PUBLICATION NO. 52

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C. S. A.

Scientific Council for Africa South of the Sahara
Conseil Scientifique pour l'Afrique au Sud du Sahara

OPEN FORESTS

FORETS CLAIRES

NDOLA
1959

C.C.T.A.

COMMISSION DE COOPERATION TECHNIQUE EN AFRIQUE AU SUD DU SAHARA

Créée en janvier 1950, la Commission de Coopération Technique en Afrique au Sud du Sahara (C.C.T.A.) a fait l'objet d'une convention intergouvernementale signée à Londres le 18 janvier 1954. Elle se compose, à l'heure actuelle, des Gouvernements suivants : Belgique, Cameroun, Fédération de la Rhodésie et du Nyassaland, République Française et Communauté, Ghana, République de Guinée, Libéria, Portugal, Royaume-Uni, Union de l'Afrique du Sud.

OBJECTIF

Assurer la coopération technique entre les territoires dont les Gouvernements Membres sont responsables en Afrique au Sud du Sahara.

ATTRIBUTIONS

1) Traiter de tout sujet concernant la coopération technique entre les Gouvernements Membres et leurs territoires dans le cadre de la compétence territoriale de la C.C.T.A.

2) Recommander aux Gouvernements Membres toutes mesures tendant à la mise en œuvre de cette coopération.

3) Convoquer les conférences techniques que les Gouvernements Membres ont décidé de tenir.

4) Contrôler du point de vue général et du point de vue financier l'activité des organismes placés sous son égide et présenter aux Gouvernements Membres toutes recommandations y afférentes.

5) Présenter des recommandations aux Gouvernements Membres en vue de la création de nouveaux organismes ou la révision des dispositions existantes pour la coopération technique, dans le cadre de la compétence territoriale de la C.C.T.A.

6) Présenter des recommandations aux Gouvernements Membres en vue de formuler des demandes conjointes d'assistance technique aux Organisations internationales.

7) Présenter des avis sur toutes questions concernant la coopération technique que lui soumettront les Gouvernements Membres.

8) Administrer le Fonds Interafricain de la Recherche et la Fondation pour l'Assistance Mutuelle en Afrique au Sud du Sahara.

BUDGET

Alimenté par les contributions des Gouvernements Membres.

ORGANISATION

1) La C.C.T.A. se réunit au moins une fois chaque année. Ses recommandations et conclusions sont portées à la connaissance des Gouvernements Membres en vue de leur adoption à l'unanimité ainsi que de leur mise en œuvre dans les territoires intéressés.

2) Le Conseil Scientifique pour l'Afrique au Sud du Sahara (C.S.A.), conseiller scientifique de la C.C.T.A., a été créé en novembre 1950, comme suite à la Conférence Scientifique de Johannesburg (1949), en vue de favoriser l'application de la science à la solution des problèmes africains. Il est composé de personnalités éminentes, choisies de telle sorte que les principales disciplines scientifiques importantes au stade actuel du développement de l'Afrique soient représentées. En tant que membres du Conseil ces personnalités n'agissent pas sur instructions de leurs Gouvernements respectifs mais sont responsables individuellement devant le Conseil.

3) Des Bureaux et Comités techniques traitent chacun un aspect particulier de la coopération régionale et interterritoriale en Afrique au Sud du Sahara.

4) Le Secrétariat de la C.C.T.A. et du C.S.A. comprend deux sièges : l'un, jusqu'ici à Londres, est en cours de transfert à Lagos, l'autre se trouve à Bukavu. Il est dirigé par un Secrétaire Général assisté de deux Secrétaires Généraux Adjoints et, à Bukavu, d'un Secrétaire Scientifique et d'un Secrétaire Scientifique Adjoint. Le Secrétaire de la F.A.M.A. est également adjoint au Secrétaire Général.

PUBLICATIONS

Des brochures traitant de problèmes scientifiques et techniques, dont les données sont habituellement rassemblées en Afrique par le C.S.A., sont publiées à Londres. Toute demande d'information devra être adressée au siège de Londres du Secrétariat, à l'attention du fonctionnaire chargé des Publications et de l'Information.

COMMISSION FOR TECHNICAL CO-OPERATION IN AFRICA SOUTH OF THE SAHARA

Established in January 1950, the Commission for Technical Co-operation in Africa South of the Sahara (C.C.T.A.) was the subject of an Inter-governmental Agreement signed in London on 18 January 1954. It consists now of the following Governments: Belgium, Cameroon, Federation of Rhodesia and Nyasaland, French Republic and Community, Ghana, Republic of Guinea, Liberia, Portugal, Union of South Africa, United Kingdom.

OBJECT

To ensure technical co-operation between territories for which Member Governments are responsible in Africa South of the Sahara.

FUNCTIONS

(1) To concern itself with all matters affecting technical co-operation between the Member Governments and their territories within the territorial scope of C.C.T.A.

(2) To recommend to Member Governments measures for achieving such co-operation.

(3) To convene technical conferences as agreed by Member Governments.

(4) To supervise, from the financial and general points of view, the work of the organisations placed under its ægis and make recommendations thereon to the Member Governments.

(5) To make recommendations to the Member Governments for the setting up of new organisations or the revision of existing arrangements for securing technical co-operation within the territorial scope of C.C.T.A.

(6) To make recommendations to the Member Governments with a view to the formulation of joint requests for technical assistance from international organisations.

(7) To advise Member Governments on any other subject in the field of technical co-operation which the Member Governments may bring to its notice.

(8) To administer the Inter-African Research Fund and the Foundation for Mutual Assistance in Africa South of the Sahara.

FINANCE

Contributions from Member Governments.

ORGANISATION

(1) C.C.T.A. meets at least once a year. Its recommendations and conclusions are submitted to Member Governments for unanimous approval and for implementation in the territories concerned.

(2) The Scientific Council for Africa South of the Sahara (C.S.A.), Scientific Adviser to C.C.T.A., was established in November 1950 following the Johannesburg Scientific Conference (1949) to further the application of science to the solution of African problems. Its members are eminent scientists chosen in such a manner that the main scientific disciplines important at the present stage of the development of Africa shall be represented. As members of the Council they do not receive instructions from Governments but are responsible individually to the Council.

(3) Technical Bureaux and Committees deal with specific aspects of regional and inter-territorial co-operation in Africa South of the Sahara.

(4) The C.C.T.A./C.S.A. Secretariat has two offices, one in London and one in Bukavu. The London office is at present being transferred to Lagos. The Secretariat has at its head a Secretary-General, who is aided in his work by two Assistant Secretaries-General and, at Bukavu, by a Scientific Secretary and an Assistant Scientific Secretary. The Secretary-General is also assisted by the Secretary of F.A.M.A.

PUBLICATIONS

Publications dealing with scientific and technical problems, the data of which are usually collected in Africa by C.S.A., are issued in London. Inquiries should be addressed to the London office of the Secretariat, for the attention of the Publications and Information Officer.

PUBLICATION No. 52

C. S. A.

CSA MEETING OF SPECIALISTS ON OPEN FORESTS IN TROPICAL AFRICA

NDOLA, NORTHERN RHODESIA

17 - 23 November 1959

REUNION DE SPECIALISTES CSA SUR LES FORETS CLAIRES DE L'AFRIQUE TROPICALE

NDOLA, RHODESIE DU NORD

17 - 23 Novembre 1959

C.C.T.A.

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AGENDA

1. Physionomic, structural and ecological definition of " Woodlands " in Africa

2. Geographical extent

   (The dividing line between dense forests, semi-deciduous and open forests —the extent of these types of forest in Southern and Northern Africa)

3. Floristic composition

   (Dominant and relevant species, classification, affinities and vitality of such forests)

4. Fire protection

   Susceptibility to and effects of ground fires
   Use of burning as a forestry technique (preventive fires or burning back)
   Prevention, control or extinguishing of forest fires

5. Principles of sylviculture—Management

   Regeneration, improvement, working methods, methods of treatment
   The introduction of exotic species or crops in open forest areas

6. Development of open forests

   Use of natural dominant species or of mixtures of species (timber—pit props—charcoal—gasification—manufacture of various by-products)

7. Research to be promoted in the scientific and technical field (arrangements for inter-African co-operation)

ORDRE DU JOUR

1. DEFINITIONS PHYSIONOMIQUES, STRUCTURALES ET ECOLOGIQUES DES FORETS CLAIRES EN AFRIQUE

2. EXTENSION GEOGRAPHIQUE
   (Limites entre forêts denses, semi-décidues et forêts claires — Extension de ces types forestiers au sud et au nord de l'Afrique)

3. COMPOSITION FLORISTIQUE
   (Espèces dominantes et significatives, classification, affinités et dynamisme des divers types forestiers)

4. PROTECTION-FEUX
   Susceptibilité aux feux-courants ; leurs effets
   Modalités de la mise à feu comme technique sylvicole (feux préventifs ou hâtifs)
   Mesures préventives ; contrôle ou suppression des feux

5. PRINCIPES DE SYLVICULTURE — AMENAGEMENT
   Régénération, enrichissement, exploitation, modes de traitements
   Implantation d'essences ou de peuplements exotiques dans l'aire des forêts claires

6. MISE EN VALEUR DES FORETS CLAIRES
   Utilisation des essences naturelles dominantes ou des mélanges d'espèces (Bois d'oeuvre, bois de mine, charbon de bois, gazéification, fabrication de dérivés divers)

7. LES RECHERCHES A PROMOUVOIR en matière scientifique ou technique (mesures de coopération interafricaine)

RECOMMENDATIONS AND CONCLUSIONS

I.

The Meeting EXPRESSES its deep gratitude to the Government of Northern Rhodesia for the facilities provided, and to the Northern Rhodesia Forestry Department for its hospitality and most efficient organisation of the Meeting.

It REQUESTS the Secretary-General of CCTA/CSA to convey to them a message of thanks in this respect.

II. Proposed study on different types of woodlands*

Recognising the difficulties encountered in defining and designating the various types of woodlands in Africa, the Meeting RECOMMENDS that CSA should organise the following preliminary surveys :

(*a*) Preparation of maps of the main distribution areas of the main species of the woodlands (see Appendix I). Skeleton maps to a scale of 1/5,000,000 are available from CCTA for the purpose. These maps showing specific areas could usefully be accompanied by lists of the main associate species usually encountered in each station.

(*b*) Description of the various types of woodland, based on a questionnaire (Appendix II).

(*c*) Comprehensive bibliography of African woodlands.

The Meeting RECOMMENDS that questionnaires and maps should be sent by CCTA to all departments and persons concerned, through a correspondent appointed for each territory. These correspondents would also be responsible for centralising replies and, as far as possible, for preparing a synthesis in co-operation with those persons responsible for providing information in neighbouring territories.

The Meeting RECOMMENDS, moreover, that in due course CSA should appoint a small committee of experts on woodlands, to make use of this documentation to prepare distribution maps, to draft the accompanying comments and to present a draft nomenclature and definitions of various types of African woodland.

III. English equivalent of the term " forêt claire "

This Meeting SUGGESTS that, in order to avoid confusion, English-speaking writers on African vegetation use the term " woodland " rather than the term " open forests " to designate " forêt claire ".

* For the purpose of this survey, the expression " woodland ", as defined at Yangambi, may be taken in its widest sense, that is to say that formations of similar types such as dense dry forest, wooded savannah etc. may be included in replies.

IV. Phytogeographical atlas of Africa

In order that the nomenclature and classification of African plant species adopted at the Yangambi meeting of specialists on Phytogeography in 1956 and endorsed by the Inter-African Forestry Conference at Pointe-Noire in 1958 should receive wider distribution and become better known, the Meeting RECOMMENDS

(i) that the nomenclature should be more widely distributed ;
(ii) that the project adopted at Yangambi to publish a Phytogeographical Atlas of Africa for the purpose of popularising the classification and completing the definitions of types of vegetation in tropical Africa, mainly by means of photography, should be implemented.

V. Fire protection

The Meeting NOTES general agreement on the following :

(i) late uncontrolled burning in most woodland types causes damage to timber, regeneration and soil cover, and may lead to progressive degeneration of the vegetation to a more open type ;
(ii) complete fire protection is impracticable except over very limited areas under intensive management ;
(iii) early burning is widely accepted as an economic and beneficial protective operation.

The Meeting further NOTES that early burning is widely practised in many countries with various adaptations to local conditions, but that the operation is frequently performed with inadequate knowledge of its long-term effects or economic justification, and in ignorance of similar techniques applied elsewhere.

In the light of the above considerations, the Meeting RECOMMENDS the exchange of information between the countries on the following matters :

(*a*) Causes, extension and effects (economic and ecological) of uncontrolled late fires in woodland.
(*b*) Methods of protection of woodland against uncontrolled late fires and their ecological and biological results.

The Meeting also RECOMMENDS that, in view of the complexity of the problems involved, a questionnaire covering the items listed in Appendix II be circulated to the Forestry Departments of interested Member Governments through the agency of CCTA/CSA.

VI. Protection of woodlands

The Meeting NOTES, on the one hand, the low yield of timber produced from woodlands generally, on the other the value of these woodlands for the purpose of meeting the domestic needs of the populations living in the vicinity, as well as of protecting soils and water in semi-arid climates with a long dry season often followed by violent rainfall in the rainy season.

It REQUESTS CSA to draw the attention of governments to the dangers that would result from the destruction of woodlands on too large a scale, namely, the extension of savannahs, an increase in the violence of bush fires, denudation and drying up of soils in the dry season, erosion of the soil with, in certain countries, formation of ferruginous crusts (bovalisation) and creation of desert areas, even where there is a fairly heavy rainfall.

In view of the urgency of the matter, it requests CSA to recommend that Member Governments take appropriate protection measures for the conservation of large areas of woodland which, in addition, could play a more important economic part in the future than they have done in the past. These measures should normally fit into more general schemes based on the suitability of soils for various crops. Inter-African co-operation would be highly desirable in the field of research in order to define the scientific considerations according to which such suitability is determined.

The Meeting, having noted that many woodlands are in the process of degradation, or even destruction, due to depredations and to bush fires in the dry season, RECOMMENDS that, for the scientific protection of fauna and flora, strictly protected nature reserves should be created with well defined limits, of a sufficient area, for each of the principal types of woodland.

VII. Sylviculture and management (Item 5 of the Agenda)*

This Meeting NOTES, in the light of its deliberations, that while expenditure on sylviculture and management of the woodlands of Africa must be kept at a minimum, owing to their low economic yield, proper attention to these aspects is essential in order to :

(i) provide for the needs of the local population in forest produce ;
(ii) support industrial development, such as copper mining ;
(iii) make the fullest use of the beneficial effects of woodland in relation to soil and water conservation.

The Meeting also NOTES the recent developments connected with, and the widespread interest in, the introduction of exotics for the purpose of forming plantations and enriching woodland.

In view of the foregoing the Meeting CONSIDERS that a very valuable opportunity exists for Member Governments to benefit by the exchange of information, collaboration in research, and standardisation of terms and definitions, in the fields of sylviculture and management of both woodlands and plantations.

The Meeting RECOMMENDS that the following subjects in particular should receive early attention from the above points of view :

* See also Recommendation IX.

1. **Climatology**

The preparation of climatic maps and indices to facilitate the choice and trial of tree species and the classification of sites for regeneration in woodlands.

2. **Forest soils**

The assessment and classification of sites for the purposes of :

(i) maintenance of protective cover
(ii) regeneration of woodland
(iii) establishment of plantations.

Studies of the effect of plantations on the soil.

3. **Forest hydrology**

The effect on the water regime in the woodlands of :

(i) various sylvicultural treatments
(ii) shifting cultivation
(iii) burning
(iv) grazing etc.

The effect of plantations on the water regime.

4. **Management of woodlands**

Methods of :

(i) determining the extent of exploitable woodlands—including the use of aerial photography
(ii) qualitative and quantitative stocktaking
(iii) determining growth and yield.

5. **Sylviculture of woodlands**

Regeneration techniques.
Sylvicultural systems.
Cultural and improvement methods—including the use of arboricides and sowing in ash patches.

6. **Plantations**

Selection of plantation sites.
Choice of species, including standardisation of species trial methods.
Seed supplies—co-ordination of information on seed supplies, exchange of seed and vegetative material, establishment of seed orchards.
Tree breeding and genetics.
Sylvicultural systems and treatments.
Mensuration methods.

VIII. Utilisation (Item 6 of the Agenda)*

The Meeting NOTES that local research facilities existing in several territories are adequate to deal with problems affecting the conversion, working, seasoning and impregnation of woodland timbers, but are not adequate to deal fully with problems of harvesting, strength testing and complete processing for use as pulp, particle board, cellulose etc.

It CONSIDERS that in view of the considerable expense of many utilisation projects and the wide-scale applicability of results, considerable opportunity exists for Member Governments to benefit by the exchange of information and possibly by the co-ordination of their research projects. There is, in addition, need for the financing of major projects from external funds, where the resources of Member Governments are inadequate.

It RECOMMENDS the following action :

(*a*) Standardisation of technical terms and criteria used in testing timbers.

(*b*) Exchange of local information already available in such matters as the durability and uses of woodland species, the methods now in use in harvesting, converting and utilising them, and the use of minor products.

(*c*) Preparation of a list of existing local or regional utilisation research centres with information on their facilities and woodland projects, in particular under the following heads :

- (i) harvesting
- (ii) conversion and woodworking
- (iii) seasoning
- (iv) impregnation
- (v) carbonisation
- (vi) marketing
- (vii) bee-keeping.

(*d*) Continued consideration on an Inter-African basis of the possibilities of utilising the total growing stock as pulp, particle board, or by chemical conversion.

IX. Research (Item 7 of the Agenda)

The Meeting NOTES

1. The recent rapid developments in woodland forestry and the creation of an African Forestry Commission by the Tenth Session of the FAO Conference.

2. The urgent need for a complete interchange of information between the countries with regard to current territorial work and research.

* See also Recommendation IX.

3. The two aspects of the work :

(*a*) co-ordination of existing local research, and
(*b*) promotion of inter-African research.

4. That in research work there is need for the correlation of standards and definitions in order that the work in one country shall be easily intelligible in another country.

5. That no country has the time, staff or funds properly to carry out all the work needed.

6. That the problems of woodland formations have not yet been considered by the Inter-African Forestry Conference ; and, in view of the fact that certain recommendations of the Pointe-Noire Conference have not yet been implemented, RECOMMENDS :

(i) that CCTA should constitute a small panel of correspondents with a Co-ordinator to ensure that the work in notes 2 and 4 above is started urgently (interchange of information and correlation of standards and definitions) ;

(ii) that maximum use should be made of the facilities offered by the various inter-African and international organisations (FAMA, FAO, UN Special Fund, etc.) for training courses and the provision of services of experts, instructors or advisers, so that the work (note 3 (*b*) above) can be initiated (promotion of inter-African woodland research) ;

(iii) that approaches should also be made through appropriate channels to international funds established for such purposes. It is suggested that some of the research projects might well be covered by series of fellowships or grants. The specialised training of research workers and provision for the interchange of visits should be included ;

(iv) that work on the following subjects should be undertaken as soon as possible :

(*a*) methods of sampling enumeration
(*b*) the effects of fire, both beneficial and harmful
(*c*) the sylvicultural treatment of woodland
(*d*) the regeneration of woodland
(*e*) the introduction of exotic species
(*f*) the utilisation of woodland species
(*g*) the development of minor forest produce such as honey, beeswax, medicinal plants etc.
(*h*) soils as related to exotics and existing woodlands (including the standardisation and collection of data)
(*i*) the forest influences of African woodlands and exotic plantations (including the aspects of water conservation, erosion, shifting cultivation etc.).

Attention is drawn to the fact that several of the items in (iv) above are expanded in some detail in the two preceding Recommendations on Agenda : Items 5 (Sylviculture—management) and 6 (Development of open forests—utilisation).

X. Publication of the working documents of the Meeting

In view of the great value of the working documents presented for future development of woodland regions, the Rapporteurs appointed by CSA SUGGEST that the following documents should be included in the publication relating to the Ndola Meeting on Woodlands :

M. S. PARRY . . .	The enumeration of miombo woodlands in Tanganyika.
M. S. PARRY . . .	Yield regulation of *Pterocarpus angolensis.*
C. R. Hursh . . .	Composition of the tropical dry forests of Nyasaland.
D. B. FANSHAWE . .	Classification of miombo woodlands.
D. B. FANSHAWE . .	Floristic composition of miombo woodlands.
D. B. FANSHAWE . .	Burning experiments in miombo woodlands.
B. E. WEBB . . .	Utilisation of miombo species in Northern Rhodesia.
E. N. COOLING . .	Softwood afforestation in Copperbelt miombo woodland.
D. G. CUMMING . .	Fire protection in the Rhodesian teak forests of Northern Rhodesia.
A. AUBREVILLE . .	Définitions physionomiques, structurales et écologiques des forêts claires en Afrique..
A. AUBREVILLE . .	Extension géographique.
J. FOUARGE and A. SCHMITZ	Les bois de mines du Haut-Katanga.
D. B. FANSHAWE . .	Sylviculture and management of miombo woodlands.
H. LEES . . .	Steps towards the planned management of Northern Rhodesia's Western Province *Brachystegia.*
P. DUVIGNEAUD . .	Composition, classification, affinités et dynamisme des peuplements.
T. McL. Dow. . .	Notes on plateau woodland soils in Northern Rhodesia.

If the working document by J. F. Hughes, *The Utilisation of Miombo Timbers,* has not already been published in the report of the Pointe-Noire Inter-African Forestry Conference, they SUGGEST that this should also be included. Other working documents will merely be mentioned by title and name of author.

RECOMMANDATIONS ET CONCLUSIONS

I. Remerciements

La Réunion tient à exprimer au Gouvernement de la Rhodésie du Nord sa très vive reconnaissance pour les facilités qui ont été mises à sa disposition, et au Service forestier de la Rhodésie du Nord ses remerciements pour son hospitalité et l'excellente organisation de la présente manifestation.

Elle PRIE le Secrétaire Général de la CCTA/CSA de leur transmettre un message de gratitude à cet effet.

II. Projet d'enquête sur les divers types de forêts claires

Constatant les difficultés rencontrées pour définir et nommer les divers types de forêts claires* en Afrique, la Réunion RECOMMANDE au CSA d'organiser les enquêtes préliminaires suivantes :

a) Etablissement de cartes d'aires de répartition des espèces principales de la forêt claire (voir annexe I). A cet effet les cartes muettes au 1/5.000.000 de la CCTA seraient employées. Ces cartes d'aires spécifiques seraient utilement accompagnées de listes par station des principales espèces compagnes habituelles.

b) Description des divers types de forêts claires, conformément à un questionnaire (voir annexe II).

c) Relevé d'une bibliographie exhaustive des forêts claires africaines.

La Réunion RECOMMANDE que questionnaires et cartes soient envoyés par la CCTA à tous services et personnes intéressés, par l'intermédiaire d'un correspondant désigné pour chaque Territoire. Ces correspondants seraient également chargés de centraliser les réponses et, dans toute la mesure du possible, d'en faire une synthèse, en collaboration avec les personnes qui établiront celles demandées aux Territoires voisins.

La Réunion RECOMMANDE, en outre, que le CSA désigne ultérieurement un petit comité d'experts chargé d'utiliser la documentation, de dresser des cartes de distribution, de rédiger les commentaires qui les accompagneront et de présenter un projet de nomenclature et de définition des différents types de forêts claires africaines.

III. Equivalent anglais de l'expression " forêt claire "

La Réunion SUGGERE que, afin d'éviter toute confusion, les auteurs d'expression anglaise traitant de la végétation africaine utilisent le terme " woodland " plutôt que le terme " open forest " pour désigner les forêts claires.

* Le terme " forêt claire " défini à Yangambi peut être compris en vue de cette enquête, dans son sens élargi, c'est-à-dire que les formations de types voisins comme la forêt sèche dense, la savane boisée, etc. pourront être l'objet de réponses.

IV. Atlas de phytogéographie africaine

Dans le dessein de répandre le plus largement possible et de mieux faire connaître la nomenclature et la classification végétales qui furent adoptées à la Réunion de Yangambi en 1956 et confirmées par la Conférence Interafricaine Forestière à Pointe-Noire en 1958, la Réunion RECOMMANDE :

i) d'étendre plus encore la diffusion de cette nomenclature ;
ii) de réaliser le projet adopté à Yangambi de la publication d'un atlas de phytogéographie africaine destiné à vulgariser la classification et à compléter, surtout par la photographie, les définitions des types de végétation de l'Afrique tropicale.

V. Protection contre le feu (point 4 de l'ordre du jour)

La Réunion enregistre un accord unanime sur les points suivants :

i) les feux tardifs non contrôlés dans la plupart des types de forêts claires causent des dommages aux bois, entravent la régénération et réduisent le couvert du sol, et peuvent entraîner une dégradation progressive de la végétation, qui tend à devenir plus ouverte ;
ii) la protection intégrale contre le feu est irréalisable, si ce n'est dans les secteurs très limités faisant l'objet d'un aménagement intensif ;
iii) les feux précoces sont généralement admis comme constituant une opération protectrice, économique et utile.

La Réunion NOTE, en outre, que les feux précoces sont pratiqués sur une grande échelle dans nombre de pays, qu'ils sont adaptés de diverses façons aux conditions locales, mais qu'ils sont fréqemment utilisés sans une connaissance suffisante de leurs effets à long terme ou sans justification économique et dans l'ignorance de méthodes similaires pratiquées ailleurs.

A la lumière des considérations ci-dessus, la Réunion RECOMMANDE qu'il soit procédé à des échanges d'informations entre les pays intéressés sur les points suivants :

a) causes, extension et effets économiques et écologiques des feux tardifs non contrôlés en forêt claire;
b) méthodes de protection de la forêt claire contre les feux tardifs non contrôlés et leurs conséquences écologiques et biologiques.

La Réunion RECOMMANDE, en outre, que, en raison de la complexité des problèmes soulevés, un questionnaire sur les points énumérés en annexe soit, par l'intermédiaire de la CCTA/CSA, adressé aux services forestiers des Gouvernements Membres intéressés.

VI. Protection des forêts claires

La Réunion CONSTATE, d'une part, la pauvreté en bois d'oeuvre des forêts claires en général, mais en revanche, leur grand intérêt pour les besoins domestiques des populations qui y vivent, ainsi que pour la protection des sols et des eaux sous les climats semi-arides, comportant une longue saison sèche suivie souvent de violentes précipitations au cours de la saison pluvieuse.

Elle DEMANDE au CSA d'attirer l'attention des autorités gouvernementales sur les dangers qui résulteraient d'une destruction à trop grande échelle des forêts claires : extension de la savanisation, accroissement de la violence des feux de brousse, dénudation et desséchement des sols en saison sèche, érosion des terres, amenant dans certains pays l'émergence de cuirasses ferrugineuses (bovalisation), et créant ainsi des aires désertiques, même sous une pluviométrie assez forte.

En raison de l'urgence, elle INVITE le CSA à recommander aux Gouvernements Membres de prendre des mesures de protection appropriées en vue de conserver des grands massifs de forêts claires qui, d'autre part, pourraient avoir dans l'avenir un rôle économique plus important qu'aujourd'hui. Ces mesures devraient normalement s'intégrer dans les plans généraux basés sur la vocation des terres et une collaboration interafricaine serait vivement souhaitable sur le plan de la recherche pour préciser les bases scientifiques de la détermination de cette vocation.

La Réunion, constatant que beaucoup de forêts claires sont en cours de dégradation ou même de destruction par déprédations et feux de brousse en saison sèche, RECOMMANDE, à des fins scientifiques de protection de la faune et de la flore, de créer des réserves naturelles intégrales, strictement protégées, aux limites bien définies et de superficie suffisante, dans chacun des principaux types de forêt claire.

VII. Sylviculture et aménagement (point 5 de l'ordre du jour)*

En conclusion de ses délibérations, la Réunion NOTE que les frais occasionnés par la sylviculture et l'aménagement des forêts claires africaines doivent être réduits à leur minimum, en raison de leur faible rendement économique, et qu'il est de la première importance d'attirer l'attention sur ces aspects lorsqu'il est question de :

i) pourvoir aux besoins de la population locale en produits forestiers ;
ii) apporter une contribution au développement industriel, par exemple, à l'exploitation du cuivre ;
iii) profiter au maximum des effets favorables de la forêt claire sur la conservation du sol et de l'eau.

La Réunion NOTE également les récents développements et l'intérêt général en matière d'introduction d'exotiques en vue de plantations et d'enrichissements de la forêt claire.

En conséquence, la Réunion CONSIDERE qu'il y a grand interêt, pour les Gouvernements Membres, à échanger des informations, collaborer dans la recherche et uniformiser la terminologie et les définitions en matière de

* voir également la Recommandation IX.

sylviculture et d'aménagement aussi bien des forêts claires naturelles que des plantations.

La Réunion RECOMMANDE que les sujets suivants, en particulier, reçoivent toute l'attention en tenant compte des considérations ci-dessus :

1. **Climatologie**

L'établissement des cartes climatologiques et l'adoption de critères facilitant le choix des espèces, les expérimentations et la classification des sites de régénération en forêt claire.

2. **Sols forestiers**

La détermination de la valeur et la classification des sites :

i) à maintenir sous leur couvert protecteur naturel
ii) aptes à la régénération des forêts claires
iii) propices à l'établissement de plantations.

L'étude de l'effet des plantations sur le sol.

3. **Hydrologie forestière**

L'effet sur le régime des eaux en forêts claires dans les cas de :

i) traitements sylvicoles divers
ii) agriculture itinérante
iii) brûlage
iv) pâturage, etc.

L'effet des plantations sur le régime des eaux.

4. **Aménagements des forêts claires**

Les méthodes de :

i) détermination de l'étendue des forêts claires exploitables, y compris les photographies aériennes
ii) inventaires qualitatifs et quantitatifs
iii) détermination de la croissance et du rendement.

5. **Sylviculture des forêts claires**

Techniques de régénération.
Méthodes sylvicoles.
Méthodes de culture et d'amélioration, y compris l'utilisation des arboricides et ensemencements sur aires d'incinération.

6. **Plantations**

Sélection des sites de plantation.
Choix des espèces, y compris l'uniformisation des méthodes d'expérimentation.
Fourniture de graines — coordination des informations relatives aux fournitures de graines, échange de matériel végétatif, établissement de parcelles de semenciers.

Sélection massale et génétique des arbres.
Méthodes de sylviculture et modes de traitement.
Méthodes de mensuration.

VIII. **Utilisation** (point 6 de l'ordre du jour)*

La Réunion NOTE que les facilités de recherche locales en divers Territoires permettent de résoudre les problèmes du débit, du travail, du séchage et de l'imprégnation des bois de forêt claire, mais n'apportent pas une solution complète aux autres problèmes de l'exploitation, des essais de resistance et de la transformation en pâte à papier, bois reconstitués, cellulose, etc.

Elle ESTIME que, en raison des frais considérables qu'entraînent nombre de recherches sur les utilisations et du fait que certains résultats sont applicables à de vastes régions, il y a grand intérêt pour les Gouvernements Membres à assurer un échange d'informations et, peut-être, à coordonner leurs projets de recherche. De plus, il est nécessaire de recourir à des fonds étrangers lorsque les ressources dont disposent les Gouvernements Membres sont insuffisantes au financement de projets coûteux.

Elle RECOMMANDE les mesures suivantes :

a) Standardisation des termes techniques et des normes d'essais technologiques.

b) Echanges d'informations locales couvrant la durabilité et l'utilisation des espèces de forêt claire, les méthodes actuellement appliquées à leur exploitation, leur transformation et leur emploi, ainsi que l'utilisation des produits secondaires.

c) Préparation d'une liste des centres locaux et régionaux de recherche sur l'utilisation, accompagnée de renseignements sur les moyens dont ils disposent et sur leurs projets en matière de forêt claire, notamment au sujet de :
   i) l'exploitation
   ii) la transformation et le travail du bois
   iii) le séchage
   iv) l'imprégnation
   v) la carbonisation
   vi) la commercialisation
   vii) l'apiculture.

d) Poursuite des études sur le plan interafricain des possibilités d'utilisation de la totalité de la production sous forme de pâtes, bois reconstitués, ou matières primaires pour l'industrie chimique.

IX. **Recherche** (point 7 de l'ordre du jour)

La Réunion NOTE :

1. Les développements récents et rapides dans le domaine de la

* voir également la Recommandation IX.

connaissance des forêts claires africaines et la création d'une Commission forestière pour l'Afrique lors de la Dixième Session de la Conférence de la FAO.

2. Le besoin urgent de parfaire l'échange d'informations entre les pays intéressés en ce qui concerne les travaux et recherches en cours sur le plan territorial.

3. Le double aspect du travail :

a) la coordination des recherches sur le plan local, et
b) l'encouragement de la recherche sur le plan interafricain.

4. L'intérêt d'assurer la corrélation des normes et définitions, dans le domaine de la recherche, afin de faciliter la compréhension, dans chaque pays, des travaux effectués dans d'autres.

5. L'insuffisance, dans chaque pays, de temps, de personnel et de fonds indispensables à l'accomplissement de certains travaux nécessaires.

6. Le fait que les problèmes des forêts claires n'ont pas encore été examinés par la Conférence Forestière Interafricaine, et considérant que certaines des recommandations de la Conférence de Pointe-Noire n'ont pas encore été mises en oeuvre, RECOMMANDE :

i) que la CCTA/CSA établisse un petit réseau de correspondants doté d'un coordinateur, afin d'assurer la mise en oeuvre immédiate des travaux faisant l'objet des alinéas 2. et 4. ci-dessus (échanges d'informations et corrélation des normes et définitions) ;
ii) qu'il soit tiré parti au maximum des facilités offertes par les différentes organisations interafricaines et internationales (FAMA, FAO, Fonds Spécial des Nations Unies, etc.) pour les cours de formation, l'envoi et éventuellement l'échange d'experts, d'instructeurs ou de conseillers en vue de l'accomplissement de la tâche faisant l'objet de l'alinéa 3.*b*) ci-dessus (encouragement de la recherche sur les forêts claires sur le plan interafricain) ;
iii) qu'en outre des démarches soient faites par les voies appropriées, auprès des Fonds internationaux créés à ces fins. Il est suggéré que certains projets de recherche pourraient faire l'objet d'attribution de bourses ou de subventions. Des dispositions devraient être prévues pour la spécialisation des chercheurs et pour l'échange de visites ;
iv) que des travaux soient entrepris dès que possible dans les domaines suivants :

a) méthodes d'inventaire par sondage
b) effets favorables et néfastes du feu
c) sylviculture en forêt claire
d) régénération de la forêt claire
e) implantation d'essences exotiques

f) utilisation des essences de forêt claire
g) exploitation des produits secondaires de la forêt (miel, cire d'abeilles, plantes à propriété médicinale, etc.)
h) rapports entre les sols et les peuplements naturels et d'exotiques (y compris la normalisation du rassemblement des données)
i) influences de la forêt claire africaine et des implantations d'exotiques (y compris la conservation de l'eau, l'érosion, la culture itinérante, etc.).

La Réunion attire l'attention sur le fait que plusieurs des questions figurant dans l'alinéa iv) ci-dessus sont reprises en détail dans les deux recommandations précédentes aux points 5 (sylviculture et aménagement) et 6 de l'ordre du jour (mise en valeur des forêts claires — utilisation).

X. Publication des documents de travail de la Réunion

Compte tenu de la grande valeur des documents de travail présentés pour l'avenir des régions des forêts claires, les Rapporteurs désignés par le CSA SUGGERENT que les documents suivants soient publiés dans la brochure relative à la Réunion de Ndola sur les Forêts claires :

M. S. PARRY	The enumeration of miombo woodlands in Tanganyika.
M. S. PARRY	Yield regulation of *Pterocarpus angolensis*.
C. R. Hursh	Composition of the tropical dry forests of Nyasaland.
D. B. FANSHAWE	Classification of miombo woodlands.
D. B. FANSHAWE	Floristic composition of miombo woodlands.
D. B. FANSHAWE	Burning experiments in miombo woodlands.
B. E. WEBB	Utilisation of miombo species in Northern Rhodesia.
E. N. COOLING	Softwood afforestation in copperbelt miombo woodland.
D. G. CUMMING	Fire protection in the Rhodesian teak forests of Northern Rhodesia.
A. AUBREVILLE	Définitions physionomiques, structurales et écologiques des forêts claires en Afrique.
A. AUBREVILLE	Extension géographique.
J. FOUARGE et A. SCHMITZ	Les bois de mines du Haut-Katanga.
D. B. FANSHAWE	Sylviculture and management of miombo woodlands.
H. LEES	Steps towards the planned management of Northern Rhodesia's Western Province *Brachystegia*.
P. DUVIGNEAUD	Composition, classification, affinités et dynamisme des peuplements.
T. McL. DOW	Notes on plateau woodland soils in Northern Rhodesia.

Dans le cas ou le travail de J. F. Hughes, *The Utilisation of Miombo Timbers*, n'aurait pas déjà été publié dans le rapport de la Conférence Interafricaine Forestière de Pointe-Noire, ils SUGGERENT que ce document soit également inclus.

Les autres contributions feront uniquement l'objet d'une mention comportant le nom de l'auteur et le titre.

LIST OF SPECIES — LISTE DES ESPECES

Acacia albida
Acacia campylacantha
Acacia nigrescens
Acacia sieberiana
Acacia tortilis
Afrormosia angolensis
Afzelia quanzensis
Albizzia adianthifolia
Albizzia antunesiana
Albizzia versicolor
Amblygonocarpus spp.
Anogeissus leiocarpus
Berlinia giorgii
Baikiaea plurijuga
Brachystegia allenii
Brachystegia boehmii
Brachystegia bussei
Brachystegia floribunda
Brachystegia gossweileri
Brachystegia longifolia
Brachystegia manga
Brachystegia microphylla
Brachystegia spiciformis
Brachystegia tamarindoides
Brachystegia taxifolia
Brachystegia utilis
Brachystegia wangermeena
Burkea africana
Canarium schweinfurthii
Chlorophora excelsa
Chrysophyllum bangweolense
Colophospermum mopane
Combretum laxiflorum
Combretum molle
Combretum mechowianum
Cryptosepalum pseudotaxus
Daniellia alsteeniana
Dialium englerianum
Entada abyssinica
Entandrophragma delevoyi
Erythrophleum africanum
Erythrophleum guineense
Faurea saligna
Guibourtia coleosperma
Isoberlinia angolensis
Isoberlinia dalziellii
Isoberlinia doka
Isoberlinia tomentosa
Julbernardia globiflora
Julbernardia paniculata
Kirkia acuminata
Lophira alata
Marquesia acuminata
Marquesia macroura
Monotes kerstingii
Oldfieldia dactylophylla
Ostryoderris stuhlmannii
Parinari curatellifolia (mobola)
Parinari excelsa
Parinari polyandra
Philippia benguellensis
Piliostigma thonningii
Pseudolachnostylis maprouneifolia
Pteleopsis anisoptera
Pteleopsis myrtifolia
Pterocarpus angolensis
Pterocarpus chrysothrix
Pterocarpus stevensonii
Ricinodendron rautanenii
Sclerocarya caffra
Sterculia quinqueloba
Syzygium guineense
Terminalia mollis
Terminalia sericea
Uapaca nitida
Uapaca kirkiana
Uapaca somon
Zeyherella magalismontana

QUESTIONNAIRE FOR ENQUIRY INTO AFRICAN WOODLANDS*

Vernacular name
Geographical situation : Locality
Longitude
Latitude
Altitude

Station : Topography
Climate
Soil
Termiteria : frequency
size
form
Litter
Fire : frequency
intensity

Stratification (if possible draw profile)

1. Tree stratum
   (*a*) Physionomy, density, degree of cover, height, distribution
   (*b*) Composition (dominant and distinctive species), average girth and height of bole

2. Taller shrub stratum
   (*a*) Physionomy, density, degree of cover, height, distribution
   (*b*) Composition (dominant and distinctive species)

3. Lower shrub stratum
   (*a*) Physionomy, density, degree of cover, height, distribution
   (*b*) Composition (dominant and distinctive species)

4. Herbaceous strata
   (*a*) Physionomy, density, degree of cover, height, distribution
   (*b*) Composition (as far as possible)

Phenology
Economic value
Geographical distribution of the type described (if possible in the form of a sketch map)

* For the purpose of this survey the expression " woodland ", as defined at Yangambi, may be taken in its widest sense, that is to say that formations of similar types such as dense dry forest, wooded savannahs etc. may be included in replies.

ANNEXE II

QUESTIONNAIRE EN VUE D'UNE ENQUETE SUR LES FORETS CLAIRES* AFRICAINES

Nom vernaculaire

Situation géographique : Localité
Longitude
Latitude
Altitude

Station : Topographie
Climat
Sol
Termitières : abondance
dimensions
forme
Couverture morte
Feu : fréquence
violence

Stratification (si possible dresser un schéma du profil)

1. St. arborescente
   a) Physionomie, densité, recouvrement, hauteur, répartition
   b) Composition (dominants et espèces remarquables), circonférence moyenne et hauteur moyenne des fûts

2. St. arbustive supérieure
   a) Physionomie, densité, recouvrement, hauteur, répartition
   b) Composition (dominants et espèces remarquables)

3. St. arbustive inférieure
   a) Physionomie, densité, recouvrement, hauteur, répartition
   b) Composition (dominants et espèces remarquables)

4. St. herbacée
   a) Physionomie, densité, recouvrement, hauteur, répartition
   b) Composition (dans la mesure du possible)

Phénologie

Valeur forestière

Répartition géographique (si possible sous forme d'une carte schématique du type décrit)

* Le terme " forêt claire " défini à Yangambi, doit être compris en vue de cette enquête, dans son sens élargi, c'est-à-dire que les formations de types voisins comme la forêt sèche dense, la savane boisée, etc. pourront être l'objet de réponses.

EFFECTS OF FIRE

Items for inclusion in draft questionnaire :

1. List of existing and proposed research projects and statement of problem not covered by the envisaged research programme (e.g. long-range effects on erosion, hydrology etc.).
2. The economics of operations now practised.
3. Variation of techniques in relation to different degrees of risk and value of the woodland.
4. The sylvicultural effects of controlled versus uncontrolled burning.
5. The effect of burning on soil structure, soil fertility, humus, run-off and infiltration.
6. The harmful effect of early burning on regeneration in certain cases and the possible alternative use of temporary complete protection or burning after the first rains.
7. The use of cattle to reduce inflammability.
8. The effect of fire on minor products, game and local customs.
9. The correlation of the effects of fire with environmental conditions.

EFFETS DU FEU

Rubriques à inclure dans un questionnaire :

1. Liste des protocoles de recherche en cours ou projetée, et exposé des problèmes non couverts par les programmes de recherche envisagés (par exemple, effet à long terme sur l'érosion, hydrologie etc.).
2. Aspects économiques des opérations actuellement pratiquées.
3. Adaptation des techniques en rapport avec les divers degrés de risque encouru par la forêt claire et de sa valeur propre.
4. L'incidence sylvicole du brûlage comparée à celle des feux non controlés.
5. L'effet du feu sur la structure des sols, leur fertilité, l'humus, le ruissellement et l'infiltration.
6. Les conséquences défavorables du brûlage hâtif sur la régénération, en certains cas, et, par contre, la possibilité de recourir à la protection absolue durant un certain temps ou à la pratique des brûlages après les premières pluies.
7. Le pâturage utilisé comme moyen de réduire la végétation qui sera brûlée.
8. L'effet du feu sur les produits secondaires, le gibier et l'objet des coutumes indigènes.
9. La corrélation reconnue entre les effets du feu et les conditions mésologiques.

LIST OF TECHNICAL DOCUMENTS
LISTE DE DOCUMENTS TECHNIQUES

The following technical documents have been issued for this meeting :
Les documents techniques dont les titres sont donnés ci-dessous ont été diffusés pour cette réunion :

No.	*Author — Auteur*	*Title — Titre*
1.	M. A. Huberman .	Tropical dry deciduous forest.
2.	Anonymous/Anonyme.	Statement by Federal Department of Forest Research, Ibadan, Western Nigeria.
3.	M. S. Parry . .	A policy for woodland research in Tanganyika.
4.	J. F. Hughes . .	The utilisation of miombo timbers.
5.	F. G. Smith . .	The miombo in relation to bee-keeping.
6.	M. S. Parry . .	The enumeration of miombo woodland in Tanganyika.
7.	M. S. Parry . .	Yield regulation of *Pterocarpus angolensis*.
8.	R. G. M. Willan .	The introduction of exotic species in open forests and woodland in Nyasaland.
9.	C. R. Hursh . .	Composition of the tropical dry forests of Nyasaland.
10.	D. B. Fanshawe. .	Definition of open woodlands in Africa.
11.	D. B. Fanshawe. .	Geographical extent of open forests and woodlands.
12.	D. B. Fanshawe. .	Floristic composition of miombo woodland.
13.	D. B. Fanshawe. .	Classification of miombo woodlands.
14.	D. B. Fanshawe. .	Burning experiments in miombo woodland.
15.	B. E. Webb . .	Utilisation of miombo species in Northern Rhodesia.
16.	E. N. Cooling . .	The potentiality of the Citemene system of woodland enrichment in Northern Rhodesia.
17.	E. N. Cooling . .	Softwood afforestation in Copperbelt miombo woodland.
18.	D. G. Cumming . .	Fire protection in the Rhodesian teak forests of Northern Rhodesia.
19.	A. Aubreville . .	Définitions physionomiques, structurales et écologiques des forêts claires en Afrique.
20.	A. Aubreville . .	Extension géographique.
21.	F. Fouarge et A. Schmitz	Les bois de mines du Haut-Katanga.
22.	R. G. M. Willan .	A note on forest management in Nyasaland with particular reference to dry deciduous forest and woodland.
23.	R. W. J. Keay and P. C. Lancaster	Miombo and other savannah woodlands of Nigeria—types, management.
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COMMUNICATIONS AND REPORTS

COMMUNICATIONS ET RAPPORTS

THE UTILISATION OF MIOMBO TIMBERS

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(Amended from a paper written for the CCTA Conference at Pointe-Noire, 1958)

SUMMARY

The practicability of bringing miombo woodlands under forest management is discussed. The main problems are listed, and possible remedies suggested :

(1) **Low stocking.** Highly efficient vehicles for transport of logs and timber, reduction of haulage distances for logs to a minimum and specialised portable mills are suggested.

(2) **Low proportion of valuable species.** An investigation of potential markets for the secondary timbers is needed.

(3) **The refractory nature of most secondary miombo species.** The necessity for the correct type of saws, good saw maintenance, sufficiently heavy equipment and adequate power is stressed, both for milling and woodworking. Seasoning and preservative treatments are discussed.

It is suggested that the Conference should list the problems of the utilisation of miombo timbers and propose plans for investigation of these problems.

I. INTRODUCTION

In Tanganyika, the Central African Territories and Portuguese East Africa there are large areas of miombo woodland which have for a long time been generally regarded as of great potential value. This opinion has been based on two premises, viz :

(*a*) The high current market price of certain constituent primary species such as *Pterocarpus angolensis*.

(*b*) The very large total quantity of secondary timbers standing in these forests.

We should ask ourselves if these premises are in fact correct. Large areas of savannah forest have been reserved in this territory, and no doubt in other territories, on the assumption presumably that they have a potential value commensurate at the least with the cost of protecting and managing them. Forestry is after all a business and there is probably no justification for reserving areas of this type unless they do in fact pay. It seems that we should give urgent attention to the following three points in connection with miombo forests rather than continue in the bland assumption that they are bound to be useful and profitable merely because there are such vast areas of them.

1. Can we manage these large areas of low quality forest with the staff and funds likely to be at our disposal ? By this I mean can they be protected against fire and theft, can they be surveyed and divided into manageable working coupes, and can we organise and control exploitation in them on a sustained yield basis ?
2. Can these areas be exploited profitably at any distance from large centres of consumption ?
3. Is there any possibility of improving the stocking per acre and the proportion of valuable species in these forests by sylvicultural means compatible with our resources of men and money ?

All these points have a bearing on the utilisation angle. Forest improvement by sylvicultural methods is likely to be a difficult problem. In any case it would be a considerable period before sylvicultural improvement could become effective, and if the miombo forests are to survive as reserved and managed forest areas they must do so on the basis of their present value and not some hypothetical future value.

The question of protecting these forests against fire and theft also requires to be considered. Theft in particular is a serious problem and could very well in this type of forest upset carefully calculated sustained-yield management. Where valuable species of exploitable size occur in the proportion of one per ten acres or more, the theft of a few thousand trees in a coupe earmarked for future exploitation may be a serious matter and could make exploitation there not worth while. We need to investigate the cost of security measures in these forests to ascertain if in fact we can " police " them at all.

The main object of this paper, however, is the utilisation value of these forests and this is taken as the value of the forest as it stands. It would be idle to pretend that successful utilisation of these areas merely awaits the development of suitable techniques. Unfortunately there are economic factors involved which may entirely preclude the application of such techniques even if suitable. We should therefore begin without delay to assess the problems of utilising miombo forests and estimate the chances of coping with these.

II. THE PROBLEMS OF UTILISING MIOMBO FORESTS

The major problems as I see them are :

1. The low stocking of the forests
2. The small proportion of species of a high value
3. The refractory nature of most of the secondary timbers which constitute the bulk of the stand.

1. Low Stocking

This is the basic difficulty, and it is a problem in exploiting the valuable species such as muninga as well as the secondaries. In our savannah areas most of the mature muninga has been cut in the areas easily accessible to markets, and millers are now working further and further each year from railhead. We hope that, with protection, a further crop of mature muninga will be available in the not too distant future from the accessible areas already cut over. Nevertheless it is clear that to obtain an annual input capable of sustaining an efficient small milling unit (minimum intake 100,000 cu. ft. hoppus of round logs) a large area will have to be worked over annually, and the total working circle for one mill will be very large.

With secondary timbers there is of course a larger concentration, but nevertheless mature trees are becoming difficult to find in accessible areas. Millers also have to site their mills to obtain muninga, and these sites very often are too far from railhead for the economic exploitation of a secondary timber. Muninga may stand one hundred miles of road transport but *Brachystegia spiciformis* will not. If these forests are to be exploited then obviously transport costs must be reduced to the minimum. There are two ways of doing this :

(i) by using highly efficient vehicles for hauling both logs and timber ;
(ii) to reduce the distance over which logs are hauled, since at least 50% of the log weight hauled will be lost in offcuts and sawdust.

Haulage equipment. This requires to be investigated thoroughly. Millers in Tanganyika use 5-ton standard commercial lorries, or 3-ton rated ex-army vehicles for logging and 5-ton standard commercial lorries for carrying sawn timber. Loading of logs is generally done by man-power and the lorries have no special equipment such as winches or stakes. It is clear that logging by such means does not pay, since millers are now keenly interested in loading devices and vehicles specially designed for log carrying. Such devices are usually expensive, and millers in a small way of business, although interested, are naturally somewhat hesitant to buy them. The Utilisation Division is urging millers to try articulated semi-trailer units for both log and sawn timber haulage and is strongly in favour of mechanised loading by independent mobile loaders or by devices fitted to the logging vehicles themselves. These recommendations are made from observation of practices carried out in other parts of the world where the logging industry is highly developed. We have very little experience of most of these practices under our conditions, and in particular of the cost of them. There is a very great need for practical research on the suitability of logging equipment for working the miombo forests and the cost of operating it. Such a project would be costly to organise and the suggestion is put forward that it may be possible to do it as a joint exercise between the various countries that have vast areas of this forest type.

Reduction of log haulage distances. The answer to this problem seems to be mobile milling units. We have had considerable experience with fixed and semi-permanent mills. With these units the logging distance is very often five miles after a year and twenty to thirty miles after five years, when it becomes completely uneconomic. The Utilisation Division is trying to convince millers that they should not aim to log more than five miles under any circumstances and that it would be advisable to have mobile or portable milling units so that they can restrict their logging to this distance.

Although millers are inclined to be conservative, most of them now agree that some form of mobile unit is essential. There are many different makes, and it is difficult to assess which are best suited to our conditions. We are recommending three types as follows, and we hope that a unit of each of these will be working before the end of 1958.

(*a*) **Heavy duty portable mill.** This is a heavy duty mill which can be erected on a new site in two or three days. It can be driven electrically (120 h.p.) or by diesel engine (180 h.p.) and has a very sturdy carriage taking logs up to 38 in. diameter. This type of unit is recommended for millers who wish to cut economically a large proportion of our difficult hardwoods, and also where the mill has to be moved only a few times a year.

(*b*) **Medium duty completely mobile mill.** This is a medium duty mill mounted on a motorised wheeled chassis so that it is completely mobile. A single gasoline or diesel engine provides motive power for moving the unit and for operating the saw. We are recommending this type of unit where a fairly high output is required of both primary and secondary hardwoods and where the mill has to be moved frequently or over long distances.

(*c*) **Light duty mobile mill.** These are light duty units mounted on wheels. They have to be hauled from site to site by lorry or tractor. Some have built-in engines for operating the saw and others are fitted for belt drive from a mobile engine. These units are recommended for the smaller operator, particularly where a high proportion of easily milled primaries are to be cut.

We have no information on the economics of operating these units and this again is a question that requires to be investigated.

2. Low Proportion of Valuable Species

Miombo forests in Tanganyika contain a low proportion of valuable timbers. In the past, large areas have been felled over for these timbers alone, thereby making an already difficult utilisation problem much worse. A few of the secondary timbers are of proved value but these usually occur in such a small proportion that the average miller gets out only a few tons of them a year in his normal work area. Small quantities of even quite good timbers are difficult to market and it seems that we need to investigate co-operative marketing for such species. In this way we may be able to produce a few thousand sleepers of acceptable species and enough flooring of certain species to establish an export trade.

Taking the broader view, however, the miombo forests are worth retaining only if we can exploit the bulk of species occurring in them. In Tanganyika that means dealing with the *Brachystegia* and *Julbernardia* species that form the bulk of the stand. These woods come into the secondary category for very good reasons. They are considerably more difficult, and therefore more costly, to exploit and to utilise, and their intrinsic value is very considerably lower than the primary miombo timbers such as muninga.

A thorough investigation is required of the potential markets for these secondary timbers to ascertain if it is likely that :

(i) they will command a price which will cover the cost of exploiting and processing them ;

(ii) steady markets can be found for them in the proportion in which they occur in the forest and in the large total quantity that would be available from sustained yield working.

Clearly if we continue to exploit muninga alone or muninga and a small undefined and fluctuating proportion of secondaries, the sylviculture and management of these forests will be extremely difficult, if not impossible, to organise.

To carry out this project a thorough knowledge is required of the amounts of various species available and their location, the properties of the various timbers and how best to use them, and the potential markets including quantities likely to be required and prices obtainable. This is a formidable task, but there really is no point in holding miombo forests unless we are prepared to make this sort of survey in the very near future. It is possible that some of these forests cannot be worked at a profit. Most Forest Departments in African territories have scanty resources of men and money and we have to decide firmly what amount of attention we can give to the various forest propositions in our charge. It may be that we have overestimated the potential of the miombo areas, and if this is so the sooner we realise it the better.

3. The Refractory Nature of the Majority of Secondary Miombo Species

The majority of secondary miombo species are very difficult timbers to utilise, and it is this fact in addition to low stocking and dispersed working that makes the exploitation of miombo forest areas a marginal undertaking.

The majority of the *Brachystegia* and *Julbernardia* are difficult to saw because of hardness and interlocked grain. The Utilisation Division has demonstrated that they can be sawn successfully and economically, provided the right type of saw is used, the saw is maintained to a high standard, and adequate power is available (at least 100 h.p. at the headsaw, 150 h.p. preferable). The majority of local millers have equipment designed for cutting muninga and these machines are neither heavy enough nor powerful enough to deal with the other hardwood species. Lack of power in particular gives slow, and therefore costly, production and furthermore is hard on the saws and equipment. Unfortunately a machine of the right type is expensive, and in view of the difficulty in marketing these woods millers are hesitant about investing large sums to produce them. The Department is convinced that it is not possible to exploit miombo successfully unless heavy duty mobile mills are used, but it is not easy to persuade the miller that this is so. Here again it is a question of economics rather than technique, and, as will be shown below, the same question arises throughout the utilisation of secondary woods. In most cases we have a technique that will deal with the refractory feature or features of the wood. But whether or not it will pay to apply these techniques is doubtful, particularly if the timber requires special treatment in two or three different ways.

The sapwood of most secondary miombo woods is susceptible to borer and fungus attack but this can be dealt with, again at a cost, by appropriate insecticidal and fungicidal treatments. Most of these species are slow to season and degrade considerably unless they are very carefully stacked and weighted. It is difficult to persuade millers to do this because of the cost involved in sheds and holding stocks. Unfortunately most of them have acquired their milling experience of muninga, which is an extremely stable timber, and are very reluctant to admit that most timbers require careful handling during drying, and miombo secondary woods very careful attention.

The heartwood of most species is durable out of contact with the ground but the sapwood is liable to attack by powder post beetles. This can be prevented by suitable preservative treatment, and since the sapwood of most species is treatable such timbers are suitable for use in normal building construction. Neither sapwood nor heartwood of *Brachystegia* and *Julbernardia* are durable in contact with the ground and unfortunately the heartwood is not treatable at normal pressures. Samples were sent to the Forest Product Research Laboratory, C.S.I.R.O., Australia, in 1957 for trials of high-pressure impregnation at 1000 lb./sq. in. but satisfactory impregnation could not be obtained. Attention is now being turned to impregnation after incising the wood. If the miombo secondary timbers can be treated successfully by this means, at an economic cost, to give a life in contact with the ground of twenty years or more, then there should be a very considerable market for these woods as railway sleepers. At present the East African Railways and Harbours use steel sleepers on the main line, largely because they cannot get wooden sleepers with an economic life. The cost of producing and treating miombo sleepers is yet another economic utilisation question that will have to be gone into if we find a suitable technique.

On the wood-working side, secondary miombo timbers are usually difficult to work both by machine tools and by hand. Saws tend to overheat but good results can be obtained if the correct tooth shape is used. In planing, these timbers are liable to pick up severely if the normal cutting angle of 30° is used but good results can be obtained by reducing this angle to 10°. This requires about 50% more h.p. and prospective users of miombo timbers should have their planers motorised accordingly. In other wood-working operations, reasonably satisfactory results can be obtained with standard tools provided that care is taken and the speed of the operation controlled. The greatest difficulty in using these woods is unfortunately in nailing them. This is a serious handicap, particularly in building construction. It can be overcome by preboring and by use of thinner gauge nails but it is difficult to persuade users to go to this trouble if more easily nailable woods are available. When timber has been in short supply, however, very considerable quantities of miombo species have been used for building. The situation calls for vigorous extension work to promote the use of these woods.

III. SUGGESTIONS ON TECHNICAL CO-OPERATION IN DEALING WITH THE PROBLEM OF UTILISATION OF MIOMBO TIMBERS

There are some very serious problems connected with the utilisation of miombo timbers which require urgent investigation so that we can define our policy on this type of forest. The investigation of these problems would require technical skill of a high order, and in some cases a considerable cash outlay. The results of such investigations would very often have a wide application and it seems that this is a suitable field for international technical co-operation. It is suggested that the Conference should consider a programme of technical co-operation on the utilisation of miombo timbers and should make recommendations on :

(*a*) subjects to be investigated
(*b*) plans to carry out these investigations.

THE ENUMERATION OF MIOMBO WOODLAND IN TANGANYIKA

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SUMMARY

A method of enumeration, which is practicable and statistically acceptable, has been developed for miombo woodland. It is planned to enumerate about 30,000 square miles of forest reserve within five to ten years.

The layout consists of five-mile long transects randomised in pairs within thirty-square-mile strata. Each transect is a line of discrete, circular plots and three levels of sampling are obtained by varying plot-size and espacement.

Skewed sampling distributions occur with rare categories of produce, especially mature *Pterocarpus*, and square-root transformation is then applied before calculating the sampling error. Excessive skewness is prevented by using a large plot for the rarer classes.

Aerial photography is used for planning and access only, not for stratification by forest types.

About 30,000 square miles of the woodland formation known as miombo have been reserved in Tanganyika for productive forestry and require detailed enumeration as a preliminary to bringing them under sustained yield management. At least twice this area of miombo remains unreserved but needs partial enumeration in connection with the salvage of valuable timber.

During the past three years a method of enumeration has been developed which is practicable and economic, and also acceptable from the statistical aspect.

Field Organisation

The chief practical difficulties centre on the problems of access and water supply. For initial planning, aerial photographs are invaluable and are used to prepare a mosaic of forest types. Large areas of floodplain grassland (mbuga), thicket and extensive cultivation can be eliminated completely, water points can be located, baselines and transects can be aligned more effectively, and one can drive around the smaller mbuga systems without getting lost.

Field work is organised under teams, each supervised by one African forest ranger. It is considered that six teams can be supervised by one professional officer and supplied by one vehicle. One team can enumerate one five-mile transect in a day but, owing to the additional work of baseline cutting, camp shifting, checking, etc., only two transects (i.e. one stratum of thirty to forty square miles) are usually completed in a week. Six teams under one European should therefore get through about 200 square miles a week or up to 4,000 square miles in one full-time dry season.

Statistical Aspects

The most important category of produce, mature muninga (*Pterocarpus angolensis*), commonly occurs at an average density of less than twenty trees per square mile. The small transects originally used were three miles long and one chain wide, or one-thirtieth of a square mile, so the number of trees booked averaged fewer than one per transect, and more than half the transects were booked as zeros. With such skewed distributions, there was some uncertainty about the method of calculating a valid sampling error. It was found that the distribution resembles Poisson when the mean is less than unity, and the total number of trees booked can be treated as a single sample with a standard error equal to its square root. For a 20% sampling error at 95% probability, which is the maximum acceptable, it would be necessary to book one hundred trees, or in other words to enumerate over one hundred transects.

In order to reduce the number of transects required, they are now made five miles long with an effective width (for rare categories) of three chains, giving an area of one-fifth of a square mile. The mean number of trees booked per transect then averages about three or four. The distribution is still skewed but there is no longer any resemblance to Poisson ; the variance rapidly increases as the mean gets above unity, and cannot be taken as the square root of the mean. It is, however, possible to reduce the calculated sampling error by square root transformation, with correction for discontinuity and downward bias.

Further reduction of sampling error is achieved by randomising the transects in pairs within arbitrary strata, and using only the differences within strata for the calculation of variance. It was feared that, with very wide strata (six miles at present), the variation within strata would be large in relation to the variation between strata, but this is not the case and stratification has been found to effect a useful reduction of sampling error.

By combining transformation and stratification, a sampling error of 20% or less is usually obtained from thirty to forty transects, where the density averages about twenty per square mile.

Layout

The transects are five miles long and arranged in randomised pairs within strata which are usually six miles wide. The strata are thus thirty square miles in area and are arranged in a row on either side of cut baselines ten miles apart. The strata are not necessarily opposite each other nor equal in number on each side of the baseline. In effect the area to be enumerated is covered by a grid of six by five mile squares with the periphery coinciding as nearly as possible with the boundaries of the forest. Stratum boundaries are not marked on the ground.

The transects run through all forest types without interruption, being summarised as complete units. It is a great convenience when summarising the data to have transects of equal length. Statistical calculations are much simplified by not having to weight for area of sample.

Each transect is a line of discrete circular plots, spaced with their centres four chains apart, as this has been found easier to enumerate than a continuous strip. The plot centres are marked on the ground by numbered stakes to permit checking.

Sub-sampling

The various categories of produce to be enumerated range in density from less than twenty to more than 2,000 per square mile and it has been found desirable to use three levels of sampling in the ratio 30 : 5 : 1 as follows :

Level I.—Twelve-square-chain plots at four-chain centres, used for (1·25%) muninga of the 4–5 ft. and 5 ft.-plus classes, also for mature *Albizzia antunesiana* and 6 ft.-plus *Brachystegia.*

Level II.—Four-square-chain plots at four-chain centres, considered (0·21%) the " normal " level and used for most categories.

Level III.—Four-square-chain plots at twenty-chain centres, used for (0·042%) smaller size-classes of abundant species, especially *Brachystegia* and *Julbernardia.*

These levels may be varied to suit local requirements. About fifteen species are separately booked by 1 ft. girth-classes, down to 1–2 ft. for muninga, 3–4 ft. for miombo timbers, and 4 ft.-plus for minor species. In future 6-in. classes will be used for muninga. Only sound trees are booked.

The plots are circular and are defined by running out a tape to any tree near the boundary. With the large plot, the radius of which is 105 ft., using a tape could be tedious, but probably fewer than one tree a mile is being recorded at this level and many of them will be obviously in or out.

Size of Enumeration Unit

Each enumeration is planned for a particular forest reserve, covering usually from one to several thousand square miles, but the reserves frequently adjoin each other, so the enumerations can be lumped together or broken up into smaller units. It is expected that reliable data for mature muninga will be obtained within units of from 500 to 1,000 square miles and, for more abundant categories, within units of a few hundred square miles. For overall planning and yield regulation, data are required only for whole concession areas of several thousand square miles, and considerable thought has been devoted to the possibility of ultra-low percentage enumeration using perhaps fifty transects over an area of 5,000 square miles. This has not been followed up because with such widely spaced transects the time spent on administrative activities, especially transport, supply, labour recruitment etc., becomes disproportionately large. An even lower percentage enumeration, to give an overall " census " of the miombo reserves, or even of the entire miombo formation, is also under consideration and is statistically feasible. The sampling error is not much affected by the level of sampling, given transects large enough to control skewness, and it is thought that fifty purely random samples would suffice for a 20% sampling error over an area of woodland of any size.

Forest Type Separation

Typical woodland is a mosaic of forest types and only about half the area is timber-bearing woodland. It was hoped that type mapping from aerial photographs would permit stratification by types so that transects could be confined to productive land. In practice, however, the need for long transects to reduce skewness made this impossible, as the pattern of types is on too small a scale for a transect to lie only or largely in one type. Each plot along a transect is booked as belonging to a particular type, and this would permit summary by separate types, but the additional office work involved has not been found necessary or desirable. The main unproductive type, mbuga, is open grassland and not much time is wasted in running the transects through it.

Photo-interpretation

A few specially flown aerial photographs taken at 5,000 ft. and 2,500 ft. have been studied with a view to assessing at least the merchantable sized muninga, but the results are not promising in view of the additional source of error from correlating crown diameter with merchantable girth, allowing also for defective trees.

YIELD REGULATION OF PTEROCARPUS ANGOLENSIS

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SUMMARY

It is suggested that the sustained yield of *Pterocarpus* is best calculated by an adaptation of the Indian " Safeguarding Formula " based on the current rate at which trees are attaining merchantable size.

The stocking of mature timber does not affect the yield but determines the maximum felling cycle.

The focus of management research should thus be the stocking, increment, and mortality of Class II trees.

THE GROWING STOCK

The size-class distribution of muninga (*Pterocarpus angolensis*) nearly always displays a considerable deficit of mature and nearly-mature trees. It is usual to find that barely 2% of the trees and less than 10% of the volume is of merchantable size.

The growing stock can be regarded as normal only if one assumes the most calamitous rates of mortality. Natural mortality is reinforced by theft and exploitation, but in addition there are two other factors which may account for the deficit of larger trees :

> Firstly, in some areas, the woodland is believed to be genuinely immature, representing a seral stage following a period of extensive shifting cultivation.
>
> Secondly, there is an accumulation in the smaller size classes of trees which have stagnated, but which remain alive and even healthy while making negligible growth.

YIELD REGULATION

In most unmanaged forests there is an accumulation of mature and over-mature timber and the problem is to maintain the yield after this surplus has been removed. In muninga woodland the problem is the reverse. There is insufficient mature timber initially to provide the yield which is theoretically available.

Most methods of calculating the yield utilise the total enumerated growing stock. With muninga this would mean estimating the increment and mortality of small trees over a period of a hundred years or more and could not conceivably be very accurate.

Moreover if the yield is calculated from a growing stock consisting largely of small trees, the permissible cut is bound to come out too high in the sense that it can be maintained only by felling immature trees. It is therefore necessary to " correct " this already inaccurate estimate to allow for the deficit of mature timber.

In these circumstances the permissible yield is simply and solely the rate at which merchantable trees are recruited from the next size class below, and it is easier to calculate this directly than to try to arrive at it by a series of approximations. There is no question of having to take part of the yield as immature stock for sylvicultural reasons nor of having to retain mature trees as seed-bearers. Trees can be removed as and when they reach merchantable size subject only to the initial provision of a working stock of mature trees sufficient to permit a felling cycle which is not too short for economic harvesting. The calculation may be based on volume, but with muninga, which has a small range of log size, it is more convenient to use the number of trees per square mile and convert the yield to volume by a local factor for average log volume.

The yield therefore should be calculated from the number of surviving Class II trees, divided by the average time taken for a tree to pass through this class. This is the basis of the old Indian " Safeguarding Formula " devised by Smithies for *Shorea.*

A great advantage of this method is that the information required can be obtained accurately within a short period. One needs to know only the stocking of Class II trees, their average increment, and the proportion of them which will survive to maturity.

An example makes the method clearer. The following figures are typical (rounded) enumeration data for Tanganyika, with very approximate local increment and mortality data :

Girth class (feet)		*Present stocking* (per sq. mile)	*No of trees which will survive to maturity (ignoring theft)* (per sq. mile)	*Period to maturity (of survivors)* (years)
I	5+	20	20	0
II	4–5	85	80	40
III	3–4	300	250	80
IV	2–3	500	300	110
V	1–2	700	250	140
			900	

If the minimum merchantable girth is 5 ft. the yield is given by 80/40 or two trees a year per square mile. This yield can be sustained for forty years after which there should in theory be a substantial increase, unless the survival data are optimistic. (It is fairly certain that the mortality of younger trees is underestimated in the above table but this does not affect the method. There is no reason to expect that mortality will be severe enough to reduce the yield.)

It should be noted that the (apparent) surplus of young trees does not allow an increase in the yield. For example if the Brandis formula, utilising the whole growing stock, is applied, the yield is given by (900–20)/140 or six trees a year per square mile, which could not be sustained for more than five years without cutting trees less than 5 ft. girth.

THE FELLING CYCLE

It should be noted that the stocking of mature trees does not affect the calculation of sustained yield. What it does affect is the maximum felling cycle. In the above example there is a working stock of twenty trees per square mile, so the permitted yield of two trees per square mile could be harvested from one-tenth of the total area. In a 1,000 square-mile concession the annual yield would be 2,000 trees, which could be harvested from an area of one hundred square miles. This assumes that the mature timber is fairly uniformly distributed.

Eventually, with regulated cutting, the working stock could be brought into the form of a felling series, ranging from forty trees per square mile down to zero (still with an average of twenty per square mile). The yield would then be obtainable from one-twentieth of the area giving a maximum felling cycle of twenty years.

It should be further noted that even if the stocking of mature trees were zero, the yield of two per square mile would still be available (after the first year) though, in order to harvest it, the sawmiller would have to range over the whole concession every year. As this is usually impracticable the concession would have to remain unworked until an adequate working stock of mature trees had been built up to permit a more adequate felling cycle.

MERCHANTABLE GIRTH

The above example assumes that it is uneconomic to exploit trees less than 5 ft. in girth. If, however, a tree is merchantable at 4 ft. girth, the yield becomes 250/40 or six trees a year per square mile, and the initial felling cycle is given by (80 + 20)/6, or sixteen and a half years rising to thirty-three years when a felling series is established.

The question then arises whether a yield of six trees of the 4–5 ft. class is better than a yield of two trees of the 5 ft.-plus class. From the management point of view, both yields can be sustained, and both are equally permissible. This is a matter which can be settled only by a utilisation study taking into consideration the lower out-turn, smaller dimensions, and higher sapwood proportion of the smaller trees. Other factors to be considered include the desirability of maintaining a large reserve against periods of emergency, or to smooth out irregularities due to patchy distribution. The probability that mortality in the 3–4 ft. class has been underestimated should also be borne in mind.

In Tanganyika the present minimum girth is 5 ft. in forest reserves, but evidence is accumulating that it should be reduced to 4 ft. 6 in. It is generally agreed that a 4 ft. tree is definitely sub-economic.

RESEARCH

In future, timber will be enumerated in 6-in. classes. Special increment plots covering several square miles are now being laid down to give reliable increment and mortality data in respect of trees of 3 ft. girth and over. The older increment plots, covering a few acres only, contain a preponderance of small trees which, with this method of yield regulation, do not come into the picture at all.

COMPOSITION OF THE TROPICAL DRY FORESTS OF NYASALAND

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The vegetation over a large part of Nyasaland falls within Aubreville's description of closed or open tropical dry forests, with a pluviometric index of (5 – 0 – 7), 30–40 in. rainfall, and cool winters, 45–50 °F. mean minimum temperatures (May to September). The term " dry forest " is realistic for Nyasaland only as it refers to the seven months without significant rainfall when grass dries out in the open forest and the forest floor has little or no moisture in the surface layers. The annual rainfall is actually quite efficient for plant growth within the dry forest area as shown by the commercial production of tobacco, maize and groundnuts. Tree growth can also be very satisfactory. For example, on favourable sites individual tree specimens of common *Brachystegia* species may have a height of 22 m. or more, and 60–90 in. girth. It is therefore of much ecological interest that the most conspicuous feature of the tropical dry forest areas of Nyasaland today are irregular, fire-damaged stands of poor growth and form and low in quality wood products.

COMPONENTS OF THE DRY FOREST

The principal tree components of the tropical dry forests of Nyasaland can be grouped into several catagories as shown in the accompanying outline. It will be seen that certain trees from the riverine and lower montane evergreen forests, *Bridelia*, *Rauvolfia*, *Cordia* and *Pygeum* are present in the broad-leaf deciduous dry forest on good soils. On clearing the land for agriculture some of these became conspicuous in the cultivation steppe that characterises the areas of good soil throughout Nyasaland. The cultivation steppe has resulted from the fact that originally very large trees were too difficult to cut. Later certain timber trees were put on a protected list and their cutting was more or less restricted. It is from these relics and occasional remnants of the earlier forest that it is possible to define the composition of the broad-leaf deciduous dry forest.

The fact that certain evergreen forest species do occur in the broad-leaf deciduous forest areas has led some observers, for example Jackson, to favour the thesis that the broad-leaf deciduous forest is a natural succession from evergreen forest to *Brachystegia* woodlands. Many scattered remnants of lower montane evergreen forest throughout Nyasaland do suggest the possibility that there was once a contiguous evergreen forest throughout the country. Certainly, the evergreen forest was far more extensive even within the past century. On the other hand, a study of the wide edaphic and local climate variations existing because of elevation, topography, and aspect with relation to the summer monsoons, also suggests the possibility that the broad-leaf deciduous forest of *Combretum*, *Terminalia*, *Pterocarpus*, *Afrormosia*, *Burkea*, etc., is in itself a forest of long standing. Also, it is conceivable that exposed steep slopes and ridges of low soil fertility and particularly susceptible to primitive wild fires, have long been occupied by certain species of poor site *Brachystegia* and other species.

RECENT ORIGIN OF BRACHYSTEGIA WOODLAND

There is ample evidence that a high closed forest of reasonably good quality extended over most of the Central and Northern Provinces of Nyasaland within the last hundred years. Reliable observers, such as Dr. Laws of Livingstonia, who travelled throughout the Northern Province for many decades, testified before the Lands Commission in 1920 that he had personally witnessed in his lifetime the destruction of vast areas of well-wooded hill land by shifting agriculture. Today, this same region presents the largest continuous expanse of poor quality *Brachystegia/Uapaca* woodland in Nyasaland.

This rapid devolution from high closed forest to poor *Brachystegia* is considered by Hornby to be due to profound soil changes initiated by clearing the virgin forest and burning logs and debris together to sterilise and prepare the soil for growing finger-millet. The value of mineral nutrients from the ashes was a minor consideration. Sterilisation of the soil to eliminate competition with the millet was the primary intent. In the Rumpi District, a large acreage of finger-millet is still being grown today under the most primitive practices of shifting agriculture, now, however, in poor *Brachystegia* woodland.

Here the natives still consider that cutting the meagre stands in full foliage and burning the dried-out stems and debris on the new garden is a required cultural technique.

If we can accept Hornby's belief that it is sterilisation and the resulting physical changes in the soil that constitute the primary cause for site deterioration, this can well explain the very rapid vegetation change that has taken place in Nyasaland. Willan expressed the opinion that, in Nyasaland at least, *Brachystegia* woodland is " definitely a secondary type of vegetation which has successfully asserted itself and assumed a degree of stability on degraded and impoverished soils ". Clements and others also reached this same general conclusion on the basis of their own personal observations.

The inferior and crippled form of individual trees in most *Brachystegia* stands obviously can be accounted for in terms of the crippling effects of annual burning on young vegetation, and the persistent stripping and cutting by natives to obtain bark rope and small poles for their huts and storage bins.

The accompanying classification of the dry forests of Nyasaland is based on the concept that an extensive broad-leaf deciduous dry forest with a small component of *Brachystegia*, and also a characteristic poor site *Brachystegia* forest of limited extent, have both been in existence for many centuries. The extensive dry forest *Brachystegia* woodlands of today result from a direct primary invasion made possible by edaphic changes brought about through primitive shifting agriculture.

OUTLINE OF THE PRINCIPAL TREE COMPONENTS OF THE TROPICAL DRY FORESTS OF NYASALAND

Escarpment and Plateau Forests 2,000–5,000 ft. Elevation

A. Broad-leaf deciduous dry forest occurring as occasional remnants or relatively undisturbed woodland

1. On deep fertile well-drained soils :

Combretum zeyheri	*Kigelia pinnata*
Combretum molle	*Vitex cuneata*
Terminalia mollis	*Acacia galpinii*
Piliostigma thonningii	*Acacia campylacantha*
Erythrina abyssinica	*Albizzia antunesiana*
Burkea africana	*Albizzia harveyi*

(Evergreen components of limited extent)

Bridelia micrantha	*Syzygium cordatum*
Rauvolfia natalensis	*Pygeum africanum*
Cordia abyssinica	

2. On sandy, stony, shallow and less fertile soils :

Afrormosia angolensis	*Afzelia quanzensis*
Pterocarpus angolensis	*Dalbergia nitida*
Parinari mobola	*Terminalia sericea*
Monotes africanus	*Lonchocarpus capassa*
Dombeya rotundifolia	*Bauhinia petersiana*
Cussonia kirkii	*Pseudolachnostylis maprouneifolia*
Sclerocarya caffra	*Securidaca longipedunculata*
Strychnos spinosa	*Diplorrhynchus condylocarpon*
Faurea saligna	*Uapaca kirkiana*
Protea spp.	*Oxynanthera abyssinica*

(The riverine forest, although it cuts through the entire range of the dry forest from the highest elevations to the lake shore, is not considered as a dry forest)

Khaya nyasica	*Parkia filicoidea*
Adina microcephala	*Syzygium cordatum*

B. The cultivation steppe—large relic trees from the broad-leaf deciduous forests A1 and A2, a conspicuous feature of the landscape throughout the agricultural region of the Central Plateau. Almost any species may be found occasionally in the cultivation steppe, but the most frequent are :

Erythrina abyssinica	*Parinari mobola*
Rauvolfia natalensis	*Terminalia sericea*
Bridelia micrantha	*Burkea africana*
Piliostigma thonningii	*Combretum zeyheri*
Afrormosia angolensis	*Albizzia antunesiana*
Pterocarpus angolensis	*Acacia campylacantha*

C. Secondary forest after cutting and clearing A1, and allowed to regenerate without fire. Many original species return, but there is an increase in those with vigorous root sprouting and having heavy seeding characteristics, such as :

Piliostigma thonningii
Kigelia pinnata
Acacia campylacantha
Brachystegia appendiculata
Brachystegia boehmii
Albizzia antunesiana

D. Secondary forest after cutting and clearing A2 and allowed to regenerate without fire. Most of the original species return, but with a strong increase in the following :

Parinaria mobola
Terminalia sericea
Bauhinia petersiana
Lonchocarpus capassa
Brachystegia floribunda
Brachystegia boehmii
Afrormosia angolensis
Faurea saligna
Pseudolachnostylis maprouneifolia
Uapaca kirkiana
Brachystegia spiciformis
Julbernardia globiflora

E. Secondary or derived forest sometimes produced directly by clearing and abandonment of A with severe annual fires during the period of regeneration, or derived through repeated clearing and abandonment of A, C and D. Relatively pure or mixed stands of any of a number of *Brachystegia* with minor broad-leaf and other components as listed below.

1. On deeper soils :

Brachystegia appendiculata
Brachystegia bussei

2. On sandy, shallow or stony soils :

Brachystegia floribunda
Brachystegia boehmii
Brachystegia longifolia
Brachystegia spiciformis
Julbernardia globiflora
Uapaca kirkiana

Varying amounts of broad-leaf deciduous and other species may be present, frequently of inferior form and quality :

Parinari mobola
Monotes africanus
Kigelia pinnata
Lonchocarpus capassa
Faurea saligna
Diplorrhynchus condylocarpon
Albizzia harveyi
Bauhinia petersiana
Uapaca nitida
Lannea discolor
Markhamia obtusifolia
Cussonia kirkii
Protea spp.
Acacia macrothyrsa
Securidaca longipedunculata

F. Degeneration stages of dry forest derived from E through progressive deterioration, due to annual fires, damage by natives, over trampling by livestock and soil erosion.

1. Open *Brachystegia/Isoberlinia/Uapaca* woodland with a conspicuous grass understorey and minor elements of *Cussonia*, *Protea* and others.

2. Almost pure stands of poor growth *Uapaca kirkiana* on eroding, infertile soils, often on ridges and steep upper slopes.

3. Almost pure stands of poor growth *Brachystegia taxifolia* at high elevations, such as the hill country of Mzimba. (Other individual *Brachystegia* species produce similar stands elsewhere.)

4. Open semi-scrub produced by heavy use of cattle and goats with sparse grass and progressive exposure of the bare soil, increasing in amount in centres of heavy livestock concentration in Nyasaland.

Diplorrhynchus condylocarpon
Acacia karroo
Markhamia obtusifolia
Protea spp.
Dichrostachys nyassana
Cussonia kirkii

5. Poor scrub after continual over-trampling by livestock and active sheet and gully erosion. This type has much the same appearance as similar areas in British East Africa in regions of very much less rainfall.

Dichrostachys nyassana
Markhamia obtusifolia
Acacia karroo

Tropical Dry Forest of the Lake Shore and Southern Lowlands 500–2,000 ft. Elevation

H. The cultivation steppe—large trees of uncertain origin on good to medium soils.

1. Broad-leaf deciduous trees with counterparts in the plateau and escarpment dry forest :

Pterocarpus angolensis
Pterocarpus spp.
Burkea africana
Terminalia sericea
Kigelia pinnata
Afrormosia angolensis
Pseudolachnostylis maprouneifolia
Lonchocarpus capassa
Sclerocarya caffra
Combretum ternifolium
Trichilia emetica
Acacia nigrescens

2. Trees with much more limited range than above :

Tamarindus indica
Cordyla africana
Acacia albida
Albizzia versicolor
Chlorophora excelsa

I. Brachystegia woodlands—occurring with almost any possible combination of the broad-leaf deciduous species listed above, and typical hot climate species.

Brachystegia spiciformis
Brachystegia boehmii
Brachystegia tamarindoides

J. Typical hot climate species—generally on coarse detritus or poor quality soils, but also on sandy alluvium which is cultivated, and in this case relic trees appear in the cultivation steppe.

Adansonia digitata
Sterculia africana
Sterculia appendiculata
Kirkia acuminata
Sterculia quinqueloba

K. Species found usually in special edaphic situations

Colophospermum mopane
Borassus aethiopicum
Hyphaene crinita

FLORISTIC COMPOSITION OF MIOMBO WOODLAND

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Miombo woodland has a strikingly homogeneous appearance over the whole of its range, largely due to the limited number of canopy dominants which are mostly social tropophilous species.

There are just under fifty species which have been noted as occurring in the canopy but 50% of these are rare or occasional species in miombo. Half of the remainder are local dominants or locally frequent but the following fourteen are widespread dominants or canopy components.

Afrormosia angolensis
Albizzia antunesiana
Brachystegia boehmii
Brachystegia floribunda
Brachystegia longifolia
Brachystegia spiciformis
Brachystegia utilis
Erythrophleum africanum
Isoberlinia angolensis
Julbernardia globiflora
Julbernardia paniculata
Marquesia macroura
Parinari curatellifolia
Syzygium guineense

It is interesting to note that with three exceptions—*Marquesia, Parinari* and *Syzygium*—the widespread dominants are entirely leguminous.

Some ninety species of smaller trees do not quite reach the canopy except occasionally in regrowth or in openings in more mature woodland. A wide range of families is represented, but almost all species are semi-deciduous. The following twenty species are reasonably common and widely distributed. *Uapaca spp.* are essentially pioneers of the regrowth woodland.

Anisopyllea boehmii
Baphia bequaertii
Combretum zeyheri
Dialiopsis africana
Diplorrhynchus condylocarpon
Faurea speciosa
Memecylon flavovirens
Ochna schweinfurthiana
Monotes africanus
Ochthocosmus lemaireanus
Pseudolachnostylis maprouneifolia
Rothmannia englerana
Strychnos innocua
Strychnos cocculoides
Strychnos pungens
Swartzia madagascariensis
Uapaca kirkiana
Uapaca nitida
Uapaca sansibarica

Almost a hundred small trees and shrubs have been noted in miombo undergrowth, but only the following are at all common :

Bridelia duvigneaudii
Byrsocarpus orientalis
Canthium crassum
Diospyros virgata
Eriosema ellipticum
Flacourtia indica
Hexalobus monopetalus
Hymenocardia acida
Indigofera spp. (6)
Kotschya spp. (3)
Pavetta schulmanniana
Protea angolensis
Psorospermum febrifugum
Salacia rhodesiaca
Securidaca longipedunculata
Uapaca pilosa
Xylopia odoratissima

The ground flora consists of 300 to 400 species of woody herbs, suffrutices, herbs, grasses, sedges and ferns, and the odd saprophyte.

The commonest woody herbs and suffrutices out of some fifty species noted are :

Cryptosepalum maraviensis
Desmodium helenae
Dolichos eriocaulos
Fadogia spp. (2)
Sphenostylis erecta
Strobilanthopsis linifolia
Tricalysia suffruticosa

Some 300 or more herbs occur in the ground flora of miombo. Many of them have not yet been named. Certain groups like *Cissus*, *Commelina*, *Crotalaria*, *Dolichos*, *Indigofera*, *Tephrosia*, *Thunbergia*, *Vernonia* and *Vigna* are well represented by numerous species. Apart from these big groups the commonest herbaceous species are the following :

Adenodolichos punctatus
Adenodolichos rhomboideus
Becium obovatum
Borreria dibrachiata
Clematopsis scabiosifolia
Coreopsis mattfieldii
Costus macranthus
Diplolophium zambesianum
Droogmansia platypus
Elephantopus scaber
Eulophia cucullata
Euphorbia cyparissoides
Geophila ioides
Gloriosa carsonii
Helichrysum kirkii
Hibiscus rhodanthus
Kaempferia aethiopica
Lactuca capensis
Laggera alata
Murdannia simplex
Oxalis semiloba
Triumfetta reticulata

Of a dozen sedges represented, only three are fairly common :

Carex echinochloa
Scleria bulbifera
Scleria woodii

Forty or more grasses occur in miombo in due season. The most abundant are :

Andropogon shirensis
Anthephora acuminata
Brachiaria brizantha
Brachiaria humidicola
Hyparrhenia spp. (3)
Loudetia bequaertii
Loudetia superba
Melinis longicauda
Rhynchelytrum repens
Sporobolus rhodesiensis
Themeda triandra
Tristachya bequaertii
Urochloa spp. (2)

Epiphytes are not characteristic of miombo but do occur occasionally. They are represented by twelve to fifteen *Loranthus spp.*, six genera of orchids and *Piliostyles* of the *Rafflesiaceae*. At least one saprophyte—*Thonningia sanguinea*—occurs in the ground flora.

On deeper, sandier, better drained soils, miombo woodland carries evergreen thicket in the high rainfall belt and a semi-deciduous thicket in the low rainfall belt. This can vary from the odd creeper like *Landolphia* or *Opilia* or the scrambling evergreen bush like *Canthium guenzii* to a thicket tangle of small trees, shrubs, scramblers and lianes covering many square yards. Evergreen or semi-deciduous species typical of thicket have not been included in the appendix as being outside the scope of miombo woodland in a restricted sense. Those scramblers listed are not necessarily associated with thicket and are often found on their own.

On similar soils or associated with thicket are found the gregarious herbs and ferns which are popularly associated with the type of woodland known as " chipya ". They are :

Aframomum biauriculatum
Pteridium aquilinum
Smilax kraussianus

They may occur singly or together or in any combination of two species.

Apart from these gregarious species on the forest floor there appear to be certain species of trees and shrubs which prefer the deeper, better drained soils and can be regarded as indicator plants for such soils. They are :

Albizzia adianthifolia
Erythrophleum africanum
Syzygium guineense
Paropsia brazzaeana
Landolphia kirkii
Landolphia parvifolia
Rhynchosia resinosa

Conversely, certain species seem to be characteristic of very poor, badly drained miombo woodland. They are :

Monotes africanus
Monotes caloneura
Monotes englerana
Uapaca kirkiana
Uapaca nitida
Uapaca sansibarica

The total flora of miombo woodland runs to some 700 species, despite the limited number and homogeneity of the canopy dominants. Approximately 50% of this total is woody, 50% herbaceous. Individual stands on the other hand rarely carry more than seventy woody species and say eighty herbaceous species, a total of 150 or approximately a quarter of the possible number of woody and herbaceous species. Despite the dry conditions of the woodland, not normally associated with a wide range of species, miombo has approximately one-quarter of the woody species known to occur in the territory.

CLASSIFICATION OF MIOMBO WOODLANDS

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Trapnell (1937, 1943) produced the first classification of the open woodlands of the territory in the course of his work on soils, vegetation and agriculture. Later Trapnell, Brockington and Fanshawe subdivided Trapnell's original broad classification to fit the miombo woodlands of the Copperbelt. Over the last three years Forest Survey Units of the Forest Department have produced management books for almost half of the districts in the territory. Each book contains a chapter, often amplified in the appendix on the vegetation of the district. Such descriptions are largely based on Trapnell's early work but modified for forestry purposes into sub-types and local variants.

The following classification of miombo woodland takes all this into account. The woodland is primarily divided into broad soil and topographic groups. Notation of the group subdivisions follows Trapnell.

Plateau Soils
Transition soils
Lake Basin soils
Escarpment soils
Upper Valley soils
Kalahari sands

Plateau Soils

P.1. Marquesia woodland

Associates : *Brachystegia spiciformis/Br. longifolia/Syzygium guineense.*

P.2. Northern Brachystegia floribunda/Br. boehmii/Br. spiciformis/ Isoberlinia woodlands of North Western Province

Associates : *Marquesia macroura/Br. wangermeeana/Br. longifolia.*

P.3. Northern Julbernardia globiflora/Brachystegia floribunda/Br. glaberrima/Br. wangermeeana woodlands

Associates : *Isoberlinia/Brachystegia spiciformis/ Br. utilis.*

Sub-types (*a*) *Br. spiciformis*
(*b*) *Br. wangermeeana*
(*c*) *Br. glaberrina*
(*d*) *Br. utilis*
(*e*) *Isoberlinia.*

Julbernardia globiflora is co-dominant in each sub-type.

P.4. Northern Julbernardia paniculata/Brachystegia floribunda/Br. longifolia woodlands

Associates : *Isoberlinia/Br. spiciformis/Br. boehmii/Marquesia/Br. wangermeeana/Br. utilis.*

Sub-types (*a*) *Br. spiciformis/Br. longifolia/Isoberlinia*

(*b*) *Br. longifolia/Br. utilis/Br. spiciformis/Br. floribunda*

(*c*) *Br. floribunda/Br. wangermeena.*

Julbernardia paniculata is co-dominant in each sub-type.

P.5. Central Julbernardia paniculata/Brachystegia longifolia woodlands

Associates : *Brachystegia utilis/Julbernardia globiflora/Isoberlinia.*

Sub-types (*a*) *Br. utilis/Julbernardia globiflora*

(*b*) *Isoberlinia/Julbernardia globiflora.*

Br. longifolia and *Julbernardia paniculata* are co-dominant in each sub-type.

P.6. Eastern Julbernardia paniculata/J. globiflora/Brachystegia stipulata woodlands

P.7. Southern Julbernardia globiflora/Brachystegia spiciformis/Br. boehmii woodlands

P.8. Brachystegia spiciformis woodland, pure or almost so.

Transition Soils

P.9. Brachystegia spiciformis/Br. longifolia woodland—copperbelt " chipya ".

Associates : *Erythrophleum africanum/Albizzia adianthifolia/Amblygonocarpus/Parinari curatellifolia/Pterocarpus angolensis.*

On the transition to Kalahari sands.

B.2. Brachystegia spiciformis/Julbernardia globiflora woodlands

Associates : *Marquesia macroura/Isoberlinia/Albizzia adianthifolia/Afrormosia/Parinari caratellifolia.*

Sub-type—*Daniellia alsteeniana/Berlinia craibiana* woodland of Kawambwa district.

On the transition to Lake Basin soils.

U.1. Brachystegia spiciformis/Julbernardia globiflora woodlands

Associates : *Afrormosia/Albizzia spp./Pterocarpus angolensis/Brachystegia spp.*

On the transition to Upper Valley soils.

Lake Basin Soils

B.1. Marquesia woodland

Associates : *Brachystegia spiciformis/Julbernardia globiflora/Syzygium guineense.*

Escarpment Soils

E. Northern Brachystegia spp. woodlands

Sub-types (*a*) *Br. allenii*
(*b*) *Br. bussei*
(*c*) *Br. microphylla.*

E.1. Eastern : Brachystegia manga/Julbernardia paniculata/J. globiflora woodlands

Associates : *Br. allenii/Br. boehmii/Br. longifolia/Br. utilis/Br. taxifolia/Br. stipulata.*

Sub-types (*a*) *Br. manga*
(*b*) *Br. boehmii/Julbernardia globiflora.*

Julbernardia paniculata is co-dominant in each sub-type.

E.2. Southern : Brachystegia boehmii/Julbernardia globiflora/Br. longifolia/Br. utilis woodlands

Associates : *Br. spiciformis/Br. taxifolia/Albizzia antunesiana/Parinari curatellifolia.*

Upper Valley Soils

L.P. Julbernardia globiflora/Brachystegia allenii/B. taxifolia woodlands

Kalahari Sands

K.2. Brachystegia spiciformis/Cryptosepalum pseudotaxus

Associates : *Br. longifolia/Marquesia spp./Parinari spp./Isoberlinia/Guibourtia coleosperma.*

K.3. Brachystegia spiciformis/Br. longifolia woodlands

Associates : *Julbernardia paniculata/Erythrophleum africanum/Pterocarpus angolensis.*

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BURNING EXPERIMENTS IN MIOMBO WOODLAND

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It becomes obvious to foresters after one dry season that the usual African practice of late burning just before the rains break in early November leads to soil deterioration and the killing-off of the trees. The area of miombo woodland is far too large to protect completely from fire, but controlled early burning can prevent the damaging late fires and favour the spread of evergreen thicket on the deeper soils.

To study the effects of fire, four one-acre plots were laid out in semi-mature miombo woodland by Mr. Duff, the Conservator of Forests in Ndola West Forest Reserve in February to March 1933. Ever since, Plot 1 has been early burnt in June–July each year, Plot 2 late burnt in October and Plots 3 and 4 completely protected from fire. Replications of the burning regimes were laid out in nearby ten-acre plots of semi-mature woodland and a replicated series of one-acre coppice plots felled in 1933–4.

The original vegetation of the plots was forty to fifty year old, miombo regrowth following native gardening, dominated by *Julbernardia paniculata* associated with *Isoberlinia angolensis*, *Brachystegia longifolia*, *Br. spiciformis* and *Erythrophleum africanum*. By Copperbelt standards it was good quality II to poor quality I miombo woodland.

After twenty-six years, the following conclusions can be drawn.

ANNUAL LATE BURNING

This regime drastically reduces the stocking of canopy trees especially among the fire-sensitive *Brachystegia*, *Isoberlinia* and *Julbernardia*. Only the fire-tolerant *Parinari curatellifolia*, *Erythrophleum africanum* and *Pterocarpus angolensis* survive and they formed only a small percentage of the original stocking. Rate of growth and volume increment naturally fall off. There is a smaller decrease in stocking of under-storey species, largely because many of them are fire-tolerant. Late burning favours the rate of growth of the surviving under-storey trees.

In the undergrowth, the stocking first decreases and later increases as the canopy and under-storey die off. Both the lower layers contain many fire-tolerant species, e.g. *Anisophyllea boehmii*, *Diplorrhynchus condylocarpon*, *Strychnos innocua*, *Uapaca nitida* and *Dialiopsis africana* among others. Late burning favours a marked increase in the ground flora, both herbs and suffrutices, and the grass flora gradually changes from the weaker woodland grasses like *Hyparrhenia lecomtei*, *Rhynchelytrum*, *Melinis*, *Tristachya* and

Loudetia bequaertii to the coarser dambo-chipya grasses like *Andropogon schirensis*, *Loudetia superba*, *Digitaria diagonalis* and *Hyparrhenia filipendula*. Young regeneration cannot succeed with a late burning regime. Two other changes are associated : (1) increase in the number of small termite mounds per acre ; (2) incipient sheet erosion.

ANNUAL EARLY BURNING

This regime tends to promote the *status quo* of the original woodland. There is a slight increase in stocking of both canopy and under-storey trees, and an initial increase in stocking of undergrowth species followed later by a falling-off in numbers. Regeneration of woody, especially canopy, species is maintained and eventually slightly increases. The ground flora retains more or less its original coverage. The grass flora does not change. Finally, the numbers of small ant-hills per acre does not significantly increase and there is no sign of erosion.

COMPLETE PROTECTION

Under this regime, the canopy is maintained but a dense undergrowth, mostly new recruitment, develops, partly at the expense of the under-storey. The ground flora decreases. Protection allows entry of fire-intolerant, shade-loving evergreens, if local soil-moisture conditions are suitable and there is a nearby focus of evergreen thicket to initiate colonisation. The intruders are mostly scramblers or lianes like *Uvaria angolensis*, *Artabotrys monteiroae*, *Canthium guenzii*, *Opilia celtidifolia* and *Landolphia kirkii*. Later evergreen seedlings of *Entandrophragma*, *Syzygium*, *Chrysophyllum* and *Pittosporum* appear. *Entandrophragma* and *Syzygium* may eventually attain canopy status as they have done elsewhere in the past. The rate of growth and volume increment are favoured by complete protection. The number of small termite mounds per acre decreases.

To sum up, the Ndola burning plots show that complete protection is an unattainable ideal, that annual late burning is an excellent way of getting rid of the woodland, and that early burning maintains the *status quo* by preventing the damaging late fires. The only reason why miombo woodland still survives is that, in the past, burning of the woodland has been haphazard, not necessarily annual and not always late. The combination of regular, annual late burns would have wiped out miombo woodland long ago.

It is now departmental policy to do intensive early burning in all the felled coupes to promote regeneration and keep out late fires, and do protective early burning in forest reserves and protected forest areas to prevent the late fires.

Reference

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UTILISATION OF MIOMBO SPECIES IN NORTHERN RHODESIA

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SPECIES USED

Large quantities of miombo timber are cut each year in Northern Rhodesia, more than 90% of which is derived from *Brachystegia longifolia* and *B. spiciformis*, *Julbernardia paniculata* and *Isoberlinia angolensis*. The remainder is made up of small quantities of *Pterocarpus angolensis*, *Erythrophleum africanum*, *Afrormosia angolensis*, *Albizzia antunesiana* and other *Brachystegia spp.*

USES

By far the greatest use of the four main species is for fuel and charcoal, for which purpose its slow and even combustion is ideal. During the years 1952–6 when the mines were using cordwood for generating electricity, 35–50 million cu. ft. were consumed annually, or over 90% of the annual cut of miombo.

For the same reason they make good smelter poles for refining copper and between 500,000 and 1,000,000 cu. ft. of standing timber are used annually for this purpose.

As mining timber the main species have all been tested in 9 in. × 9 in. sizes by the Transvaal Chamber of Mines. The strength properties are good and in general one-and-a-half times to twice as strong as Oregon. Between 500,000 and 1,000,000 cu. ft. standing timber per annum are consumed by the mines. The timbers soon lose their strength, however, due to their low durability and resistance to borers. Only the sapwood can be impregnated. Miombo timbers are in direct competition with imported Oregon which is much preferred owing to its rather better durability, lighter weight and easy working properties, and it is only when the price of Oregon rises above approximately 13s. per cu. ft. that the local timbers become generally acceptable. The bulk of it is used only for temporary purposes where a life of not more than three years is required. In places underground conducive to fungal attack the life is only one to one-and-a-half years when untreated with preservatives.

A few of the less common species such as *Erythrophleum africanum* and *Afrormosia angolensis* are highly durable and consequently much in demand for shafting timber and sleepers.

Large numbers of posts and poles are used by the rural population for hut and fence construction, not because they are particularly good but because there is little else. The four main species have only a short life in the ground and are soon destroyed by termites and borers.

As constructional and joinery timbers they are little used, except in rural areas, where most of the demand is for *Pterocarpus angolensis*, which is a high-class timber that commands a ready market for furniture making. The common species have nothing to recommend them for this purpose ; they are not available in long lengths, they are mostly hard to saw and work, they warp and split rather freely and are impossible to nail without pre-boring.

Tests carried out on fourteen common timbers, though not conclusive, showed that most of the *Brachystegia* and *Isoberlinia* together with *Parinari mabola*, *Marquesia macroura* and *Erythrophleum africanum*, all made reasonably good tool handles with comparable strength to hickory handles.

In 1951 South African Pulp and Paper Industries Ltd. carried out preliminary pulping tests on the four main timbers. Using the " soda " process they reported that the fibres were short length—*Brachystegia spiciformis* produced the longest, averaging 1·6 mm., while the others ranged between 0·8 and 1·1 mm., rather similar to wattle and eucalyptus pulps. The tests indicated low yields of pulp around 35 to 41%. Strength properties were low and it would probably be necessary to add some long-fibred pulp ± 3 mm. to give them enough strength to carry them through the paper machine. It was not felt that the pulp would be suitable for anything better than the cheapest writings and printings.

In 1954 Professor Steenberg of FAO made a survey of the pulp possibilities in the area, using miombo timbers, and reported adversely : " because of the low yield of pulpwood per acre . . . high production and transport costs, it is at present not an economic venture to contemplate the erection of a pulp mill for the export market even if a market existed ".

The quality of pulp that can be obtained is not in great demand and would have to be exported abroad, where it would be in competition with better and cheaper products. The only circumstance that might possibly alter this situation would be the availability of large quantities of waste material from coniferous plantations in the area for admixture with the miombo pulp.

It is possible that the greatest commercial value of miombo woodland lies in honey production, which it provides " par excellence ". With proper development it is not impossible that the value of the honey crop could exceed that of the timber, with the added advantage that the timber remains standing.

SOFTWOOD AFFORESTATION IN COPPERBELT MIOMBO WOODLAND

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SUMMARY

Attention is drawn to the lack of either mountain grassland or of mist-belt zones in Northern Rhodesia suitable for large-scale softwood afforestation, and the resulting necessity to afforest miombo sites. The main conclusions from over twenty years of species trials and site testing are presented, and the special methods of land-clearing and preparation, and of planting and tending, that have been evolved to enable large-scale economic afforestation of Copperbelt miombo woodland sites are described and discussed.

I. INTRODUCTION

Northern Rhodesia has no exploitable indigenous softwoods and, indeed, few hardwoods that can be classed as easily worked, general utility timbers. Softwood timber required for heavy construction and general building purposes has to be imported, mainly from Canada. This represents not only a drain on the country's finances but also a burden upon the freight-carrying capacity of our single-track railway system.

In order to fulfil its obligation to produce locally as much as possible of the softwood requirements, the Forest Department has undertaken a programme of afforestation with exotic conifers, mainly tropical pines. Unfortunately, Northern Rhodesia has only very limited, and no accessible, areas of mountain grassland or of mist-belt zones—the usual sites chosen in African territories, both tropical and sub-tropical, for conifers. In addition, the land that is available on the Copperbelt, which is the main timber-consuming centre, all supports relatively dense miombo woodland.

These circumstances have made it essential for the Forest Department to feel its way cautiously since the afforestation techniques of more favoured countries could not, with safety, be adopted on a large scale. Accordingly, a testing station for the Copperbelt was established at Dola Hill, near Ndola, and as a first step species trials were commenced. Conifers, mainly pines, but including cypresses and callitris, were given most attention. Truly tropical species, sub-tropical species known to do well in neighbouring countries, and those from low rainfall areas were concentrated upon.

The more successful of the initial introductions were then re-tested on a larger scale and finally a small percentage was judged worth pilot-planting at the nearby Chichele Plantation.

During the course of this initial testing it became increasingly apparent that not only was species selection of paramount importance but that, if even the most successful species were to be established on a large scale, new nursery techniques as well as methods of land-clearing, soil preparation, planting and tending would have to be evolved to meet local conditions.

The purpose of this paper is to describe the methods that have been developed to permit the large-scale planting which is now commencing. Of course it is to be expected, and hoped, that the methods here outlined will themselves be modified and improved upon as experience is gained.

II. CHOICE OF SPECIES AND SELECTION OF SITES

The results of species trials conducted over the past twenty years clearly show that the only consistently reliable coniferous species so far tested are the truly tropical pines, unfortunately few in number.

These species not only show appreciable hardiness and the ability to withstand the considerable variation in seasonal rainfall experienced on the Copperbelt but, in addition, are comparatively little affected by site variation in miombo woodland.

The species involved are *P. insularis*, *P. khasya* and *P. merkusii*. *P. michoacana*, a sub-tropical species, has also proved very successful in trial plots. In contrast, the tropical but low-altitude *P. caribaea* Morelet has not shown much promise in miombo woodland sites but may prove well suited to certain dambo sites.

Two tropical pines have not yet been tested owing to our inability to secure seed. They are *P. strobus chiapensis* and *P. oocarpa*.

The main lesson learned from species trials is that, while tropical species from regions of similar or higher temperatures, but often greater rainfall (summer), adapt well to local conditions, those species of pine from equally dry, or even considerably drier, natural habitats with lower mean temperatures and a winter rainfall regime fail. An intermediate class is to be found in many of the warm-temperate to sub-tropical species. These prove more exacting in their site requirements than the tropical species, and are very prone to damage when the hot dry season is unusually prolonged.

On Copperbelt miombo sites, and indeed on the vast majority of sites tested throughout the territory, clean weeding for the first few years following planting has been found essential if adequate growth and consistently high survival is to be assured. It is suggested that the scrupulous removal of all competing vegetation has the effect of greatly increasing the proportion of the rainfall available to and used by the pine crop, and that this explains the apparently anomalous success of the " wet tropics " species.

On present knowledge, it is expected that the tropical pines will make satisfactory growth on most sites carrying well grown miombo woodland. The main characters looked for in a good plantation soil are freedom from impediments to rooting for a depth of at least 6–8 ft., adequate soil moisture during the dry season, and good aeration throughout the year as evidenced by free drainage and friability. Colluvial and upper eluvial sites are preferred.

The same criteria probably also decide what is a high quality indigenous woodland site.

Shallow soils over indurated laterite and pallid, highly compact sandy clays are the main types avoided. Scrub growth usually betrays the former, while the latter frequently carry *Julbernardia paniculata/Brachystegia floribunda* associations of poor growth and form.

Seed supplies of the tropical pines are far from adequate and it has been necessary to use, on a limited scale, the more promising of the sub-tropical species such as *P. patula*, *P. montezumae*, *P. pseudostrobus* and *P. leiophylla*. These species are confined to the most favourable sites as indicated by well developed chipya or evergreen vegetation and deep humic topsoil.

III. METHODS OF LAND-CLEARING AND PREPARATION AND THE FACTORS DETERMINING THEM

As already noted, observations and experiments have shown that, to obtain good initial growth and an acceptable percentage establishment, freedom from competition with grass, weeds, and regrowth is essential during the first few years following planting.

Attempts have been made to avoid the costly operation of stumping by exploiting the woodland some years in advance of planting, protecting it for a year or two after felling in order to encourage a rank growth of invading grasses and to ensure prolific coppicing, and then subjecting it to late fires with the intention of killing off the coppice and greatly increasing stump mortality. Unfortunately, an area treated in this way, and in fact opened woodland generally, is rapidly invaded by aggressive grasses of the genera *Hyparrhenia*, *Andropogon* and *Loudetia*. Thus, this technique increases the subsequent weeding problem. This would be of little consequence were it possible to bring the weeds under control with disc harrows but, unfortunately, the prevalence of stumps makes this impracticable.

It is true that a regime of deliberate late burning does increase stump mortality, but the stumps show extraordinary vitality, and more than sufficient remain sound enough to make any form of mechanical cultivation distinctly hazardous. The reasons why manual labour is considered impracticable for efficient weeding of anything over an annual planting rate of some fifty acres per annum are, briefly stated, that the strongly seasonal nature of the rainfall results in a short period of active growth and hence there are at best a few weeks only at the beginning and at the end of the rains—the critical periods—in which to weed the entire acreage of pines up to three or four years old. Owing to the rank growth and deep rooting habit of the grasses and other weeds, hand weeding is laborious and slow. This means that a very considerable seasonal increase in labour force is necessary ; an undesirable feature from many points of view and, in fact, often unattainable on the Copperbelt.

In the land clearing and preparation techniques now adopted, the indigenous trees on the area to be planted are winched over, usually with the aid of a suitably equipped D4 Caterpillar tractor. The usual method is to hitch the tractor winch rope about 15–18 ft. up a tree, and then to drive the tractor in a short arc some distance away from the tree so that several others are pulled over before the anchor-tree finally comes too. Groups of up to ten trees are commonly dealt with in this way. Laterals are severed on the larger trees and quite extensive digging as well as the individual attention of the tractor is necessary to deal with well-rooted trees upwards of about 20 in. diameter. Small trees under about 5 in. diameter missed by the tractor sweeps are dug out by hand. Stumping operations are generally carried out while the soil is moist, since this greatly facilitates the task. A D4 tractor, with two attendant labourers, averages about two acres of stumping per day. Some twenty-five man/days per acre are needed to sever laterals, stump out the smaller trees, and to cope with large stumps of previously exploited trees. The presence of many large stumps in previously exploited woodland increases costs substantially. If the very powerful lever of the tree bole and branches is not available, deep excavations to cut the taproot are necessary before the stump can be pulled out.

Due to the patchy nature of the indigenous crop, it is difficult to provide average stocking per acre or size-class distribution. Stocking per acre in mature woodland of medium quality probably varies from ten to twenty timber trees above 14 in. d.b.h., with thirty to sixty trees in the 6–14 in. d.b.h. class and fifty to 150 saplings of 2–6 in. d.b.h.

Following stumping the mining timber, smelter poles and cordwood (about fifteen to twenty cords per acre) is removed, and the area is licensed to charcoal burners. Finally, the unwanted debris is stacked, as far as practicable on ant-hills, and the whole area over is burned off in the dry season. The stump holes are then filled in, and the occasional missed stump shown up by the burn is attended to. The land is then ready for ploughing. Stumping, clearing, burning-off and filling-in stump holes usually requires some fifty-five man/days per acre. The cost of logging, cording, etc. is naturally borne by the contractor taking the produce.

In order to have a reserve of cleared land, the stumping operations are usually some one to three years ahead of ploughing.

The first ploughing is done with a heavy plough, such as the John Deere 606, and Caterpillar D4 tractor. Heavy equipment of this kind is considered essential to cope with deep-rooted grasses and rhizomatous species such as *Aframomum* and *Pteridium*, and also to withstand encounters with large lateral roots, the removal of which is quite impracticable.

Ploughing is followed by harrowing with a heavy multi-gang implement. The first ploughing and harrowing is done just at the end of the rains in the season preceding planting. The object of this bare-fallow over the dry season is to prevent excessive soil-moisture depletion by ground flora and regrowth from tree rootstocks. A second harrowing immediately before planting is then done, since this eliminates any weeds from re-establishing themselves or seeding in, and gets the land into good planting condition. This second harrowing is especially necessary in chipya areas owing to the deep rooting habits and vitality of the two main grass genera *Hyparrhenia* and *Andropogon*, and particularly to the persistence of the rhizomatous *Aframomum* and of *Pteridium*.

The ground preparation described results in good penetration of rainfall, particularly since the final working is across the contour. Too fine a tilth is considered undesirable, however, and is avoided.

IV. PLANTING

Owing to the short duration of the rains, the likelihood of dry spells six to eight days long during the planting season, the need to ensure deep rooting by the plant before the dry season sets in, and the liability of open-rooted stock to termite attack, all pine species are raised in polythene pots some 4 in. wide and 5 in. deep. Plants are set out in the field without removing the polythene pots or disturbing the soil in any way. This technique has reduced manifold the deaths following planting and contributes in large measure to the essential ingredient in successful afforestation of miombo sites with pines—a quick start for the plants in the field—giving them the opportunity to become established before the onset of the dry season.

The pot plants are transported to the planting site on lorries or trailers, and are packed in wooden trays for ease of handling. They are given a good watering in the nursery before being sent out. Pot plants may be planted even in full sun, a considerable advantage owing to the frequency of sunny spells in the planting season. As far as possible, only sufficient plants for the day's planting are sent. This is not always feasible, especially if the planting programme is large, and plants can quite safely be stored at the planting site for several days provided they are watered as necessary.

The pine transplants, plastic pot and all, are planted at 9 ft. × 9 ft. or more, usually 9 ft. × $4\frac{1}{2}$ ft. The espacements used are determined primarily by considerations concerning weeding and will therefore be discussed under that heading. The plants are set in the soil at least to the same depth as that in the pot, but often a little deeper. Some 500 are planted per man/day.

The planting rains seldom start before the end of November, and not infrequently planting is delayed until December. The significance of a delay of even one or two weeks will be appreciated, since the rains end in March, even in an average year, and may well end much earlier. There is probably still a tendency to plant later than necessary, a legacy from the days of open-rooted stock for which dry spells—more frequent early in the rains—spelt certain death.

The use of pot plants has made it possible to plant regardless of weather on the day concerned, although the problem of whether or not the main rains have set in still remains. Arrangements have been made, however, to make greater use of the forecasting facilities available and the Federal Meteorological Service has agreed to supply relevant information by teleprinter to Ndola.

V. USE OF FERTILISER

Most pine species have been found to respond well to the application of NPK fertiliser, and it is a matter of common observation that plants do especially well on ash-patches. In view of the very low fertility status of the soil, this is not an unexpected result.

Further work is needed to establish whether or not the response to reasonable levels of fertiliser is sufficient to obviate some of the weedings now deemed necessary. If so, the use of fertiliser might prove economically justifiable.

VI. WEEDING

One of the main aims of the deep ploughing and the harrowing described in the preceding section is to eliminate or drastically weaken invading ground flora. In this connection, the harrowing immediately prior to planting has an important role to play, since it is obviously more efficient and economical to bring weeds under control by the use of a multi-gang harrow covering a wide swathe at a relatively high speed than it is to attempt to achieve the same aim after planting, with a combination of manual weeding and narrow-disc swathes between the rows of plants.

The value of clean weeding as compared with spot-weeding, slashing, combinations of the two, and no weeding at all, has clearly been demonstrated by experiment, and is confirmed by observations made not only on the Copperbelt but in many parts of the territory as well. While further experiments are in progress to obtain more specific information on this point, it is for the present accepted as necessary to keep even the fast-growing (but light-crowned) *P. insularis* clean weeded for up to three seasons following planting. Slower species such as *P. merkusii* and *P. michoacana* may need to be weeded for four seasons.

The timing of weeding is vital to the very survival of the plants at two periods in each season—the onset and the end of the rains. If pines are competing with indigenous ground flora at these periods, they are doing so for both nutrients and for moisture, and they are competing in relatively arid and definitely infertile conditions against species patently better equipped than themselves for the struggle. The result of severe competition at these times is a drastic reduction in the effective growing season for the pines, which thus fail to develop sufficient vigour and depth of rooting and hence succumb during the next ensuing dry season.

The weedings carried out between these two critical ones are, themselves, very necessary. During the rains there is presumably little or no severe competition for moisture, but there undoubtedly is for nutrients—the production in three to four months of the extremely dense 8–10 ft. high stands of grass, bracken, *Aframomum* and *Smilax* which develop on disturbed soil in cleared areas, must make considerable demands on soil fertility. With the emphasis on vigorous early growth of the pines in order to withstand the ensuing dry season, this competition has to be drastically reduced.

Owing to the very rapid depletion of soil moisture by indigenous ground flora in the few weeks following the cessation of the rains, it is deemed advisable to hold one weeding in reserve in case that intended to be the final one was badly timed and failed to ensure a clean compartment through the dry season. The timing of this final weeding is, in fact, most difficult to judge, since conditions vary from year to year, and while the end of the main rains may be confirmed by the Meteorological Service, it is not possible to legislate for the thunder showers which are a feature of the period at the tail end of the rains.

Table I sets out the timing and frequency of the weedings deemed necessary for fast-growing *P. insularis* to give effect to these considerations.

Table I—Schedule of weeding—P. insularis and other fast conifers

Age of trees	Initial weeding at onset of rains (Oct. to Nov.)	Mid-rains weeding (Dec. to Feb.)	End-of-rains weeding (March to May)
Season planted . .	—	2	1 (+1)*
Second season (one year old)	1	1–2	1 (+1)
Third season (two years old)	1	0–1	0–1

* (+1) indicates a weeding held in reserve in case the " final " one was mistimed.

As stated in the discussion on land-clearing, it has not proved practicable nor economically justifiable to undertake manually the frequent heavy weedings deemed essential.

Recourse has thus been had to heavy-duty cut-away disc harrows mounted on wheeled tractors, and a marked decrease in cost and a very considerable increase in effectiveness of weeding has ensued. Since the use of this equipment enables the work to be done on time, the weeds never succeed in getting away and are hence weakened, making the following operations easier and quicker. In fact, hand weeding was found to proliferate the creeping grass *Rhynchelytrum repens* unless the impossibly expensive method of trenching, forking-out, and carrying off the site was employed. Properly timed discing with the implement set for a deep cut and good throw rapidly brings this grass under control.

Two standard espacements have been adopted : 9 ft. by 9 ft. and

9 ft. by 4½ ft. The former permits mechanical weeding in two directions leaving only a small island of weeds, some 18 in. by 18 in. in size around the base of each plant, to be removed manually. With careful attention to this hand weeding for the first two seasons, the pines should themselves shade out weeds subsequently. The 9 ft. by 4½ ft. spacing is employed chiefly with species such as *P. insularis*, which is somewhat sinuous in form, and where it is desired to secure rather more selection in early thinnings than 9 ft. by 9 ft. affords. Since any spacing in the rows of less than 9 ft. makes mechanical weeding hazardous, once the need for greater selection was accepted it was decided to make the spacing within the rows as tight as practicable in order to effect elimination of weeds by shading.

It has been found most advantageous to do the manual row weeding a few days before the inter-row discing. This is because the labourers throw the grass and other root-stocks hoed out in the rows into the inter-row space, where they are subsequently effectively dealt with by the disc harrow. The cut-away discs decimate the root-stocks, which are further shaken free of adhering earth by the tossing action between the discs in the successive gangs. Careful setting is essential to obtain the full benefit of this action.

A Fordson Major tractor with a Bentall heavy-duty harrow mounted on three-point linkage is the combination at present favoured. This gives a working width of from 7 ft. to 7 ft. 6 in. depending upon the set of the harrow. A margin of some 9 in. is left on each side of plants at 9 ft. spacing. This, undoubtedly, results in the severing of some laterals but no detrimental effects of any sort have been observed to ensue.

In view of the improved vigour and colour of mechanically weeded plants as compared with those manually weeded, however meticulously, it is believed that the fine mulch of soil and incorporated organic matter resulting from discing is very beneficial. For one thing, aeration is undoubtedly improved by the discing, whereas the scraping action of manual scuffling soon results in a hard, compacted surface.

The capacity of the tractor and harrow combination described is from twelve to fifteen acres in one direction per day. If light weeding in stock under about 18 in. in height is being done, it is possible to increase this to from twenty to twenty-five acres per day by setting the harrow to straddle a row of plants and so cultivate two inter-row spaces simultaneously. The more usual method, however, is with the harrow gangs in tandem and the tractor travelling between the rows.

The manual row weeding requires on average one to two man/days per acre. This is well within the capacity of the standing labour force maintained throughout the year for each one hundred acre planting unit. A point of importance is that owing to the much more effective control of grass, especially the creeping variety, achieved by discing, not only is each successive weeding easier but, in addition, fewer weedings are needed per year as compared with manual weeding.

When the use of tractors and harrows was first mooted, considerable misgivings were expressed regarding the difficulties that would be posed by the large ant-hills which are such a feature of Copperbelt miombo woodland. Since, however, there is invariably an annulus of failed pines about the base of these ant-hills due to unfavourable dry-season conditions, there is ample space for manoeuvring the tractor with harrow in the up position from one row to the next when the obstruction of an ant-hill is reached.

Compartments are usually from twenty to forty acres in size, and it has been found that a headland of some 24 ft. in width at either end of such a compartment with plants at 9 ft. by 4½ ft. spacing, or right round it if the spacing is 9 ft. by 9 ft., provides ample space for turning the tractor. In fact, with a headland of that size, the tractor can readily be turned into the row immediately adjoining the one just completed. The headland needed for the tractor is no greater than the internal breaks and access roadways deemed necessary for purposes of fire protection and later, exploitation.

VII. RATE OF GROWTH AND YIELD

All the tropical pines grown commence their first really rapid height increment in the fifth to seventh years. This is least marked with *P. insularis*, but *P. merkusii* and *P. michoacana* persist in what may almost be described as the grass stage for about five years. At about the time the rapid growth phase is commenced, these pines show a feature taken to imply thorough adaptation to the site : they join with the miombo woodland in the characteristic pre-rains flush of growth.

Table II gives some idea of the rate of growth of *P. insularis* on the Copperbelt. It is by far the fastest of the species tested.

Table II—Rate of growth : P. insularis on Copperbelt sites

Age in years	Stems per acre	Mean diameter b.h.o.b. in in.	Mean height in ft.
2	1,210	—	3
6	430	4·1	25
16	195	11·5	82
18	170	12·3	89

No reliable data can as yet be provided as regards timber yields. *P. insularis* on a not particularly good site at eighteen years gives the following mean tree data : height 89 ft., diameter b.h.o.b. 12·3 in. There are 170 trees per acre, and the total volume produced to date is over 7,000 cu. ft. over bark. Measurements in younger plots in the same locality indicate that these too are following the same growth trend.

Since all the large-scale plantings are still in the younger age-classes, and at best are only just becoming due for thinning, not much can be said on this topic.

No fixed thinning regimes can as yet be laid down, and for the present the aim is to keep stocking dense for the first five or six years, to ensure complete elimination of aggressive grass species ; thereafter the object is to open up the crop quickly with several successive thinnings. This is in order to lay as much increment as possible upon the final crop trees, owing to the strong demand for softwoods in the larger timber dimensions. Such shade-tolerant grasses and the various herbs, ferns and hardwood seedlings that do come in as a consequence of this opening up, are not likely to be deleterious and can, if necessary, readily be controlled by cutting.

VIII. PROTECTION

No serious fungal or insect damage has been recorded on the tropical pines on the Copperbelt with the exception of the susceptibility of spot-weeded compartments to termite attack, a matter no longer of consequence.

There is a strong probability, however, that insufficient attention has, in the past, been accorded to the exposure factor. There is a good deal of evidence, in the smaller stands particularly, of decreased top height to the windward. The importance of exposure is hardly surprising in view of the rather marginal conditions afforded pines by the miombo sites as evidenced by the response to fertilisers and to weeding, and the matter is being accorded due attention in plantation plan revisions.

With the long dry season, the latter part of which is in the hottest period of the year, fire hazard is high. This is aggravated by the rapid invasion of vacant cleared land by tall grasses, a matter of which account must be taken in planning. The present policy is to make the fullest use of the relatively low fire risk of early-burned miombo woodland, and to avoid wide cleared perimeter breaks which are very costly to keep sufficiently clean to be really effective. Within planted blocks of pine, the emphasis is upon roads and rides to provide quick access. Blocks of over about 400 acres are broken up with planted evergreen firebreaks at least 100 ft. wide.

FIRE PROTECTION IN THE RHODESIAN TEAK FORESTS OF NORTHERN RHODESIA

D. G. Cumming

The *Baikiaea plurijuga* forests, locally known as the " Rhodesian Teak Forests ", occur in the dry hot areas of the south-western part of Northern Rhodesia and form a particular and specialised type of open forest of tropical Africa. These forests are at present being commercially exploited and are under intensive management. The management of the forests is controlled by the second Rhodesian Teak Forests Working Plan, in which a great deal of emphasis is placed on the fire protection aspect. Much of the information described in the paper is drawn from this Working Plan which covers an area of 950 square miles of the Sesheke District of Barotseland, a Protectorate of Northern Rhodesia.

The dominant tree species is *Baikiaea plurijuga* which on the optimum sites of extremely deep, pure, loose, course-grained Kalahari sand grows to a height of 80–90 ft. In such conditions the upper canopy consists almost exclusively of this species but co-dominants of *Pterocarpus antunesii* are also found. The proportion of the latter species increases with loss of site quality to such an extent that many of the forests on the shallower sands consist of a 50% admixture of *Pterocarpus antunesii* in the upper canopy. Below the main canopy and at a height of 10–25 ft. there exists an extremely dense under-storey of shrubs and climbers (*Dalbergia glandulosa*, *Combretum celastroides*, *Baphia obovata*, *Acacia ataxacantha*, etc.). The combined effect of the two canopies has resulted in the almost complete exclusion of all grasses and this remains so only for as long as canopies are undisturbed. Any opening of the canopy either through exploitation, honey hunting, or repeated burning results in an invasion of grasses.

The fact that forests of this type are found in an area with an average rainfall of only 24 in. per annum and a hot and extended dry season is probably attributable to the existence of previous wetter climatic conditions. The factors necessary for the survival of these forests are finely balanced and the disturbance of any one of them will hasten their destruction.

In the normal untouched conditions, the dense canopy and absence of grass provide the forest with some considerable degree of immunity from fire damage. This fact has contributed largely to the survival of the species *Baikiaea plurijuga* because the tree itself is very fire-tender. It has been found that even a very moderate bark scorch may prove fatal to the tree. In the face of hunting, honey collecting, cultivation and commercial exploitation, it is not possible to maintain normal conditions. Protective measures have had to be introduced. Legislative protection does play its part, but the main weight of protection from fire rests on more aggressive measures which have been evolved over the last decade or two.

The absence or paucity of grass in the *Baikiaea* forests make the standard fire protection system of " early burning " impractical. Early burning is a fire protection system which requires the deliberate burning of grass as soon as it will do so, within the area to be protected. The methods which have been evolved aim at excluding fire entirely from the area which is to be protected. In practice this is obtained through the use of one of two systems, known as " Boundary Burning " and " Concentrated Fire Protection " ; the choice between the two systems is dependent on the value which is attached to the particular forest being protected. " Boundary Burning " is the cheaper and more easily administered but the " Concentrated Fire Protection System " gives a higher degree of protection.

BOUNDARY BURNING

This is described in the Rhodesian Teak Forests Working Plan as " a system of fire protection peculiar to the Rhodesian Teak Forests ". Its application depends on the fact that in the early and middle portion of the dry season a fire ignited in the woodland surrounding a forest will burn up to the forest edge and then go out. Provided that the burning is not done too late and that there are no large grass-covered areas or piles of exploitation debris in the forest, this system is effective and cheap. It is the standard system of fire protection employed on all Rhodesian Teak Forests *before* they are exploited.

Boundary Burning, it will be noted, requires judgment in selecting the correct time at which burning is to be done. Uniformity in judgment cannot be guaranteed and for this reason certain of the forests are surrounded by a perimeter road which follows closely the inner limit of the burning line in order to give both ease of access and provide an extra safety measure in cases where burning is ill-timed.

In other cases it is prescribed that the windward boundaries are burnt in two stages ; first an early season burn to a width of approximately 40 yds. and secondly a subsequent burn some two or three weeks later, aimed at increasing the width of the protective strip to about 400 yds.

CONCENTRATED FIRE PROTECTION

This is described as a comprehensive system of clear-felled and stumped external and internal fire-breaks which are annually ploughed or cleared of vegetation by mechanical means. The width of the fire-breaks varies, depending on whether they exist on the windward or leeward side of the forest, being 40 ft. in the former and 15 ft. in the latter case. On the completion of the clearing of the external (perimeter) fire-breaks, burning of vegetation outside the forest area is carried out in two phases. A first burn to a width of 400 yds. round the perimeter, to be followed by a later burn to 800 yds. or to some natural feature outside the forest boundary. This system is employed in all forests which have been exploited once and are under regeneration.

In practice it differs from the Boundary Burning system in that an error in judgment is not so serious because the existence of a substantial artificial barrier between the forest and the burning area minimises danger. The existence of the artificial fire-break enables burning to be carried out at a date later in the dry season than in the Boundary Burning system and so ensures that a more complete and effective removal of inflammable material is possible.

The limitations of this system are (*a*) the high degree of mechanisation and organisation required to carry it out and (*b*) the high cost of clearing the fire-breaks.

DEFINITIONS PHYSIONOMIQUES, STRUCTURALES ET ECOLOGIQUES DES FORETS CLAIRES EN AFRIQUE

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Le terme de " forêt claire " (" woodland ") a été consacré par la réunion des phytogéographes africains à Yangambi (1956) pour désigner certaines formations mixtes forestières et graminéennes qui occupent des étendues considérables en Afrique. Il était déjà employé par de nombreux phytogéographes pour l'Afrique et l'Asie du Sud-Est. Une définition en fut donnée dans le projet de nomenclature phytogéographique recommandé à Yangambi. Je la reproduis ici : " Forêt ouverte[1]; strate arborescente décidue de taille petite ou moyenne dont les cimes sont plus ou moins jointives, l'ensemble du couvert demeurant clair ; strate graminéenne parfois peu dense ou en mélange avec une autre végétation herbacée et suffrutescente ".

Cette définition très succincte, à la fois physionomique et pour une petite part écologique, peut suffire. Il convient aussi d'observer tout de suite qu'il existe de nombreux types de forêts claires répondant à cette définition très générale, qui se distinguent par la structure, le degré de recouvrement, le spectre biologique, l'écologie, la flore caractéristique, la tropophilie, etc. Il est donc indispensable, si l'on veut rédiger une définition d'une grande unité phytogéographique mondiale comme la forêt claire, de se limiter aux grands caractères généraux, étant entendu que dans les descriptions des divers types de forêts claires, des caractères distinctifs secondaires peuvent être mis en évidence.

Ceci étant dit, la définition de Yangambi presque purement physionomique ne mentionne pas tous les caractères généraux essentiels des forêts claires. C'est ce point que je voudrais développer.

L'aspect est bien défini : une forêt de petits arbes (8 à 15–20 m., exceptionnellement plus élevés), ouverte, ayant l'apparence d'une forêt au sens commun du terme, dominant une strate graminéenne, herbacée et suffrutescente généralement peu dense. Donc une formation végétale à deux strates

[1] Je crois utile de souligner la nécessité de définir deux mots différents pour distinguer deux états d'une formation forestière. Dans formation " ouverte ", peuplement " ouvert ", etc. l'adjectif " **ouvert** " est parfois employé dans deux sens différents. L'étage arborescent d'une forêt (la futaie des forestiers) est dit " ouvert " lorsque les cimes ne sont pas jointives, les arbres plus ou moins espacés, mais le sous-bois peut être soit fermé (dense), ou pratiquement nul et alors il laisse place à une savane herbeuse, c'est-à-dire à une couverture (strate) herbacée et graminéenne (cas de la forêt claire). Dans le cas des fourrés (thickets) ceux-ci sont parfois clairièrés, c'est-à-dire qu'ils se présentent sous forme de taches ou de bandes compactes (denses), alternant avec des parties de sol nu ou couvert de plantes herbacées et graminéennes. On écrit quelquefois que les fourrés sont ainsi " ouverts ". Pour éviter toute confusion, il est préférable de dire dans ce cas qu'ils sont " **discontinus** ".

principales évidentes : une strate forestière, un tapis herbacé. Le sous-bois[1] est nul, ou très largement ouvert, ou très largement discontinu, ou les deux, jamais dense. Lorsque le sous-bois est dense, cette densité pouvant même devenir celle d'un fourré (thicket), mais la futaie demeurant ouverte, on n'est plus en présence d'une forêt claire mais d'une **forêt sèche dense, d'un type à futaie ouverte.** Ce dernier type est probablement un climax, dont la forêt claire est une forme dérivée. La composition floristique du peuplement des arbres peut être la même, ou peu différente. Physionomiquement et également d'un point de vue syngénétique, il est préférable de réserver le terme de " forêt claire " à la formation où non seulement la futaie (étage des arbres) est ouverte, mais où le sous-bois lui-même est nul ou très clair. Le **miombo** de l'Afrique australe paraît être un terme local qui englobe plusieurs types forestiers allant d'une forêt dense sèche (à futaie plus ou moins ouverte) à la forêt claire proprement dite et même à la savane boisée.

Il conviendrait d'ajouter que les herbes sont souvent brûlées par les feux de brousse, parfois annuellement. La structure particulière des forêts claires est, en effet, due à la fois au milieu et aux feux fréquents. Les forêts claires que nous connaissons ne sont pas des formations climaciques, même si, dans certains cas, il est possible qu'elles ne soient pas très éloignées des véritables formations climaciques.

Attention doit être portée tout spécialement à cette qualification en français de forêt " claire " qui est plus précise et plus générale que forêt " ouverte ", par exemple. En effet, l'impression de clarté, de légèreté que donne le groupement des arbres, provient en Afrique, non seulement de ce que ce groupement est ouvert, c'est-à-dire que les cimes sont plus ou moins jointives et laissent passer entre elles les radiations solaires, mais au surplus que ces cimes sont peu épaisses (peu feuillées), ou encore formées d'un feuillage léger (cas des feuilles composées à petites folioles de certains *Brachystegia*) et qu'elles laissent ainsi filtrer la lumière.

Le caractère " décidu " de la formation demande des explications. Il y a des degrés dans la caducité des feuilles au point de vue de la durée et de la période, suivant les espèces. En ce qui concerne la Rhodésie du Nord, D. B. Fanshawe signale, par exemple, que les espèces du miombo sont défeuillées pendant une période allant de quelques jours à 3–4 semaines. Si la défeuillaison n'est pas simultanée, il est possible que toutes les espèces soient décidues, et cependant que l'ensemble du peuplement ne soit jamais entièrement défeuillé et que l'on ait l'impression d'une forêt semi-décidue, ou même d'une forêt non véritablement décidue. Les feux de brousse modifient également l'aspect, hâtant la chute des feuilles ou, au contraire, après leur

[1] Il me paraît également utile de définir le mot "sous-bois " qui est employé parfois dans des sens différents. Pour les uns, le sous-bois c'est pratiquement la strate herbacée, graminéenne et suffrutescente qui se trouve sous les arbres, arbustes et arbrisseaux constituant les strates supérieures d'une forêt. Pour les forestiers français, le sous-bois est constitué par la ou les strates arbustives qui sont sous la ou les strates arborescentes seules susceptibles de fournir du " bois ". C'est ce dernier sens que nous donnons au terme " sous-bois ".

chute, accélérant la sortie de la nouvelle feuillaison. Dans le cas des forêts sèches denses, même à futaie ouverte, la futaie peut être décidue et le sous-bois toujours vert. Enfin, il se trouve, dans une forêt claire décidue, des espèces à feuilles persistantes (10% selon Fanshawe dans la futaie du miombo). Il est remarquable que la durée de caducité du feuillage dans le miombo ne soit que de quelques semaines au plus, alors que la saison nettement écologiquement sèche dure environ 6–7 mois.

Au point de vue de l'aspect des arbres, on peut noter qu'ils ne sont pas munis de contreforts (Excep. *Marquesia macroura*).

L'explication écologique de ce type structural n'a pas fait l'objet d'études particulières. Il est d'abord évident que " forêt claire " doit être interprété comme " forêt sèche claire " ou, plus exactement encore, " forêt claire sous un climat à longue saison sèche ". Ceci est implicite. Le type forêt claire n'existe pas dans les pays sans saison sèche accusée et de durée longue ou assez longue. Nous préciserons plus loin ce facteur climatique caractéristique de la forêt sèche. On comprend que les arbres dans de telles conditions de pluviométrie s'espacent pour disposer d'un espace souterrain le plus grand possible en vue de s'approvisionner en eau. Mais ce n'est qu'un raisonnement plausible, aucune étude n'a été faite à ma connaissance sur le développement radiculaire des arbres de la forêt claire. Il est également possible que les espèces constituantes soient très héliophiles et que les cimes aient besoin de s'épanouir librement ou presque. La densité de l'étage arborescent est d'ailleurs très variable selon la nature du sol, le climat et, probablement aussi, les feux de brousse qui entravent certainement la régénération. Il conviendrait d'ajouter que certaines forêts claires sont en réalité des formations secondaires, des strates évolutives après défrichements et cultures d'anciennes forêts (claires ou fermées). En effet, les espèces qui les constituent rejettent et drageonnent abondamment et vigoureusement après la coupe, ce qui favorise la constitution de peuplements forestiers réguliers de seconde venue, parfois à tiges nombreuses. Le feu de brousse ici devient un facteur capital de l'espacement, en intervenant dans la concurrence naturelle qui s'exerce entre toutes les tiges trop nombreuses pour un potentiel d'eau insuffisant. Cette aptitude à rejeter de souche et à drageonner est une caractéristique biologique non exclusive mais importante des espèces de la forêt claire.

Il convient de bien distinguer la forêt claire de la savane boisée. La distinction est physionomique et structurale, mais aussi dans une mesure importante floristique et sociologique. Dans les cas limites, devant certaines formations, il n'est pas toujours évident de distinguer d'après l'aspect une forêt claire d'une savane boisée. Il en est ainsi pour tout critère phytogéographique. Forêt claire et savane boisée ont été rangées, à juste titre, à Yangambi dans la classe très vaste des formations mixtes forestières et graminéennes. Il n'y a entre elles physionomiquement que des différences de degrés. La savane boisée, qu'elle soit très ouverte ou, au contraire, constituée de nombreuses tiges, ne donne pas l'impression d'une forêt, c'est-à-dire d'un groupement d'arbres assez régulier. Dans la savane il y a des arbres, mais surtout de nombreux arbustes et arbrisseaux. Sa structure n'a pas la régularité de la belle forêt claire typique, où l'étage arborescent est presque continu, quelquefois serré. En général aussi le tapis graminéen et herbacé est plus épais, plus haut dans la savane boisée que dans la forêt claire où au contraire il est parfois d'une taille et d'une densité très réduites.

La séparation entre forêt claire et savane boisée a été faite par la plupart des forestiers et botanistes qui ont observé en naturalistes sur le terrain la végétation africaine, avant même que ces termes aient été consacrés par l'usage, puis à Yangambi.

Les conditions climatiques, qui sont celles des aires géographiques des forêts claires africaines, sont celles des climats que j'ai définis[1] sous les noms de Soudano-guinéen dans l'hémisphère boréal, Haut Katanguien, Bas Katanguien-loundien, Tanganyika occidental, Tanganyika méridional, Mozambique, Rhodésien, Okavango, dans l'hémisphère austral.

Dans ce dernier, les indices pluviométriques des stations des aires de forêts claires varient entre 650 mm. et 1.300 mm. Ils sont ordinairement faibles (< 1.000 mm.) au Tanganyika, en Rhodésie du Sud ; moyens au Katanga, en Angola et dans le nord de la Rhodésie du Nord ; ils dépassent exceptionnellement 1.300 mm. Le régime des pluies est typiquement tropical, une assez longue saison des pluies estivales et une longue saison sèche hivernale. Les indices des saisons pluviométriques des stations considérées sont les suivants, rangés dans un ordre croissant d'humidité, les plus communs étant soulignés.

3 – 2 – 7
5 – 0 – 7
4 – 2 – 6

5 – 1 – 6

6 – 0 – 6
4 – 1 – 7

4 – 3 – 5
5 – 2 – 5
6 – 1 – 5

Le premier chiffre désigne le nombre de mois très pluvieux (> 100 mm.) ; le troisième celui des mois écologiquement secs (< 30 mm.) ; le second les mois écologiquement intermédiaires qui peuvent être demi-secs ou semi-humides, le véritable seuil de sécheresse écologique indéterminable se trouvant entre un indice pluviométrique mensuel inférieur à 100 mm. et supérieur à 30 mm. Comme ces indices le montrent, ces mois intermédiaires sont peu nombreux, et l'année est très nettement partagée entre mois très pluvieux et mois nettement secs. En général il y a **4–5 mois très pluvieux** et **6–7 mois écologiquement secs.** Plus rarement il y a 3 ou 6 mois très pluvieux, et 5 mois secs.

[1] Climats, Forêts et Désertification de l'Afrique tropicale. 1949.

Je ne dispose malheureusement pas d'indications suffisantes sur l'hygrométrie et le déficit de saturation qui me permettent d'apprécier quantitativement l'aridité de la saison sèche.

Dans l'hémisphère boréal sous le climat soudano-guinéen, l'indice pluviométrique des secteurs de forêts claires n'est qu'exceptionnellement un peu inférieur à 1000 mm.; il dépasse 1.700 mm. à Kankan en Haute Guinée ; les plus belles forêts claires reçoivent de 1.300 à 1.500 mm. En général donc les forêts claires soudano-guinéennes sont plus arrosées que celles du plateau austral.

Les indices des saisons pluviométriques sont les suivants, classés comme précédemment :

4 – 2 – 6
4 – 3 – 5 5 – 2 – 5
6 – 1 – 5
7 – 0 – 5 5 – 3 – 4 6 – 2 – 4
6 – 3 – 3
7 – 1 – 4 7 – 2 – 3 5 – 5 – 2

En général, il y a **4 – 5 – 6 mois très pluvieux** et **4 – 5 – 6 mois écologiquement secs.**

Parfois la saison des pluies compte 7 mois très pluvieux et la saison sèche 2–3 mois secs. En moyenne donc, le régime pluviométrique est plus favorable à la végétation des forêts claires dans l'hémisphére nord que dans l'hémisphère sud.

Cependant contradictoirement les premières sont généralement moins denses, moins hautes, moins riches en matériel ligneux que les secondes.

Le fort déficit de saturation des régions soudano-guinéennes doit être mis en cause dans une certaine mesure, c'est-à-dire une plus grande aridité de la saison sèche, due au double effet de température plus élevée (pays de faible altitude) et de la sécheresse des vents d'origine saharienne qui soufflent dans cette saison.

A Ferkessédougou (Haute Côte d'Ivoire), en dépit de la pluviosité assez forte (1.392 mm.), le déficit de saturation moyen annuel (Ds) est fort (7,3 mm.), il varie de 2,9 mm. (minimum en saison des pluies) à 12,8 mm. (maximum, très fort) en saison sèche. A Kouroussa (Haute Guinée), où la pluviosité est plus forte encore (1.570 mm.), l'aridité est plus grande encore en saison sèche ; le déficit moyen annuel est de 9,7 mm. ; il varie d'un minimum de 4,9 mm. en saison des pluies à un maximum excessif de 15,1 mm. en saison sèche. Bamako (Soudan) est à la limite nord des forêts claires à

Isoberlinia. La pluviométrie est de 1.064 mm. L'aridité devient très forte : Ds = 14,4 mm. ; les moyennes mensuelles variant de 4,7 mm. en saison des pluies à 23,3 mm. en saison sèche.

Les feux de brousse alimentés par une savane plus densément herbeuse sous climat soudano-guinéen ont aussi peut-être une part dans une altération des conditions biologiques des forêts claires de cette zone climatique.

Ces conditions climatiques sont évidemment également celles des savanes boisées et des savanes herbeuses qui se trouvent en mélange avec les forêts claires. Pour expliquer par l'écologie la présence de formations végétales différentes sous des conditions climatologiques identiques, il faut mettre en cause la nature des sols et souvent aussi les défrichements séculaires qui ont perturbé la distribution écologique normale des types végétaux. Dans la zone soudano-guinéenne les forêts claires les plus typiques à *Isoberlinia, Uapaca* et *Monotes* sont souvent distribuées sur les plateaux et les sols rocheux superficiels, tandis que les versants des vallons et les vallées sont occupés par des savanes herbeuses ou boisées. Souvent aussi dans des pays couverts normalement d'une savane boisée, la forêt claire apparaît par petites taches qui sont isolées. Cela est très visible de terre et sur les photographies aériennes. Les taches correspondent à des sols rocailleux ou ferro-latéritiques.

Il est étonnant que dans ces conditions stationnelles habituelles, alors que les forêts claires occupent souvent des sols incultes, certains auteurs aient pensé que ces forêts claires étaient d'origine secondaire et consécutives à des défrichements culturaux. Il est certain que dans la partie de la zone des forêts claires qui est habitée et cultivée, celles qui se trouvent sur les meilleures terres sont cultivées et qu'il y a donc dans les secteurs anciennement cultivés des forêts claires d'origine secondaire, d'autant mieux que les espèces constituantes rejettent et drageonnent vigoureusement, comme je l'ai fait remarquer plus haut, et qu'ainsi ces espèces ont une grande puissance de survie et aussi d'expansion. Cependant il est bien évident que, en considérant les peuplements qui occupent des sols rocheux, jamais cultivés, on se trouve, devant des formations d'origine, dégradées seulement par les feux de brousse.

Sur le plateau austral, les forêts claires s'étendent démesurément sur des sols pauvres sableux ou sablo-argileux. Elles s'arrêtent devant les dembos mal drainés, au sol gris, d'une façon générale elles évitent les sols mal drainés, mouilleux en saison des pluies, très secs en saison sèche. La forêt claire miombo ne pénètre pas dans les grandes vallées du Zambèze et du Luangwa. Un type occidental est largement répandu sur les sables du Kalahari, sables lessivés, médiocrement fertiles. Il y a donc généralement une relation entre la médiocrité des sols et les forêts claires, à l'intérieur de l'aire climatique déterminée par le régime climatique que nous venons de définir par la pluviométrie.

Une autre particularité importante des forêts claires qui contribue fortement à leur donner leur originalité physionomique est la dominance d'un relativement petit nombre d'espèces arborescentes qui se présentent parfois en peuplements presque purs parmi lesquelles, en premier lieu : des légumineuses appartenant aux genres apparentés, *Isoberlinia*, *Berlinia*, *Pseudoberlinia*, *Julbernardia* et surtout au genre *Brachystegia* ; à la suite desquels il convient d'ajouter les genres *Baikiaea*, *Monotes*, *Marquesia* et *Uapaca*. Le groupement de ces espèces caractérise les forêts claires africaines, et les distingue par exemple des forêts claires du sud-est asiatique qui ont une semblable physionomie mais qui sont caractérisées par un petit nombre de diptérocarpacées.

Ce fait de l'existence de peuplements dont la futaie est constituée d'une ou d'un petit nombre d'espèces grégaires a fait penser quelquefois à des formations secondaires, car il est bien connu que celles-ci sont généralement moins hétérogènes que les formations primitives. Ce caractère n'est cependant pas un critère absolu de la forêt secondaire, même en zone de forêt dense humide. Pour nous il s'agit bien de types primitifs de végétation, sans doute ouverts exagérément et homogénéisés par l'action répétée depuis des temps très anciens des défrichements ou des feux de brousse, ou des deux. Les formations climaciques originelles devaient être différentes de celles qui ont donné naissance aux actuelles savanes boisées non différenciées. C'est une raison supplémentaire de distinguer les forêts claires des savanes boisées, et à mon avis dans une définition de celles-là il conviendrait d'indiquer ce caractère habituel d'une communauté d'espèces grégaires dans le peuplement forestier, contribuant par leur abondance à imprimer leur aspect particulier aux forêts claires.

EXTENSION GEOGRAPHIQUE

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Les forêts claires occupent en Afrique tropicale une superficie considérable, supérieure à celle de la forêt dense humide. Elles sont surtout étendues et remarquables sur le plateau austral couvrant une grande partie du Katanga au Congo Belge, du Tanganyika, du Mozambique, du Nyassaland, des Rhodésies du Nord et du Sud, et de l'Angola. D'après les cartes publiées de ces pays, j'avais autrefois estimé ainsi les superficies de forêt claire dans chacun de ces Etats.[1]

Katanga (Congo Belge)	9.500.000 hectares
Angola . . .	30.000.000
Rhodésie du Nord .	30.000.000
Rhodésie du Sud .	22.900.000
Nyassaland . .	1.700.000
Mozambique . .	40.000.000
Tanganyika . .	40.600.000
	174.000.000

Dans l'hémisphère nord, il est impossible de citer des chiffres même approximatifs. Alors que les forêts claires du plateau austral se présentent par grands massifs qui paraissent indéfinis, au contraire dans le nord elles existent parfois à l'état de massifs importants, mais aussi de bois et de boqueteaux dispersés dans l'ordinaire savane boisée soudano-guinéenne. Tous ces îlots et massifs sont compris à l'intérieur d'une longue bande Ouest-Est qui traverse l'Afrique depuis la Haute Guinée (haut bassin du Niger) et se termine au Nil.

Ces forêts claires ont été très étudiées[2] en Afrique australe et orientale notamment par Engler (1910), Delevoy (1927), Burtt Davy (1928–1931), Henkel (1930), Rea (1935), Trapnell et Clothier (1937), Gossweiler et Mendonça (1939), von Nolde (1942), Gemese Souza (1948), Schmitz (1950), Grandvaux Barbosa (1952), Lebrun (1954), Mullenders (1954), Devred (1957), Francis G. Smith (1958), Hughes (1958), Maréchal (1958), Fanshawe (1959), Duvigneaud (—), Germain (—) ; en Afrique occidentale et centrale par Aubréville (1937–8–1948–9), Bégué (1937), Keay (1948–1953).

La synthèse de tous ces travaux et d'autres contributions ont permis de

[1] D. B. Fanshawe cite pour la Rhodésie du Nord 35 millions 483 hectares ; Parry pour le Tanganyika au moins 26 millions d'hectares.

Il est évidemment très difficile de mesurer, même très approximativement, la superficie des véritables forêts claires, puisqu'elles font souvent partie d'un complexe de savanes boisées, de savanes et steppes herbeuses, de forêts sèches denses et de cultures.

[2] Les dates citées sont celles de la publication des ouvrages où il est traité des forêts claires. Cette liste d'auteurs n'est pas exhaustive.

donner toute leur véritable importance à ces forêts claires dans la " Carte de la Végétation de l'Afrique au Sud du Tropique du Cancer " qui vient d'être publiée (1959) sous les auspices de l'AEFAT avec l'assistance de l'UNESCO.

La masse des forêts claires australes est parfaitement mise en évidence, de même la bande qui enveloppe les massifs et boqueteaux de forêts claires septentrionales entre les sources du Niger et celles du Nil.

Plusieurs grands faits géographiques, que j'avais précédemment mis en évidence dès 1949[1], apparaissent immédiatement.

1) Homologie par rapport à l'équateur des aires de forêts claires. La forme de ces aires est très différente ; une aire massive dans le sud s'oppose à une bande longue et étroite dans le nord.
2) Ces aires n'approchent pas l'Océan Atlantique. L'aire nord, en Guinée, s'arrête devant les pentes orientales du Fouta-Djalon. L'aire sud, en Angola, ne descend pas du plateau vers la mer. Il est étonnant que les espèces constitutives cependant si rustiques soient demeurées ici strictement continentales. Il semble qu'elles aient été empêchées d'atteindre l'Océan par d'autres formations végétales humides des secteurs littoraux. On pourrait en conclure que les affinités écologiques de ces espèces de forêts claires vont à des climats continentaux très arides durant la longue saison sèche. Cependant, au contraire, à l'Est dans le sud du Tanganyika et au Mozambique les forêts claires s'approchent très près de l'Océan Indien et même le borderaient[2] dans la région d'Inhambane.
3) Les lisières des aires de forêts claires sur leur face équatoriale suivent celles de la forêt dense humide mais se tiennent à distance. Il n'y a pas contact entre ces formations humides et sèches. Entre elles s'interposent des mosaïques de savanes herbeuses ou arbustives ou boisées, de forêts denses humides ou sèches avec, en plus dans le sud du Congo Belge, des steppes herbeuses sur sables du Kalahari. Ces zones relativement dénudées, qui sont intercalées entre la forêt dense humide guinéo-congolaise et sa ceinture extérieure de forêts claires, sont plus ou moins larges. Elles peuvent avoir une profondeur d'environ trois degrés de latitude. En haute Côte d'Ivoire la bande intercalaire paraît au contraire assez étroite.

   Dans l'hémisphère sud, au Congo Belge entre les rivières Kwango et Kasaï des forêts vallicoles orientées nord-sud arrivent au contact de l'aire des forêts claires vers les 8° latitude Sud.

   Dans le république du Congo (ex-Moyen-Congo) au contraire, sur les sables du Kalahari dits localement du Batéké, les steppes et savanes herbeuses avancent jusqu'à l'équateur et leur aire dessine un golfe profond dans la zone forestière équatoriale.

[1] Climats, Forêts et Désertification de l'Afrique tropicale. Carte p. 255.
[2] Ce fait paraît assez étonnant, à une latitude aussi élevée que celle d'Inhambane.

Cette couronne herbeuse de la forêt dense humide équatoriale placée dans des conditions climatiques plus favorables à la végétation forestière que celles qui sont faites aux forêts claires, cette sorte de discontinuité biologique dans la succession zonale des formations végétales en allant des pays les plus humides aux pays les plus secs, est étonnante. Le vide forestier relatif s'explique en certaines places par l'occupation humaine ancienne, les défrichements et les feux. Pour ma part, j'ai proposé une explication complémentaire fondée sur l'apparition de périodes sèches en Afrique tropicale liées aux dernières périodes glaciaires du quaternaire, au cours desquelles la forêt dense humide aurait dû reculer, mais n'aurait pu entièrement regagner le terrain perdu dans les périodes humides qui suivaient, en raison des feux de brousse et aujourd'hui d'une occupation humaine plus dense.

4) Les forêts claires n'existent pas à Madagascar. Les genres typiques de la famille des légumineuses qui caractérisent la forêt claire africaine n'existent même pas dans la Grande Ile en dépit de la proximité relative du Mozambique. Quant aux autres genres caractéristiques appartenant à d'autres familles tels que *Monotes* et *Uapaca*, il existe dans le sud-ouest une maigre espèce du premier, très peu répandue et paraissant ainsi être une relique ; un *Uapaca clusiacea* constitue sur les pentes occidentales des hauts plateaux intérieurs des peuplements très ouverts d'arbustes et de petits arbres (les bois de tapia) ayant l'aspect de savanes ou de steppes boisées ou de forêts claires ; ils dérivent de formations forestières fermées, fourrés ou forêts basses, ayant une composition floristique très particulière à Madagascar. Ces bois de tapia ne sont pas assez étendus pour être portés sur des cartes à petite échelle, telle que celle de l'AEFAT.

5) Keay a rangé dans la catégorie des forêts sèches denses, les forêts à *Baikiaea plurijuga* sur sables du Kalahari des confins de l'Angola, de la Rhodésie du Nord, du Bechuanaland et de la Rhodésie du Sud. Il a cependant indiqué, dans la notice explicative qui accompagne la carte de l'AEFAT, que ces forêts étaient quelquefois considérées plutôt comme des forêts claires. Il y a dans ces forêts une étude de syngénétique intéressante à faire, puisqu'on assiste encore actuellement, semble-t-il, à la transformation sous l'effet des feux de brousse, d'une forêt sèche dense en forêt claire, tandis que, dans une grande partie de l'Afrique semi-aride, les forêts sèches denses ont pratiquement disparu, et que leur dégradation en forêts claires et en savanes boisées est un fait accompli probablement depuis très longtemps.

6) Les forêts à *Colophospermum mopane* (mopani) sont des formations édaphico-climatiques qui se trouvent en Afrique australe dans les vallées des grands fleuves à la limite des forêts claires miombo. Certaines ont le caractère de forêts claires hautes de 15 m. ou plus,

mais se trouvent dans une mosaïque de savanes et de steppes boisées ou herbeuses, de sorte qu'il n'est pas possible de les distinguer sur une carte à petite échelle.

7) D. B. Fanshawe indique parmi les " Kalahari sand woodlands " le " *Cryptosepalum* woodland ". D'après les descriptions que j'ai pu lire, il s'agirait plutôt de forêts denses sèches basses. Trapnell appelle cette formation " Evergreen *Cryptosepalum* low forest and woodland ". Il suggère d'ailleurs qu'elle est peut-être un climax des sables du Kalahari qui a été largement remplacé par la forêt claire à *Brachystegia* et *Julbernardia*.

Les principaux types de forêts claires reconnus jusqu'à présent sont : dans l'hémisphère nord :

Forêt claire à *Isoberlinia, Monotes, Uapaca.*	(Forêt à *Sau-Somon*). De beaucoup le plus répandu.
Forêt claire à légumineuses (et à *Anogeissus*).	(Fréquence des *Burkea, Erythrophleum, Tetrapleura* (*Amblygonocarpus*), *Prosopis*). Type de l'Oubangui-Chari le plus souvent peu distinct de la savane boisée constituée de ces mêmes espèces caractéristiques.
Forêt claire à *Boswellia* (et à *Anogeissus*).	Peuplements très clairs des stations rocheuses sous climat sahélo-soudanais.

dans l'hémisphère austral :

Forêt claire à *Brachystegia-Julbernardia* (et à *Marquesia*).	Forêt miombo du plateau austral et des sables du Kalahari. Nombreux types floristiques.[1]
Forêt claire (et forêt sèche dense) à *Baikiaea.*	Sables du Kalahari. Forêt à *Umgusu* (Rhodesian Teak).
Forêt claire à *Burkea, Guibourtia-Baikiaea.*	Sables du Kalahari.
Forêt claire à *Erythrophleum.*	Aires restreintes dans le " Copperbelt " (*Copperbelt chipya*).
Forêt claire à *Colophospermum.*	Forêt mopani des vallées.

D'autres types existent probablement mais trop insuffissamment décrits pour être cités avec certitude.

[1] Forêt claire à *Pseudoberlinia Baumii* ou Forêt mikondo (Congo Belge—Districts du Kwilu et du Kwango).
Forêt claire à *Berlinia Giorgii* et *Marquesia macroura* ou Forêt matumbi (Congo Belge — Kwango).
Forêt claire à *Pseudoberlinia paniculata* ou Forêt mutondo (Northern Rhodesia) ou Forêt panda (Angola).
Forêt claire à *Brachystegia Randii* et *Pseudoberlinia paniculata* ou Forêt msasa (Southern Rhodesia), etc.

LES BOIS DE MINES DU HAUT-KATANGA

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INTRODUCTION

Les produits de la forêt claire du Haut-Katanga industriel trouvent un débouché important dans les travaux de soutènement des tailles de mines. Celles-ci sont encore rares, mais remplaceront progressivement les exploitations à ciel ouvert au fur et à mesure de l'abaissement du niveau des chantiers.

La seule Mine Prince Léopold à Kipushi utilise actuellement, par mois, quelque 3.000 tonnes de bois presqu'exclusivement fourni par les forêts voisines. L'exploitation en " square sets ", qui fut d'abord choisie, demandait de forts équarris, qu'il était difficile de trouver sur place.

Ensuite, le système du " top slicing " a permis d'utiliser les quantités citées sous forme de pièces de bois dont la majorité ne mesure que 20 à 25 cm. de diamètre et 2 à 3 m. de longueur rectiligne. Actuellement, des essais de soutènement métallique — méthode Blanzy — sont entrepris. Bien que plus onéreux, ce procédé trouve sa justification dans la difficulté croissante de se procurer les bois de mines à des distances convenables du lieu d'utilisation et surtout dans le soucis d'éviter les incendies de fond fréquents et très coûteux.

INTERET DES ESSENCES EXOTIQUES*

Le problème des incendies se déclarant périodiquement dans le matelas (masse héterogène provenant de l'ancien boisage partiellement décomposé et écrasé) peut être résolu par l'imprégnation du bois avant sa descente dans la mine. Par contre, les inconvénients découlant de la pauvreté de la forêt naturelle : éparpillement des chantiers et éloignement des coupes, ne peuvent être éliminés que par la plantation d'espèces convenables. Les besoins de la mine de Kipushi sont couverts par l'exploitation annuelle de 7.000 ha. environ de forêt naturelle. Or, le prochain passage ne peut être prévu avant une trentaine d'années, pour les bois de faible section. Alors que le centre de l'exploitation se trouvait à 7,5 km. seulement du quai de chargement (cette

* Les échantillons analysés proviennent de l'Arboretum de l'Etoile, créé par le Comité Spécial du Katanga et géré actuellement par les soins de l'INEAC. Ces éprouvettes faisant l'objet d'une étude commune, furent expédiées par les soins du Service forestier du CSK.

distance a doublé actuellement), Rousseau (1951) estimait que le bois abattu, façonné et manipulé valant 3.250 Frs sur coupe, coûtait 10.000 Frs une fois chargé sur wagon.

L'un de nous a testé divers échantillons, en vraie grandeur, de bois de mines locaux et exotiques recueillis à Elisabethville (voir annexe). Il résulte de ces essais que le refus catégorique d'utiliser les eucalyptus provient du choix malheureux des deux espèces essayées jadis dans la mine et l'industrie (perches de raffinage). En effet, ces deux essences, qui comptent parmi les producteurs de bois les plus rapides, n'ont malheureusement que des qualités technologiques faibles, il s'agit de : *Eucalyptus camaldulensis* et *E. saligna*. Par contre, d'autres espèces exotiques accusent des résistances nettement supérieures à celles trouvées pour les bois locaux employés. La résistance moyenne de ces derniers (compte tenu des proportions moyennes en chaque essence), se situe aux environs de :

240 kg./cm.^{2} de résistance à la compression
775 kg./cm.^{2} de résistance à la flexion
40% d'arrière-résistance.

En regard de ces chiffres, quelques exotiques bien acclimatés montrent une nette supériorité. Citons : *E. paniculata*, *E. citriodora*, *E. maculata*, *E. melliodora*, *E. microcorys*, *E. umbellata*, *Syncarpia laurifolia*. S'ils n'atteignent pas tous la production d'*E. camaldulensis* et *E. saligna* qui ne peuvent convenir, leur rendement en bois de mine dépasse largement celui de la forêt claire. Il n'est pas exagéré de dire que les 3.000 tonnes de bois mis en oeuvre chaque mois à Kipushi et qui nécessitent l'exploitation de 210.000 ha. de forêt naturelle peuvent être fournis par une plantation de 2.000 ha. de ces eucalyptus traités en rotation de 20 ans.

L'incidence de cette réduction de la superficie sur le coût de l'exploitation et du transport est inconnue. Le réseau de routes, en plantation, est fortement réduit, la mécanisation de la coupe et du façonnage y devient possible et la scierie ainsi que l'usine d'imprégnation peuvent être établies sur place et ne plus encombrer le carreau de la mine.

Enfin, la plantation fournira un matériau homogène calibré et sûr, et se prêtera à une exploitation plus économique que la forêt claire.

CHOIX ET CULTURE DES EXOTIQUES

Le tableau des résultats repris à l'annexe montre que seuls certains *Eucalyptus*, *Syncarpia* et *Cupressus* conviennent comme bois de mine. Les derniers cependant seront éliminés parce qu'ils ne supportent pas le feu, même hâtif, qui s'avère le seul moyen peu coûteux et sûr de protection contre les incendies tardifs nuisibles.

En fait, il n'y a guère que les *Eucalyptus* qui allient la qualité technologique à la haute production.

Divers procédés d'implantation sont applicables.

1. Mise en place de plants de pépinière

La plantation de plants, en pots de polyéthylène, ou de hautes tiges produites en pépinière, augmentée des frais d'entretien et de l'intérêt à 6% des investissements, conduit à un prix de revient total de 41.000 Frs/ha., à 20 ans. A ce moment, la coupe livrerait 40 m.^{3} de sciage et 7.000 m. courants de rondins par hectare, dont la valeur serait de 55.400 Frs si l'on comptabilisait cette production au même tarif que celui appliqué par le Comité Spécial du Katanga lors de l'exploitation de la forêt naturelle. Outre ce premier intérêt financier de la plantation, un bénéfice bien plus important pourra être réalisé sur l'ensemble des frais d'exploitation et de débardage.

2. Implantation par semis sur cendres et repiquages

a) En coupe de charbonniers

Les aires de carbonisation en meule constituent un milieu idéal pour la production de plants par semis en place, lors des pluies. D'autres semis sont réalisés sur brûlis des rémanents. Après un an, en vue d'assurer une densité correcte de peuplement, des plants prélevés dans ces groupes, débarrassés de leurs feuilles et taillés peuvent être transplantés avec succès entre les jeunes massifs. On peut aussi préparer de nouveaux semis sur brûlis de tas d'herbes (système des mafuku).

Il y a avantage à réduire la capacité des meules afin d'en augmenter le nombre. Ce procédé est parfaitement applicable à proximité des camps de travailleurs à qui l'autorisation de produire du charbon sera délivrée.

b) Semis en coupe de bois de feu

Ici, seuls les rémanents sont incinérés après nettoyage complet de la coupe : abattage des arbres abandonnés, des sujets de termitière, regroupement des branches le long des gros troncs et sur les souches. Le semis est fait après travail superficiel des aires d'incinération.

Ici encore, le peuplement sera complété par repiquage ou semis sur " mafuku " durant un ou deux ans. Il peut aussi l'être par semis sur brûlis de rémanents lors des premières exploitations ou coupes d'éclaircie des groupes.

c) Semis sur kitema

Le système des kitema (citemene en Rhodésie du Nord) consiste à assembler le bois grossièrement débité en tas continus allongés et parallèles ou en bûchers ronds régulièrement répartis. La totalité du bois est incinérée, éventuellement après récupération des produits de valeur : sciage, rondins de mines, etc.

La proportion de la superficie couverte de cendres et propre au semis dépend de la densité de la forêt. On peut obtenir, en peuplement de bonne richesse moyenne, des groupes distants de 5 m. en tous sens.

Dans le cas d'un tel écartement, les sujets d'élite sont éduqués en petits groupes denses dans le jeune âge, pour former ensuite un peuplement fermé, riche de 400 sujets à l'hectare. Après plusieurs révolutions, le peuplement sera rajeuni par un nouveau semis après incinération des rémanents sur les souches épuisées.

3. Entretien des peuplements

Dès la première saison sèche pour les semis sur cendres et la seconde dans le cas de plantation, les boisements peuvent être nettoyés par brûlage hâtif des herbes.

CONCLUSIONS

Jusqu'à présent on s'est adressé uniquement à la forêt naturelle pour s'approvisionner en bois de mine, dont la région d'Elisabethville utilise quelque 36.000 tonnes annuellement. Compte tenu de la productivité de la forêt claire et de la durée de la révolution (30 ans) pour les qualités et dimensions requises, le domaine exploité s'étend sur 210.000 ha., soit plus de 2.000 km^2.

Certains essais d'emploi de bois d'eucalyptus pour le soutènement et autres usages furent négatifs avec les espèces choisies, mais les analyses technologiques ont démontré que d'autres espèces d'eucalyptus, notamment *E. paniculata* et *E. citriodora* présentent une résistance supérieure à la plupart des essences de la forêt claire, considérées cependant comme satisfaisantes.

Par ailleurs, l'application de méthodes simples de semis direct d'eucalyptus sur brûlis aboutit à l'obtention de plantations très économiques.

Ces résultats permettent d'envisager d'assurer l'approvisionnement en bois de mine au départ de plantations d'eucalyptus et d'escompter ainsi un avantage financier considérable.

On calcule, en effet, que le prix de revient du bois sur coupe serait inférieur à celui prélevé en forêt claire, au surplus, grâce à la réduction de la superficie (2.000 ha. au lieu de 210.000) et à l'état beaucoup plus homogène des peuplements, l'organisation de l'exploitation et surtout du débardage et du sciage s'accomoderait de méthodes beaucoup plus économiques que celles applicables à la forêt claire.

Parmi ces méthodes, il faut noter avant tout la possibilité d'imprégner les bois en vue de les rendre réfractaires à la combustion spontanée, responsable de très coûteux incendies de mines. Cette nouvelle possibilité est telle que l'étançonnage des galeries et des tailles au moyen de bois d'eucalyptus revient beaucoup moins cher que l'emploi d'étançons métalliques ; une telle pratique n'est plus justifiée dès le moment où le traitement approprié et économique du bois d'eucalyptus permet d'éviter les incendies de mines.

Résultats obtenus aux essais sur pièces entières, au Laboratoire de technologie forestière de Gembloux

Essence	Indice	Essai de compression			Essai de flexion			Nerf en % du travail total de rupture
		Nombre échant.	Humidité %	Résistance unitaire kg./cm.^{2}	Nombre échant.	Humidité %	Résistance unitaire kg./cm.^{2}	
I.—Résineux								
Qualité supérieure								
Cupressus macrocarpa	7	3	16	311	2	17	662	33
Cupressus lusitanica	8	9	18	219	9	19	665	43
Cupressus torulosa	8	3	17	289	3	17	650	30
Pinus khasya	8	11	16	301	9	18	624	23
Cupressus benthamii	9	7	16	238	7	17	615	35
Pinus halepensis	9	2	19	256	3	20	721	13
Pinus radiata	9	1	25	160	1	21	619	45
Qualité inférieure								
Callitris calcarata	10	5	18	230	5	20	649	17
Pinus pseudostrobus	10	4	18	204	5	19	615	18
Thuya orientalis	10	2	19	203	1	22	616	15
Callitris robusta	11	4	18	206	4	18	455	14
Cupressus arizonica	11	7	18	204	7	18	582	21
Pinus patula	11	5	20	213	5	20	524	17
II.—Feuillus								
Qualité exceptionnelle								
Erythrophleum africanum	4	3	16	325	2	19	1.010	46
Eucalyptus paniculata	4	5	22	354	6	31	1.201	49
Swartzia madagascariensis	4	1	14	268	1	19	1.009	57
Entandrophragma delevoyi	5	4	18	312	3	18	974	48
Parinari bequaertii	5	2	19	314	2	22	774	56
Pterocarpus tinctorius var. chrysotrix	5	3	15	322	3	16	954	40
Syncarpia laurifolia	5	3	21	300	3	25	806	49

Essence	Indice	Essai de compression			Essai de flexion			Nerf en % du travail total de rupture
		Nombre échant.	Humidité %	Résistance unitaire kg./cm.^{2}	Nombre échant.	Humidité %	Résistance unitaire kg./cm.^{2}	
Qualité supérieure								
Afrormosia angolensis	6	2	17	290	2	18	1025	33
Cassia siamea	6	3	24	203	3	28	882	65
Diplorhynchus mosambicensis	6	2	12	279	2	18	764	62
Eucalyptus citriodora	6	9	22	295	8	27	1258	37
Eucalyptus maculata	6	4	23	244	5	29	1383	43
Eucalyptus melliodora	6	2	23	251	2	30	923	46
Eucalyptus microcorys	6	5	20	369	4	25	1120	27
Eucalyptus umbellata	6	9	23	317	10	45	914	33
Eucalyptus sideroxylon	6	3	26	259	2	30	1181	33
Marquesia macroura	6	4	22	306	4	27	833	34
Brachystegia spiciformis var. latifoliata	7	9	16	225	9	21	804	45
Grevillea robusta	7	4	33	227	5	44	618	57
Qualité moyenne								
Brachystegia boehmii	8	1	17	259	2	21	751	30
Cassia spectabilis	8	3	18	155	3	21	624	59
Jacaranda mimosaefolia	8	1	21	174	2	27	751	53
Julbernardia paniculata	8	4	15	231	4	18	896	34
Parinari mobola	8	2	21	188	3	22	688	58
Pterocarpus angolensis	8	4	12	217	3	16	679	48
Uapaca kirkiana	8	3	16	276	3	15	734	39
Uapaca nitida	8	2	17	183	2	20	637	53
Brachystegia longifolia	9	4	18	180	4	19	743	40
Combretum molle	9	2	15	246	2	18	781	37
Dalbergia boehmii	9	2	16	241	3	14	784	35
Eucalyptus goniocalyx	9	3	28	174	3	37	887	58
Eucalyptus polyanthemos	9	2	27	190	1	27	875	34
Eucalyptus resinifera	9	3	21	246	3	32	616	30
Eucalyptus saligna	9	4	22	216	4	26	672	34
Qualité inférieure								
Albizzia adianthifolia	10	2	16	271	3	20	470	28
Albizzia antunesiana	10	3	14	276	2	17	311	23
Baphia bequaertii	11	2	12	220	2	16	367	10
Eucalyptus camaldulensis	11	3	25	190	3	38	788	20
Brachystegia stipulata var. velutina	12	1	17	187	1	13	572	15
Maesopsis eminii	12	3	20	183	3	34	589	12

A titre de comparaison, voici quelques résultats moyens obtenus pour les mêmes essais d'essences couramment utilisées dans la métropole.

Essences	Résistances unitaires à			Indice
	la compression	la flexion	arrière résistance %	
Epicéa du Pays . .	247	535	27	11
Pin sylvestre du Pays .	219	522	26	11
Pin sylvestre du Nord .	206	749	59	7
Chêne du Pays . .	192	638	40	9
Bouleau du Pays . .	248	765	40	8

Essai de classification des essences d'après les valeurs de ces résistances unitaires.

Classe	compression	flexion	arrière résistance %
1	>300	>1000	>50
2	250–300	800–1000	40–50
3	200–250	600– 800	30–40
4	<200	<600	<30

Les trois valeurs des résistances à la compression, à la flexion et le nerf sont les plus importantes pour la qualification d'un bois de mine. Pour classer une essence, il convient donc de tenir compte de ces trois valeurs simultanément. Dans ce but, on pourrait donner à chaque essence un indice égal à la somme des classes de chacune de ses résistances. Par exemple, une essence qui serait de la classe 1 en flexion, en compression et en arrière-résistance aurait l'indice 3 et serait de qualité parfaite. Tandis qu'une essence de qualité la plus inférieure aurait l'indice 12 parce que classée en 4 pour les trois sollicitations. Un indice inférieur à 6 correspond à la qualité exceptionnelle, un indice de 6 ou 7, aux qualités supérieures, un indice de 8 ou 9, aux qualités moyennes et un indice supérieur à 9, aux qualités inférieures.

indice	
<6	qualité exceptionnelle
6–7	qualité supérieure
8–9	qualité moyenne
>9	qualité inférieure

SYLVICULTURE AND MANAGEMENT OF MIOMBO WOODLAND

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SYLVICULTURE

Regeneration of miombo woodland after clear-felling is by coppice growth, root suckers and seedlings. Under an early burning regime, most of the seedlings become coppice seedlings. Their annual shoots are burnt back repeatedly until the taproot becomes vigorous enough to push up a shoot able to withstand the fire. A comparison of the age of roots and shoots of coppice seedlings showed that on the average the roots are eight years older than the shoots.

The stools appear to have a life equivalent to the life-span of the species, about 100 to 120 years in the absence of late fires. Firewood coupes are worked on a forty-year rotation and the stool mortality at each felling cycle is approximately 40% so that there is a complete renewal of stools every 2½–3 cycles. A shorter felling cycle might lengthen the life of the stool. The deficiency caused by stool mortality at each felling cycle is made up by seedling coppice and root suckers. Root suckers will account for a high percentage of the future crop if the soil has been worked in any way, i.e. native gardening or charcoal burning.

The number of shoots produced by a stool is in direct relation to the size of the stool, up to fifteen from large stools but rarely more than three survive to grow into trees. Stool shoots are normally unaffected by early burning. There is a time lag varying from six months to five years between felling and the appearance of stool shoots depending on a number of factors, but chiefly on the habit of the species concerned. *Isoberlinia* and *Marquesia macroura* shoot within a few months of felling, *Julbernardia paniculata* may take two years and *Brachystegia utilis* up to five years.

In general, density of regeneration is dependent upon site quality, stocking of the previous crop, cultural operations subsequent to felling, i.e. native gardening, charcoal burning, fire and its intensity and grass growth, and the presence or absence of regeneration already on the ground at time of felling. Direct seeding from adjacent or nearby woodland plays little or no part.

Fire can be a big hazard to regeneration. Repeated late fires will kill root suckers and seedling coppice and kill or seriously weaken 80% of the stools. Early burning has a mildly beneficial effect. It may kill a few of the smaller stools but seems to galvanise the larger stools into producing more vigorous shoots. It helps stool shoots by temporarily at least removing the grass competition. It may kill off some of the weaker trees which would never become final crop trees in any case.

Clear-felling and especially native gardening and charcoal burning result in an invasion of coarser grasses which are a greater fire hazard than the normal woodland grasses and tend to choke seedlings and even coppice partly by competition for soil nutrients and partly by keeping sunlight off the young leaves. When the canopy closes the coarser grasses die out and the finer, shorter woodland grasses come into their own again. Grazing cattle in the young regrowth woodland, if introduced at an early stage, weakens the grass growth and by working the soil assists regeneration.

Most of the miombo woodland, on the Copperbelt at least, is in various stages of regrowth and never reaches maturity. The stocking of the older regrowth areas varies from 150 to 250 stems per acre 4 in. d.b.h. and upwards. Mature miombo probably only carries thirty to fifty stems per acre, nearly all of timber size. This fits in with the theoretical "possibilité" of fifty mature stems per acre at height 50–60 ft. based on 2 × characteristic crown spread of the dominant species. The crown spread of a given species at a given age corresponds roughly to its height at that age.

In the older stands the canopy trees are unaffected by anything but repeated late fires. Early burning on the other hand increases slightly the stocking of the lower storey components and complete protection from fire increases it even more.

The mean rate of growth of the dominant species in miombo woodland lies between 15 and 20 rings/in., i.e. M A I girth of 0·22 in. This figure was obtained from ring counts on some 600 dominant trees (it is borne out by sample plot measurements—see below). In the early stages, coppice shoots grow at the rate of 5–15 rings/in. gradually slowing down up to thirty years old to 15 rings/in. Canopy formation around thirty years induces some twenty years suppression with a growth rate of 30 rings/in. until the final crop trees get their heads free. Such trees almost immediately increase their growth rate to 15–20 rings/in. or better. Isolated trees in fact will put on 5–15 rings/in., i.e. coppice shoot rate. The ideal rate of growth would appear to be 10–15 rings/in.

Sample plot measurements show that *Brachystegia longifolia* is the fastest grower, followed by *Julbernardia paniculata* and *Brachystegia spiciformis*. Actually, up to the pole stage *Isoberlinia* is faster than *Br. longifolia*. The Sudan species of *Isoberlinia* (*I. dalziellii* and *I. doka*) appear to be even faster-growing than the local *I. angolensis*. In general, rate of growth is greatest under complete protection.

Most logs cut for timber in miombo woodland as it is today are sixty to 120 years old ; 130-year old trees have been seen. One *Brachystegia spiciformis*, of which X-sections were exhibited at the Lusaka Agricultural Show, was 210 years old when felled.

The dominant species of miombo woodland are relatively slow-growing.

The following increment figures are based on the thirty best (final crop) trees in each of three one-acre sample plots in old regrowth at Ndola, under early burning, late burning and completely protected regimes.

M A I	*Basal Area %*	
Early burning . .	31·1	
Late burning . .	31·8	
Complete protection .	38·8	
M A I girth/in.	*Northern Rhodesia*	*Sudan*
Early burning . .	0·25	0·28
Late burning . .	0·25	0·12
Complete protection .	0·22	0·34
M A I volume/cu. ft.		
Early burning . .	0·25	
Late burning . .	0·21	
Complete protection .	0·23	

Increment figures for twenty-year old coppice from the sample plots at Ndola are as follows :

	M A I height/in.	*M A I girth/in.*
Early burning . .	15	0·5
Late burning . .	12	0·4
Complete protection .	12	0·5

The young regrowth is in fact putting on 2 × as much girth increment as the older, nearly mature regrowth.

Miombo woodland produces firewood, charcoal, building poles, smelter poles and timber, the bulk of it for the copper mines and the African population which works on the mines. Yields per acre are fairly variable. Mean and maximum yields per acre are as follows :

	Mean	*Maximum*
Firewood/cords . .	25	35
Building poles—small/no.	40	100
Smelter poles—large/no..	5	10
Timber/cu. ft. . .	60	350

MANAGEMENT

The sylvicultural treatment prescribed for the miombo woodlands of the Copperbelt (the only miombo woodlands under management) is coppice with standards. At the moment the prescription is generally applied. When the new Copperbelt working plan comes into operation next year only areas capable of producing saw-logs and smelter poles will be managed under a coppice with standards system. The remaining poorer areas will probably be converted to or enriched with soft hardwoods.

The number of standards reserved has varied from five to twenty-five per acre, the more the better provided they are of good quality. Poor-quality trees are liable to die when isolated. In fact the theoretical "possibilité" based on 2 × the characteristic crown spread of the dominant species aims at fifty trees/acre for the final crop.

The regrowth will close canopy at twenty-five to thirty years of age. As soon as this happens the rate of growth falls off and only picks up again when the final crop trees manage to isolate their crowns above the general canopy level. Obviously then a thinning must take place at twenty-five to thirty years of age just before the canopy closes. If the growth rate can be kept up to the pre-closure canopy rate, the rotation for saw-logs could be reduced from eighty to sixty years.

Rotations at the moment are largely theoretical, eighty to one hundred years for saw-logs, sixty to eighty years for smelter poles, forty years for small poles and firewood. The new working plan will endeavour to manage the woodlands on a sustained yield basis with annual coupes and working cycles for the different classes of produce. At the moment yield is based on mine requirements, and what cannot be produced from forest reserves is taken from crown land and timber concessions.

Early burning is prescribed throughout the miombo woodland as a protective sylvicultural measure, mainly to prevent the damage caused by late fires in woodland which has not been early burned. Besides, early burning is mildly beneficial and complete protection is out of the question on such a vast acreage. Actually, it is doubtful whether complete protection, even if it were possible, would be best for a woodland type which has become accustomed to being fired periodically if not annually and adapted itself to it.

Two other sylvicultural measures have been suggested but not adopted except on a trial scale in Nigeria. One suggestion is to protect the felled coupes for three to five years after felling, to allow the seedling coppice which makes up 40% of the future crop to establish itself. The other suggestion is to cultivate the soil at or immediately after felling, to promote root suckers and coppice growth generally.

Finally, selected woodland areas are being turned into pine plantations or enriched with eucalyptus and fast-growing hardwoods, using a form of " chitemene " system.

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STEPS TOWARD THE PLANNED MANAGEMENT OF NORTHERN RHODESIA'S WESTERN PROVINCE BRACHYSTEGIA/ JULBERNARDIA WOODLANDS, SUPPLYING PRODUCE TO THE MINING INDUSTRY OF THE COPPERBELT

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SUMMARY

The copper industry requires 3½ million cu. ft. (99,000 m.³) of forest produce annually and domestic consumers need a further 16 million cu. ft. (453,000 m.³) of fuel wood. The Western Province Forest Estate is 1½ million acres (600,000 ha.) in extent but carries a low exploitable growing stock. A working plan for its management is now being prepared, of which the main object of management is to supply the maximum quantity of forest produce to the mining industry on a sustained yield basis. The estate is considered to be inadequate to meet the long-term requirements of the mining industry, and therefore proposals for future management have been framed to enhance production by all feasible means as quickly as possible. A 2½% strip enumeration survey is now in progress, to provide data on the growing stock, while simultaneously, qualitative data is being collated as a basis for site assessment. To obtain the quickest returns from sylvicultural treatments, these must be concentrated on better-quality sites. But site quality is largely obscured by differences in past treatment, and it is therefore necessary to make a comparative study of all criteria known often to reflect site quality. Most of the site assessment data will be handled on machine punch-cards. Features of compartmentation peculiar to local conditions are of passing note.

I. INTRODUCTION

(metric equivalents are given in brackets)

Copper mining in Western Province began in 1910. Indigenous woodlands have always supplied a proportion of the industry's wood requirements, but demands have varied greatly both with copper production and the quantity of imported softwoods, as well as with the availability of electricity, coal and oil fuels.

The copper industry currently uses the following quantities of indigenous forest produce annually :

Saw-logs and mine poles .	1¾ million cu. ft. (50,000 m.³)
Refinery poles . .	½ million cu. ft. (14,000 m.³)
Wood fuel (for charcoal) .	1¼ million cu. ft. (35,000 m.³)
Total annual requirements	3½ million cu. ft. (99,000 m.³)

In addition, 16 million cu. ft. (453,000 m.³) of wood fuel is annually converted to charcoal for African domestic use. Demand comes from six mines and their allied townships spread over an area of approximately 3,500 square miles (14,100 ha.), known as the Copperbelt.

The Western Province forest estate is 1,523,198 acres (616,407 ha.) in extent, being made up of 562,200 acres (227,511 ha.) on the Copperbelt (26%

of the land), and a further 960,958 acres (388,881 ha.) in the outlying rural areas. The estate is estimated to carry a growing stock of 65 million cu. ft. (1,840,000 m.^{3}) of saw-logs and mine poles, and 9 million cu. ft. (255,000 m.^{3}) of refinery poles, giving an average stocking for these combined classes of produce of 50 cu. ft./acre (3.5 m.^{3}/ha.). Forest reservation proposals cover an additional 490,810 acres (198,620 ha.). This estate is constituted entirely of *Brachystegia/Julbernardia* woodlands (miombo), and has been but little worked to meet past requirements.

Since 1932, forest policy on the Copperbelt has embraced the following lines :

1. Control and concentration of felling to prevent waste.
2. Full utilisation of forest produce from sites cleared for development works.
3. Conservation of water supplies by the prohibition of cutting both in sponge areas around the sources of streams, and on river and stream banks.
4. Ensuring coppice and root sucker regeneration of felled areas by carrying out intensive early burning, assisted by the strict enforcement of felling rules requiring the trimming of stumps and the safe disposal of slash between stools.
5. The retention of " standards ", and the sowing of seed in ash patches in selected better-quality sites, leading to the possibility of enhanced future yields.
6. By setting aside readily accessible strategic reserves of woodland against future requirements of mining crises, these being features common to the mining industry generally, future emergencies were catered for.
7. By directing fellings firstly on to mine properties, and subsequently on to those areas which would later probably be lost to forestry, time was bought in which the forest estate was acquired and kept intact, while sylvicultural techniques were developed and resources became available to draw up a complete full-scale working plan for the sustained-yield management of this estate.

Present Steps Towards Sustained-Yield Management

A Forest Survey is now in progress to provide data for a working plan, and work on Part I of the plan has started. These undertakings are dealt with below under the following headings :

Objects of management
Classes of forest produce in demand
Considerations affecting management
Proposals for future management
Collection of quantitative data for determination of growing stock

Collection of qualitative data for assessment of forest sites
Division of forest estate into compartments.

Objects of management

1. To supply the maximum quantities of forest produce to the mining industry compatible with a sustained yield.
2. To maintain adequate supplies of forest produce to non-mining consumers.
3. To protect and maintain water supplies.

Classes of forest produce in demand

The following are the broad classes of forest produce in demand :

Types of produce	Dimensions: Mid-girth range (over bark)		Dimensions: Length range		Required for
	inches	cm.	feet	metres	
Main classes					
Saw-logs	42+	107+	7–12	2·1–3·7	Mining use
Slab timber/Mine poles .	30–41	76–104	8–12	2·4–3·7	Mining use
Refinery poles/Smelter poles	36–72 (at butt)	91–183	20+	6·1+	Smelter and refinery furnaces
Cordwood	12–36	30–91	—	—	Industrial and domestic use
Other classes					
Saw-logs for furniture .	42+	107+	8+	2·4+	Secondary industries
Small poles	12–30	30–76	8+	2·4+	Building and fencing
Bamboos	—	—	—	—	Mining and general use

The above are the broad classes of forest produce in demand, but mine requirements are in fact far more specific and, further, are continually changing without warning. There are six mines on the Copperbelt and each one has its own particular system of using wood underground, each calling for its own special range of sizes. In the past the mines have not wished to carry very large different sized stocks of timber, which is a perishable commodity ; but recent centralising of supply has tended to spread and to steady the effects of local fluctuations in demand.

Considerations affecting management

1. It is anticipated that the existing growing stock of timber sizes and refinery poles will be inadequate to meet future long-term mine requirements.
2. Existing growing stocks of large poles probably exceed mine requirements. So long as adequate recruitment to the upper size classes is safeguarded, increased use of large poles by the mines, as a partial

substitute for saw-logs, would make supplies of this latter class of produce last longer.

3. The transport of refinery poles is relatively much more expensive than that of sawn timber because, by reason of the length and irregular shape of the poles, vehicles cannot be loaded to near weight capacity. Similarly, round poles are less economic to transport than sawn timber. For these reasons it seems desirable that the Copperbelt forest reserves should be worked for refinery poles in preference to saw-logs, and also for mine poles.
4. It seems that these miombo woodlands can be most effectively and economically brought to maximum productivity by the retention of all suitable pole stems to grow on to larger sizes, and the sale of the rest of the crop. The demand for fuel wood is from the towns, and it is therefore likely that the forest estate on the Copperbelt will be intensively worked and readily brought to maximum productivity. By contrast, however, and due to high transport costs, the outlying rural areas are likely to be worked only for timber. In these circumstances of selection felling for timber only, the cost of sylvicultural improvement works is likely to be high.
5. In order to allow for annual fluctuations in demand caused by large variations in copper production, it is proposed to determine the yield for a period of years, instead of annually. Further, because of the fluctuating demands for different sizes of produce, it is proposed to control the yield by volume for each major size-class.

Proposals for future management

In view of the anticipated shortfall in supplies of timber and refinery poles, it is proposed to concentrate felling, and consequently regeneration, on the better-quality sites now, so that the enhanced yields of these classes of produce in the second rotation, resulting from intensive sylvicultural treatment, will be reaped as early as possible.

In order to avoid unremunerative departmental expenditure on the removal of unwanted stems, it is proposed to concentrate as far as possible the felling of all consumers on the better-quality sites, rather than to allow non-mining consumers to obtain their requirements from the poorer-quality areas which can normally meet their demands.

In order to provide an interim yield of saw-logs between the felling of the last of the existing growing stock and the coming into yield of the second rotation crop, it may be necessary to retain every suitable pole-size tree to grow on to timber size on better-quality sites.

In order to meet the requirements of future emergencies, such as war, or shortage of fuel for transport, it is desirable to set aside a readily accessible, floating periodic block of timber-bearing woodland as a strategic reserve.

It is proposed to review methods of regeneration and sylvicultural treatment at three-yearly intervals, and at the same time to consider also the adequacy of the site classification.

Because refinery poles must be supplied to the copper industry in a green sappy condition, they can only be produced locally. Due to the inadequacy of existing supplies to meet the long-term demand, it is proposed to establish fast-growing plantations of heavy hardwoods, such as eucalyptus, to supplement the yield from miombo woodlands.

Because miombo woodlands are unable to supply the softwood requirements of the copper industry, which are at present imported at considerable cost, it is proposed to provide this class of produce as far as possible from local pine plantations.

Collection of quantitative data for determination of growing stock

Before the current survey began, a 100% enumeration was carried out over a 1,000-acre (405 ha.) block of representative woodland. Analysis of the data showed that a 2½% narrow-strip sample was the minimum necessary to give a statistically reliable result, and accordingly this method was chosen for the present enumeration survey. The strips are orientated to cross the contour at approximately right-angles, and are laid out systematically.

The seven species which constitute the bulk of the exploitable crop are grouped into five utilisation classes :

1. *Julbernardia paniculata*
2. *Isoberlinia angolensis*
3. *Brachystegia spiciformis* and *B. floribunda*
4. *Brachystegia longifolia* and *B. boehmii*
5. *Brachystegia utilis.*

The exploitable growing stock is booked under the following categories :

(1) **Small poles**—numbers

Girths (B.H,O.B.) .	18–35 in. in three classes of 6 in. (46–90 cm. in three classes of 15 cm.)
Length of bole .	8 ft. or 12 ft. (2.0 m. or 3.0 m.)
Utilisation classes .	five major, plus one class for other species.

(2) **Large poles**—volume and numbers

Girths (B.H,O.B.) .	36–41 in. as one class (91–106 cm. as one class)
Length of bole .	8 ft. (2.0 m.) and above, to lower foot (0.3 m.)
Utilisation classes .	five major.

(3) **Saw-logs**—volume and numbers

Girths (B.H,O.B.) .	42–47 in., 48–71 in., 72 in. and above, three classes (107–121 cm., 122–182 cm., 183 cm. and above, three classes)
Length of bole .	8 ft. (2.0 m.) and above to lower foot (0.3 m.)
Utilisation classes .	five major.

(4) **Refinery poles**—numbers

Girths (B.H,O.B.) .	36–71 in. in six classes of 6 in. (91–182 cm. in six classes of 15 cm.)
Length of bole .	20 ft. (5.1 m.) minimum, including slight bends and some defects

Management classes (*a*) Trees which by virtue of defects can be used only as refinery poles.
(*b*) Trees which contain a saw-log and which can therefore be felled either for saw-logs or for refinery poles, as dictated by the requirements of management.

(5) **Species yielding the more valuable timbers** (furniture species)—numbers
Girths (B.H,O.B.) . 42 in. (107 cm.) minimum
Length of bole . 8 ft. (2.0 m.) minimum
Utilisation class . Booked individually against a list of fourteen species, but totalled into one class.

(6) **Potential standards**—numbers
(should it be necessary to retain standards as recruits to a second felling cycle).
Defined as sound, healthy, upright trees of the seven major species, springing from ground origin, and having medium or large-sized crowns in the upper canopy, which are not obviously liable to heavy damage by the felling of surrounding trees :

(*a*) **For future saw-logs**
Girths (B.H,O.B.) . 18–41 in. in four classes of 6 in.
(46–106 cm. in four classes of 15 cm.)
Length of bole . 8 ft. (2.4 m.) minimum.

(*b*) **For future refinery poles** (and taking precedence over future saw-logs (*a*) above)
Girths (B.H,O.B.) . 18–35 in. in three classes of 6 in.
(46–90 cm. in three classes of 15 cm.)
Length of bole . 20 ft. (5.1 m.) minimum, including slight bends.

(7) **Bamboo**—frequency of clumps
Classed as : occasional, frequent or abundant.

Collection of qualitative data for assessment of forest site

Only a small proportion of the *Brachystegia/Julbernardia* woodlands of the Western Province are capable of supporting the growth of trees to timber and refinery pole size. These are the two most important classes of produce required by the mining industry, and are also those most likely to be in short supply in the future. Further, they occur on those sites supporting the highest growth rates, on which it will be most economic to spend money for sylvicultural treatment. Early assessment of site quality is therefore of paramount importance both to management and to sylviculture.

There are, however, many factors which obscure site quality ; and to date no single criterion, nor combination of few criteria, has been found against which comprehensively and uniformly to assess all the miombo woodlands of the forest estate. Before the commencement of the present enumeration survey, detailed investigations were made in an effort to correlate soil, vegetation, tree height, and basal area of the large size-classes with site quality. Some correlations were possible, but they were neither of uniform nor of comprehensive application.

The main factor obscuring site quality is the very variable condition, caused by chance differences of past treatment, of these otherwise rather uniform woodlands. The obscuring factors are specifically listed below :

1. Due to the African practice of pollarding trees in garden areas, absence of present exploitable growing stock is no indication of poor site quality.

2. Over-mature woodlands on all sites carry a low exploitable growing stock and a low basal area.
3. Fierce late fires have reduced or consumed forest growing stocks to varying degrees in most woodland types.
4. The relationships between soils and forest site quality are complex and are not fully understood ; neither have the critical factors been recognised, on which to base a satisfactory soil classification.
5. Present species composition, of the overwood, of the underwood, and of the ground vegetation, sometimes appears to be more an expression of past burning treatment than of site.
6. Growth rate, measured by increment boring, is a function of stocking both past and present, and of past burning treatment as well as of site quality.
7. Height is a function of both age and site quality. The ages of the woodlands vary considerably due to former cultivation, and cannot be simply determined.
8. It is not known to what extent African cultivation temporarily or permanently reduces the forest productivity of different forest sites. Fierce grass fires alone can prevent or hinder regeneration.
9. Variations in quality occur within all woodland types.

In view of these obscuring factors, and in the light of the previous investigations, it is considered necessary to collect and combine data on all criteria, known often to reflect site quality, and to classify and delineate boundaries of site quality from a comparative study of this data, presented in the form of coloured-line, transparent overlays, superimposed above a basic woodland type map. The data to be presented for this comparative study is given below, together with amplifying or explanatory notes :

1. Woodland type map.

   A tentative classification into eight types has been suggested by Mr. C. G. Trapnell (Ecologist, EAAFRO).
2. Exploitable volume per acre above 35 in. (90 cm.) G.B.H. (O.B.) by the following levels of stocking :

   (cu. ft.) 40, 60, 80, 100+ ($m.^3$ 1·1, 1·7, 2·3, 2·8+) and, as a corollary, also areas of frequent pollarding where exploitable volume can be no criterion of quality.
3. Average top height by the following levels :

   (ft.) 30, 40, 50, 60, 70+ (m. 9·1, 12·2, 15·2, 18·3, 21·3).
4. Geological formations immediately underlying the soil.

   It has been found that certain geological formations can be closely correlated with woodland types and quality. For example scrub woodland over shale, *Brachystegia utilis* over granite, and *B. spiciformis* over the deeper limestones.

5. Occurrence of 2·5YR and 10R coloured soils.
   Site quality has been shown to be invariably good over 10R soils, and this also holds good for many areas of 2·5YR soils.
6. Topographical contours (see following paragraphs).
7. The frequent or abundant occurrence of *Landolphia parvifolia* (see following paragraphs).
8. The occurrence by numbers present of the following tree species (see following paragraphs) :

   Syzygium guineense
   Erythrophleum africanum
   Albizzia adianthifolia.

It is of interest to note that, in selecting sites for plantations of exotic species, an adequate supply of soil moisture throughout the dry season, coupled with free drainage throughout the year, have been shown as requisites of first-quality sites. The same requisites may be necessary for good-quality miombo woodland. Study of the horizontal distances between contours, and a knowledge of the permeability of the immediately underlying geological formation, helps to define areas of waterlogging, and also of appreciable run-off during the rains, with corresponding reduction of subsoil moisture supply. The parallel, concave, or convex alignment of the contours relative to slope, shows whether a site receives normal, enhanced or reduced supply of subsoil moisture by lateral drainage from adjacent higher ground. Such interpretations, together with a knowledge of the soil parent material, as shown by the immediately underlying geological formation, may be a useful guide to assessing site quality.

Many areas of the better quality timber bearing woodland are often, but not always, characterised by the presence of one or several particular species. Consequently the presence of any one or combination of these species, is taken to indicate a better-quality site, even though actual exploitable stocking may be low or completely absent. *Landolphia parvifolia* is considered the most reliable indicator of good-quality sites, when present frequently or in abundance. *Syzygium guineense* is found to occur only on the top quality sites, and is thought to be more selective, but the significance of its frequency of occurrence is in doubt. Similarly the significance of *Erythrophleum africanum* and *Albizzia adianthifolia* is thought to lie in their frequency rather than in their presence.

It is the intention to find, by comparing data for areas of mature fully stocked woodland, what correlations exist between the qualitative data listed above and then to apply these correlations to assess the quality of sites whose growing stocks have been depleted by past treatment.

Data on the occurrence of frequent pollarding, of *L. parvifolia*, and of the three named tree species, are collected during the enumeration of the woodlands. But in order to obtain the additional data on woodland type and average top height, a descriptive survey is carried out concurrently along alternate enumeration lines, that is, at intervals of approximately two-thirds of a mile. This descriptive survey also provides other data such as crop quality, maturity, damage, outcropping geological formations, and suspected water-logging, which are required for the writing of compartment descriptions.

Most of the site assessment data will be punched on to machine cards for sorting and tabulating by Powers-Samas equipment. The following data will be handled in this way :

Serial number of sample acres
Woodland type
Exploitable volume
Occurrence of frequent pollarding
Average top height
Occurrence of *Landolphia parvifolia.*
Numerical occurrence of :
- *Syzygium guineense*
- *Erythrophleum africanum*
- *Albizzia adianthifolia.*

By sorting and tabulating, a series of lists will be provided of the serial numbers of sample acres, having each particular level of stocking or of occurrence, woodland type and average top height, required for presentation on overlays, for comparison and correlation with site. With these lists, the preparation of the transparent overlays above the base map showing serial numbers will be a quick process. Overlays showing the geological formations, the occurrence of 2·5YR and 10R soils, and topographical contours, will be prepared from existing maps.

Initially, this full set of overlays will be prepared only for representative areas containing mature woodland. Subsequently, when correlations have been established by comparative study, a comprehensive system of site assessment can be drawn up and applied to the remainder of the forest estate, using a single list of machine-tabulated data for the preparation of the overlay, presenting all data handled by machine.

Division of forest estate into compartments

The division of the forest estate into compartments for purposes of management and permanent record, follows standard forest practice. But the following features are worthy of note, being peculiar to local conditions :

1. Extent normally 1,500 acres (607 ha.), marginally stocked areas 3,000 acres (1,214 ha.), these being the areas necessary to provide a yield lasting two to three months at an average rate of cutting. As far as practicable a large area of scrub woodland is made into one compartment, regardless of size.
2. When compartment boundaries are to be cut lines, each end is chosen to coincide with a feature readily identifiable on aerial photographs, and these features are then permanently marked and numbered on both the photographs and the maps.

3. Compartment registers are likely to contain a section of a 1 : 20,000 aerial photograph mosaic, covering the compartment and its immediate surroundings.
4. Compartment registers will contain a very detailed statement of growing stock so that grouping by size and species will be possible to meet any changes in demand. To facilitate reference to this data for purposes of management, sale and record, consideration is being given to the use of manually sorted punch-cards.

COMPOSITION FLORISTIQUE, CLASSIFICATION, AFFINITES ET DYNAMISME DES PEUPLEMENTS

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I. COMPOSITION

A. Remarques préliminaires

1. Les **plantes ligneuses** (arbres, arbustes, lianes) commencent à être relativement bien connues dans toute l'aire de distribution soudano-zambézienne de la formation forêt claire, d'où certaines généralisations; certaines hypothèses aussi concernant l'origine de ces forêts, leur nature, leur distribution, leur écologie, leur dynamisme.

2. Par contre, les **plantes herbacées** qui constituent la strate au sol sont encore mal connues, particulièrement dans le domaine soudanais.

D'où certaines mésinterprétations sur la nature, l'origine et le dynamisme de ces forêts.

B. Les plantes ligneuses

La futaie (strate supérieure) est composée :

a) **principalement** d'espèces appartenant à des genres existant aussi dans la forêt guinéenne; souvent, elles constituent, avec les espèces guinéennes correspondantes, des séries écophylétiques au sens d'Aubréville : les premières paraissent dériver des secondes par divers processus d'évolution écologique recensés jadis par Bews ; réduction de la taille, augmentation du branchius, feuilles caduques avec perte de la pointe égouttoir, bourgeons protégés d'écailles, etc. La liste ci-dessous indique l'écrasante dominance des légumineuses :

Afzelia, *Albizzia*, *Afrormosia*, *Berlinia*, *Brachystegia*, *Burkea*, *Cryptosepalum*, *Dialium*, *Erythrophleum*, *Daniellia*, *Ficus*, *Guibourtia*, *Lophira*, *Marquesia*, *Parinari*, *Pterocarpus*, *Syzygium*, etc.

b) de quelques genres incipents sur le statut systématique desquels on n'est pas d'accord, tant ils sont apparentés à des genres de la forêt guinéo-congolaise :

Isoberlinia (voisin de *Berlinia*)
Pseudoberlinia (voisin de *Julbernardia*)

c) d'un très petit nombre de genres inconnus en forêt dense, bien individualisés et apparemment anciens, souvent d'ailleure monospécifiques :

Anogeissus, *Butyrospermum*, *Colophospermum* forment d'ailleurs des types forestiers particuliers.

C. Les arbustes

C'est par centaines d'espèces qu'on les compte et Aubréville a publié des listes, d'ailleurs non limitatives, où le nombre de genres dépasse 200.

Plus marqués par l'évolution écologique ; un type assez fréquent de série écophylétique est liane de la forêt dense, arbuste (parfois encore sarmenteux) de la forêt claire (cas fréquent chez les *Strychnos* ?).

On peut classer un grand nombre de ces arbustes dans les trois catégories énumérées pour les arbres.

(exemples 1 : *Uapaca*, 2 : *Monotes*, 3 : *Diplorrhynchus*).

Mais il y a en plus un certain nombre de genres ou sections de genres ayant apparemment d'autres origines : *Protea* et *Faurea*, genres d'origine gondwannienne australe ; groupes de la vieille flore sèche africaine se mêlant aux forêts claires des ceintures les plus sèches :

Acacia au *Colophospermum* ; genres afro-montagnards : *Philippia*.

Malgré le grand nombre de genres que l'on peut rassembler dans une liste, quelques-uns sont largement dominants : *Uapaca*, *Monotes*, *Combretum*, *Terminalia*, *Protea*, *Faurea*, *Ochna*, *Vitex*, *Strychnos*, *Canthium*, *Pavetta*, etc.

D. La grande pauvreté en espèces de la zone boréale (soudanaise) et la grande richesse de la zone australe (zambézienne)

Depuis qu'Aubréville a insisté sur ce phénomène, des études plus récentes n'ont pu que le confirmer (2. *Isoberlinia*, 1. *Monotes*, *Uapaca*). D'où séduisante hypothèse de travail d'Aubréville d'une oscillation de la bande équatoriale pendant le tertiaire.

E. Les plantes herbacées

Les listes de plantes herbacées du sous-bois des forêts claires sont rares et très incomplètes ; à notre connaissance :

Angola : Gossweiler, Mendonça.
Kwango : Duvigneaud, Devred.
Katanga : Duvigneaud, Schmitz.
Rhodésie du Nord : Fanshawe (liste presentée au présent meeting comportant tout aussi bien les espèces ligneuses).

C'est extraordinairement peu de choses. Cependant, certaines monographies de genres montrent que la strate herbacée de la miombo zambézienne est d'une grande homogénéité **générique** dans tout l'aire de cette formation.

Le caractère fondamental de cette strate est qu'elle comporte de nombreuses centaines et peut-être plusieurs milliers d'espèces qui lui sont propres. Nombreux sont les genres ou espèces qui appartiennent à l'élément autochtone zambézien ou zambézien à faible irradiation soudanaise (div. sp. de *Tristachya*, *Trichopteryx*, *Dicoma*, *Pleiotaxis*, *Mumularia*, *Haumaniastrum*, par exemple).

Parmi les familles typiquement tropicales, les plus largement représentées sont les Acanthacées (*Barleria*, *Phaulopsis*, *Thunbergia*, *Blepharis*, *Lepidagathis*, *Hypoestes*, *Monechma*, *Dischoriste*, *Strobilanthopsis*), les Rubiacées, (*Borreria*, *Fadogia*, *Temnocalyx*, *Tricalysia*, *Leptactinia*, *Galium*, *Geophila*, *Grumilea*, etc.) et les Commélinacées (*Cyanotis*, *Aneilema*, *Murdannia*, *Commelina*). Parmi les familles cosmopolites, les Composées (*Vernonia*, *Helichrysum*, *Hypericophyllum*, *Erythrocephalum*, *Elephantopus*, etc.) et les Papilionacées (*Crotalaria*, *Tephrosia*, *Indigofera*, *Dolichos*, *Vigna*, *Desmodium*, *Rhynchosia*, *Droogmansia*, *Eriosema*, *Aeschynomene*, *Kotschya*, *Humularia*, etc.) y présentent le plus grand nombre de genres et d'espèces. A noter encore une très bonne représentation des Labiées (*Becium*, *Haumaniastrum* = *Acrocephalus auct.*), des Scrophulariacées (*Sopubli*, *Buchnera*), des Vitacées avec le genre *Cissus*, des Euphorbiacées avec le genre *Acalypha*, des Tiliacées avec le genre *Triumfetta*, Avant les pluies et après le feu de brousse, y fleurissent de nombreuses Lialiacées et Orchidées.

Au point de vue de la biomasse, ce sont néanmoins les graminées qui dominent le plus souvent, avec des espèces spécifiques d'Arundinellées, (*Tristachya*, *Trichopteryx*, *Danthoniopsis* ?), d'Andropogonées (*Andropogon*, *Hyparrhenia*, *Homozeugos*, *Urelystrum*, *Thyrsia*, *Peltophorum*, etc.), de Panicées diverses.

F. La méconnaissance du caractère typiquement spécifique de cette flore herbacée et graminéenne de la miombo a conduit certains auteurs (Robert, Delevoy, Robyns) à considérer cette formation comme une savane boisée ; or, il s'agit d'une flore **forestière** dont les éléments ne peuvent vivre dans les savanes ou steppes de contact.

Il est vrai que dans certains stades de dégradation avancée, le sous-bois de la miombo est envahi par la flore herbacée et spécialement graminéenne des savanes ou des steppes : ce sont là des exceptions qui confirment la règle.

G. Strate herbacée des forêts claires autres que la miombo

1. On ne connaît à peu près rien de la flore herbacée des forêts claires boréales ; forêts assez drues et lianeuses à l'origine, il semble qu'elles sont le plus souvent savanisées, formant des **savanes boisées,** c'est-à-dire des formations où, à une strate herbacée de savane, se superpose une strate arborée d'essences de forêts claires.

2. La strate herbacée des forêts claires à *Colophospermum* de la Rhodésie du Sud est, selon Rattray, fort variable ; à la forêt du type Mopane s'associe suivant les cas le veld à *Eragrostis rigidior* (vivace), le veld à *Aristida pilgeri* et *graciliflora* (vivace), le veld à *Cenchrus ciliaris* ou le veld de graminées annuelles *Aristida-Dactyloctenium-Eragrostis*.

H. Manque de stabilité est un caractère général de la flore forestière soudano-zambézienne. Très grande variabilité de certains genres, rendant très difficile leur systématique.

Causes : origine récente de cette flore (Duvigneaud) ou action humaine par déboisements et incendies (Brenan). Très grande variabilité individuelle et hybridation introgressive avec essaims d'hybrides chez les *Brachystegia* (Hoyle).

II. CLASSIFICATION DES PEUPLEMENTS

A. Les unités physionomiques

1. Série de ceintures de végétation (Schmid)

Schmid divise la végétation terrestre en bandes parallèles à l'équateur qui sont caractérisées historiquement et physionomiquement en ce qui concerne l'adaption des végétaux à un certain type de climat. Les forêts claires appartiennent à une **série tropicale métamorphosée.** Cette série a été dérivée d'une série tropicale standard (absence de xéromorphisme due à une existence de longue durée dans un climat optimal ; végétation stabilisée) sous l'action de bouleversements climatiques récents ayant créé des conditions nouvelles de xéricité (tropische xerische Gürtel-Serie).

Une série peut comporter plusieurs ceintures, chaque ceinture plusieurs formations.

2. Formations

Groupement végétal de physionomie déterminée. En détaillant, on peut parvenir à un système complexe de sous-formations. Exemples pour les forêts claires africaines :

Livundia sempervirente à *Marquesia — Cryptosepalum pseudotaxus.*

Mabwati = Muulu = mélange d'espèces caducifoliées et sempervirentes.

Mikwati = Chipya = savane arborée par un certain nombre d'arbres et arbustes de la forêt claire capables de vivre en dehors de celle-ci.

Mutemwa à *Baikiaea plurijuga.*

Mopani à *Colophospermum.*

Miombo à *Pseudoberlinia-Brachystegia.*

Savane boisée à *Lophira*, etc.

Système complexe de Gomes Pedro.

B. Les unités floristiques

1. La ceinture de végétation (Belt, Gürtel) — Schmid

Se confond avec la série au sens de Gaussen ou la série au sens de Clements-Phillips. Bande de végétation de composition floristique déterminée historiquement et écologiquement, composée de plantes adaptées morphologiquement à un type de climat. La délimitation des ceintures formant la série métamorphosée de forêts claires tropicales est difficile ; nécessite la connaissance précise de toutes les aires de distribution actuelles, des aires passées (analyse pollinique), des voies migratoires ou obstacles (excellent travail d'Exell pour la *Flora zambesiaca*) ; un système de formes de vie basée sur le xéromorphisme (rejet du système de Raunakiaer) doit être élaboré, en prenant comme base les études de Bews.

Projet (d'après Keay, Nigeria, et carte AETFAT) du nord au sud.

Au nord de l'équateur :

Ceinture à *Anogeissus leiocarpus* ; le climax serait une forêt du type " Mutemwa ".

Ceinture à *Isoberlinia doka* et *dalzielii*, le climax serait une forêt du type " Miombo ".

Au sud de l'équateur, le gradient d'aridité croissante, qui se développe normalement du nord au sud, paraît se compliquer d'un gradient d'aridité croissante d'ouest en est.

D'où 3 ceintures de vegétation :

1) Au N.O. : la ceinture à *Marquesia, Daniellia, Berlinia.* Une certaine océanité du climat combinée à une saison sèche assez courte permet l'existence de nombreuses espèces sempervirentes légèrement transformées (Laurilignides au sens de Rübel et Brockmann-Jerosch). Cette " Livundia " abrite un certain nombre d'espèces de la forêt guinéo-congolaise en même temps que des *Brachystegia* et autres essences de la miombo.

2) Du N.E. au S. la ceinture à *Brachystegia-Pseudoberlinia.* C'est la miombo proprement dite, caracterisée selon Wild par des sols acides lessivés.

Peut-être 3 ou plus sous-ceintures :

a) Nord : Centrale-fraîche, à *Brachystegia floribunda-Pseudoberlinia paniculata.* Melangée d'espèces de la Livundia Optimum du genre **Monotes avec** nombreuses espèces et variétés.

b) Orientale et Australe-sèche, à *Brachystegia manga* et *Pseudoberlinia globiflora.*
Melangée d'espèces des thickets xérophiles. Le genre **Monotes** se réduit à 1 ou 2 espèces.

c) Sud Angola ?

3) Extrême-Sud : la ceinture à Mopane, caracterisée selon Wild par des sols alcalins non lessivés.

4) Un cas assez unique est la superposition, aux ceintures normales de la miombo, d'une ceinture beaucoup plus xéromorphisée, riche en Capparidacées sclérophylles, établie sur les termitières. Pour détails, voir Wild, Schmitz, Duvigneaud.

2. L'Etage de végétation

Notion féconde se confondant avec celle de ceinture ; dans les zones à relief accusé, les ceintures ont une tendance à se superposer en étages successifs.

On connaît peu de choses, mais l'étagement doit se faire, de bas en haut :

Etage du Mopane (Etage du *Pseudoberlinia globiflora* et du *Brachystegia*)

Etage du *Pseudoberlinia caniculata* et div. sp. de *Brachystegia.*

Etage du *Marquesia macroura* (Katanga) ou du *Brachystegia microphylla* sur les escarpements humides.

Les deux premiers existent en Rhodésie du Sud (Wild) ; au Mozambique, Gomes Pedro et Grandvaux Barbosa distinguent :

Mopane veld, miombo du type sec, miombo du type subhumide, miombo d'altitude.

Souvent, ce qu'on observe avec l'altitude est un appauvrissement progressif en espèces ligneuses, accompagné du rabougrissement de celles qui subsistent. (Région de Mpwapwa, Greenway).

3. Les Phytocénoses

a) **L'Association** : Groupement végétal de composition floristique déterminée :

1) Association (Zurich-Montpellier), Lebrun, Mullenders, Germain espèces caractéristiques (fidèles) exclusives ou préférantes.
2) Sociation (Upsala, Trapnell). Physionomie déterminée par constantes dominantes.

b) **La Formation** (sensu Clements-Phillips). " The climax community within a natural area in which climatic conditions are similar or identical ".

Cette formation est une " association " si elle comporte 2 à plusieurs dominantes ; une " consociation " si 1 seule dominante. Les communautés non climaxiques sont de même des " associés " ou " consociés ".

c) L'association considérée comme la somme, l'intrication de **groupes écologiques** divers (Duvigneaud). Connaissance de l'écologie des espèces encore très lacuneuse ; on trouve à peu près toutes les espèces sur tous les types de substrat, mais avec dominance ou fréquence très diverses ; établir la liaison étroite d'une espèce avec un milieu particulier, en utilisant cadenas, transects de vallées, auréoles de végétation. Utilité de surveys régionaux où l'écologie des principales essences ou communautés végétales est précisée (exemple : Rattray et Wild, Sabi valley ; Burtt, Tanganyika Territory). Carte d'Exell schématisant les faits saillants du relief ou du climat favorisant ou freinant la dispersion des espèces.

C. Classification des Phytocénoses

1) **Synthétique** en unités hiérarchisées: Alliances, Ordres, Classes. On aboutit à des résultats différents selon qu'on fait appel aux caractéristiques fidèles (Braun-Blanquet, Tuxen ?) ou aux groupes écologiques (Duvigneaud).

2) **Analytique.** Longues listes de sociations ou consociations groupées suivant le type de sol, et citées dans un ordre géographique (Trapnell, Fanshawe) ou suivant le type formationnel (Gomes Pedro).

3) **Dynamique** (Phillips). Le groupement végétal est classé suivant la **sère** à laquelle il appartient ; une sère est une succession de communautés végétales (associés ou consociés) depuis les stades pionniers jusqu'à la formation climax (association ou consociation).

Ainsi, au Tanganyika Territory, la forêt claire qui, pour Phillips, serait toujours transitoire, appartient à 2 sères distinctes:

i) La sère menant à la formation " deciduous Scrub " ; les forêts à *Pseudoberlinia* et *Brachystegia* y forment de nombreux consociés ou associés.
ii) La sère menant à la formation plus montagnarde " subtropical evergreen forest ", les forêts à *Brachystegia microphylla* y forment des consociés intermédiaires.

4) **Caténaire** (Morison, Hoyle et Hope Simpson).

III. AFFINITES ET DYNAMISME

Formations **naturelles,** lianeuses ou herbeuses suivant les cas, dégradées par l'homme, suivant le type du sol et le climat en savanes ou en steppes, arborées, arbustives ou non.

NOTES ON PLATEAU WOODLAND SOILS IN NORTHERN RHODESIA

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It is regretted that, since this paper was prepared at short notice at the end of the Conference, there was insufficient time to assemble more material. I hope, however, that the following remarks and observations will draw attention to the necessity for a thorough study of pedological conditions before the ecology of the woodland and dry forest types can be properly appreciated. Furthermore, systems of sylviculture and management must be based on an understanding of the dynamic trends of evolution and of the inherent potential of the site.

I should like to present to you two examples of the occurrence of woodlands in Northern Rhodesia and remark briefly on some of the soil features and affects.

The first example is the Copperbelt woodlands close to Ndola. The average annual rainfall of this region is between 45 and 50 in. Deep soils (sometimes over 100 ft. deep) have developed which belong to the zonal group of red yellow latasols or ferruginous earths. They occur over the schists and quartzites of the basement complex and over the dolerites, shales, sandstones and limestones of the Katanga series.

Generally speaking, the very deep regoliths which form under the intensive weathering and alteration by latosolic genesis mask, to a certain extent, the differences of parent material ; but textural variations do exist which affect the floristic composition and its development. There are also, undoubtedly, residual effects of minerals in the clay complex which again influence the vegetation, particularly with regard to iron hydroxides over the ferro-magnesium rocks and ferruginous sandstones and schists.

One point which must be noted regarding these deep latasols is that the upper soil need not necessarily have been developed on the present base rock.

These soils are controlled by the hydroxides of iron (and probably aluminium and manganese, in the clay complex. While structurally they are well developed and stable, they are very poor in bases and have an acid reaction. The principal phenomena are the accumulation of iron hydroxide enriched zones at varying depths where nodules or pisolites of iron oxide may form by " pseudo-crystallisation " processes and these pisolites will harden after oxidation and dehydration as will the whole iron hydroxide enriched zones.

Termites appear to play an important role in the formation of floats of pisolites and in the induration of the lithomarge.

Catenary transect studies show that the topography will condition the occurrence of these phenomena and also the degree of hydration of the metallic oxides. It is this factor which produces the characteristic colour change from red to yellow down a slope.

The position on a slope where concentrations of hydroxides are at a maximum has been found to be the point where, due to the presence of iron, structural development is optimal and the most favourable moisture regime obtains. It is here, therefore, that one finds the maximum occurrence of evergreen species, both in the canopy and in the under-storey thickets.

Where a permanent water-table exists at depth, the deciduous woodland will again give way to evergreen formations, but water-tables close to the soil surface give rise to hydromorphic soils bearing usually *Acacia* species. Where there is no permanent water-table, but good moisture conditions obtain, such as in the conditions already referred to, the development of a closed almost evergreen canopy can give rise to an extremely good vadose system.

Two points must be noted here. The first is, that if the vegetation is removed from an area having a permanent water-table, the water-table will rise and consequently the same vegetation type may regenerate. If, however, vegetation supported by a self-perpetuating vadose system is removed, the water regime will degrade and the area will be regenerated, in the initial stage at least, by a more xerophytic type of vegetation.

Another feature of the zone on the catena with optimum moisture conditions is that, if the canopy is opened or ground thickets are removed, then a rapid invasion of *Aframomum*, *Smilax* and *Pteris spp.* occurs. The decay of these species appears to give rise to an extremely stable type of humus which is neither readily oxidised nor destroyed by biotic agencies. This humus, which is thought to be largely composed of resins, gives rise to a ground vegetation of considerable luxuriance.

A last point concerning the type of rock folding which occurs : If on a slope the geological formation is synclinal, that is, with the strata outcropping against the slope, perched water-tables may occur which will give rise to the occurrence of evergreen and better-developed decidous types, following the porous strata and ranging over and against textural changes. Where the rock strata are anticlinal, then the whole catena may be of deciduous types except for the possible variations on the hydroxide-rich contour zones.

It is generally noted on the latasol catenas where no permanent water-tables exist that, on the removal of any one vegetation type, the site is recolonised by the type immediately up-slope from it.

On the Southern Province plateau of Northern Rhodesia, under a rainfall of 25–30 in. per annum, the soils developed are shallow in comparison with those of the higher rainfall areas and, in fact, on ridge tops may be only a few inches deep. Here the parent material has a most profound effect.

On each parent material, eluvial, colluvial and illuvial distinctions can be made. Different vegetation types can be related to different parent materials and the development and occurrence of each is again governed by slope and textural variations.

It is of interest to note that the Karroo formations overlying the basement in this region, range from coarse sandstones and conglomerates to silt and mudstone. On the latter a cracking montmorillonite clay has developed bearing *Colophospermum mopane.*

Here in Northern Rhodesia the climatic regime, coupled with generally poor edaphic conditions, has given rise to deciduous vegetation types on the pleateau except for the exceptions referred to. Everywhere the floristic composition, degree of development and vigour are governed by available moisture. The ranges for some species may be wide, but for many they are narrow, and moisture conditions may be especially critical for regeneration on cleared sites. It is especially noticeable that many species of *Isoberlinia, Julbernardia* and *Brachystegia* will regenerate in profusion, from both coppice and seedlings, on narrow fire-breaks or in small gaps within the woodland, even at the southerly limits of their clines. Regeneration, however, on cleared coupes will decrease as the size of coupe is increased.

Clements[1] in his work on ecology, used the available soil moisture concept, and this was further developed by Smith[2]. The " Chresard " or the water in the soil available to plant growth, has been shown by these workers to have considerable advantages as an index of practical value in determining the ecological potential of a site. Difficulties have been encountered, however, in determining the effective rainfall receipt, the field capacity and the wilting point level under field conditions.

Perreira[3] has recently demonstrated how the moisture receipt of a site may be more precisely calculated and Richards[4] has evolved a simple but reliable method of determining the moisture held at various pressures using the Pressure Membrane Apparatus.

By expressing the soil moisture as a percentage of volume it is, therefore, now possible to compare the available moisture ranges of different sites with some accuracy. This work is being developed here in Northern Rhodesia, as an essential preliminary to gauging site potential for the introduction of exotics ; but its value as a guide to the sylviculture and management of indigenous woodlands is obvious.

The last point I want to stress is that the soils of the Northern Rhodesian plateau are constantly undergoing changes from intensive weathering, alteration caused by termites, and the reactions of the vegetation types themselves. The whole ecological complex is highly dynamic and changes are constantly occurring due to these normal processes. Anthropic interference by fire or cultivation will accelerate or decelerate the rate of change and in many instances divert or halt the changes altogether. On the latasols, ultimate degradation may be reached by the exposure and induration of large tracts of laterite and lateritic nodules.

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