Thymol blue for soils with reactions between pH 6.0 and pH 7.6).

Whenever possible, the soils below 150 cm depth are also examined with the soil auger. Soil samples from each of the horizons studied are taken for mechanical and chemical analysis. Additional composite samples are also taken at random all over the area for fertility analysis.

The trees, shrubs and grasses growing around the area of each pit described are identified. Likewise, other physical characteristics of the area such as relief, slope of the land, class of drainage, degree of soil erosion, stoniness, depth of water table, land forms, and animal activities are also noted. Prepared forms (see Appendix 3) for this purpose are used and the items recorded on the spot. The use of such forms prevents the possibility of some features of the land being overlooked.

Soils with similar characteristics in profile development and external conditions are classified as a soil series and are given a geographical name. Lokoja, Afaka, Okene and Osara are some of the soil series described in the Guinea Zone. When the textural class of the A horizon is added to the series name, together they are called the soil type. In the case of the Lokoja soil series, the texture of the A horizon is loamy sand, thus, the soil type is Lokoja loamy sand. Sometimes within an area of a soil type, minor differences in characteristics may exist which are important only in soil management. This may be a variation either in soil depth, erosion, drainage, slope, or stoniness. In such a case, a phase of the soil type is recognised, rather than separating such an area into another soil series. Thus, in the case of Lokoja loamy sand, some areas with relatively shallower soils than is normal for the Lokoja series, are named Lokoja loamy sand, shallow phase.

The delineation of the boundaries of the soil series, types and phases are made directly on the aerial photograph using a wax coloured pencil. The lines made by this type of pencil can be erased with a medium type eraser. If it is desired to keep the face of the aerial photograph clean, an overlay is placed on the aerial photograph. The overlay has one matte surface where the soil data can be written on with a pencil or crayon. Boundaries of terraces, depressions, ironstone hills, eroded areas, inselbergs and escarpments are determined from stereoscopic study. Soil boundaries can also be determined on the photograph from the differences in tones of the vegetation, density of vegetation and colour tones of the soils. All soil information on the aerial photographs is transferred to the soil base map with the use of a Grant Projector.

The base map becomes the draft of the soil map and this is given to a draftsman to make into final form for reproduction. The area of each soil mapping unit is determined and their relative extent is computed.

SUITABILITY CLASSES FOR TREE PLANTING

The characteristics of each of the soil units mapped are further classified by grouping into capability classes soil units with similar characteristics or suitability for plant growth and similar responses to treatment or soil management. There are five land capability classes defined for agriculture in Nigeria. These have been broadly related to plantability or suitability classes for tree plantations as follows:

I. Very suitable: This includes land with deep and well drained soil where roots of trees can grow well down through the profile. The supply of soil moisture is adequate for normal growth. There is no impediment to mechanization. Trees adapted to the area respond very well to ordinary soil conservation practices.

II. Moderately suitable: This class includes; (1) land with moderately deep soil with good drainage; (2) land with deep soil that is moderately well drained; and (3) land whose supply of soil moisture is somewhat limited for normal growth of trees. There may be a few impediments to root growth in the soil profile, such as slight salinity, but mechanization is possible. Simple soil conservation practices are needed.

III. Fairly suitable: This class includes; (1) land with moderately deep to shallow soil but well drained; (2) land with poorly drained but deep soils; and (3) land where the supply of soil moisture is often times a critical factor. Few species of trees are adaptable to the area, and the soil may be moderately affected by salinity. Mechanization is somewhat restricted due to some physical obstacles. Intensive soil conservation practices are needed.

IV. Poorly suitable: This class includes; (1) land with shallow but well drained soils; (2) very poorly drained but with deep soils; (3) land with extreme climatic conditions; (4) land where mechanization is very difficult due to obstructions like boulders; (5) land with very hard and compacted soils; and (6) land whose soils are very severely eroded. Soils in the profile may be highly saline or alkaline, thereby adversely affecting the growth of many tree species. The choice of trees for planting in this class is very limited.

V. Not suitable: This class includes; (1) land with very shallow or skeletal soils where the bedrocks are near or exposed on the surface; and (2) land with extremes of moisture conditions (too wet or too dry). Mechanization or planting of trees is not recommended.

The suitability classes are determined from data on both the physical and chemical analyses of the soil units, taking into consideration the local climate. In classifying soils for plantability or suitability for trees, the soil surveyor should bear in mind that what constitutes a very suitable soil, cognizant of climate, should favour root development. He must then find out what constitutes the principal limitation and the intensity of the limitation on the use of the land being classified and from this select its place in the suitability classification.

Rainfall of the area should be considered when one determines effective soil depth. Under similar rainfall conditions, site quality generally increases with soil depth. A 100 cm soil depth with 1,270 mm of rainfall may be just as good a site as another with deeper soil receiving less rainfall. With restricted growing season rainfall (1,000 mm), a suitable soil depth is over 2 metres (Samie, 1973).

Plinthite, which is a very common characteristic of savanna soils, is often a limiting factor in soil depth, but the roots of some species of trees like Eucalyptus propinqua can penetrate 120 cm of dense plinthite. On the other hand, roots of Isoberlinia doka bend horizontally upon encountering the plinthite layer. Effective soil depth also varies depending upon soil textures, kind of clay mineral in the profile and the bulk density of the plinthite layer. An average bulk density of savanna soils is (surface soil) 1.55 g/cc; those with 2.05 g/cc are impenetrable by roots of most species (Samie, 1973).

Soil fertility is another factor in site quality. Based on the results of chemical analysis, roots of endemic trees concentrate their growth in the upper part of the solum where soil fertility is much higher than the C horizon. This is generally true where the texture of the C horizon is coarse sand, as found in the Ejidogari Forest Reserve, Nigeria.

Soil drainage is another limiting factor in tree growth. Preliminary studies on a soil catena at the Afaka Forest Reserve planted to Pinus caribaea, showed it to be progressively affected as drainage became poorer. However, in the case of Eucalyptus citriodora, E. saligna and E. tereticornis, these trees do not seem to be affected by seasonal drainage impediments.

Eroded soils, iron stone outcrops and soil depth (effective depth) directly affect tree growth. Again, the preliminary studies made in the 1971 pilot plantation at the Afaka Forest Reserve on a 4-year old E. camaldulensis showed an average height of 9.8 metres on the non-eroded soil, and an average height of 6.5 metres on the eroded parts of the plot. Similarly, in the case of E. grandis, the presence of ironstones affected their height growth by 2 metres over those where ironstones were not present.

Also in a soil catena at the Afaka Forest Reserve, growth of E. saligna during the first year was adversely affected by difference in soil depth (thickness of soil horizons). However, it appears that after subsequent years (3rd year) growth difference became gradually less significant. In this case, effective depth is more important than soil horizon depths as a site quality factor.

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Plinthite can be a limiting factor for tree growth, especially when indurated and near the soil surface. Some species, however, are able to penetrate the plinthite and draw water from beneath. Here Eucalyptus cloeziana roots pass through a 10 cm thick plinthite layer about 60 cm below the surface.

Appendix 1

OFFICE AND FIELD EQUIPMENT FOR SOIL SURVEYS

Office Equipment

1. Stereoscope. This can be either the scanning or the mirror type but large enough to examine the full view of a 23 x 23 cm aerial photograph. This machine is essential in studying the physical features of the aerial photograph as it will reveal the landscape in its tri-dimensional features.

2. Pantograph (mechanical). Used for enlarging or reducing maps.

3. Projector. Similar in use to the pantograph above, this is used generally for enlarging the features from aerial photographs to the scale of the desired map. This equipment, however, produces some distortion in the size of image, being a natural physical characteristic of the lenses. This distortion can be corrected by proper manipulation of the machine.

4. Planimeter. An instrument used to determine areas on maps. It registers the number of square units (usually square centimetres), so that by correlation with the scale of the map, the area of any soil unit can be determined.

Field Equipment

1. Soil auger. This is used to examine soils below the surface of the ground. It is usually provided with extensions and is able to dig down to 3 metres. There are various types to suit different soil conditions.

2. Spade. To dig soil profile pit or to get soil samples.

3. Bronton compass with attached clinometer. The former to determine directions and the latter slope of the land.

4. Munsell Colour Chart with supplements for use in the tropics.

5. Geological hammer, with one prong chisel-shaped. Used to break rocks for examination, to break hard pans or for sampling small lumps of soil.

6. Soil testing kit for pH. The reactions of most soils in West Africa range from pH 3.5 to pH 8.5, pH 5.0 to pH 6.5 being the most common.

7. Trowel. This will be used to sample soils, especially in the profile.

8. Broad blade knife. To examine and mark on faces of soil profiles.

9. A 3-metre steel tape measure. To measure depth of horizons.

10. Plastic bottle with spout. To moisten soils with water for examination with fingers.

11. Hydraulic-powered soil coring machine. (Optional). This is a versatile machine which can save much of the surveyor's energy. It can bore holes with augers to any depth as long as there are extension rods. It can thrust a steel coring tube through soft soil to get an undisturbed soil profile sample.

12. Vehicle. For movement of personnel and to carry equipment, supplies and soil samples. A four-wheel-drive vehicle is preferable. If there is a hydraulic powered coring machine this has to be mounted on a pick-up truck. This vehicle should also be of four-wheel drive and provided with power take-off.

13. Soil sample bags, either cloth or plastic.

Appendix 2

Comparison of Sampling Density, Rate of Progress and Scale of Systematic Soil Survey

(with some use of air-photo interpretation)

Scale	Kinds of Survey	Area Represented by ($1 cm^2$ of map)	Density of Sampling[1] (0.5 samples/cm^2 of map)	Approx. Average Rate of Progress[2] (per 20 day month)
1: 5,000	Very detailed	0.25 ha	1/0.5 ha	500 ha
1: 10,000	Very detailed	1.25 ha	1/2 ha	800 ha
1: 20,000	Detailed	4.0 ha	1/8 ha	1,250 ha
1: 25,000	Detailed	6.25 ha	1/12.5 ha	1,500 ha
1: 50,000	Semi-detailed	25.0 ha	1/50 ha	75 km^2
1: 100,000	Reconnaissance	1 km^2	1/2 km^2	200 km^2

1. Figures represent an average of sampling density over the entire area of the map; (acceptable sampling density usually ranges between 0.25 and 1.0 samples/cm^2 of map on this basis.)

2. Figures given represent approximate averages from the wide range of progress rates experienced in actual surveys.

Appendix 3

SOIL PROFILE DESCRIPTION

Unit	Profile No.	Date
Classification		
Location		
Vegetation		
Elevation	Rainfall	
Physiography		
Slope and Aspect		Relief
Drainage		Permeability
Moisture		Gr. Water
Root Distribution		
Remarks		

Hori-zon	Depth	Colour	Texture	Struc-ture	Consis-tence	Pores	Inclu-sions	pH	Bound-ary

LAND CLEARING AND SITE PREPARATION

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The objectives of ground preparation in savanna conditions are summarised in Chapter 9 of Laurie (1974). The choice of methods by which to achieve them will depend on local conditions and on the results of local research and user trials.

The factors to be considered in choosing between hand and mechanical methods are also stated in Laurie but an additional factor which has arisen fairly recently is the rapid rise in the price of fuels and oils - a rise which seems likely to continue. This seriously affects the relative cost of mechanical operations, not only directly, by increasing the cost of carrying out the operations but also indirectly, by increasing the cost of the machines themselves, their spares and their transportation. In some countries the cost of labour is also rising, but usually not nearly enough to maintain the relative costs of hand and mechanical operations.

Where the supply of labour is inadequate, or the time available is too short, for hand methods to be practicable, there appears to be little alternative to mechanical methods of clearing. In view of the already enormous and still rising costs, however, further thought needs to be given to the situation. Several approaches are possible.

(a) Recoup some of the costs of the clearing by making another use of the land before raising trees on it:

(i) utilise the standing timber before clearing takes place or after knock-down e.g. producing veneers from selected stems, chipping or pulping, producing charcoal efficiently on a large scale in kilns (these processes also affect the clearing costs, mostly favourably);

(ii) hire the land out to a commercial farmer for the production of agricultural crops for one or two years (strict contract conditions necessary);

(iii) produce agricultural crops on the land using paid forestry labour.

The practical, technical and economic aspects of these schemes need careful study; field trials, and in some cases research, are essential.

(b) Devise cheaper methods of doing the present job:

(i) <u>Use lighter machinery</u>

Whether this is practicable or not depends very much on the density of the bush and the average size of trees to be dealt with. If the bush is light enough then lighter machinery can be used. Not only is this cheaper to operate on the clearing process itself but such machinery can be economically used on other forestry jobs during the remainder of the year, thus reducing the capital costs to be charged to the land-clearing. The Nimbia project described by Laurie (1974) has shown that the job can be done, but careful supervision and skilled operators are essential.

It cannot be too strongly emphasised, however, that where the tree cover is heavy, calling for machines such as Caterpillar D-7's and D-8's, then it is no economy to try to "make do" with lighter machinery. At best, you will end up with greater expense owing to delays and breakages; at worst, you may find yourself with broken machinery and the job unfinished.

(ii) Use new types of machinery

Machines such as the Hydra-stumper and Tree Extractor, which are mounted on wheeled tractors and are said to be able to pull up the whole tree by the roots, have recently been publicised and demonstrated. The published results of the demonstrations have been difficult to assess owing to lack of data about the trees concerned and the time taken. The only demonstration in Zambia so far convinced the audience that the machine was not likely to be of interest to the Industrial Plantations Project. It was too slow and did not appear able to cope with trees of the size we are usually dealing with. It might be of use to have around, however, for cleaning up operations and might even have a use in small-scale clearing operations in areas of light woodland.

(c) Eliminate parts of the present job.

(i) The windrowing could be eliminated to a large extent if more charcoal were made or if the wood could be chipped (as already mentioned this could also bring in revenue to help pay for the knock-down). To do the job within the season, however, charcoal would have to be made in kilns.

(ii) Alternatively, the knocked-down timber, instead of being windrowed could be left in situ and burned in the late dry season. Two such burns would be necessary, however, and there might still be a difficulty in getting the larger logs to burn. On many soils a heavy growth of Hyparrhenia and Loudetia species can also arise.

(iii) Omit the ploughing, research in Zambia has shown that this ploughing is not strictly necessary. However, the maintenance of the crop in a clean-weeded condition during the first year is necessary, and if the land has not been ploughed the first-year weeding will be much more expensive. So these costs have to be balanced against each other, not forgetting the possible saving in capital investment in heavy ploughs.

(d) Re-examine the need for the present complete clearing of the land.

(i) Methods of ground preparation which were written off as failures in the early days of exotic plantation silviculture might now be modified to produce a viable plantation. New factors favouring this include the ability to produce high quality nursery stock, the development of chemical methods of bush killing and weeding, and the development of stump-jump ploughs and harrows.

(ii) Research in several directions is in progress or planned in Zambia, but the applicability of results elsewhere can only be determined by local trials and costings. Successful establishment is not the only consideration - the overall effect on growth rates will influence the final cost of the plantation. The saving on land clearing has to be balanced against a possibly longer rotation and other incidental costs.

The essentials of the various methods of clearing by hand and by machine are described by Laurie (1974) and do not need to be repeated here. If hand methods are used, then getting the job done is a straightforward matter of organisation and administration. If mechanical methods are to be used, then the situation is more complicated (quite apart from the considerations discussed above, decisions on which have to await the results of field trials and research). This is particularly the case where the woodland is heavy and demands the use of heavy machinery which is expensive enough when in use but most uneconomic if lying idle a large part of the year.

Zambia's Industrial Plantations Project has been lucky in the past in having in the country a contractor with the necessary heavy equipment and with a lot of experience. This is now changing in Zambia and may never be the case in other countries. In such cases then, several courses of action may be possible.

(a) join forces with another government agency which already does land-clearing for agriculture and/or road making. The addition of a forestry contract could help to make their operations profitable.

(b) encourage private enterprise with some sort of initial loan or subsidy to set up a land clearing unit, the government support involving some form of contractual obligation to undertake government's clearing programme. The promotion of one large company on which government then becomes dependent has many drawbacks. It may be better to support several smaller enterprises which could each do part of the work. This has many advantages but is only practicable if the total land-clearing work required is large.

(c) acquire a land-clearing unit for the plantation project. This is not likely to be undertaken since to make it viable, it may be necessary to hire out the unit for other land-clearing or road-making projects.

Whatever methods of land-clearing may be chosen from these currently known to be effective, the operation will take a fairly high proportion of the costs of plantation establishment in savanna areas. Nevertheless, the growth rates attainable are such that in countries where the demand for timber is high, local supplies inadequate and imports increasingly expensive, plantation-grown timbers will still be able to compete in the market at a price which gives a reasonable rate of return on the investment. Furthermore, preliminary results in Zambia at least show that it may yet be possible to devise other methods of clearing which will reduce the overall cost.

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LAND CLEARING AND SITE PREPARATION IN THE NIGERIAN SAVANNA[1/]

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

DEFINITIONS

In relation to land clearing operations the following terms and abbreviations are used in the text:

(i) "Operating time" (O.T.) for a tractor unit operation is the total working time in minutes per specific area or unit, and is calculated by adding working, minor stop and turning times.

(ii) "Basal area" (B.A.) of a tree is the area of the cross section of the stem at breast height (b.h.), or at 127 cm (4 ft 3 in) above ground level. The basal area of a crop or vegetation type is the sum of the cross sectional areas of its constituent trees and is often expressed as the total basal area per unit land area (e.g. square metres per hectare, m^2/ha).

(iii) In relation to costings, decimal currency based on the Nigeria Naira (₦) was introduced w.e.f. 1 January 1973 and is used in the text. Rate of exchange as at 1 October 1975 was:

₦1 (Naira) = US $1.626

₦0.615 = US $1.00

INTRODUCTION

Land clearing in the savanna region requires the removal of the natural woody vegetation cover for a specific purpose. As the removal of woody vegetation constitutes a major ecological change, it is essential to carefully survey and plan the use of any site, so that only those areas which will be adequately developed within a reasonable time are cleared. Land liable to erode should be neither cleared nor cultivated without planning adequate measures to prevent soil damage. In forestry, the main reason for land clearing is to remove woody material which would obstruct or hinder site preparation cultivation. Except for a few small and special sites, successful establishment of forestry plantations in the savanna region requires clean weeding (FAO, 1974; Iyamabo and Ojo, 1971). Maintaining clean weeding regimes, except on a minor scale or where taungya is possible, necessitates a high input of mechanical cultivation. For efficient mechanised weeding, land should be free of all surface woody vegetation and of all roots and stumps to the maximum depth of penetration of the weeding implements. To achieve this state requires the stumping of all standing trees and the disposal of all stumps, roots and other woody debris from the site.

For generally small-scale plantation development, land clearing using labour and hand tools is the oldest and most common method in Nigeria. Initial studies of land clearing costs for a range of sites indicated that they were some 30 to 70% of total establishment cost, which represents a major initial investment. An early mechanised knockdown trial using crawler tractors and an anchor chain was completed at Afaka in the northern Guinea zone in December 1965. The trial, which took place some two months after the end of the rains, showed up some of the initial problems of tractor operation but indicated that chaining was possible and that further investigation should be considered. Further mechanised clearing and preparation work was recorded by Barrot (1968 and 1970) at Nimbia in 1968, where even with a high level of mechanisation, land preparation costs comprised 50% of establishment costs. He also noted that there was little difference between hand or mechanised clearing costs at that time. Since that exercise, however, labour costs have risen 340% and tractor operating costs 40% to 100%, a trend that Barrot forecast although it is unlikely he anticipated the actual pace of increase. Land clearing is not difficult, given adequate labour or suitable tractor power, but the area requiring elucidation relates to that method or combination of methods, which will give the best results under specified conditions.

LAND CLEARING AND PREPARATION OPERATIONS

Land preparation for plantations in the broad sense consists of the following main operations (Allan and Akwada, 1974; Caterpillar Tractor Co., 1970a):

(i) Stumping or mechanised knockdown
(ii) Windrowing or hand piling
(iii) Cleaning up
(iv) Burning
(v) Laying out
(vi) Preplanting cultivation.

Such activities as cleaning up, burning and laying out have not as yet been studied in detail. There is, however, a considerable range of techniques for carrying out the other operations emmerated. The following are the main methods studied for plantation development in Nigeria.

Stumping is mainly by casual labour; the main tools are the native hoe and axe. The operation involves excavation, cutting of roots and felling of the main trees. Mechanised knockdown may be by single tractor or by a chaining unit. In the single tractor technique a crawler tractor uses a bulldozer blade to push over standing trees. There is little or no digging of soil. The method is adequate but capable of improvement. Chaining employs two or three heavy crawler tractors with front mounted blades or rakes and a heavy anchor chain rear-hitched between two of the tractors. The chaining tractors advance in parallel 15 to 25 m apart depending on the density of the bush, and the trailed chain pulls down a swathe of trees behind the tractors. In heavy bush the third, or back-up, tractor, equipped with a tree stinger, supports the forward tractors by pushing over any large trees which hold up the chain. In efficient operations the impact of the chain extracts a high proportion of the main and lateral roots.

If the stumped or knocked down trees cannot be sold as firewood or processed as charcoal, then it is necessary to windrow or pile this woody debris on site for burning. Windrowing of the debris into linear heaps, commonly 40 to 50 m apart, is usually done by crawler tractors equipped with front end rakes. In undulating terrain the windrows are usually sited roughly on the contour. Hand piling necessitates cutting the debris into manageable billets and packing these into tight piles or heaps for burning.

Cleaning up can be defined as an operation following windrowing or burning in which any stumps, roots or other woody debris which remain in or on the soil, are gleaned from the area and added to the windrows or are heaped separately. Burning of the debris is a straightforward activity requiring only consideration of timing relative to season and time of day.

The operation of surveying, pegging and beaconing the plantation layout including roads, rides and compartmentation is designated laying-out.

Pre-planting cultivation consists of two main activities: pioneer ploughing and harrowing. Ploughing following clearing is designated a pioneer operation because it involves breaking-in land for the first time. Such newly cleared sites are much harsher and more difficult to cultivate than developed agricultural land. A ploughing depth of 23 cm is probably just adequate, but a depth of 30 cm or more is preferable. Heavy duty harrow ploughs and conventional mounted disc ploughs allow satisfactory ploughing cultivation. The object of pre-planting harrowing is to create a favourable environment for planting, which it should immediately precede. Such harrowing creates a tilth which facilitates planting and tends to level the land. By clearing the area of all weeds and vegetation there is greater latitude in planning subsequent weeding and the number of first season weedings should be reduced. This cultivation requires only 15 cm penetration and the operation can be effectively executed by a range of heavy and light harrows. Timeliness is often of greater consequence than economic efficiency in these cultivations.

ENVIRONMENTAL FACTORS: CLIMATE AND VEGETATION

There are many variables which affect land clearing and preparation investigations and without numerous replications it is difficult to measure the effect of, or allow for, such factors as soil, topography, labour or operator efficiency. The two main environmental variables to which work must be related are climate and vegetation (Allan and Akwada, 1974a).

Climate affects many facets of land preparation. Dry season mechanised knockdown tends to result in numerous above-ground tree breakages and the subsequent removal of broken stumps can be an expensive operation. An investigation in northern Guinea savanna to relate tree breakages to rainfall, indicated that after some 100 mm of rain had fallen at the beginning of the rains, breakages ceased to be significant. At the end of the rains after the last significant recorded rain, there remains some twenty days when effective knockdown free of breakages is possible. Hand stumping outputs also tend to be greater during the rains when excavation is easier in moist soils; this factor also has a significant effect on adequate ploughing and penetration. Rainfall and temperature affect the timing of windrow burning. Climate is critical to the whole land clearing and preparation cycle, and the following is an outline of the sequence of operations, assuming that land cleared during one wet season will be planted up at the beginning of the next.

Season	Operation	Relevant month at Afaka Forest Reserve
Start of rains after 100 mm recorded	Commence knockdown or stumping. Windrowing, cleaning-up and ploughing between windrows may also begin during this period.	early June
20 days after end of rains	Stop knockdown. Complete windrowing. Clean up between windrows.	mid November
End of dry season	Burn off windrows.	March
Beginning of rains	Complete ploughing. Harrow before planting.	April/May
Start of rains after 100 mm recorded	Commence planting. Commence knockdown and ploughing for following year's planting area.	early June

The first column indicates the timing of operations relative to rainfall for any part of the Nigerian savanna and the third column simply converts this data to calendar months, in this instance, for Afaka Forest Reserve, but similar conversions could be made for any other station with adequate rainfall records.

In the savanna, density of woody vegetation is variable not only between climatic zones but even within a zone or ecological type. The density or volume, including the main root system of vegetation, is the factor critical to land clearing productivity. Outputs expressed as time per unit area (minutes/hectare) do not give sufficient indication of true performance unless the vegetation in the area is markedly uniform in density. Accurate determination of volume is difficult and time consuming. Investigations, however, have shown basal area (B.A., expressed in m^2) to be a useful, and relatively easy to determine, unit for measuring productivity or comparing efficiency between different types and densities of bush cover. As land clearing records are built up and given basal area per hectare, average tree height and type of vegetation for a particular area, it should be possible to give an estimation of the rate of productivity for a particular clearing technique.

INVESTIGATIONS AND RESULTS

Following studies of past records and current methods of land clearing and preparation up to 1971, a subsequent series of trials and investigations was set up to determine the relative efficiency of a range of methods. These trials covered knockdown, stumping, windrowing, pioneer ploughing and pre-planting harrowing.

To determine the comparative economics of the various methods investigated, costs have been applied. The basis of costing is indicated in Appendix A and in greater detail in Allan and Jackson (1972), Allan (1973a and 1973b) and FAO (1965). The costs are valid for comparison, but where more relevant data is available, such figures may be fed into cost calculations to make the result more meaningful to local conditions. The costs are based on reasonably efficient government operation costs excluding management overheads or equipment movement charges; to use the data for commercial type operations, estimates for insurance, licensing and profit margins would need to be added. The fact that all costs are historic is particularly evident in the present inflationary era. To render the evaluations comparable and up to date, all costs in the text have been recalculated on the basis of 1975 labour rates and machine costs in Nigeria. In relation to tractors, this cost concept does not allow for the fact that 1975 equipment tends to be more powerful with greater production potential than past models. Labour contract rates have been doubled on the basis of the 100% rise in direct labour rates but this may not prove to be the case in practice. The main object of these cost evaluations is to indicate management options and provide a reasonable base for planning and budgeting.

Knockdown and Stumping

A number of knockdown and stumping investigations were set up:

(a) In the northern Guinea zone

- (i) To evaluate hand stumping and single tractor knockdown (Allan and Jackson, 1972; Allan and Akwada, 1973);
- (ii) To evaluate chaining and single tractor knockdown (Allan, 1973a; Allan and Akwada, 1974a; Savanna Forestry Research Station, no date);
- (iii) To evaluate a range of equipment for mechanised knockdown (Allan and Jackson, 1972; Allan, 1973a; Allan and Akwada, 1974a and 1974b) and

(b) In the southern Guinea zone

- (i) To evaluate chaining and contract hand clearing in heavier bush conditions (Allan and Akwada, 1974b).

Table 1 sets out costs and operating times (O.T.) per hectare and per square metre of basal area (m^2B.A.) for a selected range of trials.

In chaining, trial 1 at a unit cost of ₦0.47/m^2 represents a high level of efficiency, whereas trial 2 with unskilled operators and less serviceable tractors gave poorer efficiency. A reasonable cost efficiency would be in the order of ₦0.62/m^2. Trial 3 attempted to lower power range and cost by using lighter tractors. Excessively wet conditions at the time of this trial caused flotation and traction difficulties, which adversely affected the results. The trial showed that a lighter chaining unit could clear the bush but that there was no saving in cost: the trial requires repeating under more favourable climatic conditions. Trial 4 took place in heavier southern Guinea vegetation with average basal area 27% greater and average tree height 50% more than that of the first trial in northern Guinea vegetation. The trial was of median efficiency and the unit cost of ₦0.99/m^2 compares with the average of that of the first two trials if a factor of 1.5 is applied to allow for the greater volume of woody debris. All of these results compare favourably with the introductory 1965 trial, where the estimated unit cost would be in the order of ₦3.30/m^2.

Single Tractor Knockdown

The single tractor knockdown trials 5, 6 and 7 gave comparable results with variations mainly attributable to differences in operator efficiency; an anticipated average cost efficiency would be ₦1.50. Trial 8 using a larger tractor reduced cost efficiency by 28%, indicating that by the nature of the operation the additional power could only affect cost efficiency adversely. Barrot's 1968 trials gave figures of ₦26 to ₦101/ha but are not directly comparable as density of vegetation was not calculated. The general quality of stump extraction was high.

Hand Stumping

Trial 9 showed that hand stumping in northern Guinea vegetation required 7.7 man-days per m^2 or 65 man-days per hectare with an average basal area of 8.55 m^2/ha. The work was hard and the unskilled labour found it arduous and tiring. The tools used were adequate to the skill of the operators but by no means ideal for the job. The unit cost efficiency of ₦14.66/m^2 could be considered average. Trial 10 with a cost efficiency of ₦22.86/m^2 in southern Guinea vegetation, is comparable with the previous trial if the factor of 1.5 is again applied.

When comparing the mechanised techniques with hand stumping in the northern Guinea zone, it is obvious that chaining is the most efficient, the unit cost being 4.2% that of hand labour and single tractor knockdown 10.2% of hand labour. Similarly, in the southern Guinea, chaining costs are only some 4.3% of hand stumping costs. Expressed as area per unit cost, the same data indicates that for the cost of clearing 1 ha by hand, 10 ha may be cleared by single tractor or 27 ha by chaining in light savanna; the ratio is 1:23 ha in southern savanna. It should also be noted that mechanised operations tend to extract a greater volume of root and the general quality of stumping is greater than hand operations.

These figures indicate the cost efficiency of options open to management and for a particular project should be related to scale and timeliness of operation. To justify the setting up of a chaining unit, there would have to be a large scale clearing programme for a number of years. Even very large programmes can be done by hand labour, but (1) the labour and supervision must be available when required and (2) the social benefit of providing employment has to be weighed against the cost benefit of using more economic alternatives. For smaller scale programmes, when the costs of moving equipment are considered, there are occasions when hand or single tractor clearing may prove the less expensive alternatives.

Timely completion of clearing is important as it affects such subsequent operations as windrowing, ploughing and planting. It has been observed that planting as early as possible in the rains improves and expedites establishment. Timeliness in clearing depends on the rate of productivity, which is itself dependent on available working time and the resources which can be applied to the work. For example, from Table 1 the following productivity rates provide a basis for determining options on how work might be completed relative to time and resources:

In an average 6.5 hour working day in northern Guinea savanna

(i) 65 labourers can stump 1 ha; or

(ii) a 65 horsepower crawler tractor can knockdown 2.95 ha when a 25% time loss is allowed for rest and maintenance; or

(iii) a chaining unit can knockdown 33.2 ha when allowing a similar 25% time loss.

Similar figures can be readily calculated for other operations and zones. It should be noted that the mechanised operational day may readily be extended whilst maintaining a good rate of productivity; whereas hand labour productivity tends to fall off when the normal work period is extended.

Windrowing and Hand Piling

The series of windrowing trials, which used a range of available equipment, underlined the superiority of the front end rake over the bulldozer blade (Allan and Jackson, 1972; Allan and Akwada, 1974b). The front end rake causes little soil disturbance and consequently windrows contain less soil and burn more freely. In the heavier savanna bush an investigation was set up to compare the efficiency of linear windrows or irregular heaps. In the latter, the debris is stacked round the larger trees, theoretically reducing the volume of debris to be moved. Any difference in cost efficiency was negligible, although on the credit side the heaps appeared more tightly packed for burning, whilst on the debit side cultivation in the irregular pattern created by heaping was difficult but is readily feasible between windrows (Allan and Akwada, 1974b). The general optimum spacing for windrows was 50 m apart.

Table 2 records the rates and costs for selected windrowing and hand piling trials. In lighter savanna, trials 1 and 2 using different makes of tractor, record similar results and indicate an average unit cost of ₦1.44/m^2. Trial 3 showed that in this vegetation, increased tractor power did not improve cost efficiency. In the heavier southern Guinea vegetation using a heavy tractor, the increased volume of debris, as would be anticipated, increased the unit cost to ₦1.98/m^2.

In all cases mechanised windrowing was considerably more cost efficient than hand stacking and mechanised costs were between 9.2% to 11.7% of corresponding hand costs in different densities of vegetation. Thus, for the cost of stacking 1 ha by hand, some 8 or 12 ha may be windrowed by tractor in the southern or northern Guinea zones, respectively.

Pre-planting Cultivations

Total cultivation by hand labour is possible in small scale plots, but observations indicate that costs are so high and, perhaps of greater importance, the quality of cultivation is so poor as to preclude large scale hand cultivation as a reasonable possibility. Trials have shown that oxen may be successfully used to cultivate small scale plantations but the practical development of oxen power for plantation cultivation would take considerable application and time. The main practical cultivation alternatives lie in different types and powers of tractor and a range of ploughs and harrows. Table 3 records unit costs (₦/ha) for a selected number of ploughing and harrowing trials. Some of the productivities recorded are averages from extensive investigations (Allan, 1973b; Savanna Forestry Research Station, no date).

With reference to pioneer ploughing, trials 1 and 2 using medium wheeled tractors show considerably different productivities, which may be attributed mainly to variability of operators and of soil conditions. The average unit cost is ₦10.55/ha. Trials 3 to 6 employed crawler tractors and heavy duty Rome disc harrow ploughs. Trial 4 was a skilled operation with a high level of efficiency and is directly comparable with trial 6, where efficiency was less and the tractor was at the limit of its power pulling the TACH 12-30 plough; perhaps an average unit cost between ₦11 and ₦14/ha would be readily attainable in practice and would leave some room for improvement. Trial 5 illustrates once again that additional power does not necessarily yield greater cost efficiency, with the unit cost at ₦21.56 being more than double that of the comparable trial 4.

The wheeled tractor/disc combinations are slightly more cost efficient than the crawler units, but quality and depth of cultivation is less. In the heavier ploughing units the TACH 12-30 harrow gave the best penetration and effectively severed any remaining roots or stumps. Although the heavy duty harrow plough gives a quite different cultivation from that of a disc plough, results have shown that this type of soil working is generally adequate for plantations. For larger scale ploughing operations a 70 to 80 horsepower crawler tractor with the matching TACH harrow is recommended. A small trial employing a large 100 hp wheeled tractor as power unit to a TMR harrow, showed this to be a feasible ploughing unit and further trials are recommended.

When pioneer ploughing has been adequately completed and the land is largely free of all impediments, then pre-planting harrowing is a straightforward operation. Trials 7 and 8 in Table 3, at some ₦8.17/ha, record similar unit costs for different harrows of 2.1m cultivation width. There is no great difference between these implements although the 34/20 has proved slightly more durable in practice. Both harrows by adjustment and reduction in number of discs can be adapted for inter-row weeding. Trial 9, using the M/F 28 harrow with a 3 m cultivation width and a unit cost of ₦3.57/ha, is economically efficient and gives a high rate of productivity offering an acceptable option where the scale of operation justifies having an implement specifically for harrowing. Similar observations, relative to scale, apply to the trial 10 pulverising harrow TCW 40/24 which produced quite the best tilth or seed bed; indeed the cultivation was so good as to require the greatest care in using this implement in areas liable to erosion.

With reference to rates of productivity during a 75% effective 6.5 hour working day, the 3 disc plough would cultivate 2.4 ha and the heavy TACH harrow plough between 2.9 and 5.0 ha; pre-cultivation harrowing rates vary between 3.2 ha for the 34/20 and 8.0 ha for the TCW 40/24 harrow.

CONCLUSIONS

i) There is a well established need for plantation development in the Nigerian savanna (Allan and Ojo, 1974). The need to accelerate this development continues to require study and investigations to ascertain the more efficient techniques for main operations and to provide a sound base for plantation planning and budgeting.

ii) Initial plantation development generally requires the clearing of the indigenous bush and cultivation of the soil prior to planting. Land clearing operations are not particularly difficult but require careful forward planning; firstly, to ensure that only suitable land is cleared and, secondly, to ensure a timely sequence of operations. With information on vegetation density and rainfall for a particular area, the preparation of a sound calendar of operations is the basis of good planning.

iii) The costed results of a series of investigations to determine the efficiency of different techniques for clearing and cultivation indicated that:

a) Chaining cost efficiency is less than 5% that of the cost of comparative hand stumping operations;

b) Similarly, single tractor knockdown is only some 10% of hand operations;

c) Mechanised windrowing costs are only 9 to 12% of comparative hand piling costs;

d) The mechanised clearing operations offer fast rates of productivity and the possibility of expediting development;

e) Pioneer ploughing with a light agricultural tractor and mounted disc plough unit is 4 to 32% more cost efficient than using heavier crawler units. The heavier crawler disc harrow plough unit, however, improves the quality of cultivation and can double the rate of output;

f) For pre-planting harrowing, the unit cost for the most efficient implement is only some 43% that of the least efficient unit cost recorded and the heavier crawler unit cultivates at more than double the rate of the lightest agricultural units.

The results from these trials indicate some of the options open to management, but decisions require consideration of the resources available, the scale of operation and the period during which the work has to be completed.

iv) For large scale plantation, mechanised operations have considerable advantage over other less economic alternatives. Due consideration, however, must be given to some of the constraints to efficient mechanisation which are common in a number of developing countries (Creese, 1974). Such problems may be lack of spare parts, shortage of skilled operators, poor servicing facilities and lack of incentives. Unless these problems are eliminated by the planning and provision of an adequate infrastructure, successful mechanisation is unlikely to eventuate.

v) If the considerable economic advantages of mechanisation over stumping and hand piling could be ignored, then mechanisation of such operations might be seen as erasing an opportunity for large scale employment. These economic advantages cannot be ignored, however, and the application of selective mechanisation to a marginal, labour intensity project may firstly make the project economically feasible and, secondly, the application of budget savings could allow the undertaking to be accelerated or expanded. It is suggested that a soundly based, selective, mechanised plantation project will, in the longer term, provide more permanent direct employment, as well as indirect employment in processing industries than a marginally economic labour intensive undertaking (Oluwasanmi, 1975).

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Indigenous vegetation such as this Isoberlinia doka in the northern Guinea savanna must be cleared away prior to plantation establishment. Mechanised clearing with two crawler tractors and an anchor chain is the most cost-efficient method for these conditions.

APPENDIX A

BASIS OF COSTING TRACTORS, EQUIPMENT AND LABOUR OPERATIONS IN LAND CLEARING AND PREPARATION

Costing Crawler Tractors and Matched Equipment

The costing method is mainly based on FAO Forestry Equipment Notes C 14-56 (FAO, 1965). Operating rates per hour are based on costs to Nigerian Government agencies as at 1975.

The basis of tractor cost calculations

I Estimated irreducible costs are based on the number of hours assuming:

a) Annual interest at 6% averaged and

b) Garaging cost at ₦0.02 per hour.

Insurance and road tax are omitted as Government equipment is free from such charges.

II Estimated depreciation and repair costs are based on the estimated operating hours (H) in the lifetime of the tractor (standard life). Standard life spans of 10 000 hours over 8 years have been assumed for crawler tractors and 5 000 hours over 5.6 years for wheeled tractors.

a) Depreciation is calculated on the straight line method by dividing the net 1975 purchase price of the tractor (A) by the estimated life in hours or $\frac{A}{H}$. Scrap value is taken as nil.

b) Estimated cost per operating hour for repairs is expressed as a fraction (r) of the depreciation per operating hour. Based on experience, the index of 1.0 is used for standard lives.

III Tractor costs directly incurred when working are taken as follows:

a) Cost per operating hour for diesel oil consumption is based on average performance figures, diesel being costed at ₦0.46 per gallon;

b) Cost for lubrication is also based on handbook data (Caterpillar Tractor Co., 1970b) and current costs for materials;

c) Additional cost for maintenance and cleaning is estimated as ₦0.10 and can be considered a non operative cost against the tractor operator.

IV Wages and associated expenditure are based as follows:

a) Wages per hour of machine operators are based on the Federal Tractor Driver 1975 award at the top of the scale, i.e. ₦3.75 per 6.5 hour day. Allowing that only 75% of time will be operational and assuming that total hours should be charged to tractor work, this gives an hourly operating rate of ₦0.77. It is further assumed that when a tractor driver is on other work his time will be charged to such work;

b) Estimated expenditure for pension, paid holidays and sick pay is taken as 15% of IV a) i.e. ₦0.12. Estimated hourly tractor and implement costs are detailed in Table 4.

V Implements are costed as per tractor calculations under items I and II.

Costing Labour Operations

The costs for hand labour stumping are based on actual 1975 rates assessed as follows:

a) Daily labour is based on a basic ₦2.02 per man day with working hours of 7 hours per day Monday to Thursday, 5 hours on Friday and 6 hours on Saturday giving a total of 39 hours and an average of 6.5 hours per day over a six day week. An allowance of 10% to reflect leave and public holidays and other benefits makes the total cost of labour per man day ₦2.22;

b) The cost of hand tools has been excluded.

TABLE 1

ESTIMATED 1975 KNOCKDOWN RATES AND COSTS IN NIGERIA

Operation and Equipment	Ref No.	Year of Trial	Cost/hr (₦)	O.T./ha (mins)	Cost / ha (₦)	Cost / ha (US $)	O.T./m² B.A.(mins)	Cost / m² B.A. (₦)	Cost / m² B.A. (US $)	Climatic Zone
Knockdown Chaining										
2 x 180 hp crawlers and chain	1	1972	37.88	7.19	4.53	7.36	0.75	0.47	0.76	N.Guinea
2 x 180 hp crawlers and chain	2	1974	37.88	9.42	5.94	9.65	1.20	0.75	1.22	"
2 x 125 hp crawlers and chain and 1 x 85 hp crawler	3	1974	32.10	23.00	12.30	20.00	2.58	1.38	2.24	"
2 x 180 hp crawlers and chain and 1 x 65 hp crawler	4	1973	46.10	15.77	12.11	19.69	1.29	0.99	1.60	S.Guinea
Single Tractor Knockdown										
1 x 65 hp crawler	5	1971	8.05	114.6	15.37	24.99	11.93	1.60	2.60	N.Guinea
1 x 65 hp crawler	6	1972	8.05	81.26	10.90	17.72	10.10	1.35	2.19	"
1 x 65 hp crawler	7	1974	8.05	102.60	13.76	22.87	11.39	1.52	2.47	"
1 x 125 hp crawler	8	1974	11.71	79.62	15.54	25.26	9.76	1.90	3.08	"
Hand Stumping										
Direct hand labour	9	1971	-	-	145.41	236.43	-	14.66	23.84	"
Contract hand labour	10	1973	-	-	276.00	448.78	-	22.86	37.17	S.Guinea

TABLE 2

ESTIMATED 1975 WINDROWING RATES AND COSTS IN NIGERIA

Zone, Operation and Equipment		Year of Trial	Cost/hr (₦)	O.T./ha	Cost / ha (₦)	Cost / ha (US $)	O.T./m^2 B.A. (mins)	Cost / m^2 B.A. (₦)	Cost / m^2 B.A. (US $)
Northern Guinea Zone									
1 x 65 hp crawler tractor	1	1971	8.05	79.56	10.67	17.34	11.01	1.47	2.39
1 x 65 hp crawler tractor	2	1971	8.05	102.50	13.75	22.35	10.55	1.41	2.29
1 x 90 hp crawler tractor	3	1971	11.71	94.08	18.36	29.85	9.56	1.86	3.02
Contract hand labour	4	1971	-	-	148.00	240.65	-	15.60	25.36
Southern Guinea Zone									
1 x 180 hp crawler tractor	5	1973	18.71	76.93	23.99	39.00	6.36	1.98	3.21
Direct hand labour	6	1973	-	-	204.00	331.70	-	16.90	27.47

TABLE 3

ESTIMATED 1975 COSTS FOR PRE-PLANTING CULTIVATION

Operation Equipment and Ref. No.		Year of Trials	Cost/hr (N)	O.T./ha (mins)	Cost / ha (N)	Cost / ha (US$)
Pioneer Ploughing						
1 x wheeled tractor 50 hp with 3 disc plough	1	1972	5.23	139.10	12.12	19.70
1 x wheeled tractor 50 hp with 3 disc plough	2	1971	5.23	103.02	8.98	14.60
1 x 65 hp crawler with Rome TMR 10-30 disc harrow	3	1972	10.21	72.61	12.35	20.08
1 x 70 hp crawler with Rome TACH 12-30	4	1972	10.72	57.98	10.35	16.82
1 x 180 hp crawler with Rome TRH 16-30	5	1972	23.18	55.81	21.56	35.05
1 x 65 hp crawler with Rome TACH 12-30	6	1974	10.72	102.18	18.25	29.67
Pre-planting Harrowing						
1 wheeled tractor 50 hp with M/F 34/20 harrow	7	1972	5.41	91.62	8.26	13.43
1 wheeled tractor 50 hp with H/R 35/70 harrow	8	1972	5.49	88.41	8.09	13.15
1 wheeled tractor 50 hp with M/F 28/26 harrow	9	1974	5.53	38.82	3.57	5.80
1 x crawler 70 hp with Rome TCW 40/24 harrow	10	1972	11.87	36.78	7.27	11.82

TABLE 4

ESTIMATED OPERATING COST PER HOUR FOR SELECTED MECHANICAL EQUIPMENT

Machine and/ or Equipment	Annual Operating (Hours)	Expected Life (Hours)	Net Cost (Naira)	Cost per hour in Naira									Total Naira
				Irreducible Costs				Working Costs			Operators		
				In-terest	Garage	Depre-cia-tion	Re-pairs	Fuel	Lub.	Clean-ing	Wages	Other	
180 hp crawler tractor	1 250	10 000	63 350	1.52	0.02	6.33	6.33	3.28	0.24	0.10	0.77	0.12	18.71
65-70 hp crawler tractor	1 250	10 000	25 500	0.61	0.02	2.55	2.55	1.21	0.12	0.10	0.77	0.12	8.05
50 hp wheeled tractor	900	5 000	6 000	0.22	0.01	1.32	1.32	0.37	0.08	0.10	0.77	0.12	4.31
heavy duty disc harrow 34/16	400	2 000	858	0.06	0.01	0.43	0.43	-	-	-	-	-	0.93
anchor chain	1 250	10 000	2 850	0.07	-	0.29	0.10	-	-	-	-	-	0.46

PLANTATION PLANTING AND WEEDING IN SAVANNA

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CONTENTS

This discussion is based on Chapter 12 of Tree Planting Practices in African Savannas (FAO, 1974); the following notes supplement the relevant sections.

SPACING AND PEGGING

Spacing

Recommended spacings in savanna have usually been determined from silvicultural investigations largely based on rates of growth and form, but they can influence plantation profitability. The costs of planting, beating up, weeding, pruning, harvesting and yield are affected by spacing.

The closer the plant spacing, the greater the number of plants and the larger the actual planting input required per unit area. Both these factors can considerably increase planting costs. With a larger number of plants per hectare, however, losses become less critical and it may be possible to dispense with beating up, whereas at wider spacing making good any losses could be essential. The closer the initial plant spacing the earlier canopy closures can be anticipated and this in turn affects the duration of the weeding regime. The suppression of ground vegetation by canopy closure also reduces fire hazard. Wider spacing is likely to induce heavier branching with consequent higher pruning costs, but on the other hand there are fewer trees to be pruned. Plantation revenue is dependent on the volume and timing of production; spacing obviously can influence both factors.

If it is assumed that plantation weeding will be mechanised, then the first constraint is that the spacing must be sufficient to allow a tractor and implement between the planted trees. Specialised small or narrow tractors are not a reasonable possibility at this point in time so use is made of the normal agricultural type tractor which requires a minimum spacing of 2.8 m. Accepting this constraint, the main objectives in selecting a spacing are to achieve an economic establishment and to close canopy (or take over the site) as early as possible.

Planting may be on the square allowing mechanised weeding in two directions at right angles, on the diagonal or with reduced spacing in the lines allowing mechanised interrow weeding in one direction only. Table 1 gives some cost indications of the effect of spacing on establishment costs for the following options:

<u>Option 1</u>. Planting eucalypts on the square at 3 m x 3 m (1111 plants per ha) with one year's spot weeding and two way mechanised interrow weeding.

<u>Option 2</u>. Planting eucalypts in lines at 3 m x 1.5 m (2222 plants per ha) with one year's line weeding and one way mechanised interrow weeding.

<u>Table 1</u>

Indicative Establishment Costs

Operation	Costs per hectare			
	Option 1		Option 2	
	₦	US $	₦	US $
Planting stock	33.33	53.99	66.66	107.98
Planting	7.26	11.76	14.50	23.49
Hand spot weeding x 4	24.00	38.88	-	-
Hand line weeding x 4	-	-	60.00	97.20
Mechanised interrow weeding	(a) 19.80	32.07	(b) 13.20	21.38
Total	84.39	136.70	154.36	250.05

(a) 6 mechanical weedings, 3 in each direction at ₦ 3.31/ha

(b) 4 mechanical weedings, all in one direction at ₦ 3.31/ha

In this example, by reducing the spacing from 3 m x 3 m to 3 m x 1.5 m the selected first year costs are increased by some 83%. The benefits of closer spacing such as elimination of beating up and increased selectivity for thinning should also be quantified.

The optimum spacing clearly depends on a number of factors that do not allow general conclusions to be drawn. In the first instance, it is often necessary to choose that spacing which within the given environment and with the available knowledge and resources will generally meet the objectives, whilst research gives consideration to the effect of other variations in spacing and their interaction with other factors.

Having decided on spacing, the marking for planting by pegs has to be related to the plantation and compartment layout. In undulating country it may be necessary to use contour planting, but in savanna the general pattern is square or rectangular. Marking for planting may be done by tractor with a tool-bar and tines, but this requires a skilled operator; pegging by hand is more commonly the method used. Pegging may range from marking each individual planting spot to pegging squares and subsequently using marked chains to indicate planting spots in the squares. At 3 m x 3 m spacing the former method requires 1111 pegs/ha and the latter slightly under 3 pegs/ha.

Pegging Squares Method

Assume a plant spacing of 3 m x 3 m on clean harrowed ground with a ready supply of 6 pegs. The pegging is based on 60 m^2. (The length of the sides of the squares must be a multiple of the plant spacing.)

Equipment Prismatic compass or right angled prism,
2 mallets or hammers,
Pegs (allow 3 per ha), and
1 x 60 m chain.

Manpower 1 supervisor and a minimum of 4 labourers consisting of
2 chainmen, 2 carrying pegs and mallets.

Method From the starting point, lay out and peg an exact 60 m^2 using the prismatic compass or optical square. From these pegs lay out two base lines at right angles with pegs at 60 m intervals. From the initial square using the chain sight in the corners of other 60 m^2, until the entire area is squared.

It is important to carry out periodic checks to ensure that pegs are exactly 60 m apart. The chain should be checked for stretching during the exercise. When pegging, it is important firstly to leave a margin around the compartment for weeding and secondly, at compartment ends with stretches of less than 60 m, pegs should be put in at the multiple of 3 m that can be fitted in.

Outputs Nigeria 4 to 5.0 ha/hr clear areas.
Zambia 2.25 ha/hr in areas with anthills.

PLANTING

Timing of Planting

Planting should be completed early in the rains in as short a time as possible, to allow the trees to become well established prior to the severe dry season. The importance of timely and good quality planting should be stressed. The Zambian method of commencing planting when the soil is moist to 30 cm is a good rule of thumb.

Kowal (1975) worked out planting dates based on the start of the rains according to the following definitions:

(a) the first ten day period (decade) during the year having at least one inch of rainfall with subsequent two decades of at least half evapotranspiration (calculated by Penman's formula using a 25 % reflection co-efficient)

(b) the ten day period during which the cumulative annual rainfall is at least 100 mm, with falls of less than 10 mm in any decade excluded.

The following are Nigerian samples.

Table 2

Start of rainy season for selected stations in northern Nigeria

Station	date of start of rains				Estimated Target Planting Date
	method (a)		method (b)		
	average	latest 1/	average	latest 1/	
Sokoto	7 June	29 June	22 June	10 July	1 July
Maiduguri	22 May	14 June	5 June	23 June	14 June
Samaru	12 May	4 June	26 May	14 June	5 June
Kaduna	4 May	26 May	17 May	5 June	26 May

1/ The latest likely date of the start of the rains at a confidence limit 1:9; i.e. only once in 20 years is the start of the rains likely to be later than the dates.

Such data give a planning date for planting and for such associated operations as ground preparation and nursery production. For plantation planting, the object should be to complete the planting programme within a period of four weeks from the starting date.

The effect of timely planting is related to and can affect the results of such other factors as fertiliser application, weeding regimes and consequent growth, but measuring such interactions is not easy. Research into this aspect has been done in savanna agriculture and for maize it was found (Baker, 1975) that planting at the optimum time gave some 50 % to 84 % increased yield over planting one month later under specific conditions. Similar trends could be anticipated with plantation crops.

Transport of Plants

One of the important factors related to transport and distribution is the weight of full plant-carrying boxes; trials in Nigeria used the following types:

Table 3

Weight of plant-carrying boxes and different types of polypots

Type of Box	Weight empty (kg)	Weight full with 15 large pots (kg)	Weight full with 15 medium pots (kg)
Wire tray 41 x 29 x 10 cm	1.10	28.5	14.7
Wooden boxes 39 x 24 x 10 cm	1.53	29.3	15.1
Metal boxes 41 x 28 x 5 cm	2.00	29.60	15.6

Large pots: 25 cm x 7.5 cm diameter
Medium pots: 15 cm x 7.5 cm diameter

The weight of over 28 kg of the boxes with large pots proved to be a strain for lifting and carrying during a working day. The wire basket with medium pots proved the more successful in use. For drier areas where larger pots are essential the use of smaller boxes holding 9 or 10 plants should be considered.

Planting Method

When using polypots, the plant and its growing medium are transferred to the field, and as long as the plant has been hardened-off there is no severe shock in changing the environment. Mechanised planting is possible, but the well organised use of labour is generally preferable in savanna areas. The adequate and timely distribution of plants to the site is of critical importance to planting efficiency.

Planting comprises the following activities:

Pitting,
Distribution of plants on site,
Planting.

By pre-plantingharrowing and using specific hand tools it is possible to combine these separate activities so that they are mainly carried out as a single operation by one man. This type of combined operation can considerably improve productivity.

The following section gives an outline planting method for specified assumptions, but requirements and productivity can be readily recalculated and measured when these assumptions are varied. In describing this planting method the following assumptions are made:

(a) that the land has been harrowed and pegged in 60 m squares;

(b) plant spacing is 3 m x 3 m;and

(c) that medium sized polypots 15 cm high by 7.5 cm diameter are used; and that there is an adequate supply of full planting trays on site.

<u>Equipment</u>: 60 m planting chain with 3 m tags,
300 to 600 plant-carrying trays of 15 polypot capacity,
19 planting trowels with spares, and
a tractor with plant-carrying trailer.

<u>Manpower</u>: 1 supervisor, 1 tractor driver, 27 labourers consisting of 2 chainmen, 19 planters and 6 distributors.

<u>Method</u>: Distribute plants for line planting 20 seedlings at each peg. Using chain and 20 planters, plant in parallel lines 60 m apart. When this line planting is complete, just over one twentieth of the area is covered. These plants serve as markers for full planting carried out at right angles to and between the planted lines.

Between marker trees on the base line, and at each interval of 16 trees, lay out 19 full planting boxes 3 m apart. To start planting, the chain is placed between the base line tree markers to indicate the 3 m planting spots where planters with trowels pit and plant. The chain is advanced 3 m to the next markers and the process is repeated. After planting 15 trees each, the empty trays are discarded and full ones are picked up by each planter and the planting operation is continued to the end of the area. Empty trays are collected and full trays are distributed in advance of the planting gang. Stretching of the chain is possible and requires checking.

<u>Output</u>: 8.5 to 9.5 ha/day initial instructional trials in Nigeria.
15 to 16 ha/day based on standard times for Zambia using mini pots.

WEEDING

Except at higher altitudes or in areas where moisture is plentiful, it is generally better to start plantation development with a clean weeding regime, whilst research determines what degree of tolerance to weeds the selected species might have. It is of equal importance to clean weed species trials and early research plots, as the presence of weeds often affects or negates the results obtained. Under most conditions, even outside the savanna region, clean weeding will produce faster growth and increased yields, but it is necessary to have some indication that the value of the increased growth is greater than the cost of the weeding inputs. It is of consequence to maintain a weeding cycle that does not allow the weed cover to become heavily established, as heavy weed is often difficult and extremely costly to eliminate.

The main methods or combinations of methods of eliminating weeds are hand, mechanised or chemical weeding.

Complete Hand Weeding

Hand weeding in savanna implies cultivation of the soil by hoe or a similar implement. Scraping only severs roots and can produce undesirable soil capping. Cutting back of weeds generally stimulates growth and does not reduce competition for soil moisture (Chapman, 1973).

The main constraints to hand weeding, particularly in large scale operations, are the size and cost of the labour inputs. Zambian data indicate that in very light weed cover weeding takes 7.2 man-days per ha, and that in heavier weed this rises to 25 man-days/ha. Task weeding in heavy grass in Nigeria required 32 man-days/ha. Assuming 1000 ha and that it is necessary to carry out a heavy weeding every 5 weeks, the figures indicate that a labour force of between 800 and 1100 men is required during the weeding season. At 1975 rates each weeding would cost ₦ 55 ($89) to ₦ 70 ($113) per hectare. In general, hand weeding seldom produces as intense a cultivation as mechanised cultivation.

Mechanised Weeding

Mechanised weeding covers only the interrow area and requires supplementary hand weeding of the area adjacent to the trees left uncultivated in the mechanised operation (Baker, 1975). To avoid damaging the plantation crop, initial mechanised weeding should be kept fully 30 to 45 cm from the trees, and as the crop grows this distance should be increased. Interrow weeding may be by oxen or tractor power.

When evaluating different types of mechanised equipment the comparative unit measure is the "cultivated plantation hectare" (C.P. ha), which is a measure of the area effectively cultivated excluding the area to be supplementary hand weeded, i.e. one C.P. ha is 10 000 m^2 (length x width) of effectively cultivated plantation land. For management purposes, however, the "gross plantation hectare" is the unit measure used and refers to a hectare of trees i.e. when the number of trees including blanks treated equals the number of trees per ha planted, the area is a G.P. ha. The G.P. ha includes the area to be hand weeded, but that actual area will vary with the width of the implement used for the interrow weeding.

Investigations employing oxen with Ariana spring tine cultivators have indicated the feasibility of interrow weeding with this combination in the Nigerian northern Guinea/Sudan zones (Allan, 1972; Makin-Taylor, 1974). A two oxen team averaged some 94 to 141 min to weed a G.P. hectare, which in a 4 to 6 hour day indicates outputs of 2 to 3 ha. On the assumption that costs will have doubled since 1971, costs per ha would be of the order of ₦ 3 ($4.80) to ₦ 4 ($6.40). (The capital cost of the oxen will have more than doubled during the period, but the salvage, or meat, value will have risen in slightly more than compensatory fashion.) The setting up of oxen units requires considerable application and training and has not so far been implemented at other than the investigatory level.

A number of trials to evaluate a range of weeding implements have been carried out in Nigeria and Zambia (Allan, 1973; Deveria, 1972; Forestry Department Zambia, 1971). Columns 7 and 8 of Table 4 indicate the greater cost efficiency of harrows compared to rotavators, and of the harrows the M/F 34/16 is marginally the best. Similar conclusions were reached in Zambia. The average trial output of the medium wheeled tractor and harrow is indicated as 1.58 G.P. ha/hr (column 3) but for practical purposes a standard time would be of the order of 1.0 to 1.2 G.P. ha/hr. mechanised interrow weeding may be done in one direction with supplementary line weeding, or in two directions at right angles with supplementary spot weeding. Referring back to Table 1 shows that a complete weeding in one direction would cost ₦ 18.30 ($29.65) whereas spot weeding and two mechanised weedings at right angles would cost ₦ 12.60 ($20.41); and the cost difference over a season is 67 %. These are not directly comparable because the two-way weeding gives double cultivation to 60 % of the area and, as Deveria (1972) points out, cross cultivation can put a strain on the tractor and implement.

Table 4

Estimated 1975 cost per unit area for mechanised interrow weeding

Tractor & Implement	Operating Cost 1/ per hr (₦)	O.T. 2/ per 3/ G.P. ha (min)	Cost/G.P. ha		O.T. per 4/ C.P. ha (min)	Cost/C.P. ha	
			(₦)	($ US)		(₦)	($ US)
M/F 165 + M/F 34/16 harrow	5.24	37.75	3.29	5.33	45.30	3.96	6.41
M/F 165 + Howard 1.52 m rotavator	5.79	42.50	4.10	6.64	69.66	6.72	10.88
M/F 165 + Ransome HR 35 harrow	5.67	42.73	4.04	6.54	51.27	4.84	7.84
M/F 165 + Ransome HR 29 harrow	5.02	38.66	3.23	5.23	49.87	4.17	6.75

1/ 1973 costs updated to 1975. Tractor costs increased by 78 % and implements by 29 %.

2/ O.T. (operating time) for a tractor unit operation is the total working time in minutes per specific area or unit, and is calculated by adding working, minor stop and turning times.

3/ G.P. ha = "gross plantation hectare", refers to a hectare of plantation trees. For post planting mechanised weeding, when the number of trees including blanks treated is equal to the number of trees per hectare at time of planting, this is a unit G.P. ha.

4/ C.P. ha = "cultivated plantation hectare". In a plantation, when the area cultivated, as calculated by length times breadth in metres effectively cultivated is 10 000 m^2, this is a unit C.P. ha. (In a weeding operation this excludes the area to be hand weeded.)

Considerable studies of supplementary hand spot weeding have been completed in Zambia (Forestry Department Zambia, 1971). The vegetative weed cover is assessed by the number of hoe strokes required to weed around each tree as:

Extra light - less than 10 hoe strokes
Light - 10/20 hoe strokes
Medium - 20/30 hoe strokes
Heavy - 30 or more hoe strokes per spot.

Table 5

Standard times and outputs for spot weeding

Item & Unit	Weed Cover			
	Extra light	Light	Medium	Heavy
Standard time in minutes	0.28	0.38	0.55	0.96
Time per ha in minutes (3m x 3m)	311	422	611	1067
Output in man-days/ ha*	1.25	0.92	0.60	0.36

* taken as a Nigerian 6.5 hour man-day.

The data in Table 5 are based on Zambian work study (Forestry Department Zambia, 1971) but initial studies in Nigeria indicate that with adequate supervision and some allowance for higher temperatures similar outputs could be anticipated. Estimated line weeding outputs can be readily calculated from this data. Spot weeding costs would vary from ₦ 1.76 ($2.85) per ha in sparse weed to ₦ 6.11 ($9.90) in heavy weed cover.

Chemical Weeding

The use of herbicides or arboricides have been curtailed in many countries, due in some measure to fear of the danger in using such chemicals, in particular health hazards to operators and adverse ecological effects. Many of the dangers have been exaggerated (see Dost et al, 1975, on 2, 4, 5 - T and T.C.D.D.) but discussions have become emotional, and though clearance investigations have been run and proved it is not always easy to change public opinion. It is vital, therefore, to make a careful study of the background information and correct usage of any chemical weedicide before introduction into plantation practice (Barring, 1974).

The main reasons for trying out chemical weeding are:

(i) where labour is in short supply,
(ii) where present weeding methods are inefficient,
(iii) where the land is liable to erosion, or where rocks or outcrops preclude mechanised weeding,
(iv) as a supplement to hand or mechanical weeding.

There is a need for an extensive research programme which would offer an opportunity for co-ordinated work between savanna countries. Use should be made of agricultural results as many of the problems are common to both disciplines. One basic silvicultural question is whether chemical weeding will give the same benefits in growth and yield as have been observed from cultivation weeding.

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NOTES ON CHEMICAL WEED CONTROL IN SAVANNA PLANTATION FORESTRY

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CONTENTS

FEATURES OF CHEMICAL WEED CONTROL

Advantages

1. Risk of erosion reduced through the mulching effect;
2. Generally specific to one type of weed and
3. Effects generally longer lasting than mechanical methods.

Disadvantages

1. Generally (but not always) more costly than mechanical weeding;
2. Timing of application is usually important;
3. Large quantities of diluent must be carried into the field (but this is being overcome by ultra low volume applications) and
4. Toxicity.

NURSERY WEED CONTROL

Sterile Seed Bed Technique

Using paraquat (trade name Gramoxone), the beds are made up before transplanting and watered to encourage the weeds to germinate before they are sprayed. Paraquat is an overall herbicide that kills all green tissue. It is not translocated to the roots; therefore the weeds must be young (no more than 5 cm high).

Rate: 1 litre product/ha. Can also be used on nursery paths.
Cost: Approximately ₦0.20 (about U.S.$0.32) per 30 x 1 m bed, generally cheaper than hand weeding.
Toxicity: Very high if ingested, but quickly inactivated in most soils.

Fumigation

Methyl bromide is used. It kills weed seeds and pathogens, but also kills nitrifying bacteria; therefore a soluble fertilizer must be used. It is applied in gaseous form before transplanting.

Toxicity: Very high.

WEED CONTROL IN THE ESTABLISHMENT PHASE

Dalapon

Dalapon is specific to grasses. Best kill is when the grasses are freshly shooting. It can be mixed with 2,4-D to control broadleaved weeds as well.

Rate: 6 - 10 kg active ingredient/ha in 100 litres water.
Cost: About ₦15/ha (about U.S. $24/ha)
Toxicity: Low.

Triazines

Simazine, atrazine, etc., act on emerging seedlings principally through root uptake. Some of the newer formulations are more soluble and also act through the leaf, but generally good soil preparation is necessary to remove the existing vegetation. Triazines give overall weed control of most species except maize (physiological selectivity).

Rate: 1 - 3 kg active ingredient per ha.
Cost: About ₦15/ha (about U.S. $24/ha)
Toxicity: Low.

WOODY WEEDS

Although most savanna plantations will be established by complete clearing, some woody weeds may still arise from roots or seed. The usual chemicals for their control are 2,4-D and 2,4,5-T or more recently, picloram. They may kill through foliar or bark sprays, but they may also affect many of the species (especially broadleaves) used in savanna afforestation.

Where stumping has not been done, coppicing may be prevented by these chemicals, or ammonium sulphamate or sodium arsenite. The last is very poisonous. Generally, chemicals diluted in oil give better bark penetration.

METHODS OF APPLICATION

1. Hand. Knapsack sprayer, often with guards to prevent drift. Cheap to buy, but slow (1 - 2 ha per day).

2. Tractor. Faster, but ground may be too wet at the best time for application. Dangers of drift. 5 - 10 ha per day.

3. Aeroplane. Very fast, but need runways and support facilities close at hand. Independent of soil condition. Considerable dangers of drift. 100 ha + per day.

FURTHER INFORMATION

A useful source of further information on chemical weed control is the Weed Control Handbook. The full references to this are:

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USE OF FERTILIZERS IN SAVANNA PLANTATIONS

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CONTENTS

INTRODUCTION

It is only in the last two or three decades that the use of fertilizers in forest plantations has become widespread. Before that it was assumed that the expense of fertilizers was too great if they were used for a relatively slow-maturing crop like forest trees. Nowadays it is realized that if the diminishing area of land available for forestry is to meet the needs of a world population which is both increasing in numbers and demanding a higher standard of living, this land must be managed to produce the maximum economic yield. This is being achieved by improved cultural practices, selection and breeding of higher yielding trees, and, in appropriate circumstances, by the use of fertilizers.

There are two main situations in which fertilizers are needed, though there are borderline cases between the two. The first is where a species of tree cannot be grown satisfactorily on certain sites without the use of fertilizers. Examples are eucalypts, which need boron on many African savanna sites, and pines, which will not grow satisfactorily on some Nigerian soils without added phosphate. Here the choice is simple: apply fertilizer, or do not grow these species on such sites. The second case is where fairly satisfactory plantations can be established without the use of fertilizers, but where the yield is increased if they are applied. In this case the decision is an economic one; do the increased yields compensate for the extra cost, compounded appropriately?

The work of the Savanna Forestry Research Station in Nigeria included a series of experiments on the use of fertilizers in plantations. These are covered in fair detail by Jackson (1974). Work elsewhere in the savanna region of Africa is dealt with by Laurie (1974) pp. 37, 104-105.

ESTIMATION OF FERTILIZER NEED

A number of techniques are available for estimating the need for fertilizers. Shortage of certain plant nutrients will show up in visual symptoms, such as discoloration and deformation of leaves and stems. With experience it is often possible to know which nutrient is lacking, but even if this can be done with some certainty the amount of the nutrient required to correct the deficiency is unknown. Frequently, also, plants show no outward signs of nutrient deficiency, but still give greatly increased yields if fertilizers are applied.

Soil analysis is useful to give an indication of what additional nutrients are likely to be needed. It can be misleading, however, as certain nutrients may be present in abundance, and yet be unavailable to plants. An example is certain soils on the Mambilla Plateau, which have a high phosphorus content; yet trees on these soils show a marked response to phosphate fertilizers. Also different species of trees vary in their nutrient requirements, and a soil which has adequate supplies for one species may have insufficient for another.

Studies of nutrient content of plant tissues can be valuable, but before they can be used the levels of nutrients found need to be calibrated against those found in trees of known health and growth rate so that optimum levels can be determined.

Pot experiments can give valuable indications of likely nutrient deficiencies, but it is rarely possible to extrapolate directly from the results of such experiments to field practice. For one thing the volume of soil available in a pot is much less than the volume available to the roots of a growing tree.

Thus the basis of estimation of fertilizer needs must eventually be field experiments. When these have been established, results of soil and tissue analysis can be correlated with them, and used for further estimations.

In field experiments, factorial designs with nutrients at, if possible, at least three levels each, are to be preferred. This method not only shows what nutrients are needed, but also enables the optimum levels of each to be estimated. Unfortunately the large areas needed for field trials of fertilizers in forestry often preclude the use of more than three levels of say three nutrients in a single trial.

RESPONSE OF DIFFERENT SPECIES TO FERTILIZERS

Eucalypts

Boron deficiency is a common cause of poor growth of eucalypts in many parts of the savanna region of Africa. It was first described from Zambia by Savory (1962). Its symptoms are distortion and discoloration of the leaves, followed by dieback of the leading shoot; this dieback may be repeated for several years, until in the end all that is left is a densely branching bush. In less severe cases repeated dieback causes the stem to become crooked, reducing its value.

The remedy is to apply fertilizer borate (14 percent B) soon after planting. In Nigeria 50-60 g per tree has been found to be adequate, but in Zambia "at least 57 g are required on shallow soils in low rainfall areas, and 144 g on the deep sands or in areas of high rainfall" (Laurie, 1974).

Caution must be used in applying borate to very sandy soils of low buffering capacity, as in these conditions boron toxicity is very likely. Considerable damage was caused to *Eucalyptus* trials in the area north of Kano by application of borate. In such circumstances very light doses, repeated a number of times, should be tried.

Eucalypts generally also respond to other fertilizers, especially phosphate, but quite often to nitrogen as well. There is also quite often a strong interaction, in that nitrogen without phosphate has little effect, and to some extent vice versa, but when the two are combined the effect is much greater. Particularly with nitrogenous fertilizers, too much can be as harmful as too little.

Tables 1-3 give some results from fertilizer trials on eucalypts in Nigeria to illustrate some of these points.

In Zambia, Laurie (1974) reports that standard practice is to apply an NPK fertilizer, with the proportions of 11:22:11, at the rate of 57 g per plant. This is equivalent to 14 g of urea (or 35 g ammonium sulphate), 70 g of superphosphates, and about 12 g of muriate of potash (KCL) per tree.

Pines

In Nigeria phosphate has been found to be the most commonly limiting nutrient, and on many soils it is essential to add phosphatic fertilizers to obtain satisfactory survival and growth. Phosphate-deficient pines are typically stunted, with little branching, and needles which tend to turn brown at the tips. These are very similar to the symptoms of mycorrhiza deficiency, and it is possible that the effect of the phosphate acts through stimulating mycorrhiza development.

The effect of nitrogenous fertilizers is much less, and some forms have been found to be injurious, especially urea. For examples see Tables 4 and 5. At Mokwa, even with the phosphate, growth is unsatisfactory, but the striking difference in mortality should be noted.

Boron deficiency has been recorded from pines in various parts of Africa, but so far there are no records of trials in the savanna region.

Teak (Tectona grandis)

In Nigeria, on good sites, the general effect of applying fertilizers to teak has been an improvement in growth during the first three or four years, after which the unfertilized plots caught up with the rest. On poor sites fertilizers had a marked effect, but even with their use growth was unsatisfactory; growth of fertilized trees was poor, that of unfertilized trees even poorer.

As teak is a relatively slow growing species, considerable increases in growth would be required to cover the cost of the fertilizer if compounded to the end of the rotation.

Gmelina arborea

Results from trials in Nigeria showed a considerable variation from site to site. In some cases there was a response to urea but not to superphosphate, and in others the reverse, while elsewhere there was a marked interaction between the two. The proportions which, on the whole, gave the best results, were $N:P_2O_5$ 5:4, when the nitrogen was applied as urea. In one group of trials this combination considerably increased height growth in the first year, but caused a marked colour change in the leaves, the lamina turning bright yellow while the veins and a narrow strip along them remained bright green. This is presumably due to a trace element deficiency, and is an example of how, when one limiting factor is removed, the effects of others may become apparent.

Neem (Azadirachta indica)

Some trials were made north of Kano on a very poor sandy site. Although nitrogen and phosphate stimulated growth during the first two years, this increased growth was not maintained, and it was clear that the main obstacles to good growth were the very poor physical conditions of the site, a very freely draining, almost pure, sand. Some encouraging results were obtained during the first two years by incorporating animal manure in the planting holes at the time of planting.

TYPES OF FERTILIZERS

There are many types of commercial fertilizers on the market, and often the decision on which one to use will depend on what is available locally. A large proportion of the cost of fertilizers is freight. If a certain fertilizer is widely used in a country it is likely to be imported by the ship load (if not manufactured locally), and will be much cheaper than if a load of a few tons is specially imported. This effect of freight costs also means that, in countries remote from a port or source of manufacture, highly concentrated fertilizers may be considerably cheaper in use than less concentrated ones. For instance it may be cheaper to use triple superphosphate (45 percent P_2O_5) than single superphosphate (18 percent), although the initial cost of the former is higher.

The nutrient content of commercial fertilizers is usually expressed as percentage nitrogen, percentage phosphorus pentoxide (P_2O) or its equivalent, and percentage potassium oxide (K_2O) or its equivalent in potassium. (P_2O_5 contains 42 percent P, and K_2O contains 70 percent K). Thus a compound fertilizer with the formula 11:22:11 will contain the equivalent of 110 g nitrogen, 220 g phosphorus pentoxide, and 110 g of potassium oxide per kg. This allows the cost of the nutrients in different fertilizers to be compared.

Sometimes local sources of fertilizers can be located. For instance in the north of Thailand locally produced rock phosphate costs $67 per ton, with 25 percent P_2O_5, while superphosphate (18 percent P_2O_5) costs about $270 per ton. Per unit of phosphorus the superphosphate costs over 5 times as much as the rock phosphate.

Rock phosphate is a "slow release" fertilizer, in that its phosphate is only converted into a form usable by plants over several years (though it can be released more quickly if the finely ground rock phosphate is mixed with sulphur). This is sometimes an advantage for forest trees, and in different parts of the world other slow release fertilizers as sources of nitrogen, boron, and other elements, are being experimented with quite widely, though little has been done in the savanna zone in Africa.

Some fertilizers have side effects which may be harmful. The harmful effects of urea on pines have been already mentioned. Ammonium sulphate if used over a number of years increases the acidity of the soil; this might not be important for some species of trees, but can be harmful to agricultural crops. Not harmful, but in some circumstances beneficial, is the fact that superphosphate contains a high percentage of sulphur in the form of calcium sulphate; sulphur is known to be deficient in some savanna soils.

METHOD OF APPLICATION OF FERTILIZERS

The simplest method of application is to apply the fertilizer in two small patches on each side of the tree, 15-30 cm from the stem, and hoe it in. (If the plantation is mechanically cultivated by disc harrow, the harrow will turn the fertilizer in during weeding operations). Especially with borate and potassium chloride, care should be taken that the fertilizer does not come in direct contact with the foliage of the tree.

The fertilizer should be applied a few weeks after planting, preferably during a relatively dry period, if this is possible.

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TABLE 1

EFFECT OF FERTILIZERS ON EUCALYPTUS CAMALDULENSIS
PLANTED 1967 AT KABAMA, ZARIA. ASSESSED SEPTEMBER 1972
MEAN BASAL AREA m^2/ha

	Borate			
Superphosphate	0	28 g	57 g	Mean
0	6.7	8.4	10.4	8.5
57 g	9.2	9.1	11.9	10.1
113 g	8.5	10.5	10.6	9.9
Mean	8.2	9.3	11.0	

Least significant difference means within table ± 2.25

Least significant difference marginal means ± 1.30

No significant effects from urea in this experiment

TABLE 2

EFFECT OF FERTILIZERS ON EUCALYPTUS CITRIODORA
PLANTED 1965 AT MAIRABO, ZARIA. ASSESSED SEPTEMBER 1969
MEAN BASAL AREA m^2/ha

	Ammonium Sulphate			
Superphosphate	0	113 g	227 g	Mean
0	4.9	4.9	5.3	5.1
113 g	5.6	8.0	5.5	6.4
227 g	6.7	11.5	6.7	8.4
Mean	5.8	8.2	5.9	

Least significant difference means within table ± 2.98

Least significant difference marginal means ± 1.72

No borate added. No effect from potassium chloride

TABLE 3

EFFECT OF FERTILIZERS ON *EUCALYPTUS TERETICORNIS* PLANTED 1971 AT AFAKA. ASSESSED MARCH 1972 MEAN HEIGHT cm

Superphosphate	Ammonium Sulphate 0	100 g	200 g	Mean
0	158	190	152	167
100 g	171	189	191	184
200 g	172	212	207	197
Mean	167	197	183	

Least significant difference means within table ± 32

Least significant difference marginal means ± 18

TABLE 4

EFFECT OF DIFFERENT FORMS OF NITROGEN ON *PINUS CARIBAEA* AT AFAKA. PLANTED JULY 1969, MEASURED MARCH 1972

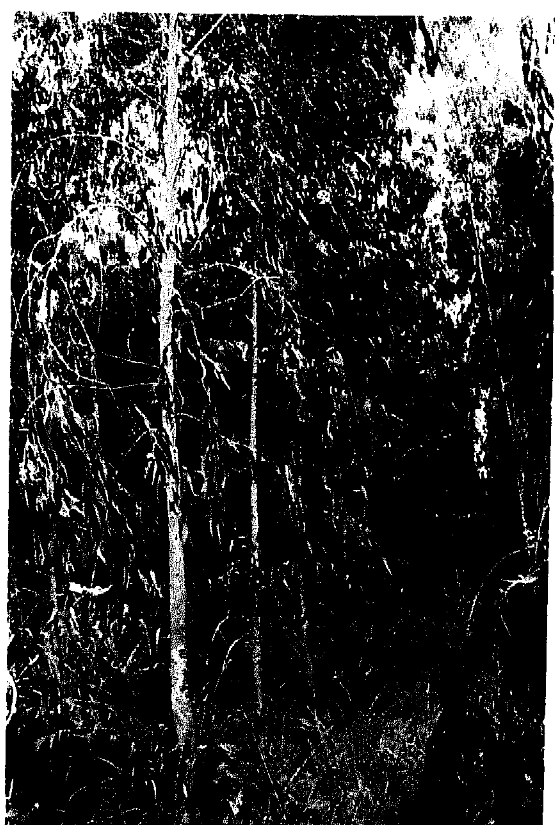
	Phosphate absent		Phosphate present		Mean	
Nitrogen fertilizer	Deaths %	Mean height m	Deaths %	Mean height m	Deaths %	Height m
Nil	12	1.17	6	2.45	9	1.81
Urea	30	1.04	33	2.45	31	1.74
Ammonium sulphate	16	1.10	5	2.77	10	1.94
Nitrochalk	34	1.14	5	2.62	20	1.88
Mean	23	1.11	12	2.57	18	1.84

Least significant difference of 2 mean heights in table ± 0.29 m

TABLE 5

EFFECT OF SUPERPHOSPHATE ON GROWTH OF PINUS CARIBAEA
AT MOKWA PLANTED 1969. ASSESSED SPRING 1972

	Soil Series			
Superphosphate, g/tree	Kulfo sandy loam		Takumah loamy sand	
	percent survivors	mean height, m	percent survivors	mean height, m
0	12	1.1	21	81
100	71	1.9	50	1.0
200	66	1.8	52	1.5
Least significant difference		±0.48		±0.49



Boron deficiency is a common cause of poor growth of eucalypts in many savanna soils, and without addition of borate fertilizers plantations such as this *Eucalyptus tereticornis* (three years old and beginning to close canopy) at Afaka, Nigeria, would not be possible.

SPECIES, TECHNIQUES AND PROBLEMS OF SEMI-ARID ZONES (THE SAHEL)

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CONTENTS

Emphasis in this paper will be on village woodlots and the role of *Acacia albida* and *A. senegal* in Sahel-zone forestry.

ESTABLISHMENT OF VILLAGE WOODLOTS

A village woodlot is a small area, usually less than 5 hectares in size, to be planted to trees by villagers with the technical assistance of the forest service.

Arousing Public Consciousness

The first step in creating a village woodlot is to interest the local population by explaining the intended goals, how they will be expected to participate, and who will own the woodlot (as a rule it is the village). For an operation of rather large scope, this phase calls for the participation of administrative cadre, the customary chiefs, forest agents and rural extension officers.

Site Selection

The problems of selecting a site is particularly difficult because successful establishment of woodlots can only be accomplished on farmland, whereas the villages naturally prefer to donate only poor land for woodlots. It is absolutely necessary to refuse such land and to seek a compromise, even being prepared to use a smaller plot of land than initially anticipated.

Land Clearing

Clearing of land for village woodlots is done by hand. The following steps are usually followed (unless the land had been cultivated previously):

1) felling of all trees on the plot;
2) extraction of stumps; and
3) removal of roots and cutting up into steres.

Obviously, the time required for clearing will depend on the type of vegetation. On savanna sites moderately densely covered with Combretaceae and below the 600 mm isohyet, roughly 85 man-days per ha will be required.

Pegging Out

It is not absolutely necessary that staking out be highly accurate, but trees should be spaced approximately 4 m apart. It is, therefore, advisable that this operation be done under the supervision of a forester.

Soil Working

In establishing village woodlots, it is best to work the soil manually, as there is no justification for the use of machinery for small-scale operations; furthermore, a purpose of establishing these woodlots is to involve the villagers in the operation.

Two types of tasks have to be done:

1) initial ploughing of the entire area for the sole purpose of improving the catchment of the first rains; this should be done with traditional farm implements;
2) digging of holes on the land where the plantation is to be set out.

Many trials of manual soil working have been conducted in the Sahel in order to find out which techniques are most effective. In particular, techniques devised for the arid zones of North Africa (mounding, ridging, etc) were tested and did not prove good. Following is a brief description of one such trial:

Place of trial: Niger
Total annual rainfall: 281 mm
Treatments, corresponding to five soil working techniques:

A. control plot (holes of pot size)
B. digging of holes 60 x 60 x 80 cm
C. digging of holes 40 x 40 x 40 cm
D. burrowing
E. furrowing and ridging

Design: 1 species of tree, 250 replications, or 1250 plants spaced 3.50 x 3.50 m apart.
Species used: Eucalyptus camaldulensis 8411
Date of planting: 11 and 12 July 1972

Results by end of November 1972: given in table below.

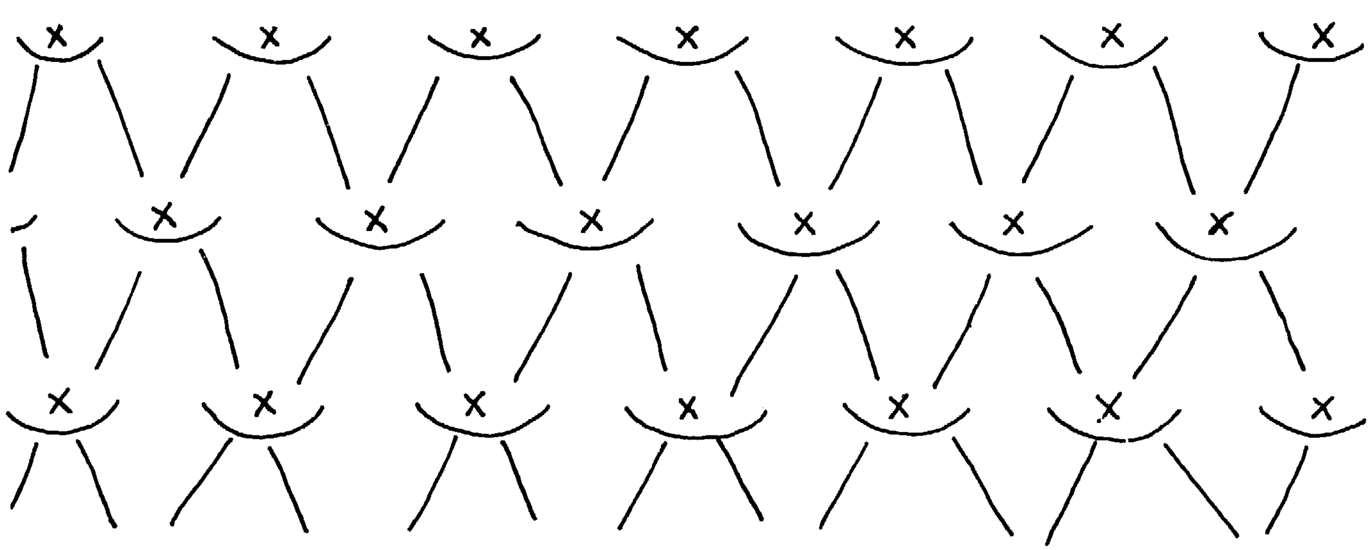
TREATMENT	A	B	C	D	E
Percent survival	86.8	96.4	93.6	59.2	79.6
Height (cm) of live plants	104	117	109	105	106

From this trial, as well as others, the following conclusion is drawn: In arid zones the best results are obtained by the method of large holes ("grand potet").

The cost and time involved in digging holes vary greatly depending on the kinds of soil. On soils of average difficulty, from 10 to 25 holes of 60 x 60 x 60 cm dimensions can be dug by one man per day. The holes are then immediately filled in; it not being necessary to wait for the first rains.

Fishbone Water Catchment Pattern

In the arid zone most of the water that falls on the plot has to infiltrate into the soil; losses due to runoff must be reduced to a minimum. It is also advisable, if possible, to concentrate the water around the plants, as this can especially help them withstand a drought period. To that end a so-called "fishbone" pattern or design has been worked out. On sloping ground (no matter how slight the slope) a slight ridging 10 cm high is required below the plants, forming for each plant a curved water retention basin. Two furrow-drains for each basin lead off to two other basins below. In a quincunx plantation pattern, one obtains the following design:



This has proven to be a perfectly efficient design, as it effectively concentrates the water around the plants.

Measurements have been taken in such an arrangement to determine the soil water content around the plants and between two plants. The following average figures were obtained one month after the end of the rainy season:

soil water content around the plant: 4.92%

between two plants: 4.11%

These notable differences are maintained for up to 6 months following the end of the rains.

Construction of the fishbone pattern is done entirely by hand and requires only a few man-days: 15 to 20 per hectare. However, careful instructions may need to be given before the work is started.

Fencing

For any plantation in the arid zone, fencing is absolutely essential and, indeed, is decisive for success. Where there is no fencing or if the fencing is poorly made or not kept up, livestock quickly penetrate and can ruin the plantation within a few hours.

There are several possible types of fencing, including barbed wire, grillwork and live hedges. The simplest and most rustic type, requiring no investment of funds, is the "zeriba". By zeriba is meant an entanglement of spiny or thorny branches kept erect by wooden stakes. If well made, it is fully efficient as a fence but it has to be kept in good condition. About 180 man-hours are required to erect a 1 000 m long zeriba.

Planting

Although termite damage in the arid zone is generally rather limited and termites are often incorrectly blamed, as they often appear to devour deadwood of plants of the previous season, whenever possible it is necessary to give the soil an anti-termite treatment, usually with dieldrin, prior to planting. In such cases, the technical assistance service must be called on to help.

An absolute rule is that planting must be done after the rains have started. From experience it is known that this is generally around 15 July in the Sahel. It is always too risky to plant in June and it is too late to plant in August, the best planting season being, in at least 90 cases out of 100, between 15 and 30 July.

In the arid zone it is always necessary to set out potted plants (see also paper entitled "Soil mixtures, use of containers and other methods of plant raising", page). Depending on the nature of the soil, one should use either neem (Azadirachta indica), Cassia siamea, Prosopis chilensis, Parkinsonia aculeata or certain African acacias (A. nilotica var. adansonii, A. seyal, A. nilotica var. nilotica, A. tortilis, etc.). These plants will be furnished by the nearest forest tree nursery. Planting is an easy task but it may require certain preliminary explanation (especially regarding the cutting away of the bottom of the pot). It is relatively rapid, requiring a maximum of 8 man-days per ha.

Maintenance

Unfortunately it often happens in the Sahel that plantations set out under good conditions are not well maintained, usually for lack of funds or follow-up of the operation. Even if such plantations are not ravaged by fire, their growth is very poor because of the tremendous competition from grasses, causing the forest trees to suffer and die for lack of water for which they are obliged to compete.

During the first year after the plantation is set out maintenance work has to be done twice - once during the rainy season before the grasses go to seed, that is in the second half of August, and again at the end of the rainy season, during the first half of October. The maintenance work done at the end of the rainy season needs to be repeated in the second and third years. In subsequent years such maintenance seems desirable but is not absolutely essential. Maintenance is done with traditional farm implements (the hoe or 'daba' and 'hilaire' in particular).

ACACIA ALBIDA

Acacia albida has many local names - it is called 'gao' by the Haoussas, 'cadde' by the Wolofs, 'balanza' by the Bambaras, 'zaanga' by the Mossis and 'tchaski' by the Peuls. It is a common tree in many farming areas of the Sahel-Sudan zone.

It is a valuable tree for farmers because it enriches the soil and, being decidious, loses its leaves during the rainy season so that it does not interfere with crops. This characteristic has long been recognized and it deserves the name of "miracle tree" given it.

The following sections on A. albida will provide some succinct information, in annotated outline form, which shows the value of this species and indicates planting costs in French-speaking arid countries of Africa.

Acacia albida and the Farmer

Research in Senegal by I.R.A.T. demonstrated the beneficial effect of Acacia albida on soils. Increases in soil properties under A. albida were:

- 7% - clay content
- 134% - assimilable phosphorus
- 60% - total carbon content
- 43% - equivalent moisture, consequently, water retention capacity
- 100% - total nitrogen
- 100% - exchangeable calcium content
- 70% - exchangeable magnesium content

In Niger, O.R.S.T.O.M. measurements showed that the increase in the contents of certain minerals in soils under Acacia albida corresponds to the following quantities of fertilizers and soil amendments:

synthetic fertilizer	- 50 to 60 t/ha (300 kg of organic nitrogen)
potassium chloride	- 50 kg/ha (24 kg of potassium)
bicalcium phosphate	- 80 kg/ha (31 kg of soluble P_2O_5 and 25 kg of Ca)
dolomite	- 125 kg/ha (15 kg of Mg and 25 kg of Ca)
lime	- 100 kg/ha (43 kg of Ca)

The reasons for the beneficial effect of A. albida on the soil are the following:

1. very active decomposition of leaves when crops are starting to sprout;
2. fertilization by livestock which finds shade under the acacia;
3. diminution of dessication by wind, and of evapotranspiration during the dry season, as well as of leaching by rain, and of fluctuations in temperature at all seasons;
4. possibility of fixing atmospheric nitrogen;
5. bringing fertilizing elements up to the surface from very deep in the soil (in relation with point 1).

The fertilizing and improving action of A. albida on soils is beneficial to crops. In experimental plots of I.R.A.T. in Senegal mean yields of millet were:

a. 600 kg not under A. albida (traditional millet growing);

b. 1 000 kg at a distance of 5 m from A. albida stems and

c. 1 700 kg at less than 5 m from the tree.

Planting under A. albida it is possible to obtain millet yields three times greater than those in open fields were there are no Acacia.

Acacia albida and Stockraising

A. albida is valuable as forage and fodder crop. The leaves are edible and assimilable. As regards protein content, they provide an excellent forage or fodder.

As for the pods, a yield of from 400 to 600 kg may be obtained from a stand of 60 acacias per ha, equivalent to the fodder consumed between two over-wintering periods.

Planting

The planting of one hectare of Acacia albida at the rate of 100 stems spaced 10 x 10m apart, preferably in quincunx, costs about 30 000 CFA francs. Spacing of 10 x 10 m is optimum. Even when reduced to 50 trees per hectare due to gaps, failure to take, natural selection or artificial thinning, the trees still cover the soil, yet without interfering with the use of draught animals in crop farming.

Operation	Cost (CFA F)
Raising of 100 nursery plants in polyethylene wrappings	3 500
Marking out the plantation area, soil preparation and staking out	
10 man-days at a rate of 400 CFAF/man-day	4 000*
2 man-days at a rate of 600 CFAF/man-day	1 200
Transporting of nursery plants to the plantation grounds, and distribution on the ground (using an all-purpose vehicle)	5 100
Actual planting	
3 man-days at a rate of 400 CFAF/man-day	1 200*
Small implements	1 000
Surveillance and protection against livestock	
1st year	5 000*
2nd year	5 000*
3rd year	4 000*
TOTAL	30 000 CFA F

These costs are distributed as follows:

1st year	21 000 CFA F
2nd year	5 000 CFA F
3rd year	4 000 CFA F

* These prices may possibly be reduced if, as is desirable, the local population is directly involved in the operation (bonuses awarded for good plant survival).

ACACIA SENEGAL

As for Acacia albida, it would be possible to discuss A. senegal, the gum-tree, at great length. Here only certain ideas will be expressed relative to the various possibilities for its use offered foresters in the Sahel - that is, the establishment of groves of gum-trees.

Organization of Gum Gathering

Nomadic, pastoral peoples generally collect gum, provided a market for it exists. To illustrate, little more than 20 years ago the production of gum in a country like Chad was insignificant, certainly less than 100 tons per year. Then in the geographic departments of Ouaddai and Biltine a publicity campaign was launched and an agency was set up to purchase the gum at a price fixed annually. This caused a considerable increase in the annual production in Chad, to about 2 000 tons in the years 1965 to 1968.

Since then there has been a spectacular decline in the production of gum in Chad, now running from 200 to 300 tons annually. Certainly the drought in recent years was largely responsible for this decline but it was accelerated by the almost complete stoppage of publicity and a purchase price that offered no incentive whatsoever; in fact, a good portion of the gum produced had to be sold in the Sudan.

Wherever natural stands of gum trees exist, the first step to be taken is therefore to make the population aware of the value of this commodity, to be followed by organization of the market and setting of good incentive prices.

Safeguarding Natural Stands

The gum-tree is a pioneer species that gains a foothold on abandoned land, especially former cropland. Gum-trees grow in virtually pure, even-aged stands and start to produce at about five years of age, continuing up to 25 years of age; they then grow old and die off at from 40 to 50 years of age. As a rule, no natural regeneration occurs under gum-trees. Consequently where there were gum-trees in full production, around the years 1940 to 1950, there are now dying stands on land which bear no other trees. This is what was observed during a study tour on the gum-tree in 1972 in Niger, in the 'manga' country, where the only large stands of gum-trees that were seen were outside classified forests.

Spots where regeneration is occuring, sometimes large ones, do appear almost every year on abandoned land. These regeneration spots will turn into future gum-tree stands but they are exposed to three hazards, especially during the first 3 years, namely: fire, livestock browsing and renewed crop growing.

It seems that a well thought out gum-tree policy should have among its goals, and before any planting work is undertaken, the safeguarding of such naturally regenerated stands. Also forest laws should give foresters the authority to protect young gum-tree stands discovered in this way so long as they continue to produce. This solution, which is being developed in Niger, seems far preferable to establishment of man-made stands.

Man-made Gum-tree Stands

The planting of potted gum-trees om land that has been worked is easy from the technical standpoint but a heresy in economic terms because of the high cost of working the soil and planting.

It was thought that it would be possible to establish man-made gum-tree stands by direct seeding after harrowing of the soil. This is technically possible but definitely raises the question of protection. However, from results obtained with the gum-tree project now underway in Chad in the Chari Baguirmi (a European Development Fund - EDF project), this is a technically feasible solution only if the soil is harrowed after the first rains. It appears that it is impossible to work large areas by machines because they can be used for only 15 days to one month, it being necessary to have a rainfall potential of 250 mm after seeding. Such a solution is therefore only possible if done by the local farmers, as in the Sudanese system.

The Sudanese System

The Sudan supplies 80 to 90% of the world market for gum, this being due to the fact that the gum-tree is included in the normal crop rotation. In that part of the Sudan where gum-trees are grown, the farmers practice the following rotation: 4 to 5 years of millet growing and about 20 years of gum-trees. The soils are appropriate for this purpose. Gum-trees are grown and gum collected by farmers; this makes possible the practice of tapping the trees, a practice which is almost impossible to develop in countries where nomadism is usual, nomads not being gum gatherers.

It is in those parts of the Sahel where there is a settled farm population and which lie within the natural range of the gum-tree and in its production area, that this solution is advisable. The matter of production area is particularly important because the gum-tree yields little or no gum when it grows on sites which get too much water (500 mm). Apparently the trial development of gum-trees in Assale, Chad, failed to take this particular aspect of the ecology of the gum-tree into account.

IRRIGATED PLANTATIONS

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CONTENTS

INTRODUCTION

Irrigated forestry plantations have been established in the drier parts of Asia for many years; the famous Changa Manga plantations in the Punjab were begun in 1866. In the savanna region of Africa, on the other hand, there has been relatively little development of irrigated plantations. The most important area in which they have been established is in the Gezira area of the Republic of the Sudan. This paper, therefore, will begin with a description of the plantations in the Gezira, and then go on to discuss some more general problems of irrigated plantations.

THE SUDAN GEZIRA

The Sudan Gezira is a vast plain, of alluvial origin, lying between the Blue Nile and the White Nile south of Khartoum. The rainfall ranges from about 150 mm near Khartoum to about 550 mm in the south. The soils are mostly dark cracking clays, or vertisols, with a high pH (over 8.5), and high clay content. During the dry season they are divided into a network of deep and wide cracks. When the soil is moist these close, and further penetration of water into the soil becomes very slow, so much so that no matter how much water is applied to the surface of the soil, moisture movement below two or three metres is negligible. The original vegetation was probably mainly open grassland in the north, *Acacia mellifera* scrub in the centre, and open *Acacia seyal*-*Balanites aegyptiaca* woodland in the south.

The Gezira Irrigation Scheme came into being in the years immediately following the First World War. It was based on the cultivation of long-staple cotton as a cash crop and sorghum as a subsistence crop for the farmers. The scheme was originally a partnership between the Sudan Government, the tenant farmers, and a private company, the Sudan Plantations Syndicate, who shared the proceeds of the cotton crop in the ratio of 40 per cent, 40 per cent, and 20 per cent respectively. Other crops, including the sorghum, were entirely the property of the tenant farmers. The Government constructed the dam at Sennar and the major irrigation works, and was responsible for supplying the irrigation water; the company took care of technical supervision of agriculture in the field, and of marketing the cotton crop; and the tenant farmers provided the manpower. A few years before The Sudan attained independence in 1955, the Government bought out the Sudan Plantations Syndicate whose functions were then taken over by a quasi-Government organization, the Sudan Gezira Board.

The amount of water which could be used in the Gezira was regulated by the Nile Water agreement with Egypt. This has since been amended several times, but originally allowed free use of water between August and December, when the Blue Nile was in flood; between January and March water use was restricted to the amount which could be stored in the Sennar reservoir; while from March onwards water supplies were severely restricted to the drinking water needs of stock and people, and very limited irrigation of orchards and other perennial crops.

In the early years of the Gezira scheme the Sudan Plantations Syndicate was strongly opposed to the establishment of forestry plantations, on the ostensible grounds that the trees might harbour cotton pests. However in the mid-1930's it was possible to begin irrigated plantations on a small scale, partly on land allotted for resettlement of the people who were moved from their homes when the Jebel Aulia dam was established on the White Nile (to help regulate water supplies in Egypt), and partly on land managed by a smaller company, the Kassala Cotton Company. This company had been formed to grow cotton in the Gash delta, near Kassala, but local opposition prevented this and they were given a concession in the Gezira area instead, on similar terms to those enjoyed by the Sudan Plantations Syndicate. After the formation of the Sudan Gezira Board irrigated plantations were extended to other parts of the Gezira.

The original irrigated plantations were of two types, village woodlots on a very small scale to provide firewood and small timber for individual villages, and larger areas of plantation, usually on land relatively unsuitable for cotton. The village wood lots were on the whole a failure, as it was difficult to protect these small scattered areas, especially from the depredations of goats and other domestic livestock. The other areas were more successful.

A number of species were tried initially including neem (Azadirachta indica), sunt (Acacia nilotica), sissoo (Dalbergia sissoo) and various eucalypts. Sunt was disliked as it provided a refuge for grain-eating birds, and neem was susceptible to moderate salinity. Sissoo never did very well. The most promising species was found to be Eucalyptus microtheca F.V. Mull. (including E. coolabah Blakely and Jacobs). This is a species occurring near seasonal water-courses in dry regions of Australia. Its form is not very good, and, for a eucalypt, its growth rate is not very rapid; however it has the supreme advantage of being able to withstand the long, hot period between March and August when no irrigation water is available and there is very little rainfall.

Originally the Eucalyptus seedlings were raised in metal containers 25 cm long by 7.5 cm in diameter, made from old petrol tins. They were slit up one side, and provided with tabs so that they could be removed when the seedlings were planted and re-used. Nowadays these containers have been replaced by polythene tubes. The potting mixture was river silt mixed with sand, and the seed was sown direct into the tubes. No anti-termite treatment was used.

Before planting, the area was ploughed with a very large plough to produce a series of low ridges, separated by channels, the ridges being 2.4 to 2.7 metres apart, and 60 cm to 1 m vertically from crest to hollow. The plantations were irrigated by letting water into the channels between the ridges.

In theory the plantations were irrigated at 15 day intervals from August to March. In practice this was not often attained. During periods of water shortage cotton and other crops had priority, and so one or more waterings might be missed at times of high water demand, particularly in September and October. On the other hand, the plantations were often used as dumping grounds for surplus water and some suffered from waterlogging. Thus increment rates have been very uneven, ranging from just over one to nearly 10 m^3/ha/year. A good average yield from fairly regularly watered plantations would be about 6 m^3/ha/year for first rotation trees, with about 25 per cent more from subsequent coppice rotations. The normal rotation is 8 years for the first rotation, and 6 years for subsequent coppice rotations.

LATER DEVELOPMENTS IN THE SUDAN

In the early 1960's work was begun on the establishment of an irrigated "Green Belt" to the south of the city of Khartoum. The first part was irrigated by purified effluent from the recently installed Khartoum sewage works; later extensions received their water from a canal. In this area year-round watering was possible, and thus a much wider range of species could be grown. Among the more promising are *Conocarpus lancifolius*, *Eucalyptus camaldulensis*, and *E. tereticornis* (especially the Mysore provenance).

The Khartoum Green Belt included some areas of very saline soils, and there were doubts on how these would behave under irrigation. However, in the early stages at any rate, although there was considerable deposition of salt at the soil surface in some places, it was still possible to grow satisfactory tree crops.

SOME GENERAL ASPECTS OF IRRIGATED PLANTATIONS

Water Requirements

Water needs will vary with the climate, the type of soil, the species of tree to be grown, and the method of application. Obviously in hot, dry climates where there is a high rate of potential evapo-transpiration the amount of water needed will also be high. A very permeable soil, which allows much of the water applied to percolate to beyond the rooting depth of the trees, will need more water than a less permeable soil; in permeable soils there will also be greater losses in canals, unless these are lined. Drought tolerant species will need less water than more mesophytic species. Water requirements can be reduced by special methods of application (see below).

In the Sudan Gezira reasonable growth of *Eucalyptus microtheca* has been obtained from the application of about 1100 mm of extra water, by irrigation per year, but Foggie (1967) considers about 1700 mm is necessary to obtain optimum growth. In the Central Gezira the total amount of water received, including rainfall, would be about 1550 and 2050 mm respectively. In Pakistan the optimum water requirements of five year old *Dalbergia sissoo* were estimated at 1200 mm, but rates as high as nearly 2000 mm were applied (Siddiqui, 1967). In Iraq, Gülçur and Nouri (1975) estimate water application in existing plantations at between 200 and 800 mm annually, but suggest that optimum water requirements might be considerably higher (1200-1360 mm). All this data is from furrow irrigation.

Quality of Water

The lower the salt-content of the water, the more suitable it is for irrigation. In this respect the Sudan Gezira is fortunate, in that the Blue Nile water has a low salt content and is of high quality. However in other countries, especially Kuwait and Abu Dhabi, water of a fairly high salt-content has been successfully used for irrigating tree crops. If saline water is used, larger quantities must be supplied, to leach the salts to depths where they will be harmless to the threes (Wormald, undated).

METHODS OF APPLICATION OF WATER

The most common method is by furrows, either very large furrows as used in the Sudan plantations, or in smaller trenches for instance 30 cm deep, as in Pakistan. In the Khartoum Green Belt, where furrows 2 m wide by 60 cm deep were used, Bosshard (1966) found some advantages in applying water to every second or third furrow only once the trees had established their root systems (one year or more after initial planting). The use of very large furrows, as in the Sudan, will tend to increase losses of water by evaporation.

Flood irrigation, of level land, has generally been found to be impracticable for tree crops, as it is very difficult to obtain uniform distribution of water using this method.

Of more sophisticated methods of irrigation, rotating sprinklers were used at Malam Fatori on the shores of Lake Chad in Nigeria, to establish a provenance trial of *Eucalyptus camaldulensis*. This was on a permeable lacustrine sand, and irrigation was applied for one year only, until it was considered that the tree roots had reached the water table. Over most of the area results were very good, the trees of the best provenance producing an average of 87 m^3/ha (solid volume) at the age of 4 years. On a small area of slightly higher ground, more distant from the lake, growth was poorer and there were some deaths from drought. This method, although needing a fairly heavy capital outlay, is worth considering in areas where there is a high water table, and only temporary irrigation is needed.

Drip irrigation, developed originally for fruit trees, has been used for establishing forest plantations in Abu Dhabi (Wormald, undated) and experimentally in Pakistan (Sheikh and Masrur, 1972). In Abu Dhabi the water is pumped from wells to a control head and filter. From the control head it is piped through polyvinyl chloride laterals 10-15 mm in diameter, which are provided with nozzles at intervals. These nozzles are designed so that, provided a constant pressure is maintained in the drip lines, a fixed quantity of water per hour is delivered through each nozzle. One nozzle serves each tree. This is again a method requiring a high capital outlay, but is the most economical in the use of water: in the experiments in Pakistan, drip irrigation used only 22 percent as much water as trench irrigation, and 15 percent as much as flood irrigation.

CHOICE OF SPECIES

Here it is impossible to generalize. The use of *Eucalyptus microtheca* in the Sudan Gezira was dictated by the peculiar circumstances there, in the soil type and in the times at which water was available. For most other areas it is probable that better species can be found. Some further references to choice of species for irrigated plantations, and on irrigated plantations generally may be found in Laurie (1974) pp. 44-47, 49, 52, 114-115, and 141.

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SHELTERBELTS AND ENVIRONMENTAL FORESTRY [1]

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

The term shelterbelts will be used to embrace live hedges and windbreaks. This paper is confined to arid tropical Africa.

LIVE HEDGES

General Remarks

From experience in recent years one can make some very positive statements on certain points pertaining to the growing of live hedges in the Sahel-Sudan zone, viz:

a) Any planted stand not protected during the first three years of life is doomed to failure.

b) No live hedges are absolutely impenetrable to livestock, particularly goats, either because of failed spots or because the lower portion of plant stems become more or less bare in time.

c) Not even barbed wire fences will keep livestock out; a common sight is goats forcing their way on the run into areas protected with five rows of barbed wire! Fencing of this type moreover never resists the assault of large animals very long (by large animals is meant cows, camels, antelopes, giraffes, etc.).

d) The combination of live hedges plus barbed wire fencing provides almost complete protection against invasion of protected areas by animals. From the above it follows that live hedges should be planted inside enclosed areas up against the fencing which delimits them.

Tree Species that can be Used

The main reason for planting live hedges is to protect certain areas against intrusion by animals. The species to be used must therefore form a continuous shield that is difficult for animals to break through because of entanglement of branches and/or the presence of thorns or prickles. The species used should be of limited height and pruning, clipping or cutting should be possible.

If it is possible to make a choice between several species, other possible uses of live hedges should be looked into, namely, supplying forage or fodder, or producing edible seed, nuts or fruit.

Prosopis

Prosopis juliflora (= *P. chilensis*), or mesquite, is a spiny deep-rooted tree or shrub of southwestern USA, Mexico, Venezuela, Peru and Colombia. This is the species most commonly used as live hedges due to its rapid growth, ease of producing nursery stock, the high rate of "take" on appropriate soils and its ease of clipping. Disadvantages are its small spines, which make it not entirely impenetrable, and its tendency to shoot up in height so that frequent topping is necessary.

Seeds. *Prosopis* seeds number from 20 000 to 35 000 per kg. Fruiting occurs around the month of March. When old seeds are used it is necessary to dip them in boiling water and then let them cool for 24 hours before sowing.

Additional uses. *Prosopis* is also used for fuelwood and stakes bearing inscriptions. The leaves yield an excellent forage or fodder and their shoots are relished by animals. There are 0.70 forage units per gross kg containing 75 grams of digestible protein per gross kg. The dry matter yield per hectare may amount, in irrigated plantations, to twelve tons per year.

Soil. Prosopis adapts well to many types of soil except those that are two sandy or in bottomlands so wet as to asphixiate it.

Acacias

There are about 24 species of Acacia in Africa but only a few of them have been experimented with as live hedges.

Acacia nilotica var. adansonii. This species is particularly well adapted to arid lands and can also grow fairly well on sandy soils. Its rate of growth, although less than that of Prosopis is fairly rapid. The size (from 6 to 10 cm) of its very hard, straight white thorns makes it a species that is highly recommendable as a live hedge.

Seeds are collected in December in stands along watercourses and near stagnant ponds. The seed has to be scarified in boiling water before being sown. It is sown directly in pots in March, with an 80 percent germination rate.

Acacia seyal. This Acacia is usually grown on loam or sandy-clay soils that are flooded during the rainy season. Sometimes however it is found on hill crests that remain dry all year round, so there could be several races. When grown as live hedges it gives good results, and this is probably also true of its close relative, Acacia ehrenbergiana, which is suited to drier soils.

Acacia ataxacantha. We have had only limited experience with this sarmentous or rambling species which, because of the intertwining of its branches and its big thorns, should be excellent for live hedges. The plants are easily grown in nurseries but we have always found that when it was planted out in the field the "take" was not good. We do know of one instance of a successful planting of a live hedge of this species.

Parkinsonia aculeata

This sarmentous bush has terrible thorns, but if not pruned quickly it tends to become barren at the base. This species succeeds better on heavy than on sandy soils. Paradoxically, the finest specimens that we know of are found at far northern latitutes (Agadèz, Niger, 17°N) with a rainfall of 150 mm.

The seeds have to be emersed in boiling water prior to sowing. The seeds are gathered from November to February and sown in pots or in beds from January to February. When planting in pots care has to be taken to move them occasionally because of the taproot which tends to grow out of the pot quickly.

Ziziphus

There are in the Sahel several species of Ziziphus, the most common being Z. mauritiana and mucronata. The seeds have to be sown in pots because pricking out is a very delicate matter. Sowing is done toward mid-February. Raising in nurseries and plantation is easy, and the live hedges are particularly thick and inextricable, although once they have been set out in plantations growth is rather slow.

Bauhinia refescens

This species produces one of the best live hedges we know of. There is virtually no problem with it in the nursery (sowing is done in January or February) and it adapts well to a wide range of soil types. Take is not always excellent however.

Planting of Live Hedges

Planting should be done as soon as the rainy season starts, usually about 15 July. A good live hedge consists of two, or even better three, rows of plants spaced 80 cm apart in quincunx formation. Prior to planting subsoiling should be done or else 50-cm deep trenches should be dug and re-filled. Topping the plants in the nursery (cutting 5 cm from the top when the plants have reached a height of about 20 cm) favours the growth of low branches.

WINDBREAKS

Winds

There are two wind regimes in the continental Sahel - dry season winds and rainy season winds. The harmattan dry season wind blows very regularly each morning from about 9 to 13 hours from November to March. It is a hot, dry wind usually from the northeast. Rainy season winds are much more regular and may blow in real squalls from May to September, generally from the south or southwest.

Windbreaks aligned in the NW to SE direction will therefore be of maximum effectiveness against either the harmattan or the rainy season winds.

Effect of the Wind

Winds affect both soil and vegetation in several ways:

a) by causing soil erosion;

b) by mechanical impact on vegetation; and

c) by affecting evapotranspiration.

Windbreaks

Here we shall discuss only live windbreaks consisting of trees or bushes or even simple rows of annuals such as millet, sorghum and certain grasses (*Pennisetum purpureum*).

Windbreaks as Mechanical Obstacles

A windbreak separates two zones: the windward one, that is, the one on the side from which the wind blows, and the leeward one, that is, the one on the side where the wind passes. As a rule it is said that a windbreak protects a distance up to its own height on the windward side and up to 10 to 12 times its height on the leeward side.

The effectiveness of the windbreak depends on its permeability. Low permeability lessens the speed of the wind but because it creates turbulence, the protected area is smaller. Optimum permeability is that with 40 to 50 percent of space (i.e. 50 to 60 percent density of vegetation). Gaps in the hedge are particularly dangerous because the wind rushes violently into them; therefore, windbreaks must be continuous. The thickness of windbreaks is of little importance and,provided that there are no gaps in theory, a single row of trees suffices.

Windbreaks should be at least 12 times as long as they are tall in order to eliminate turbulence along the sides.

Maximum protection is afforded when the windbreak runs perpendicular to the direction in which the wind blows,so it is very important before planting windbreaks to make a thorough study of local winds and make a graphic representation showing the relative strength of the winds blowing from different directions.

The length of the protected zone (10 to 12 times the height of the windbreak) is lessened as the speed of the wind increases so it is almost always necessary to plant several parallel successive rows in order to protect large areas. Optimum spacing between rows is from 10 to 20 times the height of the windbreak. Closer spacing increases air turbulence and diminishes the effectiveness of the system.

Effect of Windbreaks on Microclimate

Windbreaks in addition to presenting mechanical obstacles also affect the microclimate, and the importance of this is no less great than that of reducing wind speed. Generally speaking, windbreaks diminish evapotranspiration. Experiments conducted in the USSR in 1953 enable certain authors to state that water losses due to evaporation are reduced by at least 20 percent in the shelter of windbreaks. This reduction of evapotranspiration leads to increased photosynthesis in the vegetation, the stomata remaining open for a longer part of the day. In arid zones, however, windbreaks cause increased evapotranspiration due, in particular, to the fact that they themselves evaporate large quantities of water; to compensate for this water deficit it is necessary to irrigate.

On the other hand, as a rule windbreaks even out extremes of temperature, raising the lowest temperatures and lowering the highest, which helps provide better growing conditions for vegetation.

The result of these changes in microclimate is markedly increased yields of the protected crops.

Yields decrease slightly in close vicinity to windbreaks due to the effect of shading and to competition of the plant roots, but this competition occurs only on a strip of land not more than half the height of the windbreak in width while yields of cereal grains on the entire plot may be increased by as much as 40 percent. This increase is higher in dry climates with plants whose roots do not penetrate deep, such as prairie grasses.

Summing up, windbreaks are always beneficial to crops not only because of the protection they afford against the mechanical impact of the wind but also due to their influence upon the microclimate due to a marked increase in photosynthesis of the plants that is translated into a higher crop yields. In arid zones the use of windbreaks should however be confined to protection of irrigated districts.

Planting of Windbreaks

The most usual type of windbreak consists of one or several rows of trees. Theoretically, one row should suffice because windbreak width is to little importance, but it is always possible that several trees will die leaving a gap which spoils the effectiveness of the entire windbreak. Furthermore, when the trees are cut it is necessary to be able to leave at least one row standing in order for the windbreak to continue to perform its function. Finally, young trees are better protected against violent winds if planted more thickly. Experience has shown that the most effective windbreaks are those consisting of at least four rows of trees, that is, those from 10 to 12 m wide.

If the windbreak reaches 10 m in height and protects a strip of land 12 times that height, windbreaks 10 m wide should be set out every 120 m. The maximum amount of land that they occupy with their roots is 20 m (10 m for the windbreak proper plus 5 m of roots extending on either side), all together 16 percent of the cropland. This seems to be a reasonable proportion considering that crop yields may be increased by as much as 40 percent because of the combined mechanical and physiological effect of windbreaks on the vegetation; but it is best not to exceed this size of windbreak.

The species used for windbreaks should insofar as possible have the following characteristics: adequate height, rapid growth, evergreen foliage, compact form, limited root competition and resistance to windfall and wind breakage.

Planting should not be too close in order to allow sufficient air permeation of the windbreaks. Trees should therefore be spaced not less than 1.50 m apart.

For the rest, the manner of soil preparation and planting are the same as those in conventional reforestation work (subsoiling or digging of holes 50 x 50 x 60 cm). However, since in this case what one is dealing with are row plantations usually cutting across grassland or cropland where animals are allowed to pasture on stubble or straw, special attention should be paid to the protection of crops or plantations, lest the success of the operation be jeopardized. To that end it may be advantageous to plant thorny vegetation along the edges of the windbreaks to protect forest tree species from livestock.

Finally, no matter what species is used, the correct planting dates must be respected (cf Prosopis).

Maintenance of the windbreaks is indispensable in order to:

a) make sure that they remain continuous (obviously replacement of any failed trees is necessary) and

b) prevent them from becoming too thick and consequently absolutely impervious to wind; the branches therefore have to be clipped or trimmed frequently.

It is best not to top the trees, since the size of the protected zone depends on the height of the windbreak.

ENVIRONMENTAL FORESTRY

Under this heading one could discuss planting of woodlots inside or around the large towns of the Sahel and even the growing of ornamental trees. We shall not elaborate on these points, however, except possibly during the discussion, considering it preferable here to speak of the role of trees in sand dune fixation, a very important matter for maritime countries. Senegal, for instance, is at present taking new steps along these lines.

Formation and Development of Sand Dunes

Whenever regular violent winds blow over vast expanses of sandy desert, sand dunes are formed. There are continental dunes, particularly in the Sahara, but more often such dunes are formed along the sea coast, on the sandy shores at sea level swept by regular winds (in Africa and Madagascar, usually the trade winds).

When sand dunes are not covered with vegetation or when, for any reason whatsoever, whether it be repeated passages over the land, pasturing or grazing of herds and flocks, or cropping, whatever vegetation once covered them has been destroyed, they start to move in the direction of the wind at a speed which may attain as much as 10 m per year. When this happens they cover everything as they move along - crops, plantations, roads and railways and sometimes even houses and villages; all the inhabitants can do is to abandon land invaded by moving sand dunes.

To prevent this from happening and in order to protect engineering works and crops against being covered with sand, the vegetative cover has either to be established or re-established, this being the most effective protection against soil erosion. However, in order to establish vegetation on moving sand dunes, it is necessary first of all to fix them using techniques that are both delicate and costly.

Sand Dune Fixation Techniques

One technique for fixing coastal sand dunes was devised in Europe in the last century; it can be applied without great change in Africa and Madagascar except of course as regards the plant species to be used.

The first operation consists of constructing as close as possible to the sea an artificial sand dune, called the coastal cordon, in order to stop the piling up of more sand on the dunes. The way to start is by erecting along the coast a 0.75 to 1 m high wattle fencing; this wattle fencing is composed of wooden stakes driven into the sand and tied together by branches sufficiently closely matted to form an obstacle to the sand blown against it by the wind. The grains of sand pile up behind this palisade and when the little hill thus formed reaches a height of 0.50 to 0.75 m, a second wattle fencing is built up on top of it and so on until one has a dune of a slope and of a height such that it is impossible for the sand to be blown up over it. For a 30 to 40 percent slope this equilibrium soil profile is reached in 2 or 3 years. If the sea coast runs obliquely to the direction of the prevailing winds, it is necessary in addition to construct transversal spurs that will prevent the formation of "whistle holes" into which the wind penetrates.

It then is possible to fix the sand dunes behind the coastal cordon by planting either slips or seed of plant species that provide good ground cover and are able to withstand being at least partly buried in sand. Ammophila arenaria, which is very useful in Europe and North Africa, does not give good results on the sand dunes south of the Sahara or in Madagascar. There one must preferably use local, rapid-growth species with creeping roots which make it possible to get a hold on the sand quickly; in Madagascar the best is a plant of the Convolvulaceae family, Ipomea pescaprae, which sprouts very easily and quickly covers the soil. Certain grass species can also be tried under the same conditions, namely Sporobolus spicatus, Aristida stipoides, Panicum turgidum. Sand dune fixation trials have also been conducted in the Adamaoua (Northern Cameroon) with Stylosanthes gracilis, Melinis tenuissima, Digitaria unifolozi, Cynodon dactylon and Pennisetum.

Such vegetation has a threefold purpose: the aerial portions act as a windbreak at ground level; the debris consisting of leaves, stems, pods etc. provides a dead cover which, as it decomposes, enriches the sand with humus; and, finally, the creeping roots hold the sand and help stabilize the dunes.

Despite the rapidity of growth of the plants used for sand dune fixation it sometimes happens that the seeds or the slips are either exposed by the wind or buried in sand, so in regions where the winds are particularly violent it is necessary to keep the sand down by means of cover materials before undertaking any sowing or planting of slips. The materials used are generally plant debris - branches, palm leaves, etc., gathered in the nearest groves or woods. Since several tons are required per hectare, their transport often involves a difficult problem and considerably increases cost prices of such fixation work.

On the areas most exposed to wind it is also possible to do some dense checkering, that is setting out squares of wattle fencing dug into the sand. Obviously plants will grow much better if protected by such wattle fencing than without.

Planting of Sand Dunes with Trees

Along the sea coast and inland up to about 200 m usually only grasses and certain bushes will grow. Tree growth is badly slowed by wind, fog and drift; furthermore the first rows of the plantations are scorched by the sea winds. Nevertheless certain species are fairly resistant and can be used for planting, this being the ultimate purpose of the operation.

The species most commonly used are:

a) Arborescent species

Acacia cyanophylla, A. ataxancantha
Casuarina equisetifolia (filao)
Prosopis africana and P. juliflora
Eucalyptus spp.; E. camaldulensis

b) Bush species

Opuntia
Euphorbia balsaminifera
Atriplex halimus
Gymnosporia senegalensis
Solanum sp. (tsingivy of Madagascar)

It is necessary to set out fairly large, nursery-grown plants very close together, that is to say 1 x 1 m on the side exposed to the wind and 2 x 2 m on the sheltered side. Such planting is customarily done at the onset of the rainy season.

In arid climates, it is much more difficult to plant trees on sand dunes already colonized by grass vegetation than on barren sand dunes because of the considerable competition of the roots for water and because the presence of already well developed root systems hampers the "take" of young plants. It is therefore preferable to plant the trees at the same time as the grass vegetation; this always gives a definitely better take.

Plantations must be well maintained, as always in the tropics; this must be done by hand to avoid having machinery criss-cross the sand dunes. In fact as a rule, all traffic on sand dunes must be prohibited and especially all movement of livestock, as this again destroys the vegetation, the sand then becomes mobile and the dunes begin their march once again. If it is absolutely necessary to allow livestock to cross the sand dunes, they should do so by routes marked ahead of time where constant surveillance is practised. These routes should, as much as possible, run obliquely to the slope and to the direction of the winds; they should be protected and delimited on either side by hedges of bushes, whether thorny or not, viz: Euphorbia balsaminifera, Opuntia, Fagara xanthoxloides and Acacia ataxacantha.

AFFORESTATION OF DIFFICULT SITES, ERODED AREAS AND STEEP SLOPES: WITH SPECIAL EMPHASIS ON THE MAMBILLA PLATEAU[1]

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CONTENTS

INTRODUCTION AND BACKGROUND

The Mambilla Plateau, situated on the eastern border of Nigeria and at the southern extremity of the North-Eastern State, forms part of the Cameroon Highlands geographically and is an extension of such. The plateau occupies an area of approximately 1 500 square miles (388 500 hectares) with a high proportion of it topographically gently undulating to steep slopes. Afforestation started in the early 1940's with introductions from the Cameroon Republic (Fox,1973), and continued on a local moderate scale until 1962 when the Mambilla Afforestation Scheme was first started under the First National Development Plan. This plan has been enlarged through successive plans, and a Hillside Afforestation Scheme has also been added to the present Forestry Development Programme, which was initially introduced in the Second National Plan 1970-74.

Land use allocation on such a potentially productive area results generally in forestry being given the steepest slopes. Although there is a need for the afforestation of the steep slopes, there is also a need for large scale mechanised plantations which require relatively gently sloping areas. A large part of the government and local authority afforestation programme, however, has been confined to the steep, eroded hill slopes, and has been implemented mainly by manual means. At present sufficient information is available on species and techniques to embark on a larger scale programme, either by mechanical means on the flatter areas, or by manual means on the steeper, eroded slopes.

1/ Paper for Symposium on Savanna Afforestation

The altitude of the main stations on Mambilla varies from 1 524 m to some 1 981 m. The annual rainfall at Gembu is 1 981 mm with some slight variations over the rest of the plateau. The mean monthly temperature is probably 85°F (Kemp, 1969) and minimum monthly temperatures are generally around 50°F. There is a heavy cattle population in the area and the soils are subject to over grazing and annual burning and consequently there are signs of accelerated erosion in some of the steeper areas. These steeper sites for afforestation are, therefore, shallow highly acidic lithosols with a silt loam texture and free drainage, developed under a temperate, high rainfall climate.

SPECIES/GROWTH/PROVENANCE TRIALS

Provenance trials can indicate the best species/provenance for a particular site.

Replicated species elimination trials of pines and eucalypts were started on the plateau in 1966 at Maisamari, Nguroje and Gembu. Of all the *Eucalyptus* species/provenances tested in the programme, none is as successful as the long established *Eucalyptus grandis* hybrid. Of the pines, *P. caribaea*, *P. kesiya* and *P. oocarpa* were selected for further testing after the initial elimination trials. The results of a species elimination trial at Nguroje, planted in 1966 on basalt soils, Number SM2/66/1 is as follows:

Table 1

Mean height and survival of coniferous species trials planted in 1966

Species	Origin	Mean height (m) after		Survival % after	
		32 months	46 months	32 months	46 months
Cupressus lusitanica	Bussaco	3.8	5.0	93	93
Pinus ayacahuite	Mexico	1.1	2.0	86	83
P. caribaea	Belize	2.2	3.6	90	90
P. kesiya	Philippines	3.1	5.1	97	96
P. massoniana	Hong Kong	2.6	4.0	100	100
P. montezumae	Mexico	0.1	0.6	36	25
P. oocarpa (I. 1136)	Mexico	0.7	1.8	56	44
P. oocarpa (I. 1157)	Belize	4.3	6.3	97	97
P. pseudostrobus	Mexico	1.0	2.1	89	85
P. teocote	Mexico	0.8	2.9	80	72

Species growth trials commenced in 1967 with mainly four pine species which were planted in four large replicated blocks per species and at the normal plantation espacement of 3 m by 3 m. Further development of species/provenance testing was limited by the availability of seed, and thanks must be recorded to the Federal Department of Forestry, Ibadan, Nigeria and to the Commonwealth Forestry Institute, Oxford, U.K. who provided all of the seed for the further trials.

Table 2: Summary of mean height, maximum height and survival, % of 4 year old P. caribaea and P. kesiya, provenance trial, Maisamari, Mambilla.

Species	Origin	Basalt Site			Basement Site		
		Mean ht (m)	Maximum ht (m)	Survival %	Mean ht (m)	Maximum ht (m)	Survival %
P. caribaea	Gt. Abaco, Bahamas	2.7	5.5	99	3.3	8.6	93
"	Cuba	1.8	6.4	93	2.4	8.6	81
"	Puerto Cabezas, Nicaragua	3.1	6.4	95	3.2	7.5	80
P. kesiya	Baw Luang, Thailand	3.6	4.9	96	4.6	7.2	89
"	Dalat, S. Vietnam	6.3	9.0	98	5.7	9.4	95
"	Rangoon, Burma	3.9	5.6	95	3.8	7.0	93
"	Khasi Hills, Assam	4.9	7.2	96	4.5	7.0	93
"	Philippines	3.1	6.7	78	-	-	-

Table 3: Summary of mean height, maximum height and survival % of 3 year old P. oocarpa provenance trial, Nguroje, Mambilla.

Provenance	Mean ht (m)	Maximum ht (m)	Survival %
K1 1/70 Nicaragua/Camelias	4.7	6.4	96
K7 7/70 Honduras/San Marcos	3.2	5.4	94
K9 9/70 Guatemala/Canas	3.6	5.1	97
K34 3/71 Guatemala/Bucaral	2.8	4.6	95
K35 4/71 Honduras/Angeles	3.5	5.6	98
K36 5/71 Honduras/Zamorano	3.6	5.7	96
Oxon I.2326 Guatemala/El Lobo	3.8	6.2	100
K44 27/71 Nicaragua/Rafael	4.9	7.2	99

Two provenance trials of P. caribaea and P. kesiya were planted on the soils derived from basalt and granite at Maisamari in 1971. In 1972, 113 g of superphosphate was applied to each plant and after 4 years, P. kesiya from Dalat, South Vietnam, was dominant on both sites. The mean height on the granite soils was 5.7 m and on the basalt soils 6.3 m. For the trial results see Table 2.

A P. oocarpa provenance trial was planted at Nguroje in 1972 on a soil derived from basalt. After three years, the provenance from Rafael, Nicaragua, was superior with mean and maximum heights respectively of 4.9 and 7.2 m, whereas the poorest provenance was one from Guatemala with mean and maximum heights respectively of 2.8 and 4.6 m. Both Nicaraguan provenances were superior to the rest. For full results see Table 3. In any plantation development programme it is essential that selected seed should be available in commercial quantity and that a local programme be designed and implemented to produce future seed requirements.

FERTILIZER TRIALS

In 1966, McComb, Ojo and Jackson (1970) conducted a laboratory experiment of the 'Fertilizer Response of E. grandis grown in a basaltic soil from the Mambilla Plateau'. The results suggested that it would be virtually impossible to grow E. grandis from seed on subsoil exposed by erosion, unless fertilizers were applied. Phosphate was indicated as the principal limiting element, but boron was also indicated as being necessary.

Also in 1966, Jackson (1973) conducted experiments with borate and superphosphate on E. grandis at Maisamari, Nguroje, on fairly level sites derived from basalt and at Gembu on an eroded steep slope derived from granite. At Gembu the fertilizers were applied to a two year old plantation which had been beaten up in the year prior to the application of the fertilizer. Borate was applied at 0, 57 and 113 g per tree and single superphosphate at 0, 85 and 170 g per tree. At Gembu 113 g of borate gave a response but not 57 g. The increase due to superphosphate was not significant. Generally, the application reduced terminal shoot die-back and leaf discolouration, thus improving the health and shape of the crown and hastening canopy closure.

In 1972, Fox conducted three experiments at Maisamari on steep, shallow soils derived from granite. In the first trial in a fairly steep part of the P. 71 compartment, approximately 123 kg/hectare each of borate, borate and superphosphate and borate and sulphate of amonia were applied by a rear tractor mounted mechanical spreader. There was a significant difference between the untreated and treated areas. There appears to be no difference between the formulations and the implication is to use the least costly treatment. The results are shown below in Table 4.

Table 4: Correllation of height growth of E. grandis hybrid and fertilizer applications 1972.

Treatment / On application	Heights (m)		
	13/7/72	11/73	10/74
Borate & superphosphate	1.1	5.2	8.3
Borate & ammonium sulphate	0.8	4.6	8.0
Borate	0.8	5.1	8.6
Nil	0.9	1.9	2.9

In trial 2, in the P. 72 compartment, ammonium sulphate and single superphosphate were applied by hand around the trees and below ground level at 0, 114 and 228 g per tree and borate at three levels of 0,57 and 114 g per tree in a single replicated experiment on a poor soil in a steep rocky area. Sixteen months after application the greatest responses were:

Treatment	$N_1P_2B_1$	$N_2P_1B_1$	$N_2P_2B_2$	$N_2P_1B_0$	$N_0P_0B_0$
Mean height increase (m)	5.2	5.3	5.3	5.8	1.2

After 27 months, there appears to be a substantial response to N, although there is little difference between the two rates. There is some, though rather less, evidence of a positive effect of applying B. There is also some difference between plots receiving no P and those treated with 114 and 228 g per tree.

In trial 3, boron was applied at two levels and in two forms as a granular fertilizer in a drill below ground level and as a foliar spray. All plots also received 114 g of single superphosphate. Twenty-seven months after application there were few statistically significant differences, although there was an indication that granular borate around the tree may be more lastingly beneficial than the foliar spray.

Generally, any fertilizer application should be done in the year of planting and as soon as possible after planting to accelerate height growth, crown development and canopy closure. Hand application, preferably into the soil, is all that is possible on the steep slopes. Whereas on the gentler slopes, mechanical application is possible.

SITE PLANNING AND LAYOUT

Once suitable species and techniques have been evolved for the site through species, fertilizer and other trials, then the acquisition of larger sites can commence. Sufficient land must be obtained above and below the steep slopes for afforestation. Above the steep slopes, land must be obtained for roadways for access, plant distribution at the time of planting and for extraction of produce whenever necessary. Sufficient land must also be obtained above the slopes to arrest the surface flow of water down the slope by land use techniques and to promote ground water percolation. Contour ploughing and contour bunding are useful controls. Below the slopes, land is required for access at the time of planting and throughout the life of the plantation to the time of exploitation.

The average slopes normally allow ready upper and lower access. However, on longer slopes, roads will be required at intervals along the contours. These roads are normally put in by mechanical means before planting starts while visibility in layout is easiest. The gradients should be enough to allow for the extraction of the produce throughout the life of the plantation. Natural features should be used where available, especially in the siting of the joining roads. From experience, it is of great advantage to have a road system throughout the plantation from the very start rather than making the roads when required, often through young plantations.

Some site grading is occasionally required on the over-hanging slopes and this should be done before planting starts to allow the site to resettle and to reduce site disturbance down the slope. Fencing against animals should be done as soon as possible and before planting on the current year's planting site. On Mambilla, use is made of natural features where possible and the steep sided streams make excellent boundaries where fencing is unnecessary. It is generally cheaper to fence the entire area initially than to fence only current planting areas. However, on the Mambilla Plateau it is good policy to allow cattle to graze over unplanted areas so long as they are attended by a herdsman. It is also good for public relations since the herdsmen see forestry as an acquisition of land lost to the original cattle owners. Cattle are useful in controlling the grass growth, reducing both the fire hazard and the amount of cultivation required prior to planting. They also contribute manure to the site. They should be at all times controlled and kept out of the plantation areas and off the steepest slopes.

Fencing and the exclusion of animals allow for the rapid recovery of the site if fire is also excluded, but is only a temporary solution, since degradation will follow when cattle are again allowed to utilise the site. A more permanent solution is to put the area under forestry with maintenance of canopy for the maximum period under the chosen silvicultural system.

Nurseries should be sited within the plantation area and near to water. On long slopes over several kilometres it may be better to use temporary nurseries for each year's planting as long as water and labour are available nearby. For eucalypts, a three month nursery season from early March to early June is adequate for potted stock. After germination in March much of the watering is from precipitation, since the rainy season normally starts in April.

Labour shortage can be a much more serious problem, since hillside afforestation on Mambilla is a very labour intensive operation. It is worth trying to encourage labour to settle close to plantation developments since transport and labour availability are constraints to such developments. At present most of the available labour reside in larger towns and villages and only limited numbers are available in more remote areas. The cattle owners do not generally contribute to the labour force, only the Mambilla farmers.

PLANTATION ESTABLISHMENT

Nursery techniques for Eucalyptus spp. are based on Fishwick (1966) with modifications to the semi-temperate climate of the area. Local humus and soils are used together with fertilizers and dieldrin in the potting mixture to produce strong trees of 0.3 m in height, balanced in root and shoot growth, with a reservoir of nutrients in the pot at planting time to encourage initial establishment. Tall plants are a disadvantage on the plateau due to the strong winds and occasionally have to be cut back after planting. For pine seedlings, an addition of ammonium sulphate and superphosphate to the potting mixture is recommended, but urea and potassium have been found to have harmful or negative effects.

Site clearance, either mechanical or manual, of the grass cover normally occurs in April when fire can be used carefully to reduce the heavy grass. If fire happens to enter the area earlier, then grass regrowth can form a heavy sward by the time of site cultivation. It is, therefore, best to leave the clearing as late as possible to reduce the amount of labour involved. On the steep slopes, the site clearing should be done along the contour using heavy hoes to upturn the turf placing roots uppermost to dry in the hot sun. On gentler slopes, complete cultivation is carried out, but on the steep slopes cultivation is restricted to minimum contour lines about 3 metres apart. It should be noted, however, that grass not killed during the pre- or post-planting operation will survive throughout the rotation and responds as soon as the canopy is opened. Since grass is the main retardant to eucalypts, the question of the duration and periodicity of cultivation for successful establishment is a matter of experience.

The problems of plant distribution vary with the degree of slope, but mechanical means should be used to convey the pots as near as possible to the planting site. On the steep slopes, much on site distribution has to be manual. The seedlings are planted at about 3 m by 3 m and the whole of the pot is removed. Normally, the holes are prepared by a separate labour force and only a few labourers actually do the pot removal and planting.

Approximately 4 weeks after planting, fertilizer can be applied to the plants. The area should be weeded first to reduce the competition for rooting space and available nutrients and then the fertilizer is applied manually in a slit below the surface, or by mechanical techniques on flatter sites. Afterwards, the area should be weeded as and when required. This is where experience is an essential asset. It is necessary to retain some weed cover to reduce the danger of accelerated erosion, but grass should be prevented from hindering the growth of the trees.

Inadequate weeding causes trees to quickly show signs of ill health on the steep slopes but appreciation of such indications are often too late to rectify the situation that same season. As much as possible should be done in the year of planting to achieve a healthy vigorous tree which will continue to grow over the dry season and take advantage of the early rains for maximum growth opportunity in the second year. The weedings should be continued along the contour when required. On good sites canopy closure can be obtained 18 months after planting, i.e. just before the onset of the second dry season. Eucalyptus grandis hybrid will continue to grow throughout the dry season on good sites where fertilizers have been applied. If the technique is not correct, however, terminal die-back and leaf discolouration occur which require expensive treatment to return the crop to healthy growth. The use of selective weed killers has been tried on the plateau employing mechanical applicators. Such trials have been unsuccessful due to the high cost of the weed killer, the slow rate of application and the quick recovery of the grasses. Herbicides, however, are worth further trials.

Modern technological advances are tending to overcome the inherent difficulties of species utilisation (Hardie, 1974; Alders, 1975), and at present for the steep slopes on the plateau, E. grandis hybrid can be recommended for rapid site coverage and for the production of large volumes of wood as a utilisable resource.

HILLSIDE AFFORESTATION MANAGEMENT

Protection should always be the prime consideration on steep slopes, but once a large wood resource is available there is likely to be a demand to utilise this basic raw material for some industry.

End use will no doubt influence what system is to be used in the management of the established forest. For small size fuel, poles and timber, a coppice system will be sufficient and has several advantages for steep slopes. If larger size timber is required, a selection or clear felling system will be employed according to the requirements of the species used. Coppice systems have the advantage of rapid site recovery and are suitable for the management of E. grandis hybrid on steep slopes. However, experiments conducted on the plateau, indicate that maximum coppice regeneration is obtained at the height of the rains when forest produce is not normally required in any quantity locally. Such forest produce as poles and firewood is normally required in the dry season when coppice regeneration results in up to 25% stump mortality. On high rainfall areas greater site protection is necessary during the exploitation period but this is to some extent counteracted by the faster growth and speedy site recovery.

Although most of the silvicultural and management problems in the selection and establishment of the best species for particular sites have been dealt with, research on a local scale should continue to select superior breeding material and to produce superior seed. Infact, such a programme which would confer benefits both locally and nationally might be a matter of some priority.

SUMMARY AND CONCLUSION

The afforestation of steep and eroded slopes free of tree vegetation and with shallow soils requires the selection of a fast growing tree species employing establishment techniques giving speedy establishment. Local species should be studied first but if no local species are suitable, a much longer process of species and provenance trials has to be tried.

After initial selection, there is room for further improvement through more advanced provenance trials and trials of establishment techniques. A research and development programme is required to further improve the selected species, and in the longer term to produce the estimated requirements of improved seed.

Having selected the species, for a large afforestation scheme where protection is the primary requirement, there is always the risk that demand for woody raw material could have an adverse influence on the silviculture and management of the plantation. Where possible, such demands may be accomodated within the programme, but the primary protection objective should not be sacrificed.

Fortunately on the Mambilla Plateau the species E. grandis hybrid was established and suited the forestry requirements, but even so, for the past 10 years species, growth, provenance and fertilizer trials have been conducted to try and improve efficiency and economy of establishment. With E. grandis hybrid, the fertilizer trials have been the most directly productive. Other Eucalyptus species and growth trials have not produced a comparably productive tree. However, with the introduction of the pines, two Nicaraguan provenances of P. oocarpa and the southern Vietnam provenance of P. kesiya, have shown promise for further development. At present a provenance trial of Cupressus lusitanica is required to try out the new canker resistant strains and to select provenances with finer and less persistant branches. Such a selection might then be suitable for development. The improvement of species and techniques is a long term programme and requires continuity of supervision and well defined long term management objectives.

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MINE RECLAMATION AREAS [1]

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CONTENTS

INTRODUCTION

There has been extensive open-cast mining on the Jos Plateau for the past 60 years. The mining operation leaves a desolate landscape of earth mounds, dried out mud ponds, tin tailings and reservoirs which render the land unproductive for agriculture, forestry or grazing, without expensive rehabilitation programmes.

A recent (1972) aerial photography of mined areas indicates that the tall steep-sided earth dumps cover a relatively small area of a mining lease and that the network of paddocks and tin tailings covers a much larger area.

The 1973 - 1974 estimate of the Government of the Federal Republic of Nigeria puts the total revenue from mining at ₦ 336 872 264 [2]. Of this value, the greater part came from the Jos Plateau. At present the area of land held under mining leases for tin and other minerals on the plateau exceeds 81 000 ha. A conservative estimate of the area actually disturbed by active mining is in the region of 26 730 ha. As Howard (1974) has pointed out, the rehabilitation of the mining spoil areas is important for a number of reasons:

1/ Paper for Symposium on Savanna Afforestation.

2/ 1974 exchange rate: 1 ₦ = US$ 1.62.

(a) Land is at a premium because of the high population and low yields in the existing agricultural system.

(b) Erosion is caused by the mining scars because the base level of a stream is often lowered, thereby causing gulley erosion higher up the stream.

(c) The plateau is virtually treeless and trees are needed for firewood and poles for house building. Areas of tin mining spoil may be suitable for extensive tree plantations, because *Eucalyptus* will grow on them.

(d) The plateau is heavily grazed in both the wet and dry seasons. If palatable grasses or legumes could be established on the mining spoil, this would provide valuable additional grazing.

(e) The extensive network of deep reservoirs is a valuable water resource providing possibilities for dry season irrigation, not at present utilised on any large scale for agricultural production.

PLATEAU CLIMATE, WEATHER AND VEGETATION

The Jos Plateau is situated between latitudes 9° 50' and 10° 50' N and longitudes 8° and 9° E at an elevation of about 1 200 m and covers an area of 4 662 sq km. Weather conditions are controlled by moist south-westerly winds during the summer, and dry north-easterlies during the winter months.

The highest temperature recorded since 1914 is 100° F (38° C) while the minimum is 41° F (5° C); average temperatures are around 70° F (21° C). The mean annual rainfall is approximately 1 270 mm, the total decreasing from the southwest part of the plateau to the north and east. On average, the rains occur during eight months of the year and thunderstorms of high intensity are frequent especially at the beginning and towards the end of the wet season. The variation in rainfall from year to year is considerable. Tree felling and overgrazing on the plateau have tended to reduce the efficiency of the rainfall by allowing a more rapid runoff. Relative humidity on the plateau is seldom uncomfortably high.

The plateau has been an enclave for surface mining for many years. The area consists of undulating grassland dotted with granite outcrops and occasional flat-topped hills of lateritic ironstone. During the rainy season, May - September, grain crops such as "Acha" *Digitaris excilis*, millet, *Eleusine coracana*, are extensively grown on the open plain by the Birom people, whilst numerous herds of cattle owned by nomadic Fulani graze during the wet months. When the grass is exhausted they descend to the Benue plain for the duration of the dry season.

Native smelting of tin and iron in past centuries must have caused a great deal of woodland destruction, but the present treeless state of the plateau has resulted from the development of the tin mining industry. The influx of people from the rural areas to tin mining locations such as Bukuru and Jos resulted in large increases in population and consequent demand on land for cultivation of food crops. The Birom practice of digging out tree stumps on farms does not allow coppice regeneration. Only afforestation could provide for an ever-increasing demand for firewood and poles. In the 1940's firewood became so scarce that the activities of the mining companies became threatened and it was necessary to transport firewood from Jema'a.

Thus, early recognition of the need to conserve and supplement indigenous wood species led to the development of an afforestation programme under the Mines Reclamation and Afforestation Unit. There is a great demand on land for farming and mining and it is difficult to have additional land set aside for communal tree plantations. One possible solution to the problem lies in planting up land which mining has rendered useless for farming.

Modern tin-mining on the plateau calls for the use of heavy earth moving equipment involving the removal of up to 12.20 m of earth to reach the tin-bearing ground which lies underneath. The larger companies, e.g. the Amalgamated Tin Mines of Nigeria (ATMN), normally use draglines for excavation which pile the earth in great steep-sided mounds or dumps around the rim of the excavated "paddock", as the pit is called.

RESTORING TIN MINING LAND

Site Preparation and Fertilization

In 1948 a trial was made on the mine dumps planting Eucalyptus camaldulensis, and this proved successful at little expense. Shortly afterwards, the Ministry of Agriculture followed up with land restoration experiments involving levelling the dumps, using bull-dozers and crawler tractors. Night-soil compost from Jos town was spread thinly over the levelled surface at the rate of 50.18 tonnes per hectare and cover-crops such as elephant grass Penisetum purpureum "gamba" grass (Andropogon gayamus) and Stylosanthes gracilis, were sown. It was intended that after a few years under cover-crops the restored mining land could be returned to the native owners for normal cultivation. In 1955 and 1956 experimental growing of 'acha' Digitaris excilis and other local staple crops on reclaimed mining land was further undertaken by the Ministry of Agriculture. These experiments indicated that normal yields of staple crops on restored mining land could only be attained using large application of organic compost and fertilizers. It was considered to be beyond the means and capability of the local farmers to procure fertilizers on the scale required to enable staple crops to grow.

The satisfactory indications obtained from the 1948 experimental tree planting resulted in more areas being planted. In 1959, a central forest nursery was built at Bukuru to replace the 19 scattered non-irrigated nurseries in Jos Division. Funds for the development of the nursery were jointly provided by the Ministry of Agriculture and the Jos Local Authority. Seedlings raised in the nursery were for both mine reclamation areas and communal forestry areas.

In 1959 observation plots were set up to determine if the practice of establishing Eucalyptus trees, with a headpan (18.2 kg - 22.7 kg) of compost added to each planting hole, was the most efficient.

The following treatments were included:

(a) One headpan of (18.2 kg - 22.7 kg) compost per planting hole;

(b) 1/4 headpan of (4.5 kg - 5.4 kg) compost per planting hole;

(c) 1/4 headpan followed by 112 g of sulphate of ammonia applied one month after planting;

(d) Nothing applied to the planting hole and 112 g sulphate of ammonia applied to the seedling one month after planting;

(e) No treatment.

Subsequent trials in 1960 and 1962 applied nitrogen and compost at different rates.

As a result of the above trials, when the Mine Reclamation Unit took over complete responsibility for rehabilitation and afforestation of mineland, a new method was started which employed a shovelful of organic compost and 84 g of ammonium sulphate mixed with the soil from each planting hole before planting. The results were promising and trees attained heights of 3.05 m to 3.66 m in the first year. In subsequent years, the use of compost was dropped as the distance and cost of transport from the depot to some of the planting sites became too great. Nevertheless, measurements taken in such plots eight years after establishment, averaged 9 m - 14 m height which is reasonable on disturbed soils.

In the first planting season, planting holes were dug either by hand or by post-hole digger mounted on a Ferguson 35 tractor. In the subsequent year, the planting lines were cultivated by heavy ripper or sub-soiler (powered by a D-8 caterpillar) which had the heavy tines set at a suitable planting distance. Experience has shown, however, that better results are achieved by planting trees in the same year as that in which the levelling operation is completed. Due to soil compaction, it was considered that heavy sub-soiling was necessary to allow the tree roots to penetrate to some depth. Growth of Eucalyptus and of grass improved on areas so treated.

Species of Trees Planted

The main species used in planting on the plateau both in mine reclamation areas and communal forest areas are as follows:

(i) Eucalyptus camaldulensis: This is the main species for afforestation of restored mining land and is used extensively in communal forest area plantations.

(ii) E. punctata: This species is now being used in preference to E. rostrata on coarse-grained quartz soils, which generally have a low clay content and are consequently well-drained. It forms a dense canopy at 2 years of age, suppresses grass and has a straight stem. It has been found necessary, however, to apply borate fertilizer (approximately 56 g per tree) in the first year to prevent leading shoot die-back.

(iii) E. robusta: This species has one great advantage over E. rostrata and E. tereticornis; it will readily form a closed canopy and can greatly minimise weeding costs and also reduces the danger of damage by fire. It is susceptible to termite attack and its use has been mainly on the red basalt soils in areas of high rainfall.

(iv) E. rostrata:1/ This species has proved to be generally reliable, being easy to raise in the nursery, able to stand a good deal of rough treatment in transport and planting, is adaptable to most soils and sites (except very wet sites), and is fast growing and not liable to die-back in the first year. It yields good firewood and poles and after felling coppices strongly. It is considered to be the best all-purpose short rotation plantation species on the Jos Plateau.

(v) E. saligna (hybrid): A fast growing species with a straight stem capable of forming dense canopy. Due to hybrid swarm there is a proportion of misshapen or dwarf trees. It grows successfully only on deep soils in the heavy rainfall areas of the plateau (south and west).

(vi) E. tereticornis: This species appears to be similar to E. rostrata but is generally straighter in form. It is being planted extensively on the same sites as E. rostrata.

All the foregoing species are classed as commercial timbers in Australia, E. robusta and E. saligna in the joinery class (e.g. window frames, doors and furniture) and E. rostrata and E. tereticornis in the construction class (e.g. beams, railway sleepers, bridge timber, etc.). Thus they have some potential beyond fuel and building poles if they can be grown on larger rotations.

Table 1 shows growth rates of Eucalyptus on mining spoil (Howard, 1974). According to Howard, Du CFA (D 345) and D 346 are situated on an undisturbed ironstone gravel soil. MRA 25 (D 348) and MRA 33 (D 353) are compacted mining spoils.

1/ syn. E. camaldulensis.

TABLE 1

GROWTH OF EUCALYPTUS ON MINING SPOIL AND ON UNDISTURBED SOIL

Plot No.	Location	Species	Age	Trees/ha	Average height (m)	Ave.d.bh (cm)	diam. incr cm/yr
D 346	MRA 25	E. camaldulensis	13	1 300	11.9	12.0	0.9
D 347	MRA 25	E. camaldulensis	13	1 525	9.6	10.0	0.8
D 348	MRA 25	E. camaldulensis	13	775	8.7	7.6	0.6
D 349	MRA 33	E. multiflora 1/	14	1 150	21.6	17.0	1.2
D 352	MRA 33	E. camaldulensis	14	1 420	14.6	12.9	0.9
D 353	MRA 33	E. camaldulensis	14	950	8.4	8.4	0.6
D 344	MRA 11	E. camaldulensis	12	1 300	9.9	9.7	0.8
D 339	Ryom CFA	E. mult./camald.	8	1 025	18.6	12.5	1.6
D 338	Vwang CFA No. 4	E. camaldulensis	11	1 100	14.3	11.1	1.0
D 345	Du CFA	E. camaldulensis	11	1 000	7.8	7.1	0.7

1/ syn. E. robusta

PROBLEMS AND FUTURE OF THE MINE RECLAMATION AREAS

The area of restored mining land which has been planted since 1960 is 1 336.5 hectares of which more than 202.5 hectares were established immediately after restoration. A further 202.5 - 243.0 hectares were established on land restored some years previously and sown with cover-crops of grass and legumes. It may be noted that little land has been surrendered for reclamation between 1968-1975.

Mining companies are reluctant to surrender their mining title after the ground has been worked for tin. Check-drilling of the ground, which is always done before restoration begins, often reveals the presence of small values of tin. To larger companies these values may not be worth recovering, but they may be economically exploited by small private miners who use simple hand methods and have low overhead expenses. There is always some optimism that a rise in the market value of tin or minerals in general might make it profitable for the recovery of the remaining tin, or even other minerals not presently capable of economic extraction.

Since 1967 the Forestry Division has been attempting to persuade the Jos Local Authority to have plantations on reclaimed mine lands constituted into either forest reserves or communal forestry areas to afford some security of tenure. The prospects for agricultural development on such areas are not good and there is little doubt that afforestation, which not only improves the environment, but also provides much needed firewood and poles, is a sound form of land use.

CONCLUSION

Most of the *Eucalyptus* species so far raised on the mine reclamation areas have some wood potentialities but unless there is some security of tenure of existing and future plantations, it will not be possible for the Forestry Division to carry out the essential long term research on improvement of the environment, on wood production and on possible soil improvement potentialities of *Eucalyptus* and other species. This mine land reclamation project has assumed a small but important place in shaping the land-use pattern on the Jos Plateau and further soundly based development is essential if land deterioration and erosion is to be controlled.

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FIRE PROTECTION IN INDUSTRIAL PLANTATIONS OF ZAMBIA 1/

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

FIRE PROTECTION

History

The present system of fire protection in Zambia is based almost entirely on the work in 1970, of Mr. N.P. Cheney, a summary of whose report (Cheney, 1971) appears in Appendix 7 of Tree Planting Practices in African Savannas (Laurie, 1974). This led to the setting up of a Fire Control Section to get the organization going; work is now sufficiently advanced to bring it under the control of line management from the beginning of this year.

Degree of Hazard

The long dry season with increasing temperature, decreasing humidity and often strong winds, especially in September, combined with plentiful fuel, give conditions for severe fires. The exotic trees grown are inherently fire prone and there is a considerable build up of fuel from pruning and thinning wastes under the trees, especially pines. Large blocks of even-aged trees, sometimes unavoidably orientated along the prevailing wind, give a potential, according to Cheney, of fires up to 1 600 ha.

The population traditionally uses fire for land clearing and hunting and is only slowly becoming aware of the need for avoiding fire in plantations.

In 1975, the worst season to date, a total of fifty six fires occured, eighteen of them originating outside and thirty-eight inside the plantation.

A total of 602 hectares were involved, of which 120 ha were killed and 225 ha suffered severe scorch.

Damage by Fire

Pines are most susceptable to death and severe damage up to year twelve, and eucalypts throughout the rotation. Damage is by leaf scorch and destruction of the cambium. Overall scorch normally leads to death, whereas cambial damage is usually only partial and leads to degrade of timber. Because of their thinner bark, eucalypts can suffer cambial damage very readily, and for this reason fuel reduction by burning cannot be practised.

Cost of Fire Control

The approximate cost of establishment per hectare of pines is K 3 985[1/] and eucalypts K 670 calculated at 7 percent compound interest to the end of the rotation (based on 1975 costs). Fire control costs are about 5 percent of this figure.

FIRE PREVENTION

General

Fire prevention within the pine plantation only becomes a problem after the sencond year when weeding normally ceases. Some third year weeding is carried out in dangerous locations, but this tends, owing to the work load, to be just a rolling down of the grass. Past fires indicate that it will be possible to burn this off early in the season with only minor damage; this is preferable to severe damage at a later date. The heavy grass growth normally found in young pine plantings makes for an extremely fast moving fire, especially if there is any wind.

1/ 1 K = US$ 1.56.

Pruning to 2.2 metres is carried out when the mean top height is 10.5 m (at approximately 5 years of age), which leads to a considerable increase in the fuel on the ground. This is perhaps the most dangerous stage in the life of the tree from the point of view of fire. A programme of control burning after pruning has been carried out since 1971. It should be noted that slash is scattered as evenly as possible and no of piling branch wood must take place as this leads to hot spots and consequent damage.

Control Burning

The object is to reduce the amount of fuel on the ground to keep damage by scorch to a minimum. It has been found that trial fires can only give an indication of rate of spread and flame height and that when fires join up both are increased, flame heights being almost doubled. As scorch height is approximately five times flame height it is necessary to keep flames as low as possible. The fuel which causes difficulty is the dry needles on pruned branches not lying flat on the forest floor; it may be necessary to burn these off in one operation and burn again later to reduce the compact needle litter remaining.

Practical application

Burning is carried out in March/April when the rains are tailing off and in the late afternoon when there is little or no wind. Lighting is done on a grid pattern using the lines of trees as a guide. A trial fire gives the rate of spread and as a result of this lighters are spaced out along the side of the compartment and given a track along which they must walk, counting lines of trees as they go. Espacement is generally between 30 and 40 metres, and men must be cautioned only to light one spot of fire at the prescribed distance.

When lighters emerge on the other side of the compartment they are assembled and again sent off in the opposite direction till the area is completed. General direction of advances is into the prevailing wind. Detailed directions for carrying out control burning are given in Cheney's report, and persons interested in this work should study these carefully. Caution is necessary in the use of fire as once lighting up has taken place it is usually too late to put out the many spots burning in one compartment. While isolated cases of crowning have occurred, damage is usually minor, but this should not be confused with trees with persistent needles which occasionally flare up in an alarming fashion, but seem to suffer no damage as a result. Weather conditions must be taken into consideration and any cumulonimbus clouds in vicinity treated with suspicion as they can cause severe turbulence. In case of doubt a weather forecast for the locality should be obtained.

Successive burns

There is no doubt that control burning reduces danger of damage from wild fire and gives supression forces a better chance of success, but this is dependent on the amount of fuel removed. It is therefore recommended, as a result of 1975 experience, that fuel in dangerous edge compartments exposed to the prevailing wind be kept to an absolute minimum.

Normally in other compartments additional control burning should be carried out when there is a significant increase in the fuel on the ground. Poisoning of unproductive thinnings has been successfully carried out. This allows the trees poisoned to remain standing and gradually disintegrate instead of encumbering the forest floor as they would do if felled. This is of course better from the fire point of view, but has now been abandoned owing to a change in thinning schedules which delays the first thinning to age nine when more utilisable material can be obtained.

Effect on increment

Measurements carried out in a series of nine plots in three compartments and burned yearly since 1972 indicate that so far there is no significant effect on increment.

Understory species

At Chichele Plantation infestation by Lantana camara is extensive, and it has been found that the stocking of this has been considerably reduced by repeated control burning. It is unlikely that complete eradication by fire will be possible due to infested anthills, but lantana can be kept sufficiently in check to allow almost unrestricted access. This is important in allowing forest operations to take place and for fire control, especially as lantana burns severely later in the dry season.

Costs

The cost of the operation using an average gang of eight men and two vehicles is 0.30 K[1/] per hectare. This does not include the cost of one forester, and one forest ranger who are also normally in attendance. About 80 ha can be burned in one night by this force.

Firebreaks

Internal firebreaks

In the past a number of different firebreaks have been tried, but now the leaving of large areas of unplanted land, with a high work load for no return, and of doubtful value for stopping high intensity fires, has been discontinued. It is considered that graded compartment roads combined with control burning and compartments of thick barked eucalypts strategically placed across the prevailing wind to break up large pine areas will be adequate. The graded roads will stop low intensity fires and allow speedy access, and control burning will provide areas of low fuel loading. The species favoured for planted firebreak compartments is Eucalyptus cloeziana which can be safely burned at about age four and is useful commercially.

External firebreaks

Boundaries are protected by a graded strip five metres wide immediately alongside the plantation. In addition between this and the indigenous woodland a ten metre wide strip is rolled and burned off at the end of the rains. On certain dangerous boundaries where there is much foot traffic, there is a further graded strip outside this.

There are obvious advantages in streamlining boundaries and this is being done in new areas even though it may mean the inclusion of some poorer planting land.

Woodland

The adjacent woodland is intensively early burned as the grass dries out, and again after leaf fall, care being taken to avoid damage to the canopy. Anthills in the fire-break and on the edge of the woodland have in the past provided a spring-board for fire to jump into the plantation so these are now being systematically cleared of vegetation. Dead and dangerous trees on the woodland edge need to be felled and cleared away.

Costs

Grading with a caterpillar 120 Grader costs K 15[1/] per kilometre and rolling a further K 15/km.

1/ 1 K = US$ 1.56

FIRE WARNING SYSTEM

Fire Towers

Fire warning is based on a series of steel towers strategically placed throughout the plantation at roughly 10 km intervals. Advantage is taken of any suitably placed hills to reduce the height of towers at these points.

It is important in locating towers that good cross bearings can be obtained.

Equipment

Towers are fitted with a bearing indicator with a simple sighting device reading horizontal angles to the nearest degree. These are set up to coincide with protractors marked on the plotting map in the fire control centre. Communication is by means of a portable radio powered by a heavy duty 12v battery kept in a locked steel box at ground level. Batteries last on an average three weeks before having to be brought in for charging. Look-outs are provided with binoculars, water bag, protective clothing and a seat.

Manning

As fire danger progressively increases, tower manning is increased from a single shift at the beginning of the season to three eight hour shifts on strategic towers. Only five fires were recorded as having started between 22.00 hours and 06.00 hours during the 1975 season; these did little damage and were readily controlled.

Fire Control Centres

Easch plantation group has its own control centre manned by a radio dispatcher on an eight hour shift basis. This man is responsible for plotting smoke reports from the towers and taking appropriate action. He maintains a log book, checks vehicles and towers in the field hourly, changes batteries and takes meteorological readings. Much of the radio time is occupied by administrative messages, but in case of fire these can be halted.

Frequency of Fires

In 1975 at the two main plantation centres, 2 721 smoke reports were received of which 691 were investigated and 47 fires were suppressed.

Normally, fire watch begins in May. There is a build-up of fires until June when the total remains fairly constant. It starts falling off in October, with the fire season ending towards the end of November.

FIRE SUPPRESSION

General Organization

Every employee is liable to fire fighting duties, but initial investigation and suppression is carried out by trained teams normally consisting of two gangs of six men plus supervisor stationed at each plantation centre and travelling in fully equipped vehicles. It is only when conditions warrant that the larger organization is called into service, as detailed in the fire plan. Full-time fire teams are backed up by stand-by gangs. It is hoped that the whole labour force will eventually become versed in the elements of fire suppression.

Types of Fire

(1) Grass fires in young plantations spread rapidly, but vehicles using water can usually be driven into the compartments. Knock-down can be accomplished quickly, but there is need for efficient follow-up by men on foot to ensure that the fire does not restart.

(2) In older compartments trees reduce the wind, and rate of spread is less, especially if control burning has been practiced, but here vehicles are confined to roads and so are mainly useful in stopping spread from one compartment to the other. In this case control must be achieved by hand methods as detailed in Cheney's report.

Hand Equipment

McLeod tools imported and fitted with bamboo handles locally, are excellent for fire line construction in litter fuels.

Shovels are used nosed, fitted with long handles and sharpened.

Brush hooks are used for clearing branches and light growth ahead of fire line construction.

Axes are useful when larger material such as trees felled in thinnings, is encountered.

Knapsack sprayers — An excellent design has been imported from Australia consisting of a sixteen litre plastic tank with pump and hose clipping neatly round the outside.

Drip torches are very efficient when quick lighting up is required.

Mechanical Equipment

Vehicles

For Zambian conditions experience indicates that a fast (at least 100 km/hour top speed) 4-wheel drive vehicle of about 3 tons capacity is best. This should be fitted with an internally baffled steel tank capable of holding about 1 400 litres of water, pump, hose reel and hand tools. At least one larger tanker should be available in each area.

Water pumps

A centrifugal pump producing a pressure of at least 10 bars with a good filling rate at low pressure and hand or other priming facilities is recommended.

Other equipment

Hose reels should be of the vehicle type supported at both ends and capable of carrying up to 60 metres of 20 mm rubber hose.

Branch pipes should have spray and jet facilities and positive shut off.

Hose — Strong fabric reinforced rubber hose of 20 mm and 25 mm is used. Canvas hose is mainly used for tank filling, but a few lengths of 38 mm are carried on the large tankers for use in case of a sawmill or other static fire. Generally, vehicles fight fires while on the move so it is undesirable to have them anchored to long lengths of hose.

Slip-on units can be useful on conventional lorries or light trucks, and should consist of light steel, internally baffled tanks with a small pump and hose reel mounted on the top. These are loaded empty and then filled with water. Hand tools and all other equipment necessary should be kept at the loading point.

Wheeled bowsers towed by tractor or land rover can be useful.

Fire Weather Information

Generally speaking, fire weather in Zambia gets progressively worse as the dry season progresses, though there are days when conditions can be more severe than expected. With this in mind forecasts are obtained form the Meteorological Department each afternoon for the following day of: (1) maximum wind speed, (2) wind direction, (3) maximum temperature and (4) minimum humidity.

This gives a chance to plan activities ahead and to alert any extra forces which may be necessary.

In addition, local weather information is collected at fire control centres at 09:00 and 16:30 daily consisting of air temperature, wet bulb and maximum and minimum temperature. Wind direction and speed are recorded hourly. Any rainfall is measured and a thermohygrograph makes a seven day chart of temperature and humidity.

Weather information is used in compiling fire reports, calculating the drought index figure (see Cheney, 1971) and computing the fire danger rating using the McArthur Forest Fire Danger Meter.

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PROTECTION AGAINST INSECT PESTS AND DISEASES 1/

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CONTENTS

INTRODUCTION

The savanna occupies between 75-80% of the entire vegetational area of Nigeria. Thus, of the total forest reserve area of about 96 000 km^2, the savanna covers about 76 000 km^2. However, much of the savanna reserves are low value forests with a lot of grasslands. On the other hand, the estimated 20 000 km^2 of high forest reserves which have considerable industrial potential may be unable to sustain the extremely heavy demand to which timber is put.

At present, about 1½ million cubic metres of wood is consumed annually in Nigeria. At this rate, the high forest would be used up in not more than 30 years. It is therefore essential to find means of augmenting the supply of timber in the country, partly through rehabilitation of the savanna. Besides, ready availability of timber for immediate local consumption is also desirable for the savannas.

In these circumstances, the vast savanna needs to be converted into productive forests. Such massive efforts to establish man-made forests require intensive research and large-scale management techniques. No doubt, the resulting artificial forests would conspicuously lack the biological balance which is obtainable in natural forests. Subsequently, this has given rise to a number of forest and timber diseases and insect problems, some of which have, on occasions, assumed epidemic dimensions in monocultural practices. Some of these have either directly seriously discouraged the successful establishment or the management of

1/ Paper for Symposium on Savanna Afforestation

certain tree species, or have adversely influenced the morphogenesis of nursery and plantation stands, resulting in very poor yield.

There has been very little research conducted on forest and timber insect pests in the savannas of Nigeria. Roberts (1969) conducted the first general forest insect studies in the savanna beginning in 1962, which was in the form of a forest insect survey. This was a continuation of a similar work initiated in Nigeria by Eidt (1963), but which was then restricted to insect pests of indigenous tree species of only the lowland rain forests. Earlier, the West African Timber Borer Research Unit (WATBRU), with its main activity centre in Ghana, also extended its timber insect research to Nigeria but on a relatively smaller scale. However, detailed biological studies on some important timber insects, mainly beetles, were carried out (WATBRU Reports 1953-58, 1959, 1960, 1961-62). In addition, effective methods of control of termite in young Eucalyptus plantations were initiated by Lowe in 1960. Further experiments were also carried out by Sands (1962 a, b). It is now the normal practice to treat Eucalyptus seedlings for termites before they are planted out in the field.

The forest disease survey of Parker (1964) noted a number of plantation and nursery diseases in the savanna areas of Nigeria. Most of these were at that time causing only minor damages, notable exceptions being damping off diseases in some nurseries and the root rot of E. camaldulensis at Okene caused by Polyporus sp.

As teak planting became extensive in the savanna areas, the root rot of the genus became so significant that much attention was devoted to it (Momoh, 1973 and 1974). Other disease problems relating to plantation establishments in the savanna have also been recorded and studied briefly or in detail (FAO, 1970).

MAJOR INSECT PEST PROBLEMS

The savanna forests have had less frequent serious outbreaks of insect pests compared to the rain forests. The major reason for this is probably climatic. Nonetheless, there have been sporadic insect problems of major dimensions.

Perhaps one of the major serious insect problems is found on the mahogany. The mahogany is a composite name embracing the group of trees in the Meliaceae family. This family represents some of the most prized and popular indigenous tree species of local and export value. In Nigeria, all members of one subfamily, the Swietenoideae, are attacked by the well-known "Mahogany Borer" Hypsipyla, a pyralid, and closely related species. They attack the shoot, stem, bark, flowers and fruits of the host trees. The impact of this pest generally discourages the establishment and successful management of the susceptible species. However, in the savanna Khaya senegalensis, aptly called the savanna mahogany, is the more widely planted (as shade trees) particularly in the northern Guinea and Sudan zones. In the derived savanna, K. ivorensis and K. grandifoliola are examples of the other common plantation mahogany species. All these are similarly severely attacked, although, according to Roberts (1969), there are usually fewer generations annually than in the rain forests of the south.

There are a number of other insect pests of the mahogany, but the impact of these is much less severe than that of the Pyralid borers. A few important defoliators and borers include: Pachypasa denticula Bethune-Baker (Lasiocampidae); Pseudobuneae epithyrena (Maasen & Weyding), Lobobuneae christyi Sharpe, Nudaurelia dione (Fabricius) (Saturniidae); Cryptoblabes ghidiella (Milliero), Pyralis manihotalis (Guenee) (Pyralidae), the calliphorid fly Lucilia cuprina (Wiedmann) and a host of others, including some beetles. Some of these pests have a wide host range. For example, Roberts (1969) found P. denticula to occur throughout most of the savanna and was recorded on Eucalyptus camaldulensis, the favoured host, E. deglupta, E. microtheca and E. tereticornis. The larvae of this species attacked eucalypts of between 3-16 years old, while they attacked as much as about 18% of older stands measuring 14-20 m high.

The major insect pests of Daniellia spp. are some of the beetles which attack felled timber and lumber. Others are those which attack wood and feed on cambium of plantation and natural trees. However, much of the infestation is apparently secondary because often predisposing factors such as reduced vigour or mechanical damage, play important roles. Among the beetle timber borers of D. oliveri are the longhorn beetle (Cerambycid) Plocaederus viridipennis (Hope) which attacks felled as well as living trees, and Pachydissus camerunicus Aurivillius. In the latter case, a heap of dust under a severely attacked tree is diagnostic, and occasionally heavily attacked trees are killed. The condition of predisposed trees may be worsened by the following insects: Xyloperthella crinitarsis Imhoff a common polyphagous species, Sinoxylon ruficorne Fabricium (Bostrychidae); and certain colydid and curculionid species.

Isoberlina doka is another common indigenous savanna species which is attached by a host of insects, major among which are certain Lepidoptera. Two of these, Elaphrodes duplex (Gaede) and the processionary Epanaphe moloney, (Druce) (Notodontidae) are defoliators of I. doka, the former to such a serious level that attacked trees are often completely stripped. The Lasiocampid G. rufescens is also a serious defoliator, but such heavy defoliation is usually localized.

The noctuid Crypsotidia conifera Hampson severely defoliates certain Acacia spp., especially A. albida. It is capable of causing up to 50% defoliation on large trees. Among the other numerous insect pests of the Acacias is the noctuid Pandesma anysa Guenee, whose habit on its host is similar to that of C. conifera, and Characome nilotica Hmp., which attacks fruits of A. nilotica; and the psychid Cryptothelea junodi (Heylaerts), which is a widespread defoliator of the Acacias. Recently a new, undescribed insect species was reported severely attacking Acacia nilotica. The weevil, Pachyonx sp. bores the shoot of the host and forms galls. It is considered to be a potentially dangerous pest which has affected about 150 acres of plantations. Other important hosts of C. junodi include the exotics Eucalyptus camaldulensis, E. deglupta, the particularly favoured E. torelliana; and the native Anogeissus leiocarpus and Bauhinia rufescens. Certain species of eucalypts also suffer attack by Bunea alcinoe Cram, a saturniid defoliator whose wide host range also includes some species of mahogany, Balanites aegyptica and Cussonia bateri.

Other insect pests also occur on the eucalypts and these include defoliators, miners, rollers, and case bearers, apart from the damage done by wood and cambium coleopterous borers as well as girdlers. The former group is of more importance during the production stage as it affects the condition of the hosts to various degrees. More serious however is the damage done to Eucalyptus spp. by termites. Usually, eucalypts have to be treated at the nursery or early plantation stage against termite infection. A lack of treatment might lead to excessive losses 1/.

Termite attack also occurs on some other exotics but is normally less significant or only secondary on species like pines, neem and Acacia. According to Lowe (1960), termite attack had been a deterrent to the establishment of eucalypts in the savannas, although some treatments against termites have considerably improved the situation. Thus, the impact of termites on forestry development, especially in the savanna, cannot be overstressed, not to belittle their role in the biodeterioration of wood in storage, transit and use.

1/ See Laurie (1974) for use of insecticides dieldrin and aldrin for protection against termites.

The widespread orthopteran Zonogerus variegatus L. (Pygomor Phidae) feeds on pines, but with no severe effect. Generally, the pines, Gmelina arborea and Azadirachta indica, among others, are attacked by only few insects. Dalbergia sissoo and the eucalypts, on the other hand, suffer attack by the Diacrisia lutescens (Walker). This arctiid is found in nurseries and plantations. Also Tectona grandis harbours some insects but the damage done, though sometimes to a significant dimension, has not often caused serious concern. In general, numerous other insects have been recorded on various tree hosts in the savanna, but apparently most of these have been within tolerance levels and have so far been contained by the respective hosts.

MAJOR DISEASE PROBLEMS

The most economical plantation disease that has been recorded in Nigeria is the root rot of teak (Tectona grandis Lin. F.) caused by Rigidoporus lignosus (Klotzsch) Imazeki. The disease occurs widely in the derived savanna areas of Nigeria, except in Nimbia. The percentage death due to this disease varies from one locality to another. A loss of about 30% has however been recorded (Momoh, 1974) at age 5 in Egabada (Idah area).

The disease is more severe on poorly drained sites, although it is capable of occurring over a wide range of geological formations. The first visible signs of the disease are normally yellowing leaves which tend to drop prematurely. These visible symptoms however only develop after a severe infection of the root system and the host is on the verge of death (Momoh, 1973). Sporocarps may or may not develop on the affected host.

Teak trees have also been found to die in some localities from a die-back disease caused by Stemphyllium sp. The pathogen is closely followed by Beltrania.

Although Eucalyptus spp. are widely grown in the savanna zone of Nigeria, its diseases have been few. A Ceratocystis sp. has been found to be associated with water stress in the death of E. robusta in a few areas. Such deaths only occur at the peak of the dry season. Unidentified bacteria have also been found to cause necrosis of leaves on E. camaldulensis.

In some parts of the southern Guinea savanna there has been sporadic occurrence of the root rot of gmelina (Gmelina arborea) raised from stumps. Such infections also sometimes occur on stumped teak and are normally due to fungi of a wide host range such as Geotrichum and Gloesporoides.

Species of Pestalotia and Pestalotiopsis are frequently associated with the die-back of a number of plantation trees. They have also been found to be associated with the necrosis of ageing needles of various pines. Nigeria (and the rest of West Africa) has so far not suffered from the notorious Dothistroma blight of pines, but Pestalotia is known in East Africa to be sometimes associated with such blights on Pinus radiata which is not an important plantation species in West Africa. Nevertheless, the common occurrence of Pestalotia in West Africa gives food for thought and vigilance.

At the nursery level, damping off disease is experienced to varying degrees in a few localities. The disease is no longer significant in many nurseries which have developed valuable techniques and which use container "pots" rather than germination beds or boxes for raising seedlings. The common damping off fungi include Rhizoctonia solani and Fusarium spp.

Timber harvest is currently done only in areas of the derived savanna. The harvested species include various light coloured timbers that are susceptible to the blue staining fungus Botryodiplodia theobromae. Infection is more severe in the wet season than the dry season (Momoh, 1966). It can be controlled by quick extraction followed by rapid conversion and drying. As infection can occur within a few days, chemical treatment immediately after felling is desirable if logs are to be left in the green state for up to a week or more. Different chemicals can be used for spraying or dipping (Momoh and Oluyide 1967, Momoh and Akanbi, 1969).

CONCLUSION

Although preliminary diseases and insect pest surveys have been carried out in the savanna areas of Nigeria there is a need for constant vigilance and further periodic surveys to ensure that any disease or insect pest outbreak is cited and curbed before extensive damages are done. The root rot disease of teak and the *Pachyonyx* attack on *Acacia* are clear indicators of the necessity of a continuous survey. Such sudden outbreaks of diseases or insect pests have also been noted in savanna areas of other parts of Africa. The 1972 outbreak of *Phoracantha recurva* in Zambia, a sporadic outbreak of *Plagiotriptus pivinorus* in Malawi and the root rot of *Eucalyptus* caused by *Phaeolus manihotis* in Ghana are other notable examples.

Thus it is desirable to have a periodic routine survey for diseases and insect pests in forest nurseries and plantations. These natural human enemies know no political boundaries. A close cooperation between the pathologists and entomologists of different nations is therefore essential.

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PROTECTION OF PLANTATIONS AGAINST ANIMALS AND MAN [1/]

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CONTENTS

1/ Paper for Symposium on Savanna Afforestation

In recent times sufficiently successful methods of establishment of forest stands in the savanna areas of Nigeria have been developed.

During plantation establishment and maintenance, foresters met with many problems, dangers and various bottlenecks before achieving their desired objectives. The most difficult problem that has plagued foresters in savanna regions has, however, been the protection of plantations against the biotic elements of the environment. For this reason, various methods of protection have been devised over the years, all with varying degrees of success. Of the biotic factors, man and animals present a special type of problem. This paper deals with some aspects of the methods presently in use to protect plantations against man and animals in Kano State in particular and the savanna zones in general.

The general methods of protection include fencing, mass propaganda, cultivation, and keeping of watchmen.

FENCING

This method is found to be equally successful in keeping away both men and animals from plantations. The presence of a fence impresses upon any individual the fact that the area fenced is out of bounds, as this practice is even common among indigenous people as a means of protecting their private properties.

In Kano State, forest plantations are fenced using 4 feet (1.2m) high cattle fencing wires supported by 6 feet (1.8m) high azara (Borassus aethiopium) posts spaced 10 feet (3m) apart with one strand of barbed wire about 4 inches (10 cm) above the fencing wire. Alternatively, four strands of barbed wire spaced horizontally about 2 feet (60 cm) apart up to a height of 5 feet (1.5m) on Borassus posts is sometimes used in the absence of cattle wire.

These methods have been found to be effective only in keeping off man.

A slight modification of the first fencing method described above has been found to be effective against cattle.

Fencing a plantation by using 4 feet (1.2m) high cattle fencing wire attached to 6 feet (1.8m) azara posts spaced 10 feet (3m) apart and putting only one strand of barbed wire in the middle is highly effective in preventing cattle damage. Since cattle do not feed on Azadirachta indica (Neem), Eucalyptus species, and Cassia siamea (Kashiya), unless in extreme drought conditions, in a plantation of these species the fence could be removed two to three years after stand establishment or when the species close canopy. But in case of Khaya senegalensis (Madaci), Dalbergia sissoo (Dalbegia), Acacia nilotica (Bagaruwa), Acacia albida (Gawo), etc., fences should not be removed until the planting stocks reach a height of up to 15 - 20 feet (4.5 - 6 m). Also, if exploited the coppice should be fenced until they reach the same height before the fence is removed.

The goat is readily the most notorious animal causing damage in plantations. It feeds on almost anything green. The thorns which characterize the Acacia species do not deter this animal from browsing freely on shoots of the species. Also, because of its size, it can easily squeeze through small openings which can keep away man or cattle. Effective fencing against goats consists of using 4 feet (1.2m) high pig or cattle wire attached to 6 feet (1.8m) high Borassus posts spaced 10 feet (3m) apart but with two strands of barbed wire. One of the strands of barbed wire should be on top, while the other is in the middle of the wire netting. In addition, earth mounds are made at the base of the wire netting to cover the first two horizontal strands of the wire netting. This is to prevent the goat from slipping underneath the wire at ground level. Openings or entrances should be minimized along the fence. It is advisable to use ladders located at convenient points along the fence as a means of gaining entrance into the fenced area.

The above method is equally effective in keeping out sheep.

One or two strands of barbed wire alone have been found effective in keeping off camels.

Except in remote forest reserves, damage from wild animals is not likely as the areas in which forest plantations are located are generally in localities that have been continuously under cultivation for decades. It is thought, as of now, that the fencing method used for keeping out goats will be sufficiently effective in keeping out some wild herbivors.

MASS PROPAGANDA

This could easily be one of the most important methods of protecting plantations against man if well organised. However, experience has shown that this method does not work in sparsely populated areas. This system usually involves the broadcast of instructions in public places such as markets, festival squares, churches, and Friday Mosques, etc., that specific areas have been declared out of bounds. It is usual to stipulate a penalty of either a fine or term of imprisonment or both for offenders.

Sometimes radio discussions on the reasons for protecting these areas are held in local languages. Documentary films are also shown on mobile cinemas to get the message across to the population.

However, people are still known to trespass without being caught in spite of the propaganda.

CULTIVATION

This is a method of protecting plantations against incidental activities of man. In the savanna areas of Nigeria, various species of grasses are commonly used for thatching of roofs, mat-making and as fodder. People therefore go about collecting these grasses in plantations and very often set fires to the grasses intentionally as a means of promoting their active regrowth. Sometimes the fires are set maliciously. Clean cultivation is normally carried out in August and January in newly established plantings to keep off the grass. In Kano State, cultivation is done mechanically.

KEEPING OF WATCHMEN

In addition to a fence, a watchman (locally known as a maigadi) should be employed in an area with over 100 acres (40 hectares) of forest plantation. It has been found that in a plantation with over 100 acres (40 hectares), fencing alone could not suffice unless a proper watchman is employed to look after the area.

The main duty of a watchman is to cater for the general welfare of the plantation. This includes the repair of fences, reporting any out-break of diseases, pests, fires, etc. His main attributes should be high influence among the entire people of the area, fearlessness, devotion to duty and knowledge of the area or beat he is watching.

Experience has shown that putting a watchman in an area is much better and more economical than fencing a whole area with chain links if it comes to the protection against man's atrocities.

It is important to mention that protection is an expensive item in forest plantation establishment in the savanna areas (especially in the Sudan zone). Cost analyses of fencing in Kano State are shown in Tables 1 and 2 following. Cost figures shown do not include supervision. Fencing cost alone is known to account for about 70% of the cost of establishing plantations in the Sudan zone in Kano State.

COST ANALYSIS FOR FENCING 100 ACRES PLANTATION OF DIMENSIONS 40 x 25 CHAINS

Specifications

1. Shape of plantation: rectangular (40 x 25 chs)
2. Perimeter: 130 chains (8580 feet; 2574m)
3. Azara interval: 10 feet (3m)
4. Strands of barbed wire used: 2
5. Number of bindings against azara posts: 3
6. Length of fencing wire: 165 ft (50 meters)
7. Length of barbed wire: 660 ft (220 meters)
8. Length of binding wire: 1000 ft (333 meters)
9. Length of azaras: 6 ft (2 meters)
10. Cost of cattle fencing wire: ₦30 (about U.S. $48)
11. Cost of cattle barbed wire: ₦20 (about U.S. $32)
12. Cost of cattle binding wire: ₦20 (about U.S. $32)
13. Cost of cattle asara posts (12') - ₦1.20K (about U.S. $1.92)
14. Labour for fencing: 3 man-days/acres (7.5 man-days/hectare)
15. Labour for trench making: 5 man-days/acre (12.5 man-days/hectare)

COST

MATERIALS	NO OF ITEMS NEEDED	COST PER UNIT	TOTAL COST (100 acres)	REMARKS
Cattle fencing wire	52	₦30.00	₦1560.00	
Barbed wire	52	₦20.00	640.00	2 strands
Binding wire	3	₦20.00	60.00	
Azara posts	430	₦1.20	516.00	(to be cut into 2)
Cost of materials			₦2776.00	
Labour for fencing			525.00	
Labour for trenching			875.00	
			₦1400.00	
Grand Total			₦4176.00	

Cost per acre ₦41.76 (about U.S. $67)

Cost per hectare ₦104.40 (about U.S. $167)

COST ANALYSIS FOR FENCING 1 MILE OF SHELTERBELT

Specifications

1. Shape: linear, 1 mile by 110 feet (1.6 km x 33m)
2. Perimeter: 10780 feet (3593 meters)
3. Azara intervals: 10 feet (3m)
4. Strands of barbed wire used: 2
5. No. of bindings against azara posts: 3
6. Labour for fencing: 60 man-days
7. Labour for trenching: 100 man-days

COST

MATERIALS	NO. OF ITEMS NEEDED	COST PER UNIT ITEMS	TOTAL COST (1 MILE)	REMARKS
Cattle fencing wire	65	₦30.00	₦1950.00	
Barbed wire	34	30.00	680.00	2 strands
Binding wire	8	20.00	160.00	
Azara posts	1078	1.20	1293.60	(to be cut into 2)
Total for materials			₦4083.60	
Labour for fencing			105.00	
Labour for trenching			175.00	
Grand Total			₦4363.60	(about U.S. $6980)

N.B. Number of acres (hectares) for the above dimension - 13 acres (5.2 hectares)

Average cost per acre - ₦335.66 (N839.15 per hectare)

Cost per acre (hectare) of agricultural land protected at interval of 700 feet (210m) between belts - ₦48.00 (₦120.00 per hectare)

N.B. With reference to the tables of cost analysis, it could easily be seen that it is much cheaper to fence a plantation with more or less equal dimensions. Wherever possible, the shape of plantation should not be linear unless the desired objective is shelterbelts.

It is found that very good cattle fencing wires could continuously be used up to ten years. Also, black and matured azaras could be used for about six to ten years. Except in extreme cases, barbed wire could be used for well over two decades.

FOREST PLANTATION PLANNING AT THE NATIONAL LEVEL 1/

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CONTENTS

THE NEED FOR PLANNING

Foresters have for many years realised the need for planning because the long rotation of their crop meant that mistakes were both time-consuming and costly. The framework of their planning was the working plan, which gathered together information on a particular area and from this prescribed the action that was to be taken over a period of years to achieve the objects of management of the plan. At its simplest the working plan might prescribe no more than that records should be kept, but it is often from this repository of information that modern plans are made up.

The traditional working plan did not, however, take into account the interactions with other sectors, nor even between working plan areas within the forestry sector. The plan period was generally 10 years, but if conditions changed during that time it was necessary to get sanction from the highest authority to change the prescriptions. Although annual records were maintained, performance was not always compared with the plan targets.

1/ Paper for Symposium on Savanna Afforestation

Modern planning seeks to take into account the needs of the country and to set objectives for supplying them. Planning is the means of forecasting how those directives may be achieved, but also retaining sufficient flexibility so that the plan can be altered to meet changing circumstances quickly. For this to be done, there must be a constant flow of accurate information from the project or sector which can be readily analysed.

THE NATIONAL DEVELOPMENT PLAN

Most countries have a national development plan whose objectives are the outcome of political processes. In the long term the objectives may be unquantified and generalised, e.g. "to improve the standard of living of the people", but in the short term the objectives may be quantified, e.g. "to produce enough pulpwood to meet the country's requirement before the end of the five year period". The task of the planners is to formulate the methods by which the objectives will be achieved, and some of the objectives may in fact become constraints in certain sectors.

Forestry will have an important place in the national development plan of many countries. Demand for forest products is increasing rapidly and there is also the attraction that development takes place in rural areas.

PLANNING IN THE FORESTRY SECTOR

Regardless of the structure of the forestry sector (i.e. the division between State control and private enterprise) there must be an overall policy. This is a statement of the objectives laid down for the forestry sector.

Within the forestry sector, a planning unit should be set up to determine the means of achieving the objectives of the policy. In order to do this, the organisation should be capable of:

1) collecting and analysing the data;

2) formulating alternative courses of action for attaining the objectives;

3) evaluating the choice available according to various criteria; and

4) monitoring the implementation of the plan and taking the necessary action to correct it as conditions change.

The planning unit must first identify the services and products demanded by the sector. Table 1 illustrates this for Nigeria, and similar trends are apparent in other African countries.

TABLE 1

Projected Demand for Forest Products in Nigeria

	1974	1980	1990	2000	Units
Sawnwood	900	1600	3500	7000	'000 m^3
" per caput	0.012	0.019	0.032	0.047	m^3
Plywood	45	80	175	350	'000 m^3
" per caput	0.0005	0.0010	0.0016	0.0023	m^3
Other panels	12	66	245	446	'000 m^3
" " per caput	0.00016	0.00078	0.00230	0.00300	m^3
Paper and particle board	110	210	600	1400	'000 m^3
" " per caput	1.5	2.5	5.5	9.0	kg
Roundwood Conversion					
Sawlogs		2300	5000	10000	'000 m^3
Peelers		240	530	1000	"
Pulpwood		840	2400	5600	"
Total m^3		3380	7930	16600	"

Source: FAO High Forest Development Project,
Federal Department of Forestry, Ibadan.

In addition to the demand for products, there will be a considerable demand for services, such as shelterbelts, erosion control, etc., which will be mainly supplied by plantations because there is unlikely to be any natural tree cover where these services are required. Plantations are likely to be preferred for the supply of products too, because industrial uses require that the raw material is of uniform size with little variation in quality.

An estimate of the forest areas required to meet the likely demand can next be made. This should take into account future improvements in the efficiency of conversion, the effect of substitutes and the increased use of so-called secondary species. Present areas of natural forest and plantations are generally well knwon through the records that are maintained in working plans, etc. It is, however, important to ensure that these figures are obtained by physical survey and are not estimates of doubtful accuracy.

Yields of natural forest types and plantation species must next be determined. In the natural forest, low sampling intensity inventories have been carried out in most countries, supplemented by high intensity stock-mapping undertaken by, or for, the logging companies. There is thus a good idea of the present yields, but future yields may be less easy to predict because secondary species have not been included in the past. A further disadvantage of previous inventories is that they often made no allowance for defect or grade of log. Both of these points need to be incorporated into present day inventories to allow for technological changes that will in the future permit more complete exploitation of the natural forest.

Yields of the main plantation species have been studied in many countries, and sample plots have been laid down to obtain data for the construction of volume and yield tables. Preliminary volume tables for the smaller sizes have been produced in several countries for the main plantation species planted in the savanna, but often yield tables await the acquisition of more data as the crops are usually fairly young. The importance of establishing permanent sample plots as a routine in all plantation areas cannot be over-stressed; besides providing data for volume and yield tables, they will provide estimates of compartment yield (supplemented by temporary plots) and they will monitor the performance of the crops through the first and subsequent rotations, an important consideration in view of findings with some exotic crops that production falls off in the second rotation.

PLANTATION PLANNING

Although it may be necessary to meet much of the demand for services and products by the creation of plantations, they must always be seen as part of the whole integrated forestry sector and not be considered in isolation. The time, the location, the size, the species and the technology to be used in the establishment of the plantation must all be considered, and in evaluating the benefits there must be knowledge of the product, the quantity, the type, the price and the date that it will be available.

The planning body for the forestry sector must identify projects which will be the means by which the plantation programme will be carried out. It is important that this body is not seen as the sole source of ideas for projects, because often line managers may have a better idea of the sort of projects that are possible within certain constraints of site, staff capabilities, etc. Close contacts should be maintained too with the organization responsible for forestry research so that promising lines of study may be developed at any early stage. In fact, planning, research and management services (such as inventory) should all be part of the same organization.

After possible projects have been identified and a preliminary screening has been done, project proposals must be drawn up for each. Watt (1973) has listed the essentials of a project design for presenting to decision makers. They include studies of technical, commercial, financial, economic, organizational, social and political aspects and the way in which the project would be financed. The criteria for selection between projects have been summarised by Adeyoju (1975) as: maximum volume, employment, balance of payments, profits, net discounted revenue (NDR), internal rate of return (IRR), value added, output, capital ratio, social marginal product, benefit/cost ratio, marginal per capital reinvestment and net social benefit.

NDR and IRR are the criteria most generally quoted, and sufficiently accurate data on costs and returns can usually be collected to make the figures obtained reasonably reliable. Criteria based solely on direct economic returns such as NDR, IRR, profits, value added, etc., present only part of the picture, and may lead to a choice of project which conflicts with government social policy. Other benefits are therefore also calculated, and two of the most frequently used are employment and net social benefit. Employment may be measured as the number, the type or the location of new jobs created, or in terms of net value added, cost per new job or the effect on the re-distribution of income. The saving of foreign exchange is frequently quoted as a criterion for the evaluation of pulpwood projects in particular, but in fact it may be illusory, for in such a capital intensive industry the benefits of home production may be more than outweighed by the cost of imported machinery or raw material and the cost of servicing loans. There is increasing world shortag of pulp which makes it necessary for Nigeria to satisfy this need in the rapidly expanding home market and perhaps also for the export world. Inflation makes it better to invest now rather than to delay into the future.

In order to select between projects, they may be ranked according to several of the criteria, but even then the final choice may be influenced by other factors. These include interactions with other projects within or outside the sector and the flexibility of the project to adapt to unforeseen circumstances, in particular inflation.

The monitoring of the performance of the project against its targets will largely be done within the project as will much of the adaptation of the methods or targets to meet local conditions. There will, however, be a need for monitoring at the national level for continuing interactions between projects, reactions to national policies and evaluation of the performance of the project. The sectoral planning unit will also be responsible for co-ordination between projects.

IMPLICATIONS OF A NATIONAL PLANTATION PROGRAMME

Where it is decided that all or part of the national requirements of forest products and services may best be met at some future date by the creation of plantations, there may be implications far outside the forestry sector.

The first is that forestry may be an excellent means of implementing government plans to raise the rural standard of living and check the drift to the towns. For example in Nigeria, it is hoped to achieve this through rural forestry development projects such as agri-silviculture, promotion of the development of farm wood lots and communally owned forest plantations. Large labour forces will be required near the plantation, and it will be necessary to house the workers and offer various social services if a permanent, skilled labour force is to be retained. But full time employment of labour will remove them from subsistence farming where they worked mainly to feed themselves and their families and to sell surplus foodstuffs.

Labour forces are still likely to grow a small portion of their food requirements outside working hours, but in order to supply their total needs and to produce more food for the rest of the population, large agri-silvicultural schemes will have to be developed, based upon the proper planning of the potential of the land for growing various crops. The savanna and derived savanna are potentially suitable for this as they have high rainfall during the growing season and high sunshine hours during ripening and harvest of grain crops. This will require some degree of mechanization for the following reasons:

1) Scale. Manual methods on the scale of most large plantation schemes would impose an enormous administrative and managerial burden.

2) Timing. Several operations, such as the sowing of crops, have to be done in a very short period.

3) Cost.

Compared to most developed countries, however, the labour component will still be high, especially in nurseries, for planting and in some maintenance and harvesting operations.

It will be necessary, too, to integrate the present timber industry more closely with the plantation schemes to get the most suitable areas of high forest harvested at the right time. More coercion may be necessary to force the industry to take more of the secondary species in order to clear the land more thoroughly.

More training in managerial techniques for graduate staff will be required, possibly with a reduction in biological studies. More specialists will also be required, and there will be a need for re-training staff at frequent intervals to update their skills. In order to speed up reporting, it is likely that the traditional line of command may be short-circuited in order to produce figures for speedy monitoring.

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PLANNING OF SAVANNA PLANTATION PROJECTS [1]

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CONTENTS

[1] Paper for Symposium on Savanna Afforestation

INTRODUCTION

Foresters are long established as planners and managers. The traditional "working plan" provided a basis for effective continuity, and by collecting records a reasonable base for future planning was built up. Modern planners (Johnson, Grayson and Bradley, 1967) have suggested that these plans have three main deficiencies: they lack flexibility; there is no definition of criteria by which to judge the relative success of alternatives; and the planning was generally only at the forest level.

Planning is used to describe anything from a series of arbitrary decisions to a critical and sophisticated investigation into the whole range of possible choices open to an enterprise. The planning of a savanna afforestation enterprise will be considered in the following sequence: 1) the "outline project", 2) preparation of the "detailed project" and 3) preparation of the "project planting plan".

Subsequent to the planting or establishment plan it would be necessary to incorporate or prepare a plan for exploitation, but that consideration, which increases the complexity of planning, lies outside the scope of this discussion.

The main reason for planning a project is to maximise efficiency, so that the plan will represent the most efficient courses of action to achieve the stated objectives. The final form of a sound plan results from a process of successive approximations, and many possible activities may be repeatedly analysed with different data, but in the final analysis that what is planned on paper should be realised on the ground.

THE OUTLINE PROJECT

The outline project may be generated by a forest department or by the national planners. One of the first essentials in identifying a project is a measure of the supply and demand for forest produce which should indicate where priorities for development might occur. For instance in Nigeria, Thulin (1966 and FAO, 1970) prior to 1970 carried out a survey of the general consumption of wood products in the savanna region and of possible trends in the aggregate levels of consumption for such products in the future. More recently Enabor (1971) examined the position on a national basis. Such estimates of future consumption provide a useful framework for examining resource allocation and research needs for the forestry sector in relation to the national economy. Supplemented by input and output data, these estimates form the main basis of outline projects but are insufficient for the detailed planning and analysis of a particular development project.

From such data, the national or development planners should be able to indicate on a national or sectoral basis the extent and priority for forest development. This project generation and selection should form a preliminary process prior to detailed project planning. From a possible selection of outline projects or proposals the forest planners in turn will allocate priorities and select those which merit immediate planning in greater detail. Such projects should be technically feasible and commercially viable. This choice of outline projects represents selection and priority at the national level.

THE DETAILED PROJECT

On the assumption that the national planners have agreed on the need for afforestation and have broadly outlined a savanna plantation project, the next task is to prepare the detailed project. An afforestation project may vary in size from the planting of a few hectares for shelter or soil protection, to a large-scale scheme extending over 10 to 30 years and involving considerable investment. It is with this latter type of large-scale project that this paper is mainly concerned. It is obviously impossible to implement on an ad hoc basis a large-scale planting programme involving complex establishment systems without plunging the enterprise into chaos. To make such an enterprise efficient requires planning, and the objects of planning are:

1) to minimise costs in achieving specified ends;

2) to ensure that aims are likely to be achieved in practice by anticipating constraints;

3) to provide continuity; and

4) to provide estimates of the resources needed and the time sequence in which they will be required.

The detailed project is essentially a document setting out objectives, recording whatever data relevant to the project are available, considering alternatives and indicating what programme should be completed and when, and putting values on inputs, outputs and the project as a whole. At an early stage of development it is essentially a paper exercise based on the best available information, indicating the economics of the enterprise under specified assumptions and conditions. It provides the evidence which allows higher authority to decide whether and on what basis the project should be approved and financed. Once approved, it provides the basis for operational planning, budgeting and implementation. The more sound the planning the easier the subsequent implementation. Planning the detailed project falls into three main phases: 1) objectives, constraints and criteria, 2) data collection and 3) appraisal and decision.

Objectives, Constraints and Criteria

The outline project may have broadly based and possibly multiple objectives which require clarification in the detailed stage. Objectives have to be attainable, clearly defined, consistent and quantitative (FAO, 1973). The refinement of generally stated objectives for detailed planning purposes, can reveal limitations in the original concept requiring adjustments. Again, having determined objectives, subsequent preliminary calculations may result in further changes of priority or modification of aims. For example, the project objectives may be:

1) to produce x m^3 per/annum of wood for local industry;

2) to be labour intensive; and

3) to earn y percent on capital invested.

Subsequent study might show that as supervision is limited, the required labour force cannot be employed and the rate of planting required to attain objective (1) cannot be achieved. Or it may prove impossible to earn the required rate of interest and be labour intensive simultaneously. Such conflicts would require a replanning of the objectives and consideration of the more efficient alternatives.

Constraints are limitations imposed on the activities of a project and are generally inflexible, although in certain circumstances it is possible to remove or adjust a constraint when so doing materially improves the project. It is convenient to consider constraints in the following categories:

1) Technical: These are constraints which impose restrictions on the methods used or products created - for example, the mosaic pattern of plantable land affecting layout or technique, or the unsuitability of certain eucalypts to sawing or preservation.

2) Financial: These may be represented by restrictions on the financial resources available, or obligations to meet repayment of interest and/or capital, or erratic provision of funds.

3) Social and Economic: These can be related to opportunity costs, in that the resources being used for the project are not available for use elsewhere.

4) Institutional: These are limitations imposed by the organisational and managerial ability of the agency executing the project, by the legal framework and by the social patterns and attitudes of the local people.

Criteria are used to ascertain the ability of a project to achieve its objectives. They also provide a measure against which alternative methods of achieving the objectives can be compared and evaluated. A good criterion is applicable to all alternatives and should be readily calculable to provide in a single figure, all the information needed for decision making. One of the better known economic criterion for measuring the profitability of a project is "net discounted revenue", or the "present worth" of the future benefits created net of the capital and operating costs. Other criteria which might be applied are measurements of employment created, rate of loan repayment or, on a technical base, the rate of tree growth and the area planted annually. Where expertise is limited and where the availability of management is restricted, it is advisable to limit as far as possible, the number and complexity of objectives and criteria.

Collection of Data

Much of the background data such as methods, costs and yields required for the formulation of a project have to originate from established plantation research or development in the area. Information on demands, and value of produce requires a market study. Although it is necessary to have a reasonably clear idea of what the aims of a project are before collecting data, it may not be possible to specify attainable objectives until after certain data have been gathered.

Data are collected from best available sources to allow the construction of a realistic plan. Such data may indicate possible alternative courses of action which can be evaluated to facilitate decision making. Where data are lacking, it may be necessary to postpone planning and design systems to collect necessary figures. Any sectoral or outline planning which has occurred prior to defining projects will contain some relevant data but often too generalised for detailed planning. Data for project planning, in addition to being detailed, tend to be of a more technical nature as they will serve to specify operations in practice.

The data required for a plantation project may be classified into five categories: 1) resource data, 2) operational data, 3) market and yield data, 4) socio-economic data and 5) institutional data.

Resource data

The main resources to be considered are land, planting stock materials and equipment, human and financial. The required information on each is availability, productivity and cost.

Land resources: The first essential is sufficient plantable land to accommodate the project planting programme; indeed, excess land is required to allow for unforseen problems and possible future expansion. Where tribal or other legal rights affect the use or availability of land, such matters require clarification before further planning is undertaken.

In the early stages of development it is not possible to assign site quality classes to soil types, but a simple plantability classification can indicate the better areas for planting. The assessment of plantability requires a soil survey of the type outlined by Barrera (1969 and 1976) for Nigeria or Sanders (1967) for Zambia and the preparation of maps showing soil types, vegetation types and plantability. At the same time as the vegetation is recorded the tree cover should be sampled for basal area to give a measure of tree density, a major factor in land clearing.

Established growth trials of plantation species should indicate the productivity for the range of plantable sites. There is some merit in planning to plant the better sites whilst research and growth trials produce further data on secondary or marginal sites. If no growth data are available, a full project is premature and a well planned pilot project is a reasonable alternative. Where forest reserve land is available there are no direct costs for the resources, but where land is acquired by purchase or compensation, such costs are recorded and debited. The annual planting land requirements should be allocated using the plantable land map.

Planting stock resources: The primary requirement is an adequate and sustained supply of seed of the selected species and provenances. Selection of species is a major subject but it is presumed that species and provenance trials have been extensively evaluated prior to the preparation of a large-scale project. Seed supplies often prove major bottlenecks to the proposed rate of development. Sources of supply and storage facilities should be thoroughly determined. If importation represents a risk then local seed production and methods of expediting this must be given priority. Availability of seed must necessarily have some influence on the planting rate of species previously selected for silvicultural and utilisation reasons. Seed is readily raised to planting stock provided that the nurseries and expertise are available to produce sufficient quantity of adequate quality seedlings at the required time. When purchasing seed it is the cost per plantable seedling and not the cost per unit weight which is of consequence. The annual requirements of seed and seedlings and costs should be detailed.

Material and equipment resources: These fall into three main categories: those required for the administrative organisation, for operational activities or for maintenance and support. Administrative requirements include offices and buildings and minor items such as office equipment and stationery which are common to any enterprise. Operational materials and equipment are specific to plantation development and a general outline is listed in Appendix A. Maintenance and support items include workshop equipment, transport and spare parts. The critical factors with reference to stores, are firstly to select those items suited to the particular work and scale of the project and to ensure that such equipment or materials, together with spares, are available on site when required, which necessitates the provision of ample storage.

Equipment offers a considerable range of options, and past experience shows that operational data and selection of methods are required before the field of choice can be narrowed. Land clearing, for example, if by hand requires extensive supplies of hand tools. If, however, for reasons of efficiency this operation is to be mechanised, then clearing should commence one year before planting, and the order for clearing equipment would require to be placed at least two years before planting. If only mechanised clearing is feasible and the scale of operation does not merit purchase of a chaining unit, then such alternatives as sharing this activity with another project or projects, employing a different mechanised technique, or hiring equipment need to be considered and evaluated.

The productivity of equipment is critical to the efficiency of a project. Evaluations of the output of equipment may be of little value unless allowance is made for variables and the basis of measurements is stated (Allan and Akwada, 1976). Good productivity requires as full an annual or seasonal utilisation of equipment as possible. Scale of operation and operational data are required before any stores or equipment requirements can be set out. When the types of equipment and materials have been finalised, an assessment of the total requirements by years should be drawn up for the full period.

The purchase or capital cost of all project materials and equipment is the true cost and is required for estimates, budgets and costing the total project requirements. For comparative evaluations the planner requires the equipment hourly operating cost, which is largely a hypothetical calculation, and from which a unit productivity cost can be calculated.

Human resources: Man is the most important resource in the project, and due consideration of his abilities and reactions is required in deciding on possible courses of action. The possible sources of labour and staff require study, as they determine the need for additional investment in transport or housing. Employees benefit from a plantation project not only in cash wages but also from training, improved housing and security. Hastie and MacKenzie (1967) point out the benefits of employees living in mixed communities rather than exclusive project settlements or villages. A plantation project involves many skills and requires managers, supervisors, mechanics, machine operators, administrative and clerical staff, medical staff and both skilled and casual labour. In particular, if a project is to be selectively mechanised then the provision of a suitable infrastructure employing skilled mechanics and operators is mandatory; and where numbers are limited training will be necessary.

The productivity of labour is variable and often reflects the quality of management and control. Work study, method study and training all contribute to labour efficiency. Initial hand weeding studies in Zambia (Allan and Endean, 1966) increased output by up to 300 percent, and planting studies in Nigeria showed increases of the order of 200 percent to 500 percent. In the early stages of a project there is scope for very large increases in productivity, but even at a later stage improved methods in Zambia (Allison, 1972) were giving 30 percent increases in output which is not insignificant. Productivity can also be improved by the payment of incentives. This is not always easy under government fiscal regulations, but where benefits are significant, sanction for such payments should be pursued.

The cost of human resources is the sum of salary or wages, social and fringe benefits, leave and sick time. The manpower requirements of the project should be set out for staff by years, categories and responsibility and labour is similarly recorded, but operations replace responsibility. To calculate the annual labour force, a calendar of operations and labour inputs not only gives the necessary data but also allows fluctuations in requirements to be smoothed out to provide more regular employment. Information on the productivity and unit costs of labour may be extracted from operational data.

Financial resources: Generally some indication of the finance available for the full project, or a development plan phase of the project, will have been given at the outline stage. The detailed project should be planned to fit this financial framework, but where finance proves to be a critical constraint, the case for an additional allocation should be made. The total costs of the other resources, plus contingency, represent the allocation required, and these figures should be set out as annual requirements for the entire project period.

It is important that the financial authority should understand that a plantation is a dynamic enterprise not readily accommodated in the fiscal year concept. Plantation operations such as land clearing, nursery and weeding are interrelated in time, in that this year's programme can affect both last year's and next year's. This means that delays in funding or erratic allocations will not only effect the year of occurrence, but also past and future investments. Two possibilities of overcoming this problem are either to have the financial authority consider the project as a capital investment until normality is achieved or to make funds available on a three or five yearly allocations. The ready availability of funds, however, does not preclude carefully planning their investment.

Operational data

The data to be recorded in this section for all plantation operations are:

1) unit of measurement - ha, km or '000 plants;
2) input - man-days, machine operating time, materials;
3) output - units per hr, per day, etc. and
4) cost - cost of each resource per unit

These data allow a ready estimation of the productivity of men and machines and of the total requirements of such resources for particular project operations. Where management considers that two or more techniques offer a reasonable choice of operating method, data for each should be recorded to allow comparative evaluation. The collection of operational data is critical and fundamental to the planning process. The information must be the best available. It may be extracted from costing records where available, but when lacking, sampling work outputs as recorded for Ferguson (1973) in Nigeria, provides indicatory data. Operational data provide a basis for appraisal, for estimating resource requirements, and budgeting; consequently it is vital that the source and reliability of all such data is recorded. A project or plan is only as realistic and workable as the data used in its design.

Market and yield data

The project planner requires information on markets, outputs and the value of different categories of plantation produce. To obtain market data in the probable project catchment area it is necessary to study:

1) the current consumption of different wood categories;
2) the current price level for the different categories; and
3) population trends in this area.

A survey to determine such data is more detailed and specific than a national wood consumption survey. A relevant example is the survey made by Grut (1972) of the market for firewood, poles and sawn wood in the major towns and cities in the Nigerian savanna region. This survey covered eight cities and although sampling was from only 3.5 percent of the population in the area, this sector of the population represented the main cash market in the areas of most rapid economic development.

In addition to recording costs, which may be applied to the different categories of produce, the market survey gives a measure of demand at a particular point in time which, with information on population trends, allows a forecast of demand to be made. Such a forecast identifies factors which may cause changes in demand, and allowing for these possibilities, predicts future demands over the project period.

Data are also required on the estimated yield of different categories of produce from the selected species, noting a specific silvicultural system and rotation for each. The yields are estimated by category and year to the end of the project period. By applying the market survey prices to these yields, the yearly revenue accruing to the project is estimated. In the early stages of a project some of the growth and yield data may be based on minimal evidence and where only young trial plots are available it may be necessary to extrapolate data from elsewhere on the assumption that later growth will be comparable. Where growth data is plentiful, a supply forecast can be made noting possible changes in method, which might alter yields, quantifying the effect of these changes and predicting potential supply under different specified conditions.

To check on the commercial viability of the project the supply and demand forecasts should be reconciled. If the balance suggests a shortfall, then either the project will have to be expanded or produce will need to be imported or substituted.

Socio-economic data

Estimated costs of resources and estimated project revenue give the financial composition of the project but do not fully account for the real cost and the real benefit to the community as a whole. Socio-economic factors attempt to assess these real costs and benefits, but they are difficult to quantify and economists are still developing improved techniques to measure these factors.

The project is essentially a joint production by the practising forest manager with his support services and the forest economist, and it is in determining and calculating socio-economic data that the latter comes into his own. The main socio-economic data required are:

1) shadow costs of labour;
2) opportunity costs of land;
3) discount rate to be used;
4) shadow price of produce; and
5) value of non-marketable benefits.

For an indicative approach to deriving socio-economic data, refer to Ferguson (1973), who completed preliminary studies of the economics of selected savanna plantation enterprises in Nigeria. Socio-economic factors may often seem to be of little consequence to practising foresters, but when projects are in competition with others for limited capital, it is just such factors that can transform a marginal forestry project into a feasible and viable one. Spears (1967) stresses the importance of presenting forestry economic data in the best possible light.

Institutional data

Institutional factors to be noted are mainly of a political nature, but include the project legal framework and the commitment of the supervising agency in other fields, such as training, which might influence the acceptability of the project. Other factors on which information should be collected are the interrelationship of the local community and the project, facilities for multiple land use and information on plantation research in progress but insufficiently advanced for appraisal.

Appraisal and Decision

Having compiled all available information relevant to the project, the appraisal stage consists of the following steps:

1) identifying different courses of action which will achieve the objectives and analysing these for inputs, outputs and costs;

2) testing courses of action against identified constraints;

3) comparing alternatives, using project criteria to determine the better ones; and

4) making final project decisions.

With large quantities of reliable data, appraisal and analysis may be complex and possibly time consuming, although where efficient computing facilities are available the time required for analysis can be greatly reduced. The number of factors which can be varied in the execution of a project and the number of alternative courses of action are almost limitless. Project planners usually operate against target dates and time pressures which necessarily limit the number of alternatives that may be considered. The forest planner restricts the alternatives for analysis to those which are feasible and might give some significant benefit when judged by the project criteria. More obvious areas where different courses of action might significantly affect project results are:

1) planting rate and rotation;
2) spacing and thinning;
3) intensity of management;
4) distance from markets or processing plant;
5) degree of mechanisation; and
6) insurance factors related to timeliness or using a range of species to reduce disease hazard, or selecting species with alternative utilisation possibilities.

At an early stage in the development of a plantation project, with the main criteria being the financial and social net present values per hectare, the following analytical processes, incorporating alternative data where necessary, should indicate firstly the better alternatives and secondly the feasibility of the project:

(1) Financial analysis. Using the national development plan rate of interest, the project "net present worth" is calculated by deducting the discounted costs from the discounted revenues. Net present worth per hectare is derived by dividing by the number of hectares in the plantation area. Data for different courses of action may yield significant differences in this unit value.

(2) Social analysis. This is similar to the financial analysis but the input and output data are revalued to determine social cost benefit. The process for social revaluation is best defined by the central government to ensure uniformity in project evaluation, but might include shadow rates for labour, the social opportunity cost of net capital expenditure, foreign exchange factors and a social discount rate or social rate of time preference.

The application of sensitivity testing to both types of analyses to gauge the effect of changes in such assumptions as cost and revenue, can provide useful information and indicators. When the net unit worths from financial and social analyses exceed those of a comparable best alternative use of the land, the project is indicated as being financially and socially beneficial.

With the quantified results of analysis senior management should be able to decide whether the project will be undertaken and which specific course of action will be adopted. When the detailed project is approved the next stage is the planning and implementation of the initial phase which is mainly concerned with plantation establishment.

THE PLANTING PLAN

On the assumption that the detailed project is approved and the necessary finance authorised, the next stage is planning initial implementation by preparing a planting plan. The planting plan can be considered the operational planning section of the detailed project. It records for the plantation manager what is to be done over a period. Assuming a 30 year project, the initial planting plan should cover five years, although circumstances may vary this period. The remainder of the project time will be implemented by similar periodic plans. At this stage in development the object should be to allow some flexibility and to keep the plan as simple as possible. For complex projects or problem areas, network analysis is a useful technique that may be used by management.

The 5 year planting plan forecasts all of the project requirements annually over the period. This annual data may be extracted and set out as the annual programme of work for all project activities and represents an instructional plan for assistant managers and supervisors. If annual financial allocations cannot be avoided, the budget section may submit annual estimates of funds required. The main sections of the plan are the detailed prescription of activities, marshalling of resources, the budget and records and control.

Detailed Prescription of Activities

Detailed prescriptions of work set out the method, quantity, estimated inputs and outputs for the following main operations:

Plantation operations

a) Allocation of land and surveys
b) Establishment of nurseries and raising planting stock
c) Land clearing and preparation
d) Laying out and construction of access
e) Planting
f) Beating up
g) Fertilising
h) Weeding
i) Brashing/pruning
j) Thinning
k) Fire protection
l) Road maintenance

Other works

m) Allocation of staff and definition of responsibilities
n) Training of staff and operators
o) Maintenance of transport and equipment
p) Maintenance of building and general services.

If management has a handbook of plantation techniques as in Zambia (Allan and Endean, 1966), reference to this may reduce the length of the prescriptions and the plan. Laying out, item d), which includes the design and delineation of compartments, blocks, roads, rides and fire traces, constitutes an important management decision, and other than topography and national features, two of the main considerations influencing design are fire protection and probable logging methods. Thinning, item j), which will undoubtedly occur in the next project period, is included in the initial planting plan for contingency reasons.

Marshalling Resources

The general resource requirements for the period are in the detailed project and these should be up-dated and adjusted as necessary to the planting plan. The prescription in this section will require the manager to requisition where necessary and acquire by given dates:

1) funds,
2) staff and labour,
3) machinery, transport and equipment,
4) building materials or buildings,
5) project materials and seed, and
6) essential spares.

The detailed requirements will include timely ordering of specified resources for the start of the next project period. It is advisable to seek specialist advice in ordering certain of these resources.

The Budget

The budget is the estimated costs of all the resources to be used in achieving the detailed prescriptions, and is usually set out for the plan period by years and main operations. Much of the information for the budget may be extracted from the project financial resources data section. For convenience the budget may be set out under functional heads, such as:

Land preparation	Road construction
Nurseries	Maintenance
Plantation operations	Administration
Protection	Services

The approved budget is the authority for the allocation of funds for the enterprise and when subsequently compared with actual expenditure for the same period, is a measure of planning and management efficiency. When release of funds is requested allowance must be made for inflation, changes in methods and increased efficiency in plantation operations.

Records and Control

Complex recording methods will inevitably cause problems and fail, so it is essential to keep systems simple whilst recording only essential data. Compartment, or block records if areas are uniform, will provide basic information on the area and note what treatments are applied and when. A simple type of report may be in map form showing the area treated by shading and with operational data recorded on the back.

Control of a project concerns keeping the work completed and the expenditure within the limits set by the programme of work and budget for the year. Periodic progress reports give simultaneous information on work completed and expenditure. It is necessary to train supervisory staff in completing these reports and to advise on the reasons for submitting such data. Equally it devolves on management to check such reports and to inquire into the reasons, firstly for major deviations from budget estimates and secondly, for widely variable outputs from different supervisors for the same operation.

CONCLUSION

This paper attempts to encompass a very wide subject in a very short presentation which follows the outline of the FAO Manual on the Planning of Man Made Forests (FAO, 1973). Brevity has undoubtedly introduced some imprecisions and omissions. The outline covers planning from project initiation to point of implementation, and although this terminates the defined discussion it does not end the planning process. As has already been pointed out, the project is a dynamic conception. Experience gained, problems solved, changes in the economic climate, and data gathered when implementing the planting plan will initiate changes and modifications in subsequent plans and plan periods.

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Weeding is one of the cultural operations with which savanna plantation planners and managers must reckon. The good growth of this 4-year old *Pinus oocarpa* stand at Afaka, Nigeria, is in part the result of regular mechanical weedings in one direction, supplemented occasionally by manual spot weeding.

APPENDIX A

An Outline of Equipment and Materials for an Afforestation Project

OPERATION	EQUIPMENT	MATERIAL
land clearing	survey equipment tractors, crawler anchor chains tree dozer blade stinger front end rake root plow	arboricides fuel and oil hand tools aerial photographs
ground preparation	tractors, 50-100 HP ploughs, disc angle dozer blade	weedicides fuel and oil hand tools
nursery	wheel tractor trailer loader attachment sprinkler equipment soil mixer hand tools, spades, forks, hoes sprayer	fertilisers pots insecticides fungicides weedicides fuel and oil hand tools
planting	tractor, 50-100 HP trailer	fertilisers fencing stakes fencing wire hand tools, spades, mattocks fuel and oil tree carrying containers
Maintenance and protection	tractor, 50-100 HP soil cultivators pruning saws fire towers fire engines water pumps and hoses	fertilisers weedicides fuel and oil insecticides hand tools
road making	bulldozers tipping trucks graders excavators rollers, rubber tyred	culverts fuel and oil road ballast and gravel bridge materials cement gelignite

COST ACCOUNTING AND THE MAINTENANCE OF RECORDS FOR MONITORING AND EVALUATING PLANTATION PROJECTS

J.B. Ball
FAO/UNDP High Forest Development Project
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CONTENTS

OBJECTIVES OF COST ACCOUNTING

The objectives of cost accounting are:

1. Budgetary control,
2. Estimates,
3. Labour control,
4. Calculation of financial returns and
5. Identification of those components that would show the greatest return from improved methods.

These objectives are applicable at all levels of responsibility.

GENERAL PRINCIPLES

Six general principles are involved in cost accounting:

1. All expenditure must be included;
2. Expenditure must be allocated to an operation, either directly (e.g., labour wages) or proportionately (e.g., overheads);
3. The costs must be capable of being reconciled with the total expenditure to check that all expenditure has been included;
4. The components of the unit cost are added at different levels of responsibility, and the system must be capable of extracting the components (see diagram in Appendix 1);
5. It must also be possible to extract information for other purposes from the costing system (e.g., for compartment histories) and
6. The scheme must be simple to allow its use at the lowest levels of responsibility and to ensure that the cost figures are speedily produced.

OPERATIONS

Operations must be rigidly defined to enable comparisons to be made between years and between plantations.

A code number should be given to each operation to enable easy identification and for computer processing.

Operations can be grouped together under costings heads. For example, in the nursery the operations of sowing, making transplant beds, transplanting, weeding, watering, etc., could all be added together under the nursery head to give a nursery unit cost per planted hectare.

All jobs should be definable as operations; there should be no "miscellaneous" costings head. But one of the heads should cover general management costs, such as inventory, publicity research, training, etc., and these costs may be apportioned to quantifiable operations in the same way as overheads.

ESTIMATION OF QUANTITIES

In order to obtain the unit cost of an operation, the total quantity of work done in a particular place must be known. Area is the quantity in which most costs are expressed. Accurate maps to show net afforested areas are therefore essential. Areas should not be estimated by eye, except for 1 ha or less, nor should they be estimated from the number of blocks cleared, or trees planted.

The definition of each operation should also contain an explanation of the relevant quantity. For example, if a weeding is necessary only in a small part of a compartment, should it be costed to the actual area weeded or should it be costed to the total area of plantation of that age? The latter is usually the course adopted, as it is with fire protection, insect control, etc.

The place that an operation is carried out should also be indicated with the quantity, both to explain anomalies and for extraction for compartment and other records.

LABOUR COMPONENT

Allocation of Labour Time to Operations

This is done by the man responsible for directing the work in the field. At the end of each day he notes the number of men working on each operation in a labour abstract or distribution book. The man days for each operation are totalled at the end of each month.

Where a man works on two or more operations, his time is usually charged to the operation on which he worked longest.

Calculation of Labour Cost per Man-Day

The details of the wages of the labour are generally maintained on a pay sheet or muster roll, separate from the record of the allocation to operations.

Although labourers are paid at different rates depending on experience and responsibility, it is simplest to add all of the wages together and calculate an average cost per man-day. The alternative is to combine the pay sheet and the record of the allocation of labour to get a "true" cost, but this is time consuming and liable to error.

Labour overheads should also be included in the calculation. These are mainly the wages of staff who are also paid on the pay sheet with the labour, but who are responsible for supervision or administration, such as headmen, storekeepers, etc. Their pay is added to that of the labourers, along with other overheads such as paid holidays, paid sick leave, allowances and the cost of food where it is included as part of the wages. The cost per man-day is then calculated in the following way:

A. Total man-days worked (from the record of the allocation of labour to operations);
B. Man-days paid, but not productive (labour overheads);
C. Total man-days paid (A + B);
D. Gross wages paid, plus allowances, to the men represented at C;
E. Cost per man-day = D/A.

Calculation of the Labour Cost of Operations

The man-days per month worked on each operation are multiplied by the cost per man-day to get the labour cost of the operation, and divided by the quantity to get the unit cost.

The calculation can be simply checked by adding together all of the costs of operations, which should agree with the amount paid.

Worked examples of the calculations for determining the labour component are in Appendix 2.

MATERIALS COMPONENT

For most forestry operations, except building, the expenditure on materials is a fairly small proportion of the total cost. Approximations can therefore be made in the allocation to operations without great loss of accuracy.

Ideally, all materials issued from the store should be charged to an operation. At the end of the month, copies of the issue vouchers are used to allocate expenditure to operations. This requires well-trained storekeepers with a knowledge of the cost code and of the value of the materials that they are handling, and in the initial stages of projects they may lack the experience to do this.

If the storekeepers are inexperienced, then the officer in charge of the accounts must allocate the expenditure to operations, and without a knowledge of the day to day running of the project he cannot do this entirely accurately. He will also tend to allocate the whole expenditure, when in fact only part of the materials may have been used. He must therefore have some means of finding out unused balances.

In either case, approximations will have to be made in the case of small hand tools which may be used for several jobs. The allocation of the expenditure to operations should then be done in proportion to the labour expenditure on them.

Although the expenditure on materials used for the operation of plant and vehicles is also usually charged to the same account, it should be kept separate for the easier calculation of plant operating costs.

PLANT AND VEHICLE COMPONENT

Log Book

Close control of plant and vehicles is essential, both for the allocation of expenditure to operations and to prevent abuse, particularly of vehicles. Every item of plant and every vehicle must have a log book which must be maintained to show the reason for its use for allocation to operations, which are then summarised in terms of hours or kilometres run at the end of each month.

Calculation of Unit Cost

Expenditure on operating plant and vehicles may be incurred under the following, which should be totalled separately for subsequent analysis:

(a) Wages and allowances of the driver or operator. These must be kept separate from labour wages and not included as a labour overhead.
(b) Fuel and lubricants. The expenditure can be obtained from a materials sub-account.
(c) Spare parts, repairs. The expenditure can be obtained from another materials sub-account.
(d) Depreciation or amortisation, insurance, etc. A record of the cost of each item of plant or of each vehicle and the date of purchase should be kept at a senior level, and the annual depreciation calculated. This is most easily done in equal annual amounts.

Calculation of Plant or Vehicle Component

The simplest way to calculate the plant or vehicle component of operations costs is to do it annually, but if the costings are done on a computer, it may be done monthly. Unit costs are obtained by adding together expenditure on the items above and dividing by the total hours or kilometres run. Unit costs should be aggregated for vehicle types, rather than being assigned to individual vehicles. This evens out variations due to age.

Another way of calculating the plant and vehicle component is to use a figure based on theoretical calculations or on the previous year's running. This makes the reconciliation of costs with expenditure less easy, and due to rapidly increasing prices reduces the usefulness of the figures for estimates purposes.

Provision must be made in the system for charging the cost of a vehicle working in another project, or hired from a central pool. Generally, the details are extracted from the log book and notified to the officer to be charged, with the cost, at the end of the year. The officer who used the vehicle then allocates this cost to an operation.

The unit cost of towed equipment must also be calculated, and its use identified on the log sheet for inclusion in the cost of the operation.

It is possible to add even more information to the log sheet, for the identification of "lost time". This might include travelling to the job, minor or major repairs, time lost due to bad weather, lack of a driver, or the vehicle having no job to do. As projects become more sophisticated, this information is very useful for the control of vehicles.

Quite often the time cannot be allocated to an operation - for example, taking a worker to hospital, or a senior officer's inspection. Then the cost is charged to a management cost head.

OVERHEADS

Items Included as Overheads

Overheads include the following:

1. Staff salaries and allowances;
2. Office rents, water and electricity charges;
3. Transport of senior officers with project-wide responsibilities and
4. Management costs.

The calculation of overheads charges is done at the highest level and should include all expenditure not previously accounted for.

Allocation of Overheads to Operations and Costings Heads

Overheads should be divided between costings heads in proportion to the labour component. The reason for this is that most of the overheads are due to the supervision and administration of labour. Generally, it is of no interest to allocate overheads to operations, and the only purpose of adding in overheads anyway is for the calculation of the rate of return per hectare.

When, however, plantation projects reach the exploitation stage, it may not be correct that most of the overheads will be due to supervision and administration of labour. If exploitation is being done by contractors, then much of the time of senior staff is spent on planning, the control of harvesting and the collection of revenue. Allocation of their salaries may then be done in proportion to the time they spend on these jobs, which may be determined by means of diaries or by a system of sampling.

RECONCILIATION OF EXPENDITURE AND COSTINGS

The total expenditure should be checked against the total costs in order to ensure that all items of expenditure have been included. This is generally done at the end of the year, but a running check on sub-totals may be done each month.

The equation for the annual reconciliation is:

Total Expenditure = + Total (Cost of Labour)
+ Total (Cost of Materials Used)
+ Total (Cost of Plant Operation on the Project)
- Total (Depreciation of Plant)
+ Total (Expenditure on Unused Materials)
+ Total (Cost of Vehicles, etc., Hired to other Charges)
- Total (Cost of Vehicles, etc., Hired from other Charges)

This equation omits depreciation, staff salaries, etc., but includes management costs.

OTHER RECORDS

The practice of scientific forestry depends upon the collection of accurate figures and the maintenance of accessible records.

Compartment History

The details of work done in a compartment, with date and area covered, can be extracted from the costings system. Likewise the outturn records show the amount of each type of forest produce and the date that it was removed. It is usually not necessary to keep records of costs or revenue on a compartment basis, but they should be kept on some sub-division of the whole project such as a forest or plantation.

The compartments should also be described, and such information as seed sources, inventory results, etc., recorded. A map must be included. Descriptions should be standardized to permit comparisons of outturn, etc., between compartments. An excellent series of forms suitable for compartment descriptions are given in Anon.(1974).

Other Works

Descriptions and details of other works such as buildings, roads, etc., with date of completion and a record of maintenance should also be kept.

Distinction between Records and Correspondence

It is most important to distinguish between records, which are permanent, and correspondence, which is generally ephemeral. Where correspondence contains information that should be retained, it must be extracted and put in the records - an annual review of the correspondence files is a useful way of doing this. Likewise, correspondence must not be allowed to clog the records and prevent speedy access.

SAMPLING METHODS OF OBTAINING COST FIGURES

The system of cost accounting that has been described in this paper is the ideal, but until it has been in operation for at least a year, there will be no reliable figures for unit costs. In the meantime, data may be required for estimates or project evaluation. In this case, the cost of operations may be determined by sampling to estimate output per man-day or per machine-hour. The application of cost sampling in Nigerian savanna plantations is well described in Ferguson (1972).

The sampling is carried out by one or more small teams who observe an operation over the whole day. They mark on the ground the point at which work starts in the morning, and note the number of men employed. At the end of the day, the output (generally area) is measured. For machines, the type of machine (including attachments), the work done, and the time taken are noted. Under Nigerian conditions, it was found that for a standard error of 20% to 30%, it was necessary to observe an operation for a minimum of four days, and ten days were preferable. The operations observed should be those carried out on a reasonably large scale, say more than ten ha.

The times per unit for each operation are then multiplied by the cost per man-day or per machine-hour to get the unit cost of the operation. The cost per man-day is estimated from the same items of expenditure that are described on page 236, and for machine costs the same as are described on page 237. If materials form a significant proportion of the cost of an operation, then expenditure on them must be estimated too.

A sampling system is useful for producing cost figures quickly, but it cannot act in the same monitoring role as the cost accounting scheme. There is no check on inefficiency or dishonesty, one has to accept a fairly large standard error, and there are difficulties in the calculation of labour overheads. A sampling system may therefore precede a cost accounting scheme, but it should not be an alternative.

GLOSSARY OF TERMS

Costs: The expenditure attributable to an operation.

Components of Cost: The items of expenditure that make up the total cost - labour, materials, plant/vehicles, and overheads.

Unit cost: The total cost of an operation divided by the total number of units completed.

Expenditure: The money paid out on wages, materials, etc., from the accounts (or Vote Book).

Operation: A forestry job or process that is definable and distinct from other jobs. The smallest sub-division of the costing code.

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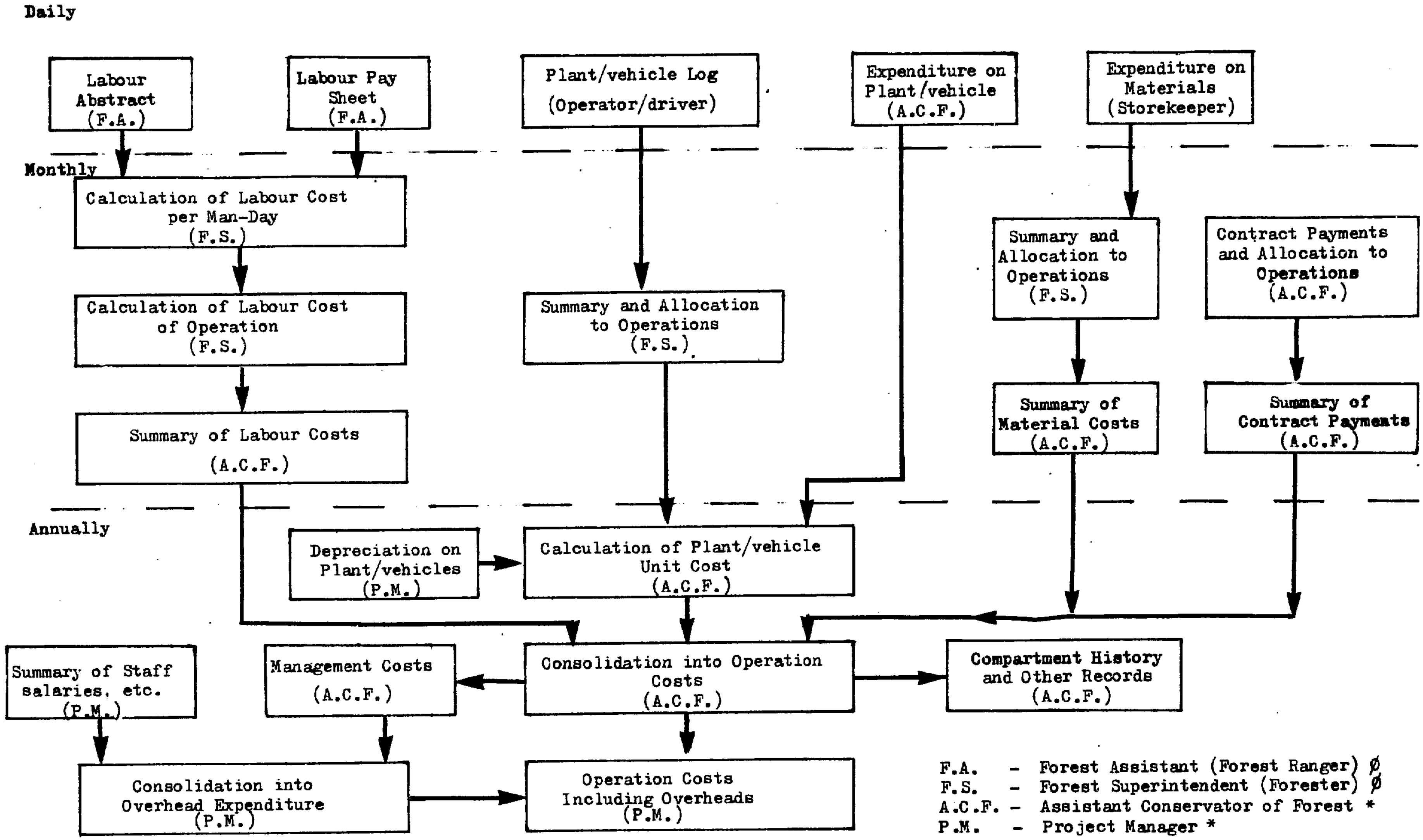
Appendix 1

FLOW CHART OF COST AND OTHER RECORDS



F.A. - Forest Assistant (Forest Ranger) ∅
F.S. - Forest Superintendent (Forester) ∅
A.C.F. - Assistant Conservator of Forest *
P.M. - Project Manager *
∅ Technical Training *Graduates

(**adapted from** Grut, 1975)

APPENDIX 2a

WORKED EXAMPLE OF LABOUR ABSTRACT

Centre: IPERU CHARGE.

SHAGAMU PULPWOOD PLANTATIONS

Month FEBRUARY Year 1975

Operation	Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Brushing	1121	S -	S -	23	20	20	20	39	S -	S -	36	39	39	38	37	S -	S -	10	10	5	-	-	S -	S -	-	-	-	-	-				336
Felling	1131	-	-	-	-	-	-	-	-	-	4	4	4	4	4	-	-	4	4	-	-	-	-	-	-	-	-	-	-				28
Packing	1141	-	-	7	8	8	8	8	-	-	8	88	8	8	8	-	-	36	18	16	10	10	-	-	9	10	5	-	-				193
Burning	1142	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	23	34	34	-	-	34	34	34	30	30				271
Poisoning	1152	-	-	1	1	1	1	1	-	-	1	1	1	1	1	-	-	1	1	1	1	1	-	-	1	1	1	1	1				20
Felling (Taungya)	1212	-	-	4	4	4	4	4	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	-	-	-	-				28
Supervision of Taungya	1213	-	-	2	2	2	2	2	-	-	2	2	2	2	2	-	-	2	2	2	2	2	-	-	2	2	2	2	2				40
Fire patrol	1522	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5				140
Road maint. 5 - 8 m.	1623	-	-	18	18	19	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				73
Compound maintenance	17221	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	2	-				4
Re-packing	1171	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	10	9				34
Re-burning	1172	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	7	7				19
	Total	5	5	60	58	59	58	59	5	5	56	59	59	58	58	5	5	58	58	56	56	52	5	5	57	57	57	57	54				1186

APPENDIX 2b

Centre: IPERU NURSERY

SHAGAMU PULPWOOD PLANTATIONS.

WORKED EXAMPLE OF LABOUR ABSTRACT

Month February Year 75

Operation	Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
		S	S						S	S						S	S						S	S									
Seed Prep.	1322			6	-	-	-	-			-	-	-	-	-			-	-	-	-	-			-	-	-	-	-				6
" Sowing	1323			1	1	1	-	-			-	1	1	-	-			-	-	-	-	-			-	-	-	-	-				5
Fill pots	1342			5	5	6	6	2			2	2	3	3	-			-	-	-	-	-			-	-	-	-	-				34
Transplant (beds)	1351			3	4	4	4	3			-	3	3	3	-			-	-	-	-	-			2	2	1	-	-				32
Transplant (pots)	1352			-	-	-	2	5			6	6	6	6	7			7	4	3	-	-			-	-	-	-	-				52
B.u beds	1353			-	4	4	-	-			-	-	-	-	-			4	-	-	-	-			-	-	-	-	-				12
B.u pots	1354			-	-	-	-	-			-	-	-	-	-			2	2	-	-	-			2	2	2	-	-				10
Weed Transplant beds	1362			3	4	3	2	4			2	3	-	-	4			1	-	-	-	-			-	-	-	-	-				26
Watering (hand)	1371	2	2	2	2	2	2	2	2	2	22	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2				56
Insect control	1391			-	-	-	-	-			-	-	-	1	1			1	-	-	-	-			-	-	1	-	-				4
Weed pots	1363			-	-	-	-	-	-		3	2	2	2	3			1	-	-	-	-			-	-	-	-	-				13
Weed paths	1364			-	-	-	3	3			3	-	2	2	2			1	-	-	-	-			-	-	-	-	-				16
	Total	2	2	20	20	20	19	19	2	2	18	19	19	19	19	2	2	19	8	5	2	2	2	2	6	6	6	2	2				266

APPENDIX 2c — JOB COSTINGS SHEET (1)

WORKED EXAMPLE OF CALCULATION OF COST PER MAN-DAY

Centre: Shagamu Pulpwood Plantations — Month: February, 1975

A	Total Man-Days Worked. (from Labour Abstract)	Field	1186
		Nursery	266
		Total A	1452
B	Man-Days Paid but not Productive. (from Pay Sheet)	Public Holidays	-
		Sick	-
		Leave	63
		Non-working	
		Headman	20
		Storekeeper	20
		Total B	103
C	Total Man-Days Paid (Total A + Total B) (This must agree with the man-days paid on the pay sheet)		1555
D	Gross Wages Paid (from pay sheet)		3445
	Labour Allowances: Bicycle allowance.		20
		Total D	3465
E	Cost per Man-Day (Total D/Total A)		2.39

APPENDIX 2d — JOB COSTINGS SHEET (2)

WORKED EXAMPLE OF CALCULATION OF LABOUR COST OF OPERATION

Centre: Shagamu Pulpwood Plantations — Month: February, 1975

Cost per Man-Day (from Job Costing Sheet 1) 2.39 per man-day.

Code	Unit	Quantity	Man Days	Cost	M. Days/ Unit	Remarks
1121	Ha	18	336	798[x]	18.67	
1131	Ha	9	28	67	3.11	
1141	Ha	11	193	461	17.55	
1142	Ha	60	271	648	4.52	
1151	Ha	150	20	48	0.13	
1171	Ha	5	34	81	6.80	
1172	Ha	5	19	45	3.80	
1212	Ha	54	28	67	0.52	
1213	Farmer	163	40	96	0.25	
1322	Kg	3	6	14	2.00	
1323	Kg	10	5	12	0.50	
1342	Pot	20400	34	81	1.67	p. thousand
1351	Seedling	32000	32	76	1.00	"
1352	"	46800	52	124	1.11	"
1353	"	9600	12	29	1.25	"
1354	"	7000	10	24	1.43	"
1362	Bed	26	26	62	1.00	
1363	Pot	19500	13	31	0.67	p. thousand
1364	Path	80	16	38	0.20	
1371	Bed	20	56	134	2.80	
1391	Plants	5000	4	10	0.80	p. thousand
1522	Ha	650	140	335	0.22	
1623	Km	5.6	73	174	13.04	
17221	-	Station	4	10		
			1452	3465		
			Checked with A on Sheet 1	₦5 substracted from x to make Total agree with D on Sheet 1		

APPENDIX 2e JOB COSTINGS SHEET (3)

WORKED EXAMPLE OF SUMMARY OF LABOUR COST OF OPERATION

Project: Lekki Lagoon Pulpwood Scheme

Operation: Brushing Code: 1121

Unit: Hectare Year: 1975

Month	Centre	Quantity	Man-Days	Cost ₦	M.-Days/Ha	₦/Ha
January	Shagamu	89	1869	4504	21.0	50.6
	Ogun	76	1350	3105	17.8	40.9
	Ijebu-Ode	161	3207	7569	19.9	47.0
		326	6426	15178	19.7	46.6
	C. Epe	150	-	5000	-	33.3
February	Shagamu	18	336	798	18.7	44.3
	Ogun	98	1793	4160	18.3	42.5
	Ijebu-Ode	125	2800	6720	22.4	53.8
	Epe	27	543	1281	20.1	47.4
		268	5472	12959	20.4	48.4
March	Ogun	26	553	1311	21.3	50.4
	Ijebu-Ode	5	117	283	23.4	56.6
		31	670	1594	21.6	51.4
Quarterly Summary by Centre	Shagamu	107	2205	5302	20.6	49.6
	Ogun	200	3696	8576	18.5	42.9
	Ijebu-Ode	291	6124	14572	21.0	50.1
	Epe	27	543	1281	20.1	47.4
		625	12568	28731	20.1	47.6

C = Contract

ANNEX 1

SUMMARIES OF SPECIAL CASE STUDIES

Part A: Pines

ESTABLISHMENT TECHNIQUES FOR PINES

G.O.A. Ojo
Forestry Research Institute of Nigeria
Ibadan, Nigeria

The aims of establishment techniques for Pinus caribaea and P. oocarpa are to establish the seedlings as quickly as possible and to provide optimal growing conditions. Existing vegetation is clear-felled, stumped and burnt and the site is mechanically cultivated. Planting is done during the rainy season, beginning when the soil is wet to about 15 cm, employing seedlings 20-30 cm high raised in polythene pots. The spacing used depends largely on the method of management adopted, with 2.8 x 2.8 m being usual where mechanical cultivation in two directions is foreseen, and 1.8 x 1.8 m where manual weeding is contemplated. Weeding is necessary about three times a year (four the first year) during the rainy season for three to four years. Hand weeding is practised around individual trees, followed by mechanical cultivation between the rows. On ferruginous tropical soils 11 g of phosphate fertilizer is applied around each tree about four weeks after planting and following manual weeding. Clean weeding is also an effective fire prevention tool, but fire tracing around plantations, fire patrols and brashing to a height of four to five feet at age four are also employed.

EARLY GROWTH PATTERNS OF PINES IN THE NIGERIAN SAVANNA

D.E. Iyamabo
Agricultural Research Council, Moor Plantation
Ibadan, Nigeria

M.A. Ogigirigi
Shelterbelt Research Station
Kano, Nigeria

This paper discusses the results of height and girth growth studies of young Pinus caribaea and P. oocarpa in relation to environmental conditions in northern Nigeria. Successive measurements at three and four years of age showed that both species exhibited continuous height growth and apical buds active all year round, but the rate of apical growth and the rate and quality of foliage production were less in the dry season than during the wet season. Dry season needles of these species are generally smaller, shorter, thinner and greatly deformed as a result of having to force their way through the dried needle sheath.

Girth growth is lowest during the dry season, but shows a gradual increase from May to June and is highest during the June to September wet season. The increase from May to June may be due to hydration of stem tissue and bark, cambial activity or both.

Some of the pine species included in elimination trials showed negative results. Following six months in the nursery at Zaria, P. montezumae did not grow at all in plantations. Also at Zaria, P. michoacana grew normally for nearly two years and then went into a prolonged period of dormancy, and at Afaka and Miango P. pseudostrobus grew very irregularly producing long terminal and lateral shoots that had no needles.

NUTRITION OF PINES (Pinus caribaea and P. oocarpa)

O. Kadeba
Savanna Forestry Research Station
Samaru, Zaria, Nigeria

Nutritional studies on Pinus species being tried in the afforestation programme of the Nigerian savanna is a recent development. So far, attention has been focussed primarily on the three major nutrients N, P, and K. Work to date has shown that the establishment phase of pines in the field would be difficult and growth rate unsatisfactory if phosphate fertilizer is not used. Effects of nitrogen fertilizers varied depending on type of material used. Urea was found to be injurious to pines with or without supplementary phosphate application. Positive response to nitrochalk and ammonium sulphate could be obtained only when phosphate was simultaneously applied. In no case was there any favourable response to K fertilizer.

EFFECTS OF PINE PLANTATIONS ON SOILS

O. Kadeba
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Samaru, Zaria, Nigeria

B.S.K. Onweluzo
Savanna Forestry Research Station
Samaru, Zaria, Nigeria

Analyses of soils under plots of Pinus caribaea, Pinus oocarpa and savanna woodland show some changes in the soil chemical properties. Acidity is intensified with increasing age of the pines. The data provide evidence of an initial reduction in organic matter content of the mineral soil. However, with increasing plantation age and canopy closure, there is a gradual build-up of organic matter in the top soil. A similar trend is demonstrated by exchangeable K. Values of 14.70, 5.44 and 6.00 tonnes/ha are estimated as oven dry weight of accumulated and un-decomposed litter under (i) 15-year Pinus caribaea (ii) 7-year Pinus caribaea and (iii) 7-year Pinus oocarpa plots respectively.

THE GROWTH AND YIELD OF PINUS SPECIES IN THE SAVANNA ZONES OF NIGERIA

J.O. Abayomi
Forestry Research Institute of Nigeria
Ibadan, Nigeria

The growth and yield of three Pinus species, P. caribaea, P. oocarpa and P. kesiya are described and compared in different localities of the savanna zones of Nigeria. The best growth of the three Pinus species has been observed at Miango on the Jos plateau. P. caribaea appears to have the best growth on all sites, followed closely by P. oocarpa. Some limitations in the comparisons made in the paper are mentioned.

EFFECT OF AGE ON ROOTING OF CUTTINGS AND COPPICING OF STUMPS OF PINUS CARIBAEA

O.O. Okoro
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Ibadan, Nigeria

Investigations were carried out to determine the rooting propensities of cuttings taken from various ages of *Pinus caribaea* trees and rooted under two environmental conditions: mist and temporary propagator. Better callusing was obtained under mist. Some cuttings from all ages of trees rooted under mist whereas only cuttings from seedlings and a few from ten-year old trees rooted in the temporary propagator. Under both environmental conditions, cuttings from six and 15 month old seedlings rooted best. When seedlings of these two ages were coppiced, the latter had better survival percent (100%) and those stumps which had 8 - 16 sprouts produced more uniform shoots with reasonable growth. Stumps of ten year old trees did not coppice at all.

Pinus oocarpa is one of the best plantation species for the northern Guinea savanna. This growth trial plot at Afaka, Nigeria, is 7-years old.

Part B: Neem

NEEM

M.A. Ogigirigi and F.Y. Adekiya
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Kano, Nigeria

This paper reviews the history of neem (*Azadirachta indica*) in the Sudan zone of northern Nigeria; gives a general description of the tree, its phenology, silvical characteristics and uses; and describes current nursery, planting and tending practices.

Following its introduction into the Sudan zone in 1928, neem has become the most important plantation species in the zone with nearly 1500 ha planted by 1964. The major uses of the wood are for poles and fuel.

The neem tree is deep rooting, has a large, heavy crown and is a prolific seeder from age five onwards. Planting is primarily with nursery stock raised in polythene tubes and outplanted at 2.4 x 2.4 m or 2.7 x 2.7 m spacings. Two mechanical harrowings per year are necessary for the first three years to reduce weed competition. Around large towns where both farmland and wood products are in short supply, farming in the plantations is successful. Groundnuts, beans, and occasionally millet are raised.

Direct sowing has also been shown to be a promising, simple and cheap method of enriching large areas of savanna.

SOME PHYSICAL PROPERTIES OF SOIL UNDER NEEM AT YAMBAWA, KANO STATE

J.E. Ujah
Shelterbelt Research Station
Kano, Nigeria

Measurements of particle size distribution, bulk density, particle density, total porosity and soil moisture content from four selected sites stocked with (a) five year old neem, (b) one year old neem, (c) only weeds, and from a site (d) where neem failed after one year, showed no significant differences between sites where neem is growing well and where it failed or was never planted.

Part C: Eucalypts

ESTABLISHMENT TECHNIQUES FOR EUCALYPTS

G.O.A. Ojo
Forestry Research Institute of Nigeria
Ibadan, Nigeria

Eucalypts used in plantation work in the Nigerian savanna are E. camaldulensis, E. tereticornis, E. citriodora, E. cloeziana and E. "saligna" hybrid.

Intensive management techniques are employed. The natural vegetation is felled, stumped and burnt and the site is ploughed. Planting stock is raised in polythene pots to a height of about 30 cm for outplanting early in the rainy season after the soil is wet to about 15 cm. The species differ in their ability to withstand dry spells immediately after planting; whereas most can tolerate a week of unexpected dry weather, E. cloeziana must be planted in very wet weather. Spacings from 1.8 x 1.8 m to 2.8 x 2.8 m are used depending on the objective of management and the weeding method to be adopted. Three to four weedings, manually around individual trees and usually mechanically between the rows, are carried out the first year during the rains. Weedings are fewer in subsequent years but are required until canopy closes, often within one to two years, depending on species. E. cloeziana gives a dense canopy, but E. citriodora is thin crowned and requires weeding for three to four years. Borate fertilizer applied to the soil a few weeks after planting at the rate of 56 g per plant is highly beneficial. On very sandy soils the application is made over a two year period.

Owing to their light crowns, clean weeding, fire tracing and fire patrols are required fire protection methods in savanna eucalypt plantations.

EARLY GROWTH PATTERNS OF SOME EUCALYPT SPECIES IN THE NIGERIAN SAVANNA

D.E. Iyamabo
Agricultural Research Council, Moor Plantations
Ibadan, Nigeria

M.A. Ogigirigi
Shelterbelt Research Station
Kano, Nigeria

Studies of the height and girth growth of Isorberlinia doka, Khaya senegalensis, Eucalyptus citriodora, E. cloeziana, E. deglupta, E. propinqua, E. robusta and E. tereticornis showed the eucalypts to have growth rates and periodicities superior to those of species indigenous to the northern Nigerian savanna. Apical and lateral meristems, dormant for part of the year in both I. doka and K. senegalensis, remain active all year round in the eucalypts, enabling them to sustain appreciable levels of growth during the dry season. Accelerated height growth, however, begins in late April to early May after soil moisture is sufficiently replenished. Accelerated girth growth starts earlier - in March - but some of this "growth" may be attributed to hydration of stem tissue following increasing atmospheric humidity.

Starting at about the middle of the wet season and continuing into the dry season, there is a progressive decrease in girth growth rates in I. doka and all species of eucalypts. This can apparently be attributed to the heavy leaching of nitrogen from the forest litter which accumulated during the dry season, rather than water stress.

NUTRITION OF EUCALYPTS

O. Kadeba
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Samaru, Zaria, Nigeria

Nutritional studies form part of the several integrated forest cultural practices employed in the establishment and management of exotic plantations of eucalypts in Nigeria.

Boron, nitrogen and phosphorus are the three elements that may limit the growth of the different species of eucalypts that are being tried in the afforestation programme. Results of all the field experiments conclusively show that the incidence of dry season die-back of eucalypts is associated with boron deficiency; application of borate fertilizer at the rate of 50g per tree would correct this deficiency. Growth increases were obtained on some sites following application of nitrogen and phosphate fertilizers. A common feature is the positive interaction between nitrogen and phosphorus. There was no response to potassium.

SOME ASPECTS OF WATER RELATIONS OF EUCALYPTUS UNDER NIGERIAN SAVANNA CONDITIONS

M.A. Ogigirigi
Shelterbelt Research Station
Kano, Nigeria

Studies on the water relations of eucalypts in the northern Nigerian savanna demonstrated that "avoidance" is a significant component of drought hardiness in *E. cloeziana*, *E. robusta*, *E. pilularis* and *E. propinqua*, while "tolerance" is important in *E. camaldulensis*. Measurements of transpiration from excised leaves of four species showed that the stomatal mechanism of *E. pilularis* was most efficient in the control of water loss, followed by *E. robusta*, *E. tereticornis* and *E. camaldulensis*. The range of seasonal variation in leaf water deficit was also less for *E. robusta*, *E. propinqua* and *E. cloezinana* than for *E. camaldulensis*.

Under conditions of high soil moisture stress, *E. camaldulensis* was more efficient in water use and put on greater height growth than *Pinus caribaea*, *E. tereticornis* and *E. robusta*. *E. robusta* showed high water use and good growth at intermediate to low levels of soil moisture, but heavy mortality occurred at the highest level of moisture stress. Water use by *P. caribaea*, on the other hand, was high under conditions of high soil moisture, but low when soil moisture became limiting.

EFFECTS OF EUCALYPTUS PLANTATIONS ON SOILS

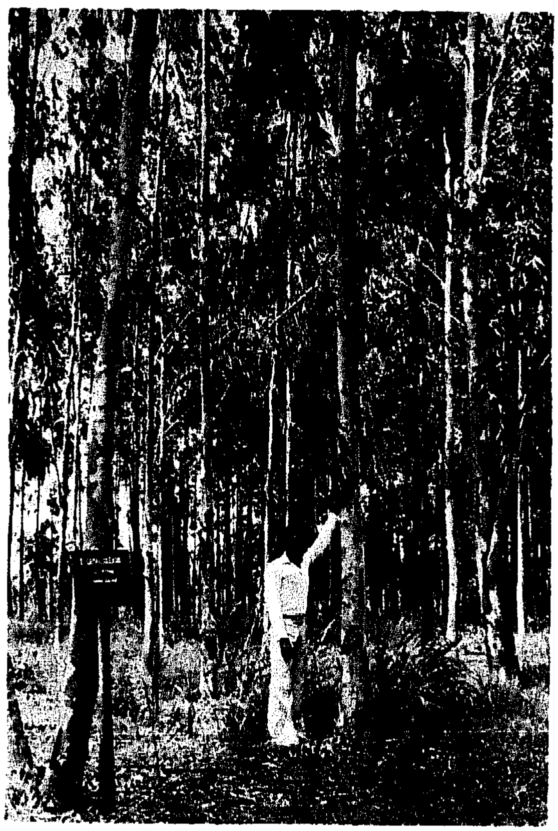
O. Kadeba and B.S.K. Onweluzo
Savanna Forestry Research Station
Samaru, Zaria, Nigeria

Analyses of soils under plots of *Eucalyptus cloeziana*, *E. torelliana* and adjacent savanna woodland provide evidence that organic matter and exchangeable potassium in the mineral soil are depleted more under the eucalypts than under woodland. No difference in calcium or magnesium were evident. There is, however, much greater litter accumulation on the forest floor under eucalypts; dry weight values were 14.59, 14.20 and 6.60 tonnes per hectare, respectively, for 8 year old *E. cloeziana* at Afaka, 9 year old *E. torelliana* at Miango and savanna woodland that had been fire protected for about 20 years.

THE GROWTH AND YIELD OF EUCALYPTUS SPECIES IN THE SAVANNA ZONES OF NIGERIA

J.O. Abayomi
Forestry Research Institute of Nigeria
Ibadan, Nigeria

The growth and yield of some *Eucalyptus* species are described and compared in different localities of the savanna zones of Nigeria. The best growth recorded is that for *Eucalyptus grandis* at Ngoroji on the Mambilla plateau, while in the plains, *Eucalyptus camaldulensis* (Petford provenance), *E. tereticornis* and some stands of *E. grandis* have produced relatively high yields. Afaka appears to be the most favourable experimental site on the plains for the establishment of *Eucalyptus* plantations. Some limitations in the comparisons made in the paper are mentioned.



The excellent performance of the Petford provenance of *Eucalyptus camaldulensis* in the northern Guinea savanna creates a demand for adequate seed supplies. This 6-year old seed stand, spaced 12 x 12 ft (3.8 x 3.8 m) at Afaka, Nigeria, began seed production after 4 years, but the tall, narrow crowns make collecting difficult.

ANNEX 2

EXAMPLES OF ZAMBIAN PLANTATION COSTS

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Kitwe, Zambia

1973 ESTIMATED DIRECT ESTABLISHMENT COSTS*

		Eucalypts (K/ha) +	Pines (K/ha) +
1.	Land Clearing	175.64	175.64
2.	Nursery Plants	4.89	8.32
3.	Planting		
	(a) Pre-discing	3.34	2.96
	(b) All Other Planting Operations	9.48	11.59
4.	Fertilisation	10.96	-
5.	1st Season Weeding		
	(a) Hand	6.53	10.45
	(b) Mechanical	17.59	18.07
6.	2nd Season Weeding		
	(a) Hand	-	-
	(b) Mechanical	-	6.77
7.	3rd Season Weeding		
	(a) Hand	-	-
	(b) Mechanical	-	4.51
8.	Total Cost	228.43	238.31

* Labour and direct field supervisory labour, their wages, social security contributions, clothing, leave and housing allowances, together with machinery used in operations and materials consumed.

\+ 1 Kwacha = US$ 1.56

BASIC LAND CLEARING COSTS

	K/acre gross	K/acre net
Knockdown	11.50	
Windrow	22.00	
Stump, Burn and Clear	12.00	
	45.50	56.74
Glean and Plough	11.50	14.34
Total Cost per acre	57.00	71.08
Total Cost per ha	140.85	175.64

The total cost per acre net (K71.08) assumes an additional charge for plant movement of 6 per cent and that the net area is 85 per cent of the gross area. It is the intention of the Industrial Plantations Project to carry-over 50 per cent of the area to safeguard against land clearing contingencies in the following year. This places an average interest charge on the ground prepared for next year's planting of K1.84 per net acre.

LABOUR COSTS PER WORKING DAY

	Labour (K)	Supervisors Field (K)	Supervisors Mechanical (K)	Drivers (K)
Basic Annual Wage	342.00	734.40	853.20	475.20
Contribution toward Social Security Plan	25.20	72.00	84.00	48.00
Clothing and Food Allowances	20.00	20.00	20.00	20.00
Housing Cost (20 yrs at 7% interest rate)	142.00	142.00	208.00	142.00
Total Basic Cost / Annum	529.20	968.40	1163.20	685.20
Basic Cost / working day (+ 230)	2.30	4.24	5.10	3.00
40% Incentive Bonus on basic daily wage	0.38	-	-	0.52
Total Cost / working day	2.68	4.24	5.10	3.52

PINES: ESTIMATED 1973 ESTABLISHMENT COSTS

		Input Units per ha	Estimated Cost per ha
1.	**Nursery Stock**		
	Labour	2.423 man-days at 2.82	6.83
	7 ton Lorry	1.639 km at 0.13	0.21
	D-4	0.024 hours at 4.00	0.09
	Materials	K1.189	1.19
			8.32
	Supervisory Ratio	1:10	

Based on 1490 plants raised for each hectare to allow for losses in nursery and beating up in field.

2.	**Planting**		
	(a) Prediscing		
	Drivers	0.175 man-days at 3.72	0.86
	Tractor	1.198 hours at 1.75	2.10
			2.96
	Supervisory Ratio	1:7	
	(b) Other Operations including Staking, Plant Distribution and Planting.		
	Labour	3.356 man-days at 2.76	9.26
	Drivers	0.361 man-days at 3.52	1.27
	Tractor	0.477 hours at 1.75	0.83
	Lorry	1.787 km at 0.13	0.23
			11.59
	Supervisory Ratio	1:18	
3.	**1st Season Weeding**		
	(a) Hand Weed (3 times)		
	Labour	3.284 man-days at 2.88	9.46
	Transport	9.941 km at 0.10	0.99
			10.45
	Supervisory Ratio	1:7	
	(b) Mechanical Weed (8 times)		
	Drivers	1.000 man-days at 3.75	3.75
	Tractor	7.910 hours at 1.75	13.84
	Transport	4.784 km at 0.10	0.48
			18.07
	Supervisory Ratio	1:6	
4.	**2nd Season Weeding (4 times)**		
	Drivers	0.371 man-days at 3.75	1.39
	Tractor	2.965 hours at 1.75	5.19
	Transport	1.853 km at 0.10	0.19
			6.77
	Supervisory Ratio	1:6	
5.	**3rd Season Weeding (2 times)**		
	Drivers	0.247 man-days at 3.75	0.93
	Tractor	1.977 hours at 1.75	3.46
	Transport	1.236 km at 0.10	0.12
			4.51
	Supervisory Ratio	1:6	

SUMMARY OF SILVICULTURAL OPERATIONS AND COSTS PER HA

Description of Work	Chati		Ndola		Ichimpe		Total Area (ha)	Average Productivities and Costs (weighted for area)			
	Area (ha)	Cost (K/ha)	Area (ha)	Cost (K/ha)	Area (ha)	Cost (K/ha)		man-days/ha	vehicle km/ha	tractor hours/ha	K/ha
Raise plants, no. of plants (1000)	(879)	(5.65)	(924)	(5.31)	(2306)	(6.19)	(4109)	2.0	(5.89)	1.8	0.2
Preplanting harrowing	1349	6.82	428	5.97	2192	5.13	3969	0.4	5.79	2.0	1.0
Squaring, planting	968	5.88	397	18.24			1365		9.47		1.1
Beating-up	528	0 44	14	3.07			542	0.3	0.50	1.0	
Fertilizing eucalypts	619	5.09	13	20.23	20	22.35	652	1.5	5.92	3.0	
Hand weeding, 1st, pine			2165	3.55	2078	2.67	4243	2.5	3.11	4.8	
Hand weeding, 2nd, pine			1899	4.85	187	3.41	2086	2.9	4.72	8.1	
Hand weeding, 1st, eucalypts	2564	2.45	26	5.38			2590	1.3	2.47	4.7	
Mechanical weeding, 1st, pine			6423	3.28	5163	2.75	11586	0.2	3.04	1.6	1.1
Mechanical weeding, 2nd, pine			5084	3.10	607	3.19	5691	0.2	3.10	3.5	1.1
Mechanical weeding, 3rd, pine			4171	2.81			4171	0.2	2.81	1.2	1.1
Mechanical weeding, 1st, eucalypts	3870	1.77					3870	1.0	1.77	1.6	0.6
Pruning, 1st, pine	175	5.09	648	5.47			823	3.4	5.38	0.6	
Pruning, 3rd, pine	91	6.01					91	3.7	6.01	8.8	
Pruning eucalypts	816	4.48					816	2.6	4.48	3.7	
Marking thinning	497	0.58	272	1.16			769	0.5	0.78	0.5	
Thinning pine 1st poisoning	138	7.09	33	32.33			171	1.4	11.96	7.9	
Singling coppice	29	2.97			31	17.13	60	8.1	10.28	0.0	
Bark beetle control	135	2.90					135		2.90		

ANNEX 3

COUNTRY STATEMENTS

Country: BENIN

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country: 112 600 km^2

1.2 Location: longitude 0°40' - 03°45'E; latitude 06°15' - 12°25'N

1.3 Population: 3 250 000 inhabitants

1.4 Main climatic and vegetative zones: Equatorial climate with vestiges of semi-deciduous forests; continental climate with tree savanna formation; continental climate with savanna woodland formation.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests - km^2

2.2 Area of savanna 1/ 22 000 km^2

2.3 Proportion of land under high forest -%; in savanna 1/ 20%

2.4 Does the country have a written statement of national forest policy?

Yes /X/ No / /

2.4.1 If a national forest policy exists, what are the main objectives stated in it? To safeguard the constitution and conservation of the national forest domain and to carry out reforestation and rational exploitation.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points. Control of bush fires; authorization of early burning under state surveillance.

2.5 Legislation available to implement policy Yes /X/ No / /

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.6 Ownership of forests and savanna	High forests	Savanna
Under state control	- %	20%
Private ownership	- %	-%
Community ownership	- %	- %
No effective control	- %	- %

2.7 Principal forest products from all regions (e.g. fuelwood,charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood).

4 300 000 steres of fuelwood and charcoal;
20 000 m^3 of sawlogs;
200 000 poles

2.8 Forestry staff	State	Others
Professional	6	-
Subprofessional(with diploma or certificate of training)	10	-

2.9 Gross annual budget for forestry 100,000 US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: - ha

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974: - ha

3.1.3 Planned annual target area of af/reforestation: - ha/yr

3.1.4 Planned annual planting rate in savanna: variable

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 100%

3.2.2. Others (specify)

....
....

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fueldwood, protection,etc.), species, growth and rotation of major savanna plantation.

End use	Species	net area(ha) 1/	Rotation (Yrs)	Mean annual increment (u.b.) at rotation age (m^3/ha/year)
lumber	teak	6 285	60	-
lumber	*Cedrela* spp.	250	under study	-
piling+posts	teak	715	7-8	-
piling+posts	*Casuarina* sp.	500	8-10	-
fuelwood	*Casuarina* sp.	1000	8-10	-

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existing permanent savanna nurseries? 1 000 000 plants.

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 750 000 plants.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? - plants.

4.2 Planting stock

4.2.1. Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
teak	stumps
Gmelina, Cedrela	bare-rooted transplants
neem	bare-rooted transplants
Casuarina	basket containers 10 x 30 cm

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene)

woven palm baskets 30 cm deep and 10 cm in diameter

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
Casuarina	10-15 cm	6

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers, etc.)
For teak, neem and Gmelina, seed is sown in lines about 10 cm apart in beds. Casuarina is broadcast sown and pricked-out after 6 weeks.

4.3.2 Briefly describe the soil mixtures and fertilizers (and quantities) used. Manure is used, but quantities are not measured. No chemical fertilizers are used.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type).
All nurseries are watered manually with watering cans, except the Casuarina nursery, which has a water tower and rotary sprinklers.

4.3.4. Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements).
Manure is treated with BHC or DDT to guard against attacks on Casuarina seed in nurseries.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1. Are detailed vegetation maps available for most savanna regions?
Yes [X] No [ ]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used. Clear felling is done by axe; tractor clearing is envisaged and is under study.

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna. After felling, the site is burned and large holes are filled in. Pegging out follows.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna ? Yes [X] No [ ]

If so, indicate for which species: Anacardium.

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted. 5 x 5 to 6 x 6 m; later thinned to 10 x 10 or 12 x 12 m.

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya. 5 000 ha.

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding. Two weedings per year for young teak, and after the fourth year one annual slashing and one singling. For Anacardium two weedings and one cultivation annually.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied. None.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals. No significant control measures but research is being done on rots, borer attacks to Khaya senegalensis and Chlorophora galls.

5.5.2 Is there a national fire danger rating system? Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [ ] No [X]

Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes [ ] No [X]

6.2 Is there a national tree seed certification system? Yes [X] No [ ]

6.3 Are there facilities for storing seed at controlled temperatures?

Yes [ ] No [X]

6.4 Indicate the main source of seed supply for the principal savanna plantation species. Seed of teak, Anacardium, Cedrela and neem is obtained from selected seed trees within the country.

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species.
Only Cedrela odorata and Gmelina arborea, introduced a long time ago, are acclimatized.

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country.

Nil.

Country: CONGO (see also Appendix 4)

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 342 000 km^2

1.2 Location: longitude 11°09'04" - 18°40'E; latitude 03°42'30"N -05°02'03"S

1.3 Population 1 500 000 inhabitants

1.4 Main climatic and vegetative zones
Equatorial climate with two seasons: dry season from May to September; wet season from October to April. Vegetation: high forest, mangrove forest, savanna and gallery forest.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests 205 000 km^2

2.2 Area of savanna 1/ 137 000 km^2

2.3 Proportion of land under high forest 60%; in savanna 1/ 40%

2.4 Does the country have a written statement of national forest policy?

Yes [X] No [ ]

2.4.1 If a national forest policy exists, what are the main objectives stated in it? To contain monopolization of commercial forestry; reinforce and develop the state's role in forest exploitation; increase the amount of wood which is processed within the country; conduct research to promote under-utilized tree species; carry out plantation programmes with eucalypts and pines.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points.
Carry out eucalypt and pine plantation programmes in accordance with the first national three-year plan.

2.5 Legislation available to implement policy Yes [X] No [ ]

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V.Laurie, 1974.

2.6 Ownership of forests and savanna	High forests	Savanna
Under state control	100%	100%
Private ownership	-	-
Community ownership	-	-
No effective control	-	-

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and hondey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood).

Fuelwood, charcoal, posts.

2.8 Forestry staff	State	Others
Professional	13	-
Subprofessional (with diploma or certificate of training)	17	-

2.9 Gross annual budget for forestry - US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area[1/] of plantations at the end of 1974: 13 827 ha

3.1.2 Net area [1/] of plantations in the savanna at the end of 1974: 7 392 ha

3.1.3 Planned annual target area of af/reforestation: - ha/year

3.1.4 Planned annual planting rate in savanna: 500 ha/year

3.2 Organization and adminstration of savanna planting schemes

3.2.1 State forest services 100%

3.2.2 Others (specify)

None

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood, protection, etc.), species, growth and rotation of major savanna plantations.

End use	Species	Net area(ha)[1/]	Rotation (Yrs)	Mean annual increment(U.b.) at rotation age (m^3/ha/yr)
Construction timber	*Terminalia superba*	6 435	35	4
pulpwood	eucalypts	5 179	4-6	20-35
pulpwood	pines	2 213	8-12	10-20

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existing permanent savanna nurseries? 2 000 000 plants

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 630 400 plants.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? - plants.

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
Eucalyptus platyphylla	containers (polythene pots)
E. XII ABL	" "
E. urophylla	" "
Pinus caribaea	" "
P. oocarpa	" "

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots",etc.) and give dimensions (lay flat for polythene). polythene pots 17 x 21 cm

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
eucalypts	10-15 cm	8
pines	10 cm	12

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers,etc.) Eucalypt seed is broadcast sown in irrigated seed beds; pricking out into polythene pots is done 4 weeks later. Pines are line sown in seed beds and pricked out (also in polythene pots) 6 weeks later.

4.3.2 Briefly describe the soil mixture and fertilizers (and quantities) used: Soil mixture is 50% black earth and 50% sand. A complete fertilizer (10-10-20) and slag are used.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type). Manual watering is with fine rose watering cans. Watering with rotary sprinklers is done twice a day when plants are young and once a day later.

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements). Insecticides (dieldrex Py or phytosol) are dusted around germination and plant holding beds.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions?
Yes [X] No [ ]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used.
In closed forest, clearing is done with axes and power saws; in the savanna crawler tractors are used.

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna.
Clearing and burning followed by ploughing with a Cropmaster or Crop Pulvérisage with pulverizing discs.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna? Yes [ ] No [X]

If so, indicate for which species

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted.
2.5 x 2.5 m and 3.12 x 3.12 m

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya: - ha

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding

Harrowing between the rows using a wheeled tractor equipped with a disc harrow or rotavator once every three months the first year (i.e. four times) and three times during the second year and manual hoeing around the trees.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals.

At the time of planting poison baits are placed around the base of each plant to protect against insect attack - particularly stem cutting crickets.

5.5.2 Is there a national fire danger rating system?

Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [X] No [ ]

Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes /X/ No / /

6.2 Is there a national tree seed certification system? Yes / / No /X/

6.3 Are there facilities for storing seed at controlled temperatures?
Yes /X/ No / /

6.4 Indicate the main sources of seed supply for the principal savanna plantation species:
eucalypts: Australia, New Guinea and Congo (old plantations)
pines: Central America and Congo (old plantations)

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species.

Various eucalypts and pines: Eucalyptus urophylla, E. tereticornis, Pinus caribaea and P. oocarpa.

VII. REFERENCE MATERIAL

List the main published source of information on afforestation and nursery practice in the savanna regions of your country.

-

Country: GHANA (see also Appendix 5)

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 238 539 km^2

1.2 Location: longitude 1^{o}E to 3^{o}W; latitude 5^{o} - 11^{o}N

1.3 Population: 10 million inhabitants

1.4 Main climatic and vegetative zones: The climate is humid to dry tropical. There are three main vegetation zones namely the coastal thicket, the high forest and savanna.

II. FOREST AND NATIONAL FOREST POLICY

2.1 Area of high forests 82 258 km^2

2.2 Area of savanna[1] 150 497 km^2

2.3 Proportion of land under high forest 34%; in savanna[1] 63%

2.4 Does the country have a written statement of national forest policy?

Yes /X/ No / /

2.4.1 If a national forest policy exists, what are the main objectives stated in it? Creation of sufficient permanent forest resources by reservation to supply direct and indirect benefits necessary for the welfare of the people of Ghana and the management of the Forest resources by methods that achieve sustained maximum productivity and value.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points.

Same as in 2.4.1

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.5 Legislation available to implement policy Yes [X] No [ ]

2.6 Ownership of forests and savanna

	High forests	Savanna
Under state control	-	-
Private ownership	-	-
Community ownership	100%	100%
No effective control	-	-

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood).

Sawlogs, veneerlogs, logs for sleepers, fuelwood, charcoal, poles, gum, export logs.

2.8 Forestry staff

	State	Others
Professional	22	-
Subprofessional (with diploma or certificate of training)	500	-

2.9 Gross annual budget for forestry 7 501 974 US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area[1/] of plantation at the end of 1974: 23 208.00 ha

3.1.2 Net area [1/] of plantations in the savanna at the end of 1974: 3 331 ha

3.1.3 Planned annual target area of af/reforestation: 7 328.00 ha/yr

3.1.4 Planned annual planting rate in savanna: 2 176.00 ha/year

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 100%

3.2.2 Others (specify) -

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood, protection, etc.), species, growth and rotation of major savanna plantations.

End use	Species	Net area(ha)[1/]	Rotation(yrs)	Mean annual increment (u.b.) at rotation age (m^3/ha/year)
Saw Log	Teak + Mahogany	-	60-70 years	-
Pulp	Gmelina + Eucalyptus Anogeissus	-	up to 10 years	-
Poles	Teak	-	10-15 years	-
Charcoal	all spp.	-	10-15 years	-
Fuelwood	all spp.	-	10-15 years	-
Fuel	Neem	-	10-15 years	-

1/ Net areas is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existing permanent savanna nurseries? 3 million plants.

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? Unknown

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? NIL

4.2 Planting stock

4.2.1 Indicate the main type of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
Anogeissus	stumps
Teak	stumps
Eucalyptus	potted
Khaya senegalensis	stripling and potted
Neem	stripling and potted

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene).
Only polythene bags are used: 5 x 7 inches

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
Teak	1½ - 2 ft.	24-30 weeks
Eucalyptus	1½ - 2 ft.	18-24 weeks
Anogeissus	1 - 2 ft.	24-30 weeks
Khaya senegalensis	1½ - 2 ft.	24-30 weeks
Neem	2 - 3 ft.	24-30 weeks

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers, etc.)

(a) Teak, Khaya and Neem are sown on seed beds and pricking out is done immediately on germination either onto transplant beds or into containers. (b) Anogeissus is sown direct on to seed beds. No pricking out is done.

4.3.2 Briefly describe the soil mixtures and fertilizers (and quantities) used. No fertilizers are used. Normally the containers are filled with top soil from the nursery site. Also compost is used.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type).
Where seedlings are raised in polythene bags, watering cans are used twice a day, morning and evening. Canal irrigation is also practised.

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements).
Aldrex is used against insects. Fences are erected against animals and sheds are raised as environmental protection for shade.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions?

Yes [ ] No [X]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used.
The annual bush fires normally leave clumps of grass which is cleared either with hoes or cutlasses. After that the area is stumped.

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna. After stumping a two-disc plough is used to make ridges on which the seedlings are planted.

5.3 Savanna planting and direct seeding.

5.3.1. Is direct seeding used in savanna? Yes [X] No [ ]
If so, indicate for which species: Anogeissus (Nangodi)

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted.
3 x 9 ft., 6 x 9 ft.

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya: - ha.

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding
Weeding on ridges twice a year.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied.
There are no irrigated plantations in Ghana.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens, and animals.
There have been no known severe insect or pathogenic attacks. Limited fencing has been practised against animals.

5.5.2 Is there a national fire danger rating system?

Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [ ] No [X]

Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes [X] No [ ]

6.2 Is there a national tree seed certification system? Yes [ ] No [X]

6.3 **Are there facilities for storing seed at controlled temperatures?**

Yes /X/ 10°C No/ /

6.4 **Indicate the main source of seed supply for the principal savanna plantation species.**
Seeds for savanna species from Jema and other places in the North.

6.5 **List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species.**
The only species being tried at the movement is Acacia senegal.
Seeds have been obtained from the Senegal, Mali and Ghana.

II. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country.

Guidelines in the M.O.P. (Manual of Procedure)

Country: IVORY COAST

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 322 500 km^2

1.2 Location: longitude 02°30' - 09°W; latitude 04° - 11°N

1.3 Population: 6 000 000 inhabitants

1.4 Main climatic and vegetative zones

Climates: Guinea (equatorial) and Sudan-Guinea (tropical)
Vegetation: humid evergreen dense forest; humid semi-deciduous dense forest; pre-forest and savanna.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests 156 719 km^2

2.2 Area of savanna 1/ 165 781 km^2

2.3 Proportion of land under high forest 48.6%; in savanna 1/ 51.4%

2.4 Does the country have a written statement of national forest policy?
Yes /X/ No / /

2.4.1 If a national forest policy exists, what are the main objectives stated in it?

Preservation of the ecological balance; Sustained yield of wood through management and reforestation.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points.
Under study, but no particular statement for the savanna region yet.

2.5 Legislation available to implement policy Yes /X/ No / /

2.6 Ownership of forests and savanna

	High forests	Savanna
Under state control	100%	100%
Forest reserves	2 898 558 ha	1 300 000 ha
National parks	548 000 ha	1 175 000 ha

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood).

For 1974:	logs	-	4 626 000 m^3
	sawntimber	-	564 000 "
	other products	-	70 000 "

2.8 Forestry staff	State	Others
Professional	53	-
Subprofession (with diploma or certificate of training)	120	-

2.9 Gross annual budget for forestry (1975) 6 031 956 US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: 35 300 ha.

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974: 10 000 ha.

3.1.3 Planned annual target area of af/reforestation: 3 500 ha/year

3.1.4 Planned annual planting rate in savanna: stopped after 1968

Questions 3.2 - 5.4.2

For all practical purposes, reforestation in the savanna zone in the Ivory Coast was stopped in 1968 because the Government decided to concentrate its efforts in the high forest by launching an industrial plantations programme.

From a beginning in 1929 and up until that time reforestation in the savanna and pre-forest zones reached a total of 19 700 ha., of which 15 400 ha. were in forest reserves and 4 300 were on village lands. Of the 15 400 ha. of plantations in reserved land, 10 000 ha. are still regularly looked after.

Anacardium was the species most used for village plantings; on forest reserves the following were used:

teak	9 300 ha
Anacardium	2 350 "
Gmelina	1 900 "
Cassia	1 750 "
neem and others	700 "

The establishment techniques used were mechanical (in the Matiemba forest from 1964 to 1966 for 950 ha of teak) and chiefly taungya.

Anacardium was direct sown (2 seeds per planting spot); stumps were used for teak and *Gmelina*; while for *Cassia* bare root seedlings were employed.

Planting densities were 625 - 1000 trees/ha for *Anacardium* and 2 500 trees/ha for most other species. For mechanized teak planting, density was 2 000/ha.

In addition to cashew nuts, fuelwood and general utility wood are produced as well as construction timber from *Gmelina* and teak. Expected commercial production for 1975 from these plantations is:

firewood	36 000 steres
poles	32 000 units
stakes	11 000 units
posts	30 000 units

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

These plantations are old enough now not to require further tending and weeding other than fire protection and improvement cuts.

The valuable plantations, that is the successful ones of sufficient area, are under management. Exploitation is according to plans drawn up for each plantation, the total area being 10 000 ha.

Although afforestation in the savanna zone ceased in 1968, agricultural industries are bringing rapid development to the region and management of rural space is becoming indispensible. Concerning forests and woodlots, the permanent state forest domaine will be consolidated and it is probable that an afforestation programme will be undertaken.

To avoid certain errors which occurred in the past, this programme will involve the local populations concerned, and chiefly the farmers. Three types of schemes are envisaged: private plantations; village and communal plantations; and afforestation on state- controlled land.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals. None.

5.5.2 Is there a national fire danger rating system?

Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [ ] No [X]

Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes [ ] No [X]

6.2 Is there a national tree seed certification system? Yes [ ] No [X]

6.3 Are there facilities for storing at controlled temperatures? Yes [ ] No [X]

6.4 Indicate the main source of seed supply for the principal savanna plantation species: See above note for questions 3.2 — 5.4.2

6.5 List the species tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species. None.

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country.

- Etude de reboisement en zone de savane dans la région de Bouaké Côte d'Ivoire (Nogent/Marne CTFT 1962)
- La protection des sols et la restauration forestière dans les régions de savane du Nord de la Côté d'Ivoire CTFT 1961 (La Mensbruge)
- Les Essences de reboisement en savane: colloque sur les Priorités de la recherche dans le développement économique de l'Afrique, Abidjan les 5 - 12 Avril 1968 (G. de la Mensbruge)
- Les expériences de reconstitution de la savane boisée en Côte d'Ivoire (Bois fer-Trop. 1953 No.32
- Résultats d'expérience forestières entreprises à Bouaké (Nogent/Marne CTFT 1942).

Country: KENYA

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 569 252 km^2

1.2 Location: longitude 34°0' - 43°50'E;latitude 5°N - 4°40'S

1.3 Population: 13 000 000 inhabitants

1.4 Main climate and vegetative zones

i. Afro-Alpine: Moorland and Grassland
ii. Humid-Dry Humid: Forests and derived grasslands
iii. Dry sub-humid - Semi-Arid: Woodland - Wooded Grassland
iv. Arid - very Arid: Dry Woodland and Grassland

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests 17 077 km^2

2.2 Area of savanna 1/ 405 343 km^2

2.3 Proportion of land under high forest 3%; in savanna 1/ 70%

2.4 Does the country have a written statement of national forest policy?
Yes [X] No [ ]

2.4.1 If a national forest policy exists, what are the main objectives stated in it? To manage forests, develop and control forestry for the greatest common good of all. Objectives include Reservation of land for Forest, protection and management of forests, conservation, provision of timber and other forest products.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points.
The Savanna regions are mainly under Private Ownership. Farm Woodlots and Afforestation are encouraged through a Rural Afforesation Scheme covering most of the country.

2.5 Legislation available to implement policy Yes [ ] No [X]

2.6 Ownership of forests and savanna

	High Forests	Savanna
Under state control	......%	......%
Private ownership	......%	......%
Community ownership	......%	......%
No effective control	......%	......%

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.7 **Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood.)**

Sawlogs, pulpwood, fuelwood, veneer logs, poles, piling and posts, gum.

2.8 **Forestry staff**

		State	Others
Professional	At least B.Sc.	45	–
Subprofessional (with diploma or certificate of training)	Diploma	140	200 Certificate

2.9 **Gross annual budget for forestry - US$**

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Area

3.1.1 Total net area 1/ of plantations at the end of 1974: 104 080 ha
3.1.2 Net area 1/ of plantations in the savanna at the end of 1974 : NIL
3.1.3 Planned annual target area of af/reforestation: 4 570 ha/year
3.1.4 Planned annual planting rate in savanna: NIL

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services –

3.2.2 Others (specify):
Rural afforestation covers most districts in Kenya

3.2 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood, protection, etc.), species, growth and rotation of major savanna plantations.

End use	Species	Net area (ha) 1/	Rotation (Yrs)	Mean annual increment (u.b.) at rotation age m^3/ha/yr)
....	.....	....	....	....
....	.....	....	....	....
....	.....	....	....	....

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1. What is the total annual production capacity of existing permanent savanna nurseries? .... plants.

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries?........plants.

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? .... plants

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
....	....
....	....
....	....

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene).
Polythene tubes.

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
....	....	....
....	....	....
....	....	....
....	....	....

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers, etc.)
1) Bedsowing and pricking out into containers.
2) Bedsowing and pricking out into boxes.

4.3.2 Briefly describe the soil mixtures and fertilizers (and quantities) used...
....

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type)
....
....

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements).
....
....

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions?

Yes [ ] No [X]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used
....
....

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna.
....
....

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna Yes [ ] No [X]
If so, indicate for which species......................

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted.

2.75 m x 2.75 m

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya........ ha

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied.

None

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals.
....
....

5.5.2 Is there a national fire danger rating system?

Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [ ] No [X]

Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes [X] No [ ]

6.2 Is there a national tree seed certification system? Yes [X] No [ ]

6.3 Are there facilities for storing seed at controlled temperatures?
Yes [X] No [ ]

6.4 Indicate the main sources of seed supply for the principal savanna plantation species. Local supply from established seed areas and orchards.

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species.
Eucalyptus tereticornis, saligna, camaldulensis
Pinus caribaea, oocarpa, kesiya

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country.
Technical notes, published for Department use.
Technical Orders, prescriptions published for the Department.
Forest Bulletins - occasional publications.

Country: SENEGAL

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 220 000 km^2

1.2 Location: longitude 11°22' - 17°32 W; latitude 12°18' - 16°41'N

1.3 Population: 4 320 000 inhabitants

1.4 Main climatic and vegetative zones

a) Sahel - Senegal climate, b) coastal Sahel - Senegal climate, c) Sahel - sahara climate, d) sahel-Sudan climate, e) Guinea climate. Vegetation types employing the same names corresponding to these climatic types.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests 500 km^2

2.2 Area of savanna 1/ 110 000 km^2

2.3 Proportion of land under high forest 0.27%; in savanna 1/ 60%

2.4 Does the country have a written statement of national forest policy?
Yes [X] No [ ]

2.4.1 If a national forest policy exists, what are the main objectives stated in it?
a) Manage forest exploitation in the short run for the production of fuelwood, general utility wood and construction timber;
b) Enrich the forest domain by introducing high value exotic species;
c) Promote the protection of nature and wildlife conservation.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points.
Same as 2.4.1 above

2.5 Legislation available to implement policy Yes [X] No [ ]

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end , desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.6 Ownership of forests and savanna

	High forests	Savanna
Under state control	100%	100%
Private ownership	-	-
Community ownership	-	-
No effective control	-	-

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood).
Sawnwood, construction timbers, veneer, stakes, props, poles, posts, and artisan wood.

2.8 Forestry staff

	State	Others
Professional	4	-
Subprofessional (with diploma or certificate of training)	208	-

2.9 Gross annual budget for forestry 1 260 870 US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: - ha

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974:- ha

3.1.3 Planned annual target area of af/reforestation:- ha/year

3.1.4 Planned annual planting rate in savanna:1 700 ha/year

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 100%

3.2.2 Others (specify -

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuel wood, protection, etc.), species, growth and rotation of major savanna plantations.

End use	Species	Net area(ha) 1/	Rotation years	Mean annual increment (u.b.) at rotation age (m^3/ha/yr)
Construction timber	teak	2 133	50-80	-
Sawtimber and veneer	Gmelina	1 266	20-25	-
Charcoal	eucalypts	-	-	-
Protection stands	Casuarina	3 200	8-10	-
General utility wood	Casuarina	1 900	8-15	15
Line plantings	neem	-	-	-
Windbreaks	Anacardium	6 200	-	-

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual capacity of existing permanent savanna nurseries ? 3 - 4 000 000 plants

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 3 000 000 plants.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? 500 000 plants.

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
teak	stumps
Gmelina	striplings
neem	bare-root
Casuarina	polythene tubes
eucalypts	polythene tubes

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene).
Polythene pots 8 - 10 cm diameter and 25 cm long are used for some species (eucalypts and Casuarina)

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
teak	stumps	52 - 104
Gmelina	striplings or stumps	52
eucalypts	60 cm	17
Casuarina	60 cm	25
Melaleuca	40 cm	25

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries(bed sowing, pricking out, direct sowing into containers, etc.).
Teak, Gmelina and neem are sown in seedbeds; Casuarina, eucalypts , Melaleuca and Acacia albida and A. senegal are direct sown into tubes.

4.3.2 Briefly describe the soil mixtures and fertilizers (and quantities) used.
The quantities of fertilizers and soil mixture are not the same for all soils, some of which are rich with a high humus content while others are poor and sandy or clayey. For Casuarina in sandy soil 1 kg of NPK fertilizer is used per m^3 of soil.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type). -

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements).
Protection methods against pathogens, insects and animals are almost always the same - knowledge of use of baits, anticoagulants and antiseptic products against rodents; insecticides dieldrin and BHC against termites; erecting fences against animals; and fire protection and surveillance.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions?
Yes [X] No [ ]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used.
The principal land clearing method is manual and occasionally mechanical. Agri-silviculture (taungya) is often practised, with farmers aiding in the land clearing, burning, planting, protection and weeding. This method is generally used for planting teak and *Gmelina* (with mountain rice) *Anacardium* (with millet) and *Acacia albida* (with millet and groundnuts).

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna.
Where rainfall is greater than 1100 mm, normal planting holes are prepared. In drier regions, large holes and sub-soiling are used. On dunes fertilizers are needed if the soil is poor.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna? Yes [X] No [ ]
If so, indicate for which species: *Anacardium occidentale*, teak and *Gmelina*

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted.
teak: 2.5 x 2.5 m eucalypts: 3 x 3 m *Anacardium*: 10 x 10 m
Gmelina: 2.5 x 2.5 m *Acacia*: 4 x 4 m

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya: 12 000 ha.

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding. Weeding is usually manual and is required only once after the winter and rarely in the dry season. Watering every two days during the first dry season is not always done.

5.4.2 If irrigation is used in plantations, give the area irrifated of each species, the frequency of watering and the quantity of water applied. Irrigation is not used.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals.
Where means permit, firebreaks are maintained. Insecticides (BHC powder) are used; pesticides and anticoagulants are employed against rodents (especially the palm rat) and barbed-wire fences are erected to guard against animals.

5.5.2 Is there a national fire danger rating system?
Yes [X] No [ ]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. ~~prescribed~~ or early) burning practiced in savanna plantations? Yes /_/ No /X/

Around plantations? Yes /_/ No /X/

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes /_/ No /X/

6.2 Is there a national tree seed certification system? Yes /X/ No /_/

6.3 Are there facilities for storing seed at controlled temperatures? Yes /_/ No /X/

6.4 Indicate the main sources of seed supply for the principal savanna plantation species. Sufficient supplies of teak, Casuarina, eucalypts and, after 1976 Gmelina, seed is available locally.

6.5 List the species being tested in comparative trials in the savanna. Indicate in paretheses the number of provenances being tested of each species.
Eucalyptus camaldulensis (100 Australian sources)
Melaleuca sp. (8 provenances) among which the best are from Casamance).

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country.
"L'arbre dans le paysage sénégalais: sylviculture en zone tropicale sèche" by P.L. Giffard, CTFT, 1974.

Country: SUDAN

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 2 506 800 km^2

1.2 Location: longitude 22 E - 37 E;latitude 4 - 22 N

1.3 Population: 16 000 000 inhabitants

1.4 Main climatic and vegetative zones

(i) Desert (ii) Semi-desert

(iii) Low rainfall savanna (iv) High rainfall Savanna (v) Montane vegetation (vi) Flood region

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests ..../........km^2

2.2 Area of savanna 1/ 445 000 km^2

2.3 Proportion of land under high forest ...../.....%; in savanna 1/ 40%

2.4 Does the country have a written statement of national forest policy?

Yes [X] No [ ]

2.4.1 If a national forest policy exists, what are the main objectives stated in it?

1) To provide forest products to the population and to forest industries. To protect and conserve existing vegetation and catchment areas.

2) To combat desert creep.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points.

(i) Levying of royalties (ii) to reserve 15% of the areas as forests (iii) prohibit overgrazing, overfelling and fires (iv) opening of fire lines

(v) Establishment of shelterbelts (2-4%) in every agricultural scheme.

2.5 Legislation available to implement policy Yes [X] No [ ]

2.6 Ownership of forests and savanna

	High forests	Savanna
Under state control	100%	100%
Private ownership	-	-
Community ownership	-	-
No effective control	-	-

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as decribed in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development paper No.19, by M.V. Laurie, 1974.

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood). Sawn timber, fuelwood, charcoal, gums, beeswax, honey, poles.

2.8 Forestry staff

	State	Others
Professional	38	-
Subprofessional (with diploma or certificate of training)	211	-

2.9 Gross annual budget for forestry 2,500.000 US$

III. AFFORESTATION AND REFORESTATION GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: 119735 ha.

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974: 100352 ha

3.1.3 Planned annual target area of af/reforestation: 10,000 ha/yr

3.1.4 Planned annual planting rate in savanna: 20,000 ha/yr

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 100%

3.2.2 Others (specify) %

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood, protection, etc.), species, growth and rotation of major savanna plantations.

End use	Species	Net area ha 1/	Rotation (yrs)	Mean annual increment (u.b.) at rotation age m^3/ha/yr
Fuelwood	A. nilotica	29117	30 - 35	-
Fuelwood	A. mellifera	1600	-	-
Gum arabic	A. senegal	36554	25 - 30	-
Post+poles	Euc. spp.	9860	8 - 10	-
Sawn Timber	Tectona grandis	9690	80	-
Protection	Prosopis chilensis	-	-	-

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existiing savanna nurseries? 6 000 000 plants.

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 2 586 251 plants

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? - Plants.

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
A. senegal	Container stock
A. nilotica	–
Tectona grandis	Stumps
Eucalyptus sp.	Container stock

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene). Polythene tubes 10 cm x 20 cm.

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
Euc. spp.	30 cm	32
Tectona grandis	8 cm	40
A . senegal	20 cm	40

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers, etc.) Bed sowing is used for preparing teak stumps. Seedlings are transplanted directly after germination into raised beds 20 cm apart and after 40 weeks stumps are planted out. Eucalypt seeds are also sown into beds and then transplanted into tubes. Other species are already sown into containers.

4.3.2 Briefly describe the soil mixtures and fertilizers (and quantities) used. Soil mixture is prepared by mixing sand and loamy soil in the ratio of 2:1. Fertilizers are not generally used; sometimes farm yard manure is added if deemed necessary.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type).

1) Spraying transplants once daily.
2) Flooding once (1 - 5 days)
3) Rain nurseries (mainly in the South)

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements).

1) Insecticides (e.g. Dieldrin)are used against insects.
2) Thorn, barbed wire enclosures are used against animals and rodents.
3) Shelterbelts are used in exposed areas.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions?
Yes [X] No [ ]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used.

(i) Mechanical clearance (in mechanised crop production schemes) followed by fire.
(ii) Axe - felling.

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna.

(i) Soil working by ploughing.
(ii) Ridge and furrow.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna? Yes /X/ No / /

If so, indicate for which species: Acacia nilotica

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted. 2 m x 3 m - Acacia senegal: 4 m x 4 m - Acacia mellifera: 4 m x 4 m

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya: 40 000 ha

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding. Hand weeding is usually carried out once in the first and second year. Another weeding if need arises is carried out in the third year.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied.

Eucalypts	30 000 ha
Frequency	fortnightly
Quantity	10 000 cu.m./ha (approx.)

5.5 Protection of savanna plantations

5.5.2 Is there a national fire danger rating system?
Yes / / No /X/

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes /X/ No / /

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes /X/ No / /

Around plantations? Yes /X/ No / /

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes / / No /X/

6.2 Is there a national tree seed certification system? Yes /X/ No / /

6.3 Are there facilities for storing seed at controlled temperatures? Yes /X/ No / /

6.4 Indicate the main sources of seed supply for the principal savanna plantation species. Locally collected from mother trees.

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species.
i) Eucalyptus hybrid (Mysore)
ii) Acacia senegal (selected seeds from high yielding trees).

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country.

i) Badi, K.H. (1972) Afforestation in the clay plains of Kassala province, For. new series No.13

ii) Booth, G.A. (155) Afforestation in Dueim Range While Nile Sudan Silva No.1.

iii) Foggie, A. (1966) Forestry and forestry policy in the Gezera area, FAO, ETAP Rep. Soudan Govt.

iv) Khan, M.A.W. (1966) Improved methods and devices in nursery practice, UNDP for Res. Ed pro Sudan 28.

Country: TOGO

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 56 000 km^2

1.2 Location: longitude 0° - 1°40'E; latitude 06° - 11°N

1.3 Population: 2 000 000 inhabitants

1.4 Main climatic and vegetative zones: a) Guinea climate in the south, corresponding to relatively dense tree savanna with some forest relics; b) Sudan climate in the north, with tree and shrub savanna, savanna woodlands and steppes; c) Equatorial climate in mountainous regions, with dry, dense forest formations and montane tree savanna.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests 1 680 km^2

2.2 Area of savanna 1/ 21 280 km^2

2.3 Proportion of land under high forest 3%; in savanna 1/ 38%

2.4 Does the country have a written statement of national forest policy?
Yes /X/ No / /

2.4.1 If a national forest policy exists, what are the main objectives stated in it? Immediate objectives: Regulate the flow of fuelwood and general utility wood from the main supply centres; Short term objectives (10 - 15 years): a) establish plantations of fast-growing species; b) manage and exploit some forest blocks in order to reduce imports; Medium and long term objectives: supply wood from plantations to processing industries beneficial to the country.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points. The above outlined policy is implemented on 80% of the savanna area with an annual rainfall of 1000-1200 mm. In the north, in grass savanna and in denuded zones, the policy is still under study.

2.5 Legislation available to implement policy Yes /X/ No / /

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.6 Ownership of forests and savanna

Ownership of the 430 000 ha of officially classified forests in the savanna and high forest regions is not yet determined.

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood). Fuelwood, sawtimber, sleepers, posts, piling, gum, besswax and honey.

2.8 Forestry staff	State	Others
Professional	11	-
Sub-professional (with diploma or certificate of training)	42	-

2.9 Gross annual budget for forestry - US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: 5 500 ha

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974: 4 500 ha

3.1.3 Planned annual target area of af/reforestation: 1 000 ha/yr

3.1.4 Planned annual planting rate in savanna: 600 ha/year

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 100 %

3.2.2 Others (specify). Private plantations are rare.

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood, protection, etc.) species, growth and rotation of major savanna plantations.

End use	Species	Net area (ha) 1/	Rotation (Yrs)	Mean annual increment (u.b.) at rotation age (m^3/Ha/yr)
firewood	eucalypts	300	10-12	-
general utility	teak	700	20-50	-
sawtimber	Terminalia			
veneer	Cedrela			

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existing permanent savanna nurseries? 1 500 000 plants

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 500 000 plants.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? 500 000 plants

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
eucalypts	polythene pots
teak	stumps
Gmelina	stumps
Cedrela	stumps

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene). Polythene pots: 25 cm long, 8 - 10 cm diameter

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
eucalypts	2.5 - 5 cm*	12 - 15
Cedrela	5 -10 cm*	20 - 24
Gmelina	5 - 10 cm*	20 - 24

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers, etc.) Sowing is into plastic or galvanised frames of 2 000 cm^2 area, seed-beds, or for teak stumps into prepared open beds. Pricking-out is done into polythene pots or beds.

4.3.2 Briefly describe the soil mixtures and fertilisers (and quantities) used: Soil mixture is composed of 50% fluvial sand and 50% earth or sifted humus. Fertilisers are not used.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type): Framed beds are mist irrigated; watering cans are used for other beds.

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements): For eucalypts, the soil/sand mixture is steam sterilised on metal sheets and sifted.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions? Yes [ ] No [X]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

* pricking-out size

5.2.1 Briefly describe the main savanna land clearing methods used.
a) Manual clearing by eliminating understorey plants and the herbaceous cover followed by windrowing; b) Mechanical clearing using crawler tractors with or without windrowing.
Note: Charcoaling is practised in some areas in conjunction with clearing

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna: Some mechanically cleared areas to be planted are worked with a heavy plough (Rome) pulled by a D-6 tractor; others are turned with a Massey-Ferguson and a 3-disc plough; while on lands to be planted by local people, traditional methods of cultivation are used.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna? Yes [ ] No [X]
If so, indicate for which species. -

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted. -

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya: about 5 000 ha

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding: a) Clean weeding manually by hoe and machete twice a year for the first two years following establishment; b) Mechanical clean weeding with a rotavator twice a year in some stands.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied.
None

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals: None

5.5.2 Is there a national fire danger system? Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [ ] No [X]
Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre ? Yes [X] No [ ]

6.2 Is there a national tree seed certification system? Yes [X] No [ ]

6.3 Are there facilities for storing seed at controlled temperatures?
Yes [X] No [ ]

6.4 Indicate the main sources of seed supply for the principal savanna plantation species. Ghana, Nigeria, Venezuela, France, Costa Rica, Australia and local stands.

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species.

Afzelia africana	Cedrela odorata	E. citriodora	Khaya grandifoliola
Anogeissus leiocarpus	Ceiba pentandra	E. ferruginea	K. senegalensis
Anthocephalus cadamba	Cordia alliodora	E. grandis	Pterocarpus angolensis
Araucaria cunninghamii	Dalbergia sp.	E. microtheca	Sterculia foetida
Azadirachta indica	Erythrophleum guineense	E. nesophila	Tectona grandis
Callitris intratropica	Eucalyptus alba	E. robusta	Triplochiton scleroxylon
Calophyllum sp.	E. brassii	E. tereticornis	
Casuarina equisetifolia	E. camaldulensis	E. torelliana	

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country. -

Country: UGANDA

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 235 890 km^2

1.2 Location: longitude 29°30' — 35°0 latitude, 1°30' S — 4°North

1.3 Population: 10 million inhabitants

1.4 Main climatic and vegetative zones: (1) Closed forest (2) Open forest and grass land (3) Steppe and grassland. Tropical climate with 2 peaks pattern rainfall April/May and October/November.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests 6 323 km^2

2.2 Area of savanna 1/ 7473 km^2

2.3 Proportion of land under high forest 41%; in savanna 1/ 49%

2.4 Does the country have a written statement of national forest policy? Yes /X/ No / /

2.4.1 If a national forest policy exists, what are the main objectives stated in it? (1) To reserve adequate land as forest estate so as to ensure a) a sustained production of timber and other forest products for the needs of the country and export, b) Protection of water catchments, soil, wildlife and amenity of land; (2) To develop that estate so as to obtain maximum economic returns to the country; (3) To ensure efficient conversion of wood and wood products so as to reduce waste; (4) Help people and organisations to grow and protect their own trees; 5) Education of the public to the role of forestry and forest industries.

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points. Not officially stated but understood to be (1) Establishment of forest plantations, both softwoods and eucalypts, for building poles and fuel. (2) As in (1) above, i.e. protection soil, wildlife and amenity of land.

2.5 Legislation available to implement policy Yes /X/ No / /

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.6 Ownership of forests and savanna

	High forests	Savanna
Under state control	97%	85%
Private ownership	1%	10%
Community ownership	-	-
No effective control	2%	5%

2.7 **Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood).** Fuelwood 185 000 m^3, Particleboard 5 584 m^2, charcoal 600 000 m^3, plywood and block-board 635 m^2, sawlogs 175 000 m^3, poles 32 500 m^3.

2.8 Forestry staff

	State	Others
Professional	43	-
Subprofessional (with diploma or certificate of training)	225	-

2.9 Gross annual budget for forestry 2 000 000 US$

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: 45 000 ha

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974: 35 000 ha

3.1.3 Planned annual target area of af/reforestation: 3 500 ha/year

3.1.4 Planned annual planting rate in savanna: 2 000 ha/year

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 95%

3.2.2 Others (specify) Tobacco Society Woodfuel Plantations 5%

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood protection, etc.), species, growth and rotation of major savanna plantations.

End use	Species	Net area (ha) 1/	Rotation(Yrs)	Mean annual increment (u.b.) at rotation age (m³/ha/yr)
Sawtimber	Cupressus lusitanica		20-25	
"	Pinus patula		20-25	
"	P. caribaea/occarpa		20-25	
Post+poles	Euc. camaldulensis			
	" tereticornis			
	" grandis		5-14	
Pulpwood	P.caribaea, P. sp.		15	
Fuelwood	Euc.camaldulensis			
	" tereticornis			
	" grandis		4-8	
Protection others			Unlimited	

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existing permanent savanna nurseries? 20 000 000 plants.

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 15 000,000 plants.

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? 1 500 000 plants.

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants, stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
P. caribaea	Container stock
P. patula	"
P. oocarpa	"
Cup. lusitanica	"
Euc. camaldulensis, Euc. tereticornis	"
Euc. grandis	"

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene).
Polythene tubes and mill pots 4" lay flat and 7" for ornamentals

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
Cypressus spp.	1 ft (30 cm)	36 weeks
Pine spp.	1 ft (30 cm)	16 - 20 weeks

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nurseries (bed sowing, pricking out, direct sowing into containers, etc.).
1) The seed is sown by broadcasting after mixing with sand and pricked out in containers when 0.5 - 1 cm tall. This is both in softwoods and eucalypts.
2) When containers are not available pricking out is done into Swaziland beds or boxes.

4.3.2 Briefly describe the soil mixtures and fertilizers (and quantities) used: Soil mixtures vary site to site but normally forest or black soil together with cow manure are used. Fertilizer is mixed thus: 1 500 gms/m^3 of soil in heaps and 100 gms/m^3 for top dressing.

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type) : 1) Watering cans are used at least twice daily, morning and evening. 2) Overhead irrigation water-pumped by hand pumps.

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements): 1) Spraying and soil pre-treatment with fungicides and insecticides, 2) Clearing around nurseries discourages rats, 3) Ditch drains prevents floods and washout, 4) Fencing prevents large animals from walking over plants.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions?
Yes [ ] No [X]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [X] No [ ]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used.
1) Manual cutting of trees and grass slashing is followed by burning,
2) Peasant farmers may be allowed to clear the bush and cultivate before planting,
3) Poisoning of large trees with aboricide in more open grassland.

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna: (1) Lining out using a pre-marked rope at planting spacing intervals and pegging, 2)Pitting using hoes and marked pits ready for planting.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna Yes [ ] No [X]
If so, indicate for which species.

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted.
For Eucalyptus - 1.8m by 1.8m, 2.1m by 2.1m and 2.4m by 2.4 m have been tried, but 2.1m by 2.1 m now predominates. For cypressus and pines 2.7m by 2.7 m is used.

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya.

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding: In first rotation eucalypt plantations,weeding is done 4 times the first year,twice the second year by clean hoeing,and once in the third year by slashing.Afrer felling only one line slashing is needed. In cypress and pine plantations,line slashing is done twice the first year and once the second year.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species the frequency of watering and the quantity of water applied.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects,pathogens and animals: 1) Insecticide treatment of plants before planting to control termite attack as well as fungus. 2) Clean weeding protects young trees from rat attack.

5.5.2 Is there a national fire danger rating system? Yes [ ] No [X]

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation establishment? Yes [X] No [ ]

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes [X] No [ ]
Around plantations? Yes [X] No [ ]

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre Yes /X/ No / /

6.2 Is there a national tree seed certification system? Yes /X/ No / /

6.3 Are there facilities for storing seed at controlled temperatures?
Yes /X/ No / /

6.4 Indicate the main source of seed supply for the principal savanna plantation species.
1) For cypressus and pines most of the seed is imported mainly from Central America and the Caribbeans. 2) For Eucalyptus most of the seed used in our plantations is collected locally from chosen seed stands.

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number or provenances being tested of each species.
Pinus patula (3), Cupressus lusitanica (2), Pinus caribaea (2), Pinus oocarpa (1).

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country. (1) Uganda Forest Department Technical Notes nos. 78/59, 135/67, 138/67, 139/67, 144/67, 145/67, 146/67, 159/69, 179/71, 181/71, 183/72, etc. (2) A Forest Resources Development Study Report by CIDA. (3) Uganda Forest Department Annual Reports. (4) Uganda Forest Departmental Standing Orders revised Edition 1970. (5) Forests and Forest Administration of Uganda 1961.

Country: ZAMBIA

I. GENERAL GEOGRAPHICAL INFORMATION

1.1 Area of country 752 613 km^2

1.2 Location: longitude 22°E to 34°E; latitude 8°S to 18°S

1.3 Population: 4½ million inhabitants

1.4 Main climatic and vegetative zones: Tropical savanna.

II. FORESTS AND NATIONAL FOREST POLICY

2.1 Area of high forests Nil

2.2 Area of savanna 1/ 600 000 km^2

2.3 Proportion of land under high forest: Nil; in savanna 1/ 80%

2.4 Does the country have a written statement of national policy?

Yes [X] No [ ]

2.4.1 If a national forest policy exists, what are the main objectives stated in it?

(a) Protection of forested areas and watersheds
(b) Provide forest produce for industry and rural users
(c) Research into indigenous and plantation wood
(d) Extension work and advice to public
(e) Training of staff

2.4.2 If there is an official statement of forest policy for the savanna region, briefly outline its main points: No separate policy except "early burning".

2.5 Legislation available to implement policy Yes [X] No [ ]

2.6 Ownership of forests and savanna

	High forests	Savanna
Under state control	Nil	8.9%
Private ownership	Nil	2.4%
Community ownership	Nil	88.7%
No effective control	Nil	-

1/ For the purpose of this questionnaire, savanna is considered as including the full range of tropical vegetation types of which grass is a significant characteristic. At one end of the spectrum, closed forest and thickets are excluded; at the other end, desert is excluded. Between these extremes, savanna comprises the various types of savanna woodland, savanna and steppe as described in Appendix 1 of Tree Planting Practices in African Savannas, FAO Forestry Development Paper No.19, by M.V. Laurie, 1974.

2.7 Principal forest products from all regions (e.g. fuelwood, charcoal, sawlogs, gum, beeswax and honey, veneerlogs, logs for sleepers, poles, piling and posts, pulpwood): Sawlogs, sleepers, poles, fuelwood, charcoal, honey, beeswax.

2.8 Forestry staff

	State	Others
Professional	44	17
Subprofessional (with diploma or certificate of training)	222	336

2.9 Gross annual budget for forestry 7 543 740 US$ (K4 804 930)

III. AFFORESTATION AND REFORESTATION, GENERAL

3.1 Areas

3.1.1 Total net area 1/ of plantations at the end of 1974: 24 900 ha

3.1.2 Net area 1/ of plantations in the savanna at the end of 1974: 24 900 ha

3.1.3 Planned annual target area of af/reforestation: 3 300 ha/year

3.1.4 Planned annual planting rate in savanna: 3 300 ha/year

3.2 Organization and administration of savanna planting schemes

3.2.1 State forest services 99%

3.2.2 Others (specify) : Agricultural scheme

3.3 Intended principal end use (e.g. sawtimber, posts and poles, pulpwood, fuelwood, protection, etc.), species, growth and rotation of major savanna plantations

End use	Species	Net area (ha) 1/	Rotation (yrs)	Mean annual increment (u.b.) at rotation age (m^3/ha/yr)
Sawlogs	P. kesiya	13 000	30	15
Sawlogs	P. oocarpa	2 100	30	15
Poles	E. grandis	6 000	8	12
Poles	E. cloeziana	1 900	10	11
Poles	others	1 900	various	-

IV. SAVANNA NURSERY PRACTICE

4.1 Nursery types and capacities

4.1.1 What is the total annual production capacity of existing permanent savanna nurseries? 4 million plants

4.1.2 What is the actual annual production (average from last 3 years) from permanent savanna nurseries? 3 million plants

4.1.3 What is the annual production (average from last 3 years) from temporary savanna nurseries? Nil

4.2 Planting stock

4.2.1 Indicate the main types of planting stock (bare-rooted transplants stumps, container stock, etc.) raised for the principal savanna plantation species.

Species	Type of stock
Pinus kesiya	Polythene tubes
Pinus oocarpa	" "
Eucalyptus cloeziana	" "
Eucalyptus grandis	" "

1/ Net area is the gross area of plantations minus the area in roads, rides, buildings and other non-stocked land.

4.2.2 If containers are used, state type (polythene tubes or pots, "jiffy pots", etc.) and give dimensions (lay flat for polythene): Black polythene tubes 12 cm x 10 cm.

4.2.3 Give average size (height) of savanna outplanting stock and length of time (weeks) required to raise it in the nursery.

Species	Outplanting size	Weeks in nursery
Pines	20 cm	16 weeks
Eucalyptus	15 cm	8 weeks

4.3 Savanna nursery methods

4.3.1 Briefly describe the sowing methods used in savanna nuseries (bed sowing, pricking out, direct sowing into containers, etc.): Pines, direct sowing. Eucalyptus, seed beds and pricking out.

4.3.2 Briefly describe the soil mixture and fertilizers (and quantities) used: top soil collected in woodland, fertilised with "Welgro" or "Wuseal"

4.3.3 Briefly describe savanna nursery watering methods and schedules (If mechanical irrigation equipment is used, indicate type): Spray irrigated by perforated pipes or "rainbirds".

4.3.4 Briefly describe the standard savanna nursery protection measures (against pathogens, insects, animals, environmental elements). Watering with Zineb fungicide. Treatment of potting soil with methyl bromide watering of Eucalyptus with Aldrin as insurance against termites in the field.

V. ESTABLISHMENT TECHNIQUES FOR SAVANNA PLANTATIONS

5.1 Site selection

5.1.1 Are detailed vegetation maps available for most savanna regions? Yes [X] No [ ]

5.1.2 Are detailed soil maps and soil survey descriptions available for most savanna regions? Yes [ ] No [X]

5.2 Land clearing and site preparation

5.2.1 Briefly describe the main savanna land clearing methods used. Large areas cleared mechanically by contractors. Small rural areas stumped by hand.

5.2.2 Briefly describe the principal site preparation techniques used after land clearing in the savanna: Ploughing and disc-harrowing.

5.3 Savanna planting and direct seeding

5.3.1 Is direct seeding used in savanna? Yes [ ] No [ ]

If so, indicate for which species.

5.3.2 Indicate the most common spacings at which the main savanna plantation species are planted: Pines and Eucalyptus = 1 000 per hectare.

5.3.3 Give the total number of hectares of plantations established to date in the savanna by means of taungya: Nil

5.4 Tending of savanna plantations

5.4.1 Briefly describe the method and frequency of weeding: Disc harrow between rows, in both directions. First year 6 times; for all species: second year twice for Eucalyptus and 4 times for pines; third year twice for pines.

5.4.2 If irrigation is used in plantations, give the area irrigated of each species, the frequency of watering and the quantity of water applied: Not used.

5.5 Protection of savanna plantations

5.5.1 Briefly describe protection measures against insects, pathogens and animals: None in the plantation.

5.5.2 Is there a national fire danger rating system?
Yes /_/ No /X/

5.5.3 Are fire breaks and fire lines allowed for at the time of savanna plantation **establishment?** Yes /X/ No /_/

5.5.4 Is controlled (i.e. prescribed or early) burning practiced in savanna plantations? Yes /X/ No /_/

Around plantations? Yes /X/ No /_/

VI. SEED AND TREE IMPROVEMENT

6.1 Is there a national tree seed coordinating centre? Yes /X/ No /_/

6.2 Is there a national tree seed certification system? Yes /X/ No /_/

6.3 Are there facilities for storing seed at controlled temperatures?
Yes /X/ No /_/

6.4 Indicate the main sources of seed supply for the principal savanna plantation species: Locally collected from selected stands and seed orchards.

6.5 List the species being tested in comparative trials in the savanna. Indicate in parentheses the number of provenances being tested of each species: All the tropical pines have been tried and all the Eucalyptus from the East Coast of Australia.

VII. REFERENCE MATERIAL

List the main published sources of information on afforestation and nursery practice in the savanna regions of your country: Methods developed locally by Forest Department.

ANNEX 4

SAVANNA AFFORESTATION IN THE PEOPLE'S REPUBLIC OF CONGO

Zinga Kanza
Office Congolais des Forêts
Pointe-Noire, Congo

TABLE OF CONTENTS

INTRODUCTION

The People's Republic of the Congo, which lies in Central Africa between 11°9'41" and 18°40" East longitude and between 3°42'30" North and 5 °2'3" South latitude is 342 000 km^2 in size. Forests in the Congo occupy choice land, covering a little over 60% of the total area. The rest of the country is savanna, comprising some 137 000 km^2 of relatively flat, unbroken land.

Three types of savanna are usually distinguished, namely:

baren savanna
bush savanna
and gallery forests.

Because of these exceptional natural conditions, Congo foresters have for both economic and scientific reasons been drawn to work largely on savanna.

BACKGROUND - PURPOSES

Trial afforestation of savanna in the Congo dates back to 1950. Initially, trials were started with local species. The first man-made stands were laid out in association with food crops (maize, groundnuts /peanuts/) using mainly 'limba' (Terminalia superba), teak, Ceiba pentandra, the 'iroko' (Chlorophora excelsa), and Cassia siamea.

Later on, research and studies were devoted mainly to the introduction, acclimatization and growing of exotic, fast-growing species - in 1953, eucalypts (Eucalyptus saligna, E. robusta, E. alba, E. paniculata and E. camaldulensis, E. 12 ABL and E. tereticornis) and toward 1959, pine (Pinus caribaea and P. oocarpa).

These plantation operations were launched initially and simultaneously at the forest research stations of Loandjili (Pointe-Noire) and Loudima (Bouenza) and subsequently at the km 45 station (Brazzaville) and at Malolo (Niari).

The original purposes were:

- to provide timber and fuelwood to the inhabitants of the large urban centres of Pointe-Noire, Loubomo (Dolisie) and Nkayi (Jacob);

- to supply the Congo-Ocean railway (CFCO) with fuelwood (this line having used steam engines before its complete changeover to diesel engines); and

- to supply pulpwood for a pulp and paper industry to be set up.

ECOLOGICAL CONDITIONS

Soils and Vegetation

Trials were conducted on three types of savanna:

- coastal savanna on sandy shores in the Kouilou area with poor, deep and highly filtering soil containing 5 to 8% clay and covered with short grasses and Annona arenaria;

- clayey savanna in the Niari and Bouenza valley, covered with shrub vegetation (Hymenocardia acida, Annona arenaria, Bridelia ferruginea, Nauclea esculenta), criss-crossed with gallery forests. The soils are clays, resulting from decalcification, rather poor in exchangeable bases and somewhat acid (pH: 4.7 to 5) but of good structure from the start;

- sandy savanna of the Pool and the Batékés plateau region, sparsely covered with shrubs and in spots with degraded gallery forests; the soils are poor sands containing a little organic matter, and are highly filtering.

Climate

The tropical climate is characterized by moderate rainfall (from 1 200 to 1 700 mm), though with great fluctuations from one year to the next, and high atmospheric humidity that does not change much over the year. The rainy season runs from October to May, with short dry seasons of one month between 15 December and 1 March. The dry season is well marked and lasts for four months, from June to September. All this time there is no rain. The average annual temperature ranges from 24°C to 26°C (24.9°C in 1973 at Pointe-Noire).

Table of Climatic Data

1973	Loudima	Loandjili (Pointe-Noire)	Km Rouge (Brazzaville)
Latitude	4°1'	4°45'	4°49'
Altitude (elevation)	150 m	80 m	700 m
Total annual rainfall	1 150 mm	1 318 mm	1 513 mm
Number of rainy days	96	123	120
Average maximum temperature of the hottest month	27.0° April	26.9° March	26.4° March
Average minimum temperature of the coldest month	22.0° July	21.7° July	21.6° July

Relief

The topography is rather flat on all three types of savanna where the forest stations are located:

Loandjili: coastal savanna at 100 m elevation,
Loudima: savanna in the Niari valley at 150 m elevation,
and Km Rouge: savanna of the Batékés Plateau at 700 m elevation.

AFFORESTATION METHODS USED FOR EUCALYPTS

Species of Eucalypts Used

Eucalyptus 12 ABL

This is a particularly excellent provenance derived from *Eucalyptus tereticornis* introduced in 1956 with seed from Madagascar. This species covers over 3 500 ha at Loudima and its growth on all forest sites is excellent. *Eucalyptus* timber is fire resistant. Ninety-nine percent of the stems give off shoots. The main drawback of *Eucalyptus* 12 ABL is that it does not protect the soil well and is sensitive to competition of other vegetation.

Eucalyptus platyphylla F1

This is a hybrid, the mother stock of which was introduced into the Congo in 1957 under the name E. platyphylla of Java. Apparently the mother stock itself is a hybrid E. urophylla x E. alba. The father stock is a eucalypt related to E. urophylla introduced under the name E. kirtoniana. This species gives higher yields than the preceding one. All of the stems give off shoots.

Eucalyptus saligna.

This was introduced very early at Loandjili (1953) using stock from South Africa, Madagascar and Brazil. However, it proved unsuited to ecological conditions along the Congo coast. One finds that the bark bursts, there is some gummatous tumor formation that causes death of the tree in most cases.

Eucalyptus deglupta

This species grows particularly well on the clayey heavy and wet soils of Loudima, but seems unsuitable for sandy savanna.

Other Eucalypts

These are Eucalyptus urophylla, E. tereticornis, E. cloeziana, E. grandis, E. citriodora, E. calmadulensis, E. alba. E. urophylla, E. tereticornis, E. saligna and E. alba are now being used in propagation of hybrids. The hybrid E. saligna x 12 ABL has proved very promising and gives good yields.

One of the most interesting species for the Congo seems to be E. urophylla. One trial with a few specimens of different provenance shows that at 2½ years of age at Pointe-Noire and 1 year of age at Loudima average growth seems to be greater than that of E. platyphilla F1 (provenance Portuguese Timor and the Sundra Islands).

Nurseries

Seed

The fine seed of Eucalyptus is mixed with fine grains of sand before being sown to prevent them from being blown away by the wind. They are sown broadcast in irrigated beds at the beginning of September.

The seedbeds at these stations in sandy areas are double-walled boxes, 300 x 70 cm, the space between the two walls forming the irrigation canal.

The soil of these seedbeds is a mixture of 2/3 black earth and 1/3 sand (200 and 100 litres), freed of insects by powdering with 25 g of 'dieldrin' or 'aldrin' per seedbed.

Right after having been sown, the seedbeds are covered with shades and are irrigated. Watering is begun immediately after sowing through the irrigation canals around the edges of the seedbed, the moisture content of the soil being kept constant in depth, combined with a system of indirect watering using a fine spray. The plants germinate about 8 days after the seed has been sown.

Careful hand-weeding of the seedbeds is necessary.

Pricking out

Four weeks after sowing, toward the end of September or the beginning of October, the plants, which by then are about 5 cm tall, are pricked out with bare roots in polyethylene pots, 17 x 21 cm in size on the average. These pots are filled with a sifted mixture of black earth and sand in the same proportions as the soil in the seedbeds, to which is added 0.8 kg of Thomas slag per m^3 to ensure a good start.

The pricked out plants are then placed in a storage area, 1 000 plants per board. Instructions regarding shade, watering and weeding must be followed meticulously up to planting time at the beginning of November, right at the start of the rainy season. A minimum of one week's cover is desirable.

Ground Preparation

Stump Removal

In the bush savannas on clayey soil of the Niari (Malolo) and Bouenza (Loudima) valleys stumps can be removed by machine, whereas on the sandy coastal savannas (Loandjili) and on the Batéké Plateau (Km Rouge) it has to be done by hand labour.

Mechanical extraction of stumps is done by two 70-hp caterpillar tractors with an old caterpillar chain tied between; both tractors pull at the same speed and the chain clears all brush as it moves across the ground.

This work is done during the rainy season from December to May of the year preceding actual planting.

The brush and tree stumps are stacked in piles.

Destruction of Grass

Grass has to be destroyed just before the dry season, in May. For this purpose one can use either a rail pulled by draught animals, an 80-hp wheel tractor, or a small caterpillar tractor ('chenillard'). This rail flattens the grass as it moves along; the grass is killed off by two passages of the tractor, first in one direction and then in the opposite.

Burning

The flattened grass dries rapidly and then the piles of wood and the grass over the entire area to be worked are burnt.

Breaking the Ground

Two methods can be used to break the ground: ploughing with a plough, followed by disk ploughing; and hoeing (of the main crop or cover crop) followed by disk ploughing.

Planting and Management

Pegging-out and Digging of Holes

Ground that has been broken as described above is then marked out in small 50 x 50 m squares. Stakes are then set out at a spacing of either 2.50 x 2.50 m or 3.12 x 3.12 m. (With the heavy equipment, which is coming more and more into use, the 3.12 x 3.12 spacing is better.)

As soon as the stakes have been set out, holes are dug using semi-circular shovels. The holes should have a diameter of 20 cm and also a depth of about 20 cm. The digging of the holes must be completed at the latest by October.

Setting Out of the Plants

In October, one month before planting, 150 g of fertilizer (complete, 10-10-20 fertilizer or potassium fertilizer) are applied to each hole in sandy soils. In the Bouenza and Niari valleys, there is no need for fertilizers.

Starting at the beginning of November the plants are set in place. Before removal from the nursery, the plants are watered heavily and the polyethylene pots removed. By that time, the plants are from 10 to 25 cm in size. There is about a 98% "take" and no need to fill in failed spots.

Protection

A dusting of the holes with either 4% Dieldrex or Phytosol prior to planting eliminates termites. To combat stem-cutting crickets in plantations, poisoned bait is applied (mixture of 1/3 flour, 2/3 bran with Dieldrin CE 20).

Maintenance

After planting, maintenance work has to be done. Initially this can be done by machinery - with either a stubble-plough (scarifier) or a rotary plough (rotavator) - at least three or four times during the first year after planting and once or twice during the second year. Manual weeding by hoeing around the plant completes the maintenance work each time the stubble-plough is used.

Protection Against Fire

Usually brush fires sweep across the savannas in about the month of June. They occur earlier on sandy savanna than on clayey savanna.

Prevention of brush fires is accomplished by breaking up the 25 ha plots into 500 x 500 m plots separated by 10 m wide firebreaks. These firebreaks have to be maintained regularly especially just before the start of the dry season in May and June. The bare firebreak strips around the sites or stations also have to be kept up at the same time. After the rail has been dragged across the ground, an early preventive and controlled burning of the bare firebreaks is done, prior to the start of the usual brush fires.

Cutting of Stands - Rotation

Eucalyptus is cut at the age of 4 to 6 years. The first rotation comprises the cut of fully grown trees derived from seed. At Loandjili, the rotation cycle takes from 7 to 10 years and at Loudima, from 5 to 7 years. Theoretically this first cut is followed by two coppice cuts.

Financial Information

The average cost of one hectare of *Eucalyptus* was estimated in 1973 to amount to about 95 000 CFA francs.

Results and Future Prospects

Results

In the People's Republic of the Congo, Eucalyptus stands cover almost 5 200 ha of savanna, the main species being the hybrids Eucalyptus 12 ABL and E. platyphylla (PF1).

Volume increment is about 20 m^3/ha/year at Loandjili and 35 m^3/ha/year at Loudima for the high-yielding species, E. PF1. Average annual increment in height is about 3.60 m at Loandjili and 4.60 m at Loudima. Annual growth in girth is 7.5 cm at Loandjili and 9 cm at Loudima.

Initial trials with propagation by cuttings installed since 1973 at the forestry research station of Loandjili (Pointe-Noire) are particularly encouraging.

Future Prospects

Such propagation by cuttings is expected to give much higher productivity of stands as a result of both the intensity of selection of plus (+) trees for propagation purposes and due to the homogeneity of the stands (pure stands). It is believed that starting from very specialized silviculture, adapted not merely to the species but to the clone, it will be possible to attain mean annual increments 40 m^3/ha/year at Loandjili - 50 m^3/ha/year at Loudima.

Paper Pulp Project

The aim of this project is to establish an ensemble of plants producing 250 000 tons of bleached pulp annually for the making of kraft paper. The raw materials for this paper plant would consist of a mixture of eucalypt and pine wood.

Plantations to feed this paper plant would consist of 27 500 ha of Eucalyptus established at the rate of 5 500 ha per year, and 22 000 ha of pine established at the rate of 2 200 ha per year.

Charcoal Making Project

This project calls for the cutting of approximately 650 ha of Eucalyptus per year for the making of 10 000 tons of charcoal for export.

AFFORESTATION METHODS FOR PINE

Species of Pine Used

Both Pinus caribaea and P. oocarpa were introduced into the Congo in 1958 after the Eucalyptus. They have proven entirely satisfactory and well suited to local ecological conditions. Other species tried were P. kesiya, P. merkusii, P. hondurensis.

Nurseries

Seed

Germination beds are prepared starting at the beginning of May. These are actually 3.00 x 0.70 m boxes filled with a mixture of ½ black earth and ½ sand to which fertilizers have been applied. The seed is sown in these boxes between 15 May and the end of June, in rows, using a plank with screw nuts for alignment and spacing of the seed (1 x 1 cm). After sowing, the boxes are covered with a layer of chopped pine needles. They are left open and not irrigated, but watered frequently. Weeding has to be done continuously.

Pricking-Out

Germination occurs within about a week. Six weeks after sowing, the plants already reach a height of 1 cm and are then pricked out into polyethylene pots filled with a mixture of sand and black earth containing fungi (mycorrhiza), the earth being obtained from old pine plantations. It is absolutely necessary to use complete fertilizers (10-10-20) when pricking-out the plants.

In pricking-out, care has to be taken to keep the taproot straight by enclosing it in a pellet of liquid mud. Subsequently, the instructions regarding applications of fertilizer, watering and weeding have to be followed carefully.

Soil Preparation

This is the same as for eucalypts.

Planting and Management

Planting

This is the same as for eucalypts.

Maintenance

The technique is the same as that used for eucalypts. During the first year mechanical and manual maintenance work has to be done 3 to 4 times, in the second year at least 2 to 3 times, in the third year twice, and once again in the fourth year.

Fire Control

Again brush fire control here calls for the division of the area into small 6.25 ha plots. Four such plots are grouped together (making 25 ha in all) and between each set 10 m wide, bare firebreaks are opened. Between each set of four plots (25 ha in all) there is laid out a peripheral firebreak, usually consisting of *Eucalyptus torelliana*.

Management of the Stand: Pruning and Thinning

Tropical pines can be used for two purposes: either for making paper pulp or for lumber. In the first instance, no thinning will be done. In the second case, once a plantation has been set out with trees at a spacing of 2.5 x 2.5 m or 3.12 x 3.12 m, it is absolutely essential that when the trees are 4 or 5 years old they be thinned out.

In both cases pruning with a lumberjack's saw is necessary when the stands reach 4 or 5 years of age.

For the production of paper pulp, the rotation cycle is from 10 to 11 years, whereas it is from 20 to 25 years for the production of lumber.

Results and Future Prospects

Results

Man-made pine stands already cover almost 2 600 ha in the People's Republic of the Congo. The increment is from 8 to 10 m^3/ha/year at Pointe-Noire and from 15 to 20 m^3/ha/year at Loudima for rapid growth tropical pines that adapt well.

Future Prospects

Plans for genetic improvement and tested seed orchards started in 1975 should make it possible to increase the production of these species.

Projects

The Congo's Development Plan includes industrial planting of pine and eucalypts on the savannas to feed a factory with an annual capacity of 250 000 tons. About 22 000 ha are to be planted to pine at an annual rate of 2 200 ha.

Finally, steps are being taken to set out plantations of Araucaria hunsteinii and A. cunninghamii, trials with which have shown them to be promising species capable of producing excellent timber on savanna.

Table 1

SAVANNA PLANTATIONS (PINES AND EUCALYPTS) OF THE OFFICE CONGOLAIS DES FORÊTS

Year of Planting	LOANDJILI (P/Noire)		LOUDIMA (Bouenza)		MALOLO (Niari)		KM ROUGE (B/city)	
	Pine	Eucalyptus	Pine	Eucalyptus	Pine	Eucalyptus	Pine	Eucalyptus
1953-54	-	17.78						
1954-55	-	1.04						
1955-56	-	-	10.00	10.00				
1956-57	-	25.90						
1957-58	-	93.20						
1958-59	3.50	150.10						
1959-60	1.00	170.92						
1960-61	16.00	261.00						
1961-62	-	66.80	1.00	5.00				
1962-63	1.20	18.00	3.00	17.00				
1963-64	4.80	30.44	7.00	13.00			0.20	0.60
1964-65	2.10	30.30	25.00	86.00			3.05	0.37
1965-66	5.40	32.20	22.00	838.00			7.99	1.42
1966-67	17.50	35.10	16.00	396.00			5.63	1.80
1967-68	14.80	26.50	50.00	572.00			0.79	4.60
1968-69	7.90	33.40	50.00	512.00	50.00	8.00	17.91	1.17
1969-70	46.70	20.80	206.00	493.00	100.00	16.00	75.50	1.40
1970-71	57.00	77.60	182.00	900.00	100.00	14.00	51.60	3.00
1971-72	37.00	29.00	740.00	43.00	75.00	-	56.00	1.00
1972-73	10.88	4.53	13.60	7.40	-	-	3.00	-
1973-74	10.00	10.00	10.00		-	-	5.00	-
1974-75	4.57	18.43	50.00	12.00	-	25.00	5.60	3.00
1975-76	10.76	47.62	419.78	16.50	-	-	38.56	13.54
	251.11	1200.66	1805.38	3930.90	325.00	63.00	270.83	31.00
Total/ Station	1451	77	5736	28	388	00	302	73

Total for the savanna: 7878.78 hectares, pines = 2652.32 hectares, Eucalyptus = 5226.46 hectares

ANNEX 5

SAVANNA AFFORESTATION IN GHANA

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TABLE OF CONTENTS

INTRODUCTION

Ghana has an area of 238 539 square kilometers and lies between longitudes 1° East and 3° West and latitudes 5° and 11° North. The current population is estimated at 10 million.

The country has a tropical climate which ranges from humid to dry, the southern portion receiving the greatest amount of rainfall.

There are four main vegetation zones: the coastal strand with mangrove swamps, followed by a narrow belt of thicket, the high forest, and the savanna zone. The high forest covers approximately an area of 82 258 square kilometers or 34.48% of the country, while the savanna covers 150 497 square kilometers or 63.09%, the remaining 2.43% being taken by the strand, mangrove swamps and thicket.

There exists a written National Forest Policy which has as its main objective the creation of sufficient permanent forest resources by reservation to supply direct and indirect benefits necessary for the welfare of the people of Ghana and the management of the forest resources by methods that achieve sustained maximum productivity and value. The other objectives of the forest policy include research into all branches of scientific forestry, emphasis being laid on silviculture, ecology and utilisation; the training of both professional and field staff and the provision of technical advice to non-Government forestry.

In order to implement the forest policy successfully, a Forests Ordinance was passed on the 30 March 1927, and in 1949 the Trees and Timber Ordinance was passed. Under the powers conferred on the Governor, later President of Republic, a number of regulations were made and a series of acts were also passed. Among the regulations are the Forests (Silvicultural Works) Regulations, 1958; the Trees and Timber, Property Marks Regulations 1950; the Trees and Timber (Control of Cutting) Regulations 1958; the Trees and Timber

(Measurement) Regulations 1958; the Trees and Timber (Control of measurement) Regulations 1960; and the Trees and Timber (Control of Export of logs) Regulations 1961. Acts passed under the Forest Ordinance to give effect to the forest policy include the Protected Timber Lands Act, 1959; the Forest Offences (Compounding of Fines) Act 1959 and the Forest Improvement Fund Act 1960, to mention a few.

In Ghana the bulk of the land (high forest or savanna) is held in trust for the stools (chiefs and people) by Government. The portion of land under purely state control is exceedingly small.

The principal forest products from the high forest zone are sawlogs, veneer logs, logs for sleepers, charcoal, poles and export logs, and in the savanna zone, poles, charcoal and gum.

STAFFING

There exists a Forestry Training School in Ghana which turns out sub-professional officers who are mainly field officers. In the past years the intake of students was small but recently with the inception of the reforestation scheme, the intake has been appreciably increased.

The current serving sub-professional staff number 500. The number of serving professional officers now stands at 22, the bulk of them having been lost to the educational institutions, the research institutions and industry.

The gross annual budget for forestry for the financial year 1975/76 amounted to US$7 501 774. Embodied in this amount are the recurrent expenditure, reforestation expenditure (development) and forest improvement expenditure.

AFFORESTATION AND REFORESTATION

As a result of the massive exploitation of timber from the high forest and the increased requirement of timber and timber products in the savanna areas, a decision was taken in 1972 to plant certain areas both in the high forest and savanna zones. Up to the end of 1974, the total area of plantation for the whole country stood at 23 208 ha. Out of this total, 3 330.8 ha have been planted in the savanna zone. The planned annual target area of afforestation and reforestation is 7 328 ha, of which 2 176 are for the savanna area. The reforestation/afforestation schemes are controlled by the state, there being virtually no private forestry organizations in Ghana.

The species currently being planted in the savanna zone include teak (*Tectona grandis*) mahogany (*Khaya senegalensis*) *Gmelina arborea*, *Anogeissus leiocarpus*, neem (*Azadirachta indica*) and *Dalbergia sissoo*. The growth rate varies for the various species in the different parts of the savanna zone. In areas where the savanna borders on the high forest and where rainfall and soil conditions are favourable, and where teak is the main species being planted, the intended end use is lumber. In areas where the soil and rainfall conditions are not so favourable, teak, *Anogeissus*, neem and *Dalbergia* are grown mainly for poles and firewood. The *Gmelina* is intended for pulp. For most of the species, no rotation has been fixed. It is estimated however that in 60 - 70 years the teak may reach sizes capable of being sawn. Species grown mainly for firewood and poles are ready for use between 10 and 15 years.

Savanna Nursery Practice

The selection of permanent nursery sites in the savanna area is limited mainly by the availability of water. In the past, deep wells were dug and the water from these wells was used to water the plants. In recent years however emphasis is being shifted onto irrigated nurseries. The irrigated nurseries are situated near dams. Water from the dams is brought to the plants either through pipes driven through the earth work of the dam or through pumping.

The total annual nursery stock production capacity of the permanent savanna nurseries is in the neighbourhood of three million plants. Figures are however not readily available for actual annual production, as the records are not up to date. The types of planting stock vary according to the species. Teak and Anogeissus are stumped before planting. Khaya and neem are planted either as striplings or as potted plants. In recent years, most of the seedlings are raised in polythene bags which measure 5" by 7" or approximately 13 cm by 18 cm. Seedlings are normally transplanted after they have attained an average height of between 30 - 45 cm. This height is attained between 24 - 30 weeks.

The methods used in savanna nurseries are:

a) Broad-casting on germination beds
b) Bed sowing (single or in drills)
c) Direct sowing into containers (polythene bags).

Seeds broad-cast onto germination beds include teak, neem and mahogany. Pricking-out is carried out as soon as germination starts. These species may also be bed sown, or sown direct into containers. Species with tiny seeds e.g. Anogeissus are sown into drills and thinned out when germination is completed. Seeds, whether they have been broad-cast on germination beds or sown into containers, are watered profusely twice daily early in the morning and late in the evening. Watering continues after germination, and in the absence of rainfall until the plants attain a suitable size for planting. No direct watering is carried out in the irrigated nurseries.

Shade is always necessary to protect the young seedlings from the heat of the sun. Grass mats raised on poles provide adequate protection.

Nurseries in the savanna zones are often disturbed by domestic animals. In such cases, strand-barbed wire fences are errected to keep the animals out. There have not been many complaints about insect attack. The termite attacks which have been reported were treated by Aldrex 40.

Establishment Techniques for Savanna Plantations

In the savanna zone, the grass burns invariably during the dry season. In many cases, the burning is quite thorough and the few trees left standing are stumped. After stumping, a two disc plough is used to make ridges on which the young trees are planted. Spacings commonly used are 3' x 9' or 6' x 9', approximately 1 m x 2 m or 2 m x 3 m.

Little direct sowing is practised.

No severe insect attacks in savanna plantations have been recorded. Fire, however, poses a serious threat, several plantations being affected each year. It is suspected that most of the fires in the plantations are deliberately set, as measures are always taken at the beginning of the dry season to forestall the out-break of fire. Some of the measures adopted to forestall fire out-break include the maintenance of internal and external fire traces and early burnings which are carried out around the plantations.

At the height of the dry season, twenty-four hour fire patrols are organized. Forest guards and labourers are detailed to keep watch, detect and control fires before they get out of hand. In some cases, these patrols have been very effective and in one particular instance no fires were reported in the plantation for a period of 10 years.