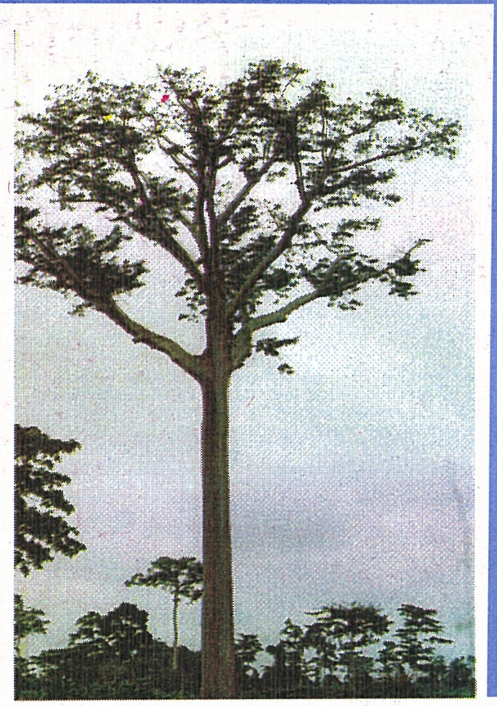
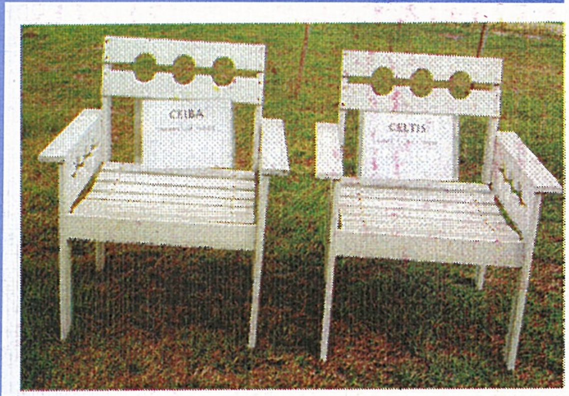
INTERNATIONAL CONFERENCE ON VALUE-ADDED PROCESSING AND UTILISATION OF LESSER-USED TIMBER SPECIES



FORIG * ITTO * TEDB
City Hotel, Kumasi, Ghana
17 - 19 February, 1998



FORIG ITTO TEDB GHANA

PROCEEDINGS

INTERNATIONAL CONFERENCE ON VALUE-ADDED PROCESSING AND UTILISATION OF LESSER-USED TIMBER SPECIES

ITTO PROJECT 179/91 Rev. 2 (M.I)

FORIG/ITTO/TEDB

City Hotel, Kumasi, Ghana
17 – 19 February 1998

PROCEEDINGS

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Cover photo: Products from some Lesser-Known / Lesser-Used Timber Species

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Contents

Foreword

The alarming rate at which the primary wood species have been dwindling from the Ghanaian forest has been a topic for discussion for sometime. But until the late 1980's, not much effort had been made to promote the utilisation of the Lesser-Used and Lesser-Known timber species to replace some of the primary species. Many serious debates and discussions have, however, been held within the timber industry sector, since the early 1990's, with emphasis on the imminent shortage of raw material supply to the industry. As a consequence of these debates, the Forestry Research Institute of Ghana (FORIG) undertook the responsibility of finding solutions to the problem. Consequently, a project proposal was submitted to the International Tropical Timber Organisation (ITTO) for funding. The principal aim was to look at the possibilities of promoting the Lesser-Known and Lesser-Used species whose availability in the forest was considered to be of potential economic interest, and whose physical and mechanical properties could also match those of most of the primary species, and could therefore become suitable substitutes.

The project spanned a period of 4 years. At the end of the project it was deemed necessary to present the results and recommendations made in the studies to the general public at a forum that would encourage exchange of ideas and experiences between the scientists, wood industry practitioners and the forestry sector as a whole. Such a forum was also considered as a suitable channel for promoting industrial utilisation and improved marketing of some of the lesser-used timber species.

The ultimate goal of the project was to enhance the marketing of products from Lesser Known / Lesser Used species to meet the development needs of the Ghanaian society. The project also sought to promote forest and environmental needs embodied in ITTO's target 2000, namely complete, sustainable management of the forest by the year 2000. The project further aimed to improve and upgrade research and development technology in the manufacture of export items such as sawn timber, veneer, plywood, joinery, wood cement board, wood-craft and furniture from the LUS under review. This technology was to be linked with specific market segments within the principal importing countries of Europe, America and the Far-East to upgrade the export-promotion techniques in order to make the products more price-competitive on the world market.

Another cardinal aim was to improve product acceptance by ensuring its sustainable production by making available the research findings on the effects of harvesting LUS on elements of the ecosystem important for maintaining the habit within which LUS and primary economic species regenerate and grow naturally. The project tried to improve existing harvest and silvicultural practices to increase sustainable management practices in the production forest reserves.

Through the implementation of product-development research and ecosystem studies in close association with the timber industries and export and marketing agencies, a linkage was achieved by engaging in studies aimed at analysing the utilisation and marketing of tropical hardwood products in Europe and America.

It is the linkage between product-development research, the market channel and consumer preference research data and the environmental research data that has now provided the basis for the unique aspect of this project. This co-operative research effort has provided the basis for the development of a method for linking the results. Generally the set aims of the project and Closing Conference were fully achieved.

These Proceedings highlight the results of the studies conducted under the Project and outcomes of the discussions held during the Conference. It has been presented to conform, as much as possible, to the general format of the Conference. Only those papers made available by the authors have been published in these proceedings.

Special thanks go to the ITTO, which provided funding for both the Project and Conference. All other support given by the industry and the general public to the Planning Committee, material, moral and otherwise, is highly commended. The Conference Organising Committee also extends sincere thanks to the Panel of Experts constituted at the Conference, whose guidance and recommendations made it all such a big success.

Finally, the Organising Committee wishes to thank all Conference participants for their worthwhile contributions and hope that the findings of the project and recommendation at the Closing Conference will help to promote LUS in the most effective way.

Dr. A.G. Addae-Mensah
(Chair, Planning Committee)

Summary of conference discussions and expert panel recommendations

Summary of Conference Discussions and Expert Panel Recommendations

Preamble

The International Conference on value-added Processing and Utilisation of Lesser-Used Timber Species was jointly organised by the Forestry Research Institute of Ghana (FORIG) and the Timber Export Development Board (TEDB), under the aegis of the International Tropical Timber Organisation (ITTO). The Conference took place in Kumasi, Ghana, at the City Hotel on 17 – 19 February 1998.

The principal objective of the Conference was to disseminate the results of a project titled '*Industrial Utilisation and Improved Marketing of some Lesser-Used Ghanaian Timber Species from Sustainably Managed Forests*' to the international scientific and industrial community. This project was funded by the ITTO under Project No. ITTO-PD 179/91 Rev. 2 (M.1).

Altogether, about 164 participants attended the Conference and contributed actively in the plenary sessions. Twenty-nine technical papers were presented and discussed under five broad themes, namely:

- Project overview;
- Ecology, hydrology and resource base;
- Processing and product development;
- Marketing and socio-economic issues; and
- Timber engineering and reconstituted wood.

Participants discussed salient issues brought up under the various themes outlined above. In the present section the general opinions expressed during the discussions, as well as the consensus reached, are summarised under the respective themes. The recommendations of an expert panel, appointed to synthesise salient issues discussed during the 3-day conference, are also presented.

Project overview

Participants generally agreed that researchers/academics and industrialists alike need more collaboration to work towards improved utilisation of LUS. This would require effective means of dissemination and application of currently available information. However, the approach must be consistent with sustainable forest management. The need to follow international trends by contacting the various digests that disseminate information on timber engineering, utilisation and marketing was emphasised.

Several sources of information on effective global overview of the progress of timber in construction were identified, including the following:

- 1984 - Pacific Timber Engineering Conference, Auckland, New Zealand, May. Chair: J. Little.
- 1988 - International Conference on Timber Engineering, Seattle, USA, September. Chair: R.Y. Itani.
- 1989 - Pacific Timber Engineering Conference, Auckland, New Zealand, August. Chair: G.B. Walford.
- 1990 - International Timber Engineering Conference, Tokyo, Japan, October. Chair: Hideo Sugiyama.
- 1991 - International Timber Engineering Conference, London, UK, September. Chair: C.J. Gill.
- 1994 - Pacific Timber Engineering Conference, Gold Coast, Australia, July. Chair: R.H. Leicester.
- 1996 - International Wood Engineering Conference, New Orleans, USA, October. Chair: V.K.A. Gopu.
- 1998 - World Conference on Timber Engineering, Lausanne, Switzerland, August. Chair: J. Natterer.
- 1999 - Pacific Timber Engineering Conference, Rotorua, New Zealand, March. Chair: G.B. Walford.

Utilisation of temperate (softwood) species was thought to be relatively easy due to advanced technology in that part of the world. Against this backdrop, the problems associated with the Lesser-Used Species (LUS) of the tropics were identified, namely the preponderance of too many species, usually with limited distribution and/or abundance, and which are likely to create problems for effective marketing.

It was agreed that, with the increase in quantity and quality of timber engineering related matters over the past two decades, it was possible for each country to develop its own technology that is suited to its climate, infrastructure, timber availability and performance expectations. This would help avoid wholesale importation of high technologies from other countries without the appropriate supporting facilities.

Ecology, hydrology and resource base

The conference discussed, *inter alia,* the following:

i. availability of the LUS and the dynamics of the resource base;

ii. assurance of the supply of timber to industry and the emerging market once their promotion has been successfully carried out, and

iii. the ecological impact on the forest after extracting more of the various species.

It was generally held that harvesting practices should be improved to make for effective utilisation of timber resources. For example, it was reported that for every cubic meter of wood removed from the forest, almost the same amount is left, usually in the form of utilisable branches and the butt end. Since trees sequester carbon, it appears that it would be appropriate to extract few but effectively utilise them.

Having regard to the fact that timber harvesting creates canopy gaps which affect the dynamics of the forest the need for a cut-off point for canopy opening to aid forest regeneration was debated exhaustively. The effect of excessive canopy opening on the hydrology of the forest in the form of excessive surface run-off, which accelerates the processes of soil erosion and the consequent siltation of rivers, was also discussed.

Further, it was observed that certain policy issues affect the utilisation of LUS and LKS. This was exemplified by several apparently conflicting policies implemented by Ghana's Ministries of Lands & Forestry and Mines & Energy, the Minerals Commission and the Forestry Department, which negatively affect the conservation of LUS and LKS off-reserve. The meeting agreed that such conflicting sectoral policies need to be streamlined through collaboration and consultation between the relevant institutions in order to promote the conservation of the LUS/LKS.

On LUS raw material expansion it was noted that an appropriate programme may have to be drawn up to embody silvicultural management and improved recovery by improving upon existing processing facilities. The way forward is through LUS conservation and propagation in plantation forest systems.

Processing and product development

Participants expressed common concern about the need for conversion technologies to meet the unusual difficulties of LUS. Much of the properties of the LUS are not known, at least to a wider segment of the consuming public. Therefore, the need to systematically study them becomes paramount. The present project concentrated on only a few species from which some prototype products were developed. The consensus was that the experiences gained from the present project should be extended to other LUS.

Marketing and socio-economic issues

Participant noted with concern the extremely competitive nature of the international furniture market. It was generally agreed that thorough market intelligence is imperative in order to penetrate it. This was viewed against the background of actual fashions, trends, designs, etc. as they influence customer preference for a particular product and/or species.

Within the framework of the present socio-economic context, it was realised that the introduction of LUS would require extensive and professional marketing campaigns. It was held that consideration should be given to consumer demand whilst, at the same time, attempts are made to promote the promotable LUS. In this direction, the need for co-operation between the producing countries, especially at the regional level in such areas as joint research and outreach, was emphasised.

Timber engineering and reconstituted wood

It was observed that the construction industry uses more wood than any other industry, and that with the dwindling abundance of the resource base of these prime species, LUS may be used in construction provided they are naturally durable or chemically treated to 'resist' fire and bio-degradation.

Research should continue to establish methods of preservation to ensure longevity of LUS both as a structural material and as components of reconstituted wood or panel products.

Conference resolutions

A panel of experts was constituted, as part of the Conference, to synthesise the salient issues discussed during the conference, and to make recommendations for further action in future. After thorough examination of the issues, the major recommendation of the expert panel was that all relevant institutions would need to work harder towards improved utilisation of LUS consistent with sustainable forest management. To give effect to the above recommendation the panel identified the following requirements:

- Dissemination and application of currently available information.
- International collaboration.
- Assured supply of timber.
- Marketing.
- Conversion technologies to meet unusual difficulties of LUS.
- Support for small-scale industries.

Conclusion

Delegates agreed that it is obvious that LUS has a future as substitutes for the prime species. However, producers and consumers alike should, as a policy, work towards their improved utilisation in a manner that is consistent with sustainable conservation of forest resources and effective support of social structures.

Pointing to the way forward, Dr. J.R. Cobbinah, Ag. Director of FORIG reiterated that though 68 species are harvested out of about 420 which grow to timber size in Ghana's forests, the trade is dominated by only about eight species. He underscored the ecological and socio-economic implications of increased utilisation of LUS and suggested possible ways of improving the future direction of the utilisation of LUS including the following:

- The need for updating information on distribution and abundance.
- The need for information on regeneration and plantation characteristics of LUS.
- Studies to improve recovery during logging and milling.
- Natural durability.
- Enhancement studies.
- Regulatory mechanisms to ensure that more LUS get to the market by reviewing the annual allowable cut for marketable species.
- Government of Ghana should promote marketing and utilisation of LUS through tax relief, low royalties and incentives for plantation development.
- Public education on the state of Ghana's timber resource with emphasis on the over-exploitation of prime species.

All told, the 3-day International Conference on Industrial Utilisation of Lesser-Used Timber Species was well attended, the discussions, interventions, and debates were lively, and the set objectives largely achieved.

Part I – Opening speeches

Résumé Des Discussions Et Recommendation du Jury d' Experts à la Conference

Préamble:

L' Institut de recherches Forestières du Ghana (FORIG) en conjointement avec le Bureau Bois d'oeuvre Export développé (TEDB) sous l'égide de 'l' ITTO (International Tropical Timber Organisation) ont organisé Une Conférence Internationale de la valeur ajoutée sur la Transformation et l'utitisation d'essence de bois moins-utilisé (LUS). La Conférence á eu lieu le 17 á 19 Fevrier, 1998 á Kumasi, au Ghana á l'Hôtel City.

L'objectif principal de la conférence en était de la diffusion des résultats de projet intitulé 'L'Utilisation Industrielles et le Marketing Amélioré pour des essences de bois moins-utilsé de bois d'oeuvre Ghanéen prevenant des forêts sous bonne gestion soutenue'. Ce projet a été finanacé par l'ITTO sous le projet No. ITTO – PD 179/91. Rev. Z (M.I).

Tout compte fait, environs 164 participants se sont présentés à la conférence et ont été contribué activement et ont assisté et ont eu des discussions en séancés plénières. Il avait en tout vingt-neuf d'articles techniques qui ont été présenté et discutaient sous les grandes lignes cinq des thèmes, à savoir.

- **Survol Du Projet** ;
- Ecologie, hydrologie et base des ressources
- Transformation et developpement des products ;
- Marketing et questions d'ordre socio-économique ; et
- Génie bois et bois reconstitué.

Les participants ont discuté des questions importantes evoquées sous les thèmes différentes dans les lignes générales au-dessus. Dans cette section les opinions exprimées lors de la conférence ainsi bien que les consensus qu'on a eus sont résumes sous les thémes respectifs. Les recomandations d'un jury d'experts élu pour faire la synthése des points importants sont aussi presentés ci-bas.

Survol du Projet

Les participants se sont mis d'accord sur le fait que les chercheurs / académiciens et industriels doivent collaborer davantage pour oeuvrer vers l'amélioration de l'utilisation du LUS. Ceci exigerait des moyens efficaces de diffusion et application des renseignements actuellements disponibles. Cepandant l'approche doit être en harmonie avec la gestion soutenable des forêts. Il faut les tendances internationales en contactant les magazins et journaux qui disséminent de l'informaton sur le genie de bois, l'utilisaton et marketing du bois a souligné la conférence.
L' on a identifié plusieurs sources, d'information sur le survol global du progrès fait dans l'industrie du bois y compris les suivants :

- 1984 - Conférence pacifique de Gènie bois d'oeuvre, Auckland, Nouvelle Zealand, Mai. Président J. Little.
- 1988 - Conférence International de Génie bois Septembré Président : R.Y. Itani.
- 1989 - Conférence Pacifique de Génie bois d'oeuvre, Auckland, Nouvelle Zealande, Août, Président ; G. B. Walford.
- 1990 - Conférence Internationale de Génie bois d'oeuvre, Tokyo, Japon, October, Président ; Hideo Sugiyama.
- 1991 - Conférence Internationale de bois d'oeuvre, Londre, U.K, Septembre Président : C.J. Gill
- 1994 - Conférence Pacifique de bois d'oeuvre, Londre, U.K, Septembre Président ; R. H Leicester
- 1996 - Conférence Internationale de Génie bois, New Orleans, Etats –Unis, Octobre, Président ; V.K.A Gopu.
- 1998 - Conférence mondiale de Génie bois d'oeuvre, Lausanne, Switzerland, Août. Président : J. Natterer.

- 1999 - Conférence Pacifique de Genie bois d'oeuvre, Rotorua, Nouvelle Zéalande, Mars, Président ; G. B. Walfore.

L'Ulilistation d'essence tempéré est supposé d'être facile grâce à la technologie avancée dans les pays developpés. Malgre cette analyse, les problèmes qui se posent aux pays tropicaux concernant LUS ont été identifiés, à savoir : la préponderance de trop d'essences habituallement avec la distribution limitée ou l'abondance et qui ont la tendance de créer des problèmes pour le Marketing efficace.

Il a été accepté qu'avec la croissance en qualité et quantité de la technique de l'exploitation du bois les questions relative depuis deux décennies, il a été possible pour chaque pays de developper sa propre technologie qui est convenable à son climat, d'infrastructure, la disponbilité du bois et les espérances de la performace. Ceci permettra à èviter l'importation en gros de hautes technologies des autres pays sans les facilités de support appropri é.

Ecologie, Hydrologie et Base des Ressources

La Conférence a discuté inter alia, les suivants

i) La disponbilite du LUS et les dynamiques de la base des resources
ii) L'assurance de la provision du bois d'oeuvre à l'industrie et le marché emergeant une fois qu'on a fait la publicité et la promotion nécessaire, et
iii) L'effet écologie sur la forêt après avoir prendre d'avantage de l'extraction des essences diffèrentes.

C'était d'accord d'une manière générale que la practique d'exploitation doivent être améliorés pour rendre efficace l'utilisation de bois d'oeuvre. Par exemple l'on a rapporté que pour chaque métre cube de bois exploité de la forêt presque le même volume est laisssé dans la forêt surtout dans la forme des branches utilisables et le gros but. Puisque les arbres sequestrent du carbone il semble bon et propre d'extraire quelques-uns de ces bois mais les utilise de manier efficace.

En tenant compte de fait que l'exploitation du bois d'oeuvre crée des vides dans la verdure, chose qui d'ailleurs affecte les dynamiques de la forêt, le besoin pour le point de couper pour la voute d'arbres l'ouverture à assister la regénération de la forêt a été discuté exhaustivenent.

L'on a également discuté l'effet de l'ouverture excessive dans la verdure compte tenu de son effet sur l'hydrologie de la forét en ce qui concerne l'erosion qui également accélére l'apport de la boue dans les fléuves.

En plus il a été observé que certains politiques affect l'utilisation du LUS et LKS (d'essence de bois mal connue). Ceci a éte exemplifié par plusiears politiques qui semble être en conflit (se contrédisent) mise en practique par les Ministres des Terres & Forestière et des Mines & le L'énergie, la Commission des Minérailles et le Department Forestière qui ont négativement un effet sur la conservation du LUS et du LKS hors réserve. La réunion est convaincue que de telles politique sectorielles conflituelles doivent être rationnaliser à travers la collaboration et la consultation entre les institutions en question afin de promouvoir la conservation du LUS / LKS.

En ce qui concerne l'expansion materielle il a été observé qu'en programmes appropriés dévrait peut-être être designé pour incorporer la gestion sylviculturelle et la reconverte améliorée par l'améliorisation des facilités déja existantes.
Le moyen de mettre en avant c'est la conservation du Lus et sa propagation dans les systéms forestiéres.

Transformation èt développment de produits

Les participant ont exprimé un souci commun sur la nécessité des technologies de conversion d'affronter les difficultés du LUS. Beaucoup des propriétés du LUS sont inconnues au moins à la devorante publique. Donc le besoin d'étudier systematiquement les devenir d'une suprême importance. Le projet actuel a été concentré sur peu des essences desquelle des produits prototypes ont été développés. Le consensus était qu'on doit porter loin vers d'autre, LUS les expériences gagnés du projet actuel.

Marketing et question socio-économique

Les participants ont noté avec concerne la compétition extrême sur le marché international des meubles. Un accord était intervenu entre les participants que la connaissance approfondi du marché était imperative pour la pénétration au marché. Ceci en prenant en compte les modes actuelles, les tendances et les dessins etc. car tout cela ont la préference des clients pour déterminer un produit particulieur et / ou une essence particuliére.

Dans le cadre du contexte socio-économique actuel il a été apperςu que l'introduction du LUS demanderait des campagnes de marketing profession d'étendues.

C'était d'accord que une considération devrait donner à l'exigence au consomateur tandis que en même temps on essaye de promouvoir le LUS plein de promesses.

Dans ce direction, le besoin de coopération entre des pays producteur particulièrement au niveau régional dans les domaines tels que la recherche en commun et de l'agrandissement a été souligné.

Génie bois et bois réconstitué

Il a été observé que l'industrie de la construction utilise plus de bois que tout autres industries et qu'avec des ressoures des base abondances en diminution des essences de ces premiers choix, LUS seraient utilisés en constructon à condition d'être naturelllement résistant ou ont été traités chimiquement à 'resister' du feu et biodégradation.

Les recherche doivent continuer à établir des méthodes de préservation pour assurer la longevité de LUS d'abord comme materiel structurel et puis comme composante de produit de bois réconstitué ou produits de boiserie.

Résolutions de Conférence

Un jury d'experts a été constitué pendant la Conférence, pour faire la synthése des questions saillant discutées lors de la Conférence et de faire des recommandations pour plus d'action dans l'avenir.

Aprés une examination approfondi des problèmes la recommandation majeure des experts fut que toutes institutions appropriees devront travailler plus dur pour assurer l'utilisaton améliorée de LUS en harmorie avec la gestion forestièe soutenue.

Pour faire un bon effect la mise en pratique des recommandations ci-dessus citèes le jure a identifiè les exigences suivantes.

- La diffusion et application de renseignments actuellement disponibles,
- Collaboration Internationale
- L'approvision du bois
- Le Marketing
- Les technologies de conversion pour affronter les difficultès de LUS
- Support pour l'industrie à l'echelle reduits.

Conclusion

Les délégués ont été du même avis que c'est évident que le LUS a un avenir comme un produit de remplacement pour des essenses de premier choix.

Il faut cependant une collaboration entre producteurs et consommaturs pour l'utilisation ameliorée du LUS d'une maniére qui est en harmonie avec la conservation sourtenue des ressources des forêts et le sourtien mésure des structures sociales.

Le DR. J.R. Cobbina, chef de FORIG par intérim a suggéré que bien que 68 espéces seulement sont exploités des 420 esences de bois dan les forêts ghanéennes, le commerce est dominé par 8 essences. Mettant l'accent sur les implications d'une utilisation du LUS, il a suggéré des moyens possibles d'améliorer l'orientation de l'utilisation du LUS y compris les suivants :

- Le besoin de mettre à jour les renseignements, sur La distribution et l'abondance
- La nécessitè des rénseignements sur la régénération et caractéristiques des plantations de LUS.

- Etudes pour améliorér le récouvrement pendant l'exploitation
- Durabilité naturelle
- Etudes de mettre en valeur
- Le mécanisme à régler d'assurer que plus de LUS entrer au marché étant révisé une diminution annuel permis pour des essences de bonne vente
- Le Governement de Ghana doit promouvoir le marketing et l'utilisation du LUS à travers le degrèment fiscal des basses rèdevances et des promes de rendement pour le développement des plantations
- Une education du public sur l'état des ressources de bois du Ghana, mettant l'accent sur l'exploitation excessive des espéces principales.

Enfin il y a eu une assistance nombrense à la conférence Internationale d'une durée de 3 jours sur l'utilisation Industrielle des Espèces de Bois moins exploitées. Les discussions, les interventions et les débats étaient animés et les objectifs visés ont été réalisés.

PART I: OPENING SPEECHES

Chairperson: Ashanti Regional Minister

Welcome Address

Prof. W.S Alhassan
Director-General, CSIR, GHANA.

Mr. Chairman, honourable Ministers of State, distinguished guests, ladies and gentlemen, I am indeed grateful to the organisers for inviting me to this conference to welcome such a distinguished gathering of scholars, experts and policy makers on the problems related to forest resources, particularly in the tropical world.

Mr. Chairman, the Forestry Research Institute of Ghana (FORIG) is one of the constituent institutes of the Council of Scientific and Industrial Research (CSIR) under the Ministry of Environment, Science and Technology. The Institute's involvement in planning and organising this conference is therefore an indication of government's commitment to ensuring that the forest resources of Ghana are properly managed. It is also indicative of CSIR's role in the promotion of Science and Technology in the country's development.

The problem in most tropical countries is that of uncontrolled exploitation of forest resources. Indeed the dependence on timber as one of the major foreign exchange earners has increased in recent times. Coupled with this is the ever-increasing population, which has resulted in the need for more agricultural land for feeding the people. Consequently forest depletion has been put into over-drive throughout the continent, at least where there is some forest cover.

It is in the light of these developments that issues relating to tropical forests are receiving more and more attention world-wide, not only in an attempt to arrest the problem of deforestation, but also to reverse its negative environmental consequences. Discussions on forest related problems are being held by most donor countries, international societies, international financial organisations, non-governmental agencies, as well as the local agencies, responsible directly or indirectly for addressing forestry issues, as part of the UNCED initiative. This conference, I am sure, is part of such a process.

Mr. Chairman, distinguished guests, ladies and gentlemen, to date forest management practices and policies have been tailored to solve most of the forestry related problems, but the problems still appear to exist owing to lack of adequate information about the natural forest ecosystem. In the forests of Ghana, hundreds of trees species grow to timber size and can provide wood for many purposes. Unfortunately, the trade in timber has for a long time concentrated on only a few 'prime' species. I am happy to note that this conference seeks to bring together experts in forestry research and the wood industry to discuss the results of research on the Lesser-Used timber species. The theme and objectives of this Conference are indeed within the broad framework of the requirements for achieving Ghana's Vision 2020. My challenge to you at this meeting is that your deliberations should focus on evolving suitable technologies for processing and utilisation of the Lesser-Used timber species. And to package such technologies for the greater benefit, not only of industry, but the economy of Ghana as a whole. The conference should also create a process that will provide us with the best tools with which to evaluate whatever set of guiding principles are inherent in our forest policy, and evolve methods, which would enhance sustainable management of our forest resources.

I am confident that the recommendations from this conference will make significant contribution to the improvement of wood processing and utilisation in this country, and lead to the broadening of the number of species that are in demand both locally and by the international market. Such a process will unquestionably bring about a substantial reduction in the pressure on a few species.

Mr. Chairman, I now have the singular pleasure and honour to welcome all participants to this conference. For those who are visiting Ghana for the first time, I hope the organisers will make it possible for you to enjoy the beautiful scenery of Kumasi and the countryside. I wish you every success in your deliberations, and a happy stay in Kumasi.

Thank you.

Statement by the Honourable Minister for Environment, Science & Technology

Hon. J. E. Afful

Mr. Chairman,

Colleague Ministers of State,

Distinguished Participants,

Ladies and Gentlemen,

It gives me great pleasure to address this international conference on value-added processing and utilisation of Lesser-Used timber species. I wish to take this opportunity to welcome all of you here, especially our foreign participants who may be visiting Ghana and Kumasi for the first time. I must say that I am indeed very glad to be here myself to share a few thoughts with you on the main theme of this august conference since activities in the timber industry impinge strongly on the environment.

Mr. Chairman, the forests of Ghana are known to be rich in terms of the diversity of species, both flora and fauna. These forests have over the years brought considerable economic benefit to the people of Ghana. However, uncontrolled forest exploitation could bring in its wake consequences that can affect the entire destiny of a people. This has led to growing concern in the last two decades or so over the depletion of tropical forests worldwide.

Mr. Chairman, I believe that this conference, apart from finding ways of expanding the use of the forest resources, also seeks to provide answers to questions related to the environmental impacts of harvesting, and I wish to say that this is indeed commendable. It is common knowledge that in the past, Ghana had considerable land coverage in terms of forests or vegetative cover. Over the years, however, with an ever growing population and the attendant increasing dependence on forest resources for timber, fuelwood, among a host of others, the area of forest land has reduced drastically. This situation is not peculiar to Ghana alone, since many countries in the humid tropics are faced with varying degrees of forest depletion for the same reasons.

Mr. Chairman, Ladies and Gentlemen, in consequence, the concern about tropical forest depletion has assumed a global dimension. Some of the global environmental issues that have captured the attention of the world community today include ozone layer depletion, desertification, acid rain, biodiversity conservation, and the related issues of increasing greenhouse gas emissions into the atmosphere contributing to global warming and climate changes, and many more. Indeed, the rapid rates of tropical forest depletion have now been closely linked to the issue of biodiversity and world climate change. It is important, however, that the extent of the linkage is clearly defined so as to place it in the proper perspective in relation to these issues.

It is clear, Mr. Chairman, that the forestry sector now faces a new challenge in the face of environmental issues being linked to natural forest resources exploitation. This is why the sector must give due cognisance to the response options available to ensure that the promotion of Lesser-Used species will lead to greater sustainability in the management of the forest resources. I believe that the options available in relation to both climate change and biodiversity should not be developed in isolation, but with due consideration and priority to the role of the forestry sector's contribution to the economy.

The general debate on the environment has come a long way, but in my view it has just began, for, until sustainable forest management is perceived as transcending traditional and conventional forestry practices to include the establishment of tree cover both in rural and urban areas, the debate will continue into the next millennium.

Ladies and Gentlemen, We all have a common objective and interest, and the responsibility to ensure that any new system that is evolved works in the best possible way. It would thus be timely at this meeting to reflect upon and review past forest management efforts and assess their impact or non-impact. This I believe, should be the way forward in developing strategies that would facilitate the achievement of our objective of harnessing and providing the many important benefits that we derive from our forests. Our vision of becoming a middle-level income economy by the year 2020 is very laudable but must not be realised at the expense of total depletion of available resources.

Mr. Chairman, I am particularly interested in the outcome of this conference, and I will be keenly following your deliberations over the next few days. I also look forward to receiving the outcome of this conference, which I am sure will be of immense assistance not only to the economy of Ghana, but to those of us who have an interest in our achieving our noble objective of sustainable development by the year 2020.

I wish you fruitful deliberations. Thank you.

Concerns of the Honourable Minister of Trade & Industry

Hon. Dr. John Abu

Mr. Chairman, Honourable Ministers, Ladies and Gentlemen, the Honourable Minister of Trade and Industry would like to apologise to the organisers of this seminar, his fellow Ministers, the research persons and to all invited guests for his inability to be with you physically today. His absence is due to an unforeseen circumstance. He sincerely apologises to you. He has however asked me to express his concern on certain issues.

Mr. Chairman, the forest is an essential resource for the country upon which manufacturing activity can be brought to bear to increase employment generation, export earnings and sustainable development.

The depletion of the tropical forest and other environmental concerns need the careful consideration of both the Government and the private sector if we are to make significant inputs into the big timber and wood export market. For instance, it has been observed that only 40 out of 680 timber species are being utilised and I believe this together with other reasons must necessitate intervention to develop the potential of the Lesser-Used species in order to reduce the strain on the traditional species.

Mr. Chairman, I believe the experts gathered here could help us to achieve this.

I wish also to caution the resource persons here gathered that during their deliberations, they should not lose sight of the fact that the country is faced with a depleting resource base which must be addressed through the mobilisation of a multi-purpose tree growing programme so as to expand the forest resources and tree cover to ensure continuous supply of wood and wood products.

The wood processing sector earned for the country in 1996, DM 222.1 million through export of wood products. The theme for the conference on "Industrial Utilisation of Lesser-Used Timber Species" should not limit itself only to the well-known timber industry alone. It should equally focus on the use of our timber and forest resources to support other emerging activities such as handicraft production and utilisation from Ghana. Handicraft export is partly wood-based in Ghana and is growing at a fast rate.

Handicraft producers should be equally trained in wood utilisation, cultivation and maintenance. We also need to explore hitherto unknown species of trees for the handicraft subsector. In this regard, the Ministry of Trade and Industry will continue to work hand in hand with its sister Ministries, Ministry of Environment, Science & Technology and Ministry of Lands & Forestry, to enhance the utilisation of wood for the handicraft industry.

The 1997 provisional figure indicates that the sector earned DM 280 million from export of wood products. The 1997 figure represents an increase of about 26.1% in terms of value. There is still room for improvement. To do this effectively requires joint effort of all stakeholders, so I will stress the need for the public and private sector to do away with tension and suspicion, which have characterised their dealings.

On behalf of the Ministry and on my own behalf I wish you successful discussions at this meeting.

Thank you.

Address by the ITTO Representative

Dr. Anthony Mapri Mainoo, Cameroon

Your Excellencies,

Ladies and Gentlemen

I feel delighted in being here in Kumasi where I represent the International Tropical Timber Organisation (ITTO) Secretariat in this International Conference on Industrial Utilisation of Lesser-Used Timber Species.

I would like firstly to express the gratitude of the ITTO Secretariat to the Organisation Committee for having extended the invitation to the ITTO.

As you all know, the ITTO objectives aim generally at promoting sustainable development of tropical forests. After 13 years of intense activities, a lot has been achieved towards this goal, despite limited means. The ITTO is considered to be nowadays a vast forum of consultation and co-operation, where 54 Producing and Consuming Member Countries represent about 75% of the world tropical dense forests and more than 90% of international market transactions of tropical wood products. Moreover about 319 Projects are being financed by the ITTO through out the tropical world for a total amount of over 130 million US$, 16% of these Projects being implemented in Africa, and among them the Project PD 179/91 (M,I) entitled: "Industrial Utilisation and improved marketing of selected Lesser-Used species from sustainable managed forest" under which the present conference is being convened.

The main preoccupation of ITTO since its creation in 1983 has already been to undertake all necessary actions in order to achieve the management of tropical forests on a sustainable basis. Three stages are worth being identified along the process of establishment of the Action Plan:

- 1989: Publication of a Document entitled "No timber without trees"
- 1990: Elaboration of Forest Management Guidelines setting up basic principles to be followed by managers and administrators of each country in its own forest practices;
- 1990: Adoption of the objective of the year 2000 that became since then the milestone of all activities of the ITTO;
- 1992: Elaboration and publication of criteria for the measurement of sustainable tropical forest management;

During the renegotiations of the 1994 Agreement, efforts were made to reinforce the commercialisation aspect of tropical timber by encouraging a better marketing of the exported products, the diversification and the broadening of the range of locally processed wood products. This can only be done with the logging, the processing and the utilisation of Lesser-Used wood species. The introduction of the non-traditional wood species to the market coupled with an efficient timber processing can in fact permit higher financial profits to accrue to the country without undue negative impact on the existing forest resources. In addition, one must note that within the sustainable management activities are also included the technical and commercial promotion of Unknown or Lesser-Known Wood Species. Research works have shown that the continuous logging of only prime timber species greatly reduced their stocks in the forests and, consequently the quality of extracted logs. These creamed forests become irreversibly impoverished.

It is the reason why among the ITTO supported projects implemented within the African Sub-region, 6 are closely related to Lesser-Used wood, species for a total financing of about 45 million US$.

We must confess however that the problem of unknown and Lesser-Known wood species has several facets. It is the reason why the 1994 Agreement has prescribed an international consultation on this theme.

In other respects, certain restrictive measures imposed on the tropical timber in some countries constitute a serious concern. Sustainable forest management when properly applied and especially the technical and commercial promotion of new species necessitate heavy investment in market research, development of new processing technology, machinery, product development and so on. How can a country invest so much on that if the commercialisation of the obtained products is uncertain? The ITTO member countries must seriously think how to get rid of these discriminating practices strongly decried by Article 36 of the Agreement.

The 1994 Agreement speaks also clearly of encouraging, stimulating the international co-operation and assistance through the transfer of technologies. Last December in Yokohama (Japan) it was decided that the Funds for the BALI partnership created by virtue of the Article 21 of the new Agreement will come into force this year. But are those unique funds enough to solve all these investment problems related to the promotion of Lesser-Used species in the tropical forests? I personally do not think so. We all, Government, Donor Agencies, existing Wood Industries must keep on looking for more means to cover all these heavy costs.

Your Excellencies,
Ladies and Gentlemen,

It can be easily understood from what is said above, that the promotion of Lesser-Used wood species necessitates a concerted effort of collaboration, co-ordination and organisation. I can assure you that the ITTO has a lot to offer in this respect.

This encounter gives us opportunity to think together about how to go about it.

In fact, it is quite clear that the topics on the promotion of Lesser-Used wood species can no more be ignored and our respective countries must address these matters with some urgency, for them to fully benefit from all their forest resources.

I feel confident that the outcome of this conference, will place us in the right position, and will foster the growth and development of our countries through sustainable forest exploitation.

Long live international solidarity and co-operation.

Thank you for your attention.

Keynote Address

Honourable Cletus A. Avoka
Minister of Lands & Forestry

Mr. Chairman,
Colleague Ministers of State,
Director-General of the CSIR,
Representative of the ITTO
Distinguished Scientists and Researchers,
Invited Guests,
Ladies and Gentlemen,

I deem it a great honour to be part of this august conference on value-added processing and utilisation of Lesser-Used timber species which has brought together experts and professionals in wood processing and utilisation from around the world to the timber metropolis of Ghana - Kumasi. Since this conference is the first of its kind in recent times, permit me to extend a warm and cordial welcome to our august visitors and guests to Ghana and Kumasi in particular. In the same vein, let me also thank the Planning Committee for selecting Ghana as the country to host such an important international conference. We wish to affirm that the selection of value-added processing and the utilisation of Lesser-Used timber species as the basis of the theme for this conference is indeed timely and relevant to our contemporary situation.

Mr. Chairman, I am reliably informed that this conference seeks to publicise and inform the timber trade and industry about the inherent potentials of LUS in various value-added processing end-uses.

I am glad for such noble objectives which will also provide the forum for presenting the results of the ITTO Project PD 179/91 - Industrial Utilisation and Improved marketing of some Ghanaian Lesser-Used Timber Species from Sustainably Managed Forests. The Ministry upholds these objectives which complement the objectives of the Forestry Development Medium Term Plan. We hope that the output of this conference will provide informed knowledge on value-added processing of forest products, transfer of technology to industry as well as improve and provide a better industrial perspective on timber processing in general.

Ladies and Gentlemen, with the inception of the fourth republic, the Ministry pursued policies based on sustainable forest management principles with the ultimate aim of transforming the timber trade from volume-oriented-less-value activity to a less-volume-high-value business. Six years after implementing these policies, there is no gain saying that the timber industry has been reaping some positive results. Growth in export of tertiary wood products has been quite remarkable. More tertiary wood products are being processed for export and the proportion of the value-added products in the total wood exports has been steadily increasing as investments into the tertiary wood-processing sector continue to grow.

Mr. Chairman, in spite of the modest achievements, the wood industry is plagued with certain problems, which have constrained growth and development especially in tertiary wood processing. Among these problems are:

i. An over concentration on few species. It is on record that out of about 420 different species of timber trees in Ghana, the wood industry relies on only about 32 species as the main traditional export species. This represents about 8% of the total timber species in Ghana. About 9 of these prime species are almost commercially extinct and the rest are being seriously threatened.

ii. Over-capacity of mostly out-dated and inefficient milling equipment, rated at an intake capacity of 2 million cubic metres of round logs per year in contrast to the Annual Allowable Cut of 1.0 million cubic metres;

iii. The reluctance of processors to explore new products and markets thereby reducing Ghana's percentage share on the international wood market.

Ladies and Gentlemen, with the annual allowable cut of 1.0 million cubic metres the problem of over-capacity within the industry and the over-reliance on few commercial species has become more pronounced, thus posing a threat on the long-term sustainability of the timber industry.

I am glad to observe that our efforts at encouraging the processing of promotable pink species have began to yield some results thereby providing some solution to the problems constraining the industry.

The increased utilisation of LUS has indeed upgraded existing manufacturing methods and improved export promotion technologies in LUS. More mills have established new production lines to produce sliced and rotary veneer, plywood, and mouldings using LUS. In the furniture and construction sub-sectors, diversification in the use of more LUS with comparable or even superior properties as the traditional species has boosted their activities.

From the national economic point of view, the increased utilisation of LUS has generated more job opportunities, introduced new technologies in wood processing, boosted the construction and housing delivery activities and significantly increased the royalties paid to stools and District Assemblies for the provision of more social and technical infrastructure at the local levels.

Mr. Chairman, although the industrial and marketing aspects of LUS have received considerable support, we need also to assess the consequences of an increased utilisation of these timber species. We need to investigate the ecological, economic and social impacts or consequences of increased utilisation of LUS. To date, this aspect has received peripheral attention. Therefore, we cannot tell whether increased harvesting and utilisation of LUS can contribute to sustainable development. This is a challenge to the scientists and researchers. We need the futurist to predict how the ecological, economic and social structures would look like if we continue harvesting LUS at present rates.

Ladies and gentlemen, in recent times, some members of the Ghana Timber Trade and Industry, reasoning from the increasing international demand for LUS, have suggested to Government to consider lifting the suspension imposed on log exports so that they can export in round log form some LUS that are not currently being milled. The request is still under review by the Ministry. However, I wish to call on the Research Scientists and Forestry practitioners herein gathered to deliberate on this issue and advice the Ministry accordingly. We as a nation need to consider carefully the following three issues:

a. Whether Ghana can afford to sustain the export of round logs (whether traditional or LUS) alongside the need of its domestic industry without permanently destroying its forest resource base;

b. Whether indeed some LUS which are not currently being processed domestically could not be processed using new technologies instead of considering them for export;

c. Whether it is economical to export round logs in the wake of the fact that, the more cherished primary timber species are commercially extinct.

Mr, Chairman, we do not need to play polities with issues concerning a resource which can be described as conditionally renewable. If we hurriedly deplete our scarce timber resources through unsustainable practices, posterity will hold us responsible for such behaviour. We need to guard against unwise decisions that in the long term will contribute to net losses to the country.

In my view, there is the need to modernise the wood industry, re-direct investment in tertiary wood processing and promote growth in the export of value-added products. We need to inject efficiency into the timber industry so that producers can achieve higher performance in sawing and precision in machining, obtain better output during kiln drying of lumber, improve the quality of further processing and finishing, speed up the processing of orders, and adhere to contract terms and delivery on time. If these qualities were attained, then the Ghanaian exporting companies would improve their image as reliable suppliers of value-added products on the international market.

The Wood Industry Training Centre has been established to provide improved technology and build the human resource capacity needed for the timber industry to take-off. It is hoped that the industry will take full advantage of its opportunity and facilities.

Mr. Chairman, very soon the Timber Resources Management Act will come into force. This law will among other things, inject discipline into the timber industry, award timber utilisation contracts in a transparent manner, ensure efficiency in milling and management of the industry and improve accessibility to raw materials. All these are aimed at enhancing the sustainable management of timber resources. I therefore invite all stakeholders to study the law and its regulations more closely so that it can be applied without much difficulty.

Ladies and gentlemen, before I conclude, I would like us to take a closer like at the following research needs which have to be investigated:

- End uses for the largely untapped Lesser-Known species in our forests:
- What operators in the industry can do to meet consumers' taste and stay competitively on the international market;
- How Ghana can take advantage of the huge "do-it-yourself" market for unpainted finished products, such as furniture parts, railing mouldings, flooring and finished items, to promote acceptance of secondary species;
- How to promote timber preservative treatment of these LUS to meet various end-used in both the domestic and international markets.

Ladies and Gentlemen, it is important for the industry to develop a closer relationship between science, technology and policy. The Forestry Research Institute of Ghana must play a pioneering role in pursuing information sharing and technology transfer. Conclusions and findings of national and international conferences must be made available in reducing volumes and in simple clear language to benefit the ordinary citizen. I believe the era where research findings gathered dust in the shelves is over. Researchers need to be more aggressive in disseminating their findings so as to bring the African timber industry at par with technologies in other advanced producer countries.

Mr. Chairman, Ladies and Gentlemen, on behalf of the Government of Ghana, I wish to extend our appreciation to the ITTO for funding the project on LUS in Ghana and also for sponsoring this workshop. Indeed the contribution of the ITTO in the Ghanaian timber sector has been very remarkable and we are very grateful.

Distinguished Participants, the whole tropical world is awaiting the outcome of this conference. Considering the objectives you have set for yourselves you must not fail the people. I am confident that with such a distinguished gathering of Research Scientists, Forestry Practitioners, Policy Makers and representatives of Donor Agencies and the timber industry, these discussions would be lively and productive. To those of us who are visitors to the Country, I am confident that you will enjoy the usual Ghanaian hospitality and would wish to come back again to join us in this crusade. To those of us living in Ghana, I wish you well and a total commitment to this conference.

Mr. Chairman, it is my privilege and honour to officially declare this International Conference duly open.

Thank you very much for your audience.

God bless you.

Part II – Technical sessions

Technical Session I: Project overview

PART II: TECHNICAL SESSIONS

Technical Session I: Project Overview

Chair: Mr. E. Kofi Smith, Technical Director, MLF

International Trends In Timber Engineering And Utilisation Of Lesser Used Species

Dr. R.H. Leicester
CSIRO, Australia

Introduction

During the past 20 years, there has been a quantum leap in the technology of timber engineering, particularly with respect to understanding the characteristics of timber structures. This has been primarily due to the increased interest of academics in the topic of timber construction; however, some of it has also been due to architects concerned with designing prestige structures, while some is also undoubtedly due to the favourable costs incurred by using timber for certain classes of residential and commercial construction.

There is now an immense quantity of literature on timber construction, but much of it is difficult to access. However, an effective global overview of progress can be found in the papers presented at the following international conferences:

- 1984: Pacific Timber Engineering Conference, Auckland, New Zealand, May. *Chairman*: J. Little;
- 1988: International Conference on Timber Engineering, Seattle, USA, September. *Chairman:* R.Y. Itani;
- 1989: Pacific Timber Engineering Conference, Auckland, New Zealand, August. *Chairman:* G.B, Walford;
- 1990: International Timber Engineering Conference, Tokyo, Japan, October. *Chairman:* Hideo Sugiyama;
- 1991: International Timber Engineering Conference, London, UK, September. *Chairman:* C.J. Gill;
- 1994: Pacific Timber Engineering Conference, Gold Coast, Australia, July. *Chairman:* R.H. Leicester;
- 1996: International Wood Engineering Conference, New Orleans, USA, October. *Chairman:* V.K.A. Gopu;
- 1998: World Conference on Timber Engineering, Lausanne, Switzerland, August. *Chairman:* J. Natterer;
- 1999: Pacific Timber Engineering Conference, Rotorua, New Zealand, March. *Chairman:* G.B. Walford.

Another good source of information are the proceedings of the meetings of CIB-W18 (International Council for Building Research Studies and Documentation, Working Commission W18-Timber Structures). These meetings are held annually; the 30th Meeting was held in Vancouver in 1997; the proceedings of these meetings contain about 450 papers, mostly on research in structural mechanics. Most of the information in these proceedings relates to softwoods used in temperature climates. Some information on engineering with hardwoods in tropical climates is given in the CIB-W18B Conference held in Malaysia in 1992 (Malek *et al*, 1992).

Good overviews of specific topics are to be found in a set of UNIDO lectures prepared by CSIRO, Australia (UNIDO, 1985), a set of timber engineering lectures prepared by an European group (Blass *et al*, 1995) and a useful guide to practical information prepared by NAFI, the National Association of Forest

Industries, Australia (NAFI 1989). International trends are best followed by reading digests such as World Wood Review (e.g. Widman 1997) and overview papers (e.g. Murray 1991).

The following text contains a brief overview of the various significant developments that have occurred during the past two decades. The references cited have been chosen solely as examples, and are intended to be neither comprehensive nor the best ones available.

Structural Mechanics

Fracture Mechanics

If linear elasticity is used to analyse structural elements containing sharp notches or manufactured cracks (such as the butt joints in glulam) such as for the examples shown in Figure 1. It will be found that the predicted stress at the notch root or crack tip is infinity. Hence, fracture initiation at a notch root is related to a stress intensity factor rather than stress. Methods for computing the stress intensity factor for practical cases have been described previously (Leicester 1974, Walsh 1974, Leicester & Walsh 1982).

For the case of a butt joint, Figure 1b, the nominal stress at failure σ_{ult} is related to the critical stress intensity factor k_{1c} by

$$\sigma_{ult} = \frac{k_{1c}}{\sqrt{2\pi a}} \qquad (1)$$

where 'a' denotes the lamination thickness and hence also the crack length. The factor k_{1c} depends on the species of timber.

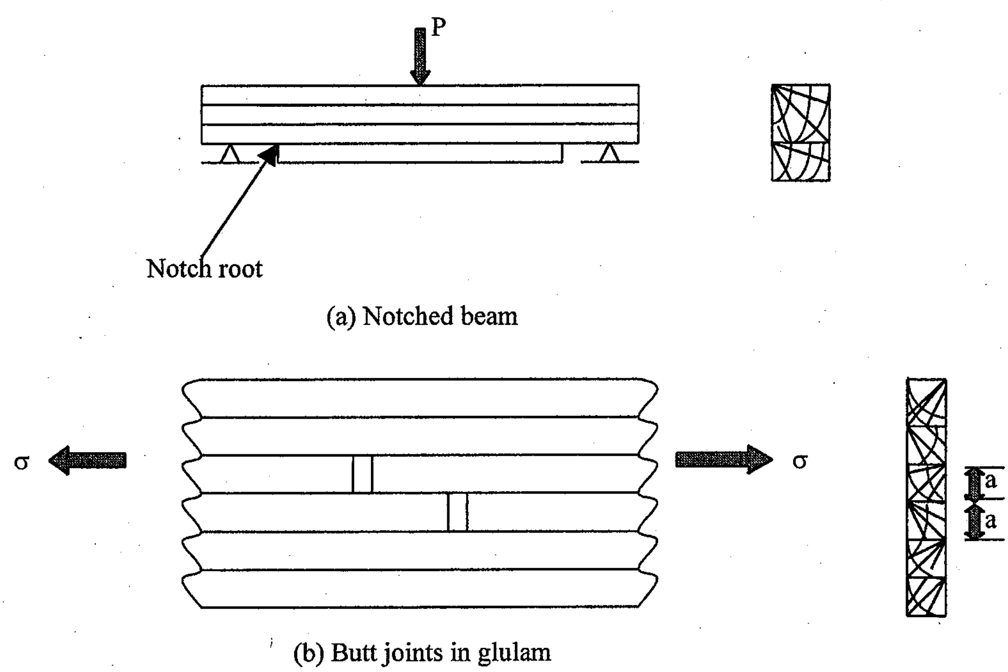


Figure 1. Examples of stress singularities

Bucking of Slender Members

Timber structures are often fabricated with members that are sufficiently slender that they have the potential to fail through a bucking mode. The mathematics of failure through a bucking mode can be extremely complex, and the successful design against such a failure mode is dependent to a large extent on developing simple design procedures for coping with this mode. In AS 1720.1, the Australian Timber

Engineering Design Code (Standards Australia 1997), the nominal failure stress of a slender member, denoted by σ_{ult} is given by:

$$\sigma_{ult} = k_{12}\sigma_{stable} \qquad (2)$$

where σ_{stable} is the ultimate strength if the member were stable and k_{12} is a stability factor; in AS 1720.1 k_{12} is specified as a simple function of member geometry and material properties. This format has been used to introduce many complex failure modes such as those related to beams, plywood webs and spaced columns (Leicester 1972, Leicester & Pham 1984).

Load Duration Effect

If a structural element is loaded continuously to a high stress level, its long term strength will be considerably reduced relative to its short term strength. Many theories have been proposed to explain the load duration effect (e.g. Foschi & Barrett 1982, Madsen 1992) and the results have been incorporated into design codes such as AS 1720.1.

Mechano-sorptive Effects

Probably one of the most amazing characteristics of timber is its deformation response when subjected to moisture cycling while stressed (Leicester 1971a, Toratti 1992). This is illustrated in Figure 2. The mathematics of this is usually expressed by use of a mechano-sorptive element combined with the usual springs and dashpots. An example of this is given is Figure 3. The deformation of a mechano-sorptive element, denoted by ε_{ms} is related to the applied stress σ and moisture change Δ_m by:

$$\varepsilon_{ms} = A\sigma\Delta_m \qquad (3)$$

where A is a constant that depends on the moisture content.

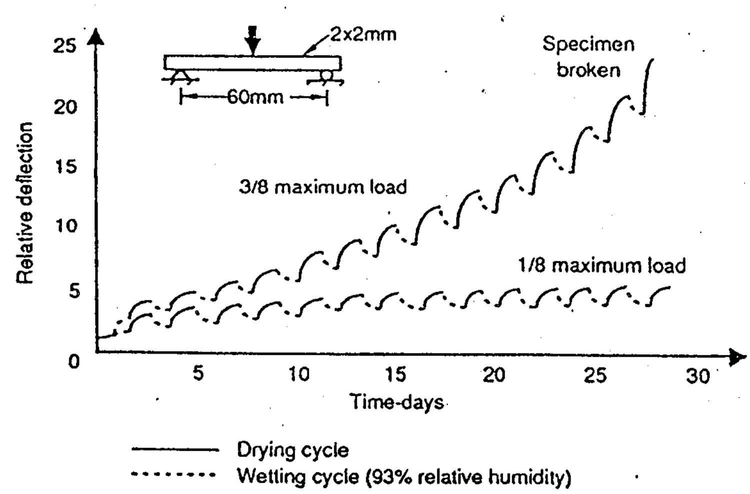


Figure 2. Load carrying wooden beam subjected to moisture cycling.

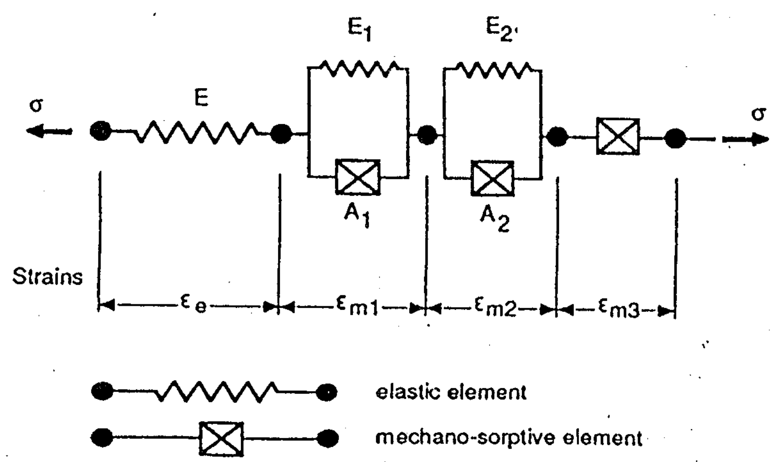


Figure 3. Typical schematic model for the mechano-sorptive deformation of a wood element

An obvious application of mechano-sorptive concepts is in the prediction of building deformation under long duration loads. A less obvious but equally interesting application is to use the theory to assess the redistribution of stress with time, Figure 4. This can lead to a reduction with time of the predicted load carrying capacity of a structural element such as those shown in Figures 5 and 6.

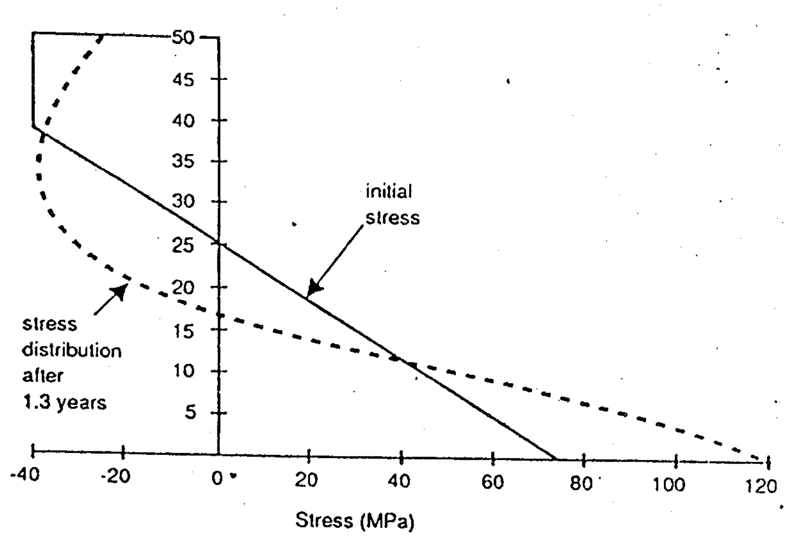


Figure 4. Computed stress redistribution of a beam due to mechano-sorptive effects (after Lu and Leicester 1994).

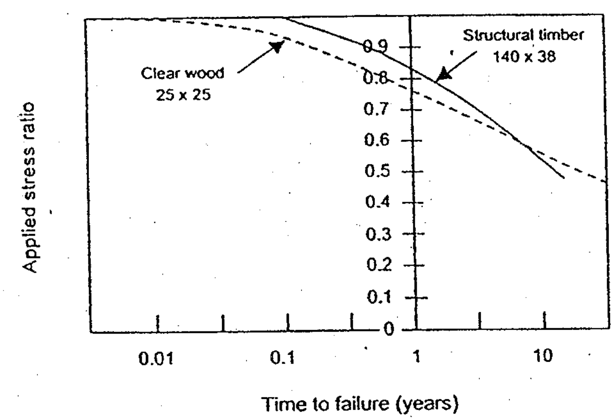


Figure 5. Theoretical prediction of time to failure due to mechano-sorptive effects (after Lu and Leicester 1994).

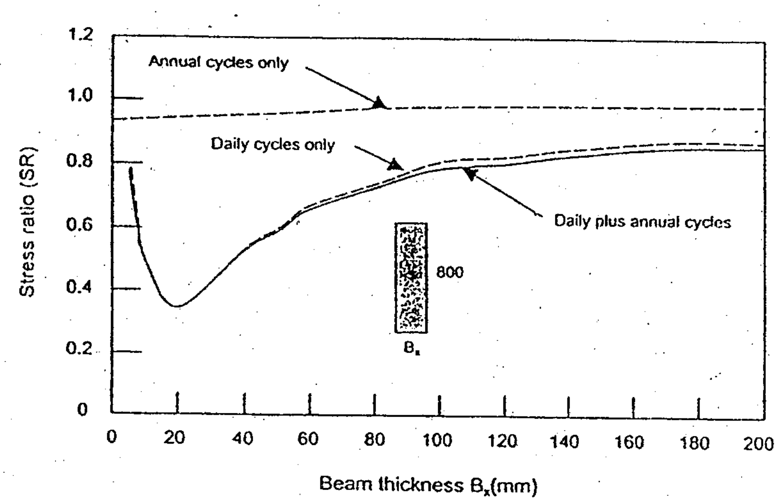


Figure 6. Theoretical prediction of stress ratio to cause failure in 20 years due to mechano-sorptive effects (after Lu and Leicester 1994).

Combined Effects

When some of the above effects are combined, some quite complex phenomena can occur. For example, consider a column under long duration load (Leicester 1971b, 1972). The buckling effects are increased by mechano-sorptive effects, and failure stress is reduced by the load duration effects. These matters have been considered in deriving the design rules for AS 1720.1

Another interesting example is the influence of mechano-sorptive effects to create internal stresses that can have a dramatic effect on the fracture strength of timber, particularly at the roots of notches. Interesting examples of this effect were given at a 1996 COST 508 Wood Mechanics Conference in Stuttgart (Jensen and Hoffmeyer 1996, Ranta-Maunus 1996).

Glulam

Because of their large size and expense, the strength of glulam is usually assessed by theory rather than by direct testing. The best procedure available at the moment is based on Norwegian research (Falk et al 1992). The results are stated in the following form for the bending strength of glulam beams, denoted by σ_{glulam},

$$\sigma_{glulam} = k_{lam1}\sigma_{FJ} \tag{4a}$$

$$\sigma_{glulam} = k_{lam2}\sigma_{stock} \tag{4b}$$

where σ_{FJ} and σ_{stock} denote the tension strength of the finger joints and the stock material of the laminates respectively, and k_{lam1} and k_{lam2} are laminating factors, typically in the range 1.3 - 1.5.

Structural Size Timber

Prior to 1970, the characteristics of timber were assessed on the basis of the characteristics of small clear pieces of wood. However, following the extraordinary pioneering work by Madsen (Madsen 1992), it was realised that this could be quite misleading. This is because the strength of structural size timber is heavily influenced by the presence of natural features such as knots, pith etc.

Two examples to illustrate the difference between the behaviour of small clears and structural size timbers are shown in Figures 7 and 8. In Figure 7 it is seen that seasoning the timber improves the strength of small clear wood specimens and also the average strength of structural size timber. However, at the 5-percentile level, the characteristic value used for design purposes, the seasoning has no effect on structural size timber. A similar effect is noted in the measured load duration effects shown in Figure 8.

Metal Connectors

Dowel Connectors

The yield loads of dowelled joints systems, such as for example, nailed and bolted joints, are very well predicted by a yield theory, often referred to as the European yield theory (Larsen 1994, Aune & Patton-Mallory 1986). By assuming that the steel dowel has a plastic moment capacity M, and the wood has a plastic yield bearing strength q per unit length of dowel, the yield load capacity of a joint system can be computed. A simple example of this is illustrated in Figure 9.

This yield theory is elegant and simple to apply: it is used in EC5: Design of Timber Structures Part 1-1 (Eurocode 5 1993). Some caution should be exercised in applying the yield theory because it covers only one mode of failure; for example, it does not take into consideration the potential for a failure through splitting.

Nail Plate Connectors

Another elegant theory for joints is one that has been developed for joints fabricated with nailed plate connections (Kallsner & Kangas 1991, UEAtc 1979). This theory takes into account the fact that these joints have many potential modes of failure: as a result, the strength for each mode must be evaluated as input data for the design procedure, Figure 10. This theory is also used in Eurocode 5.

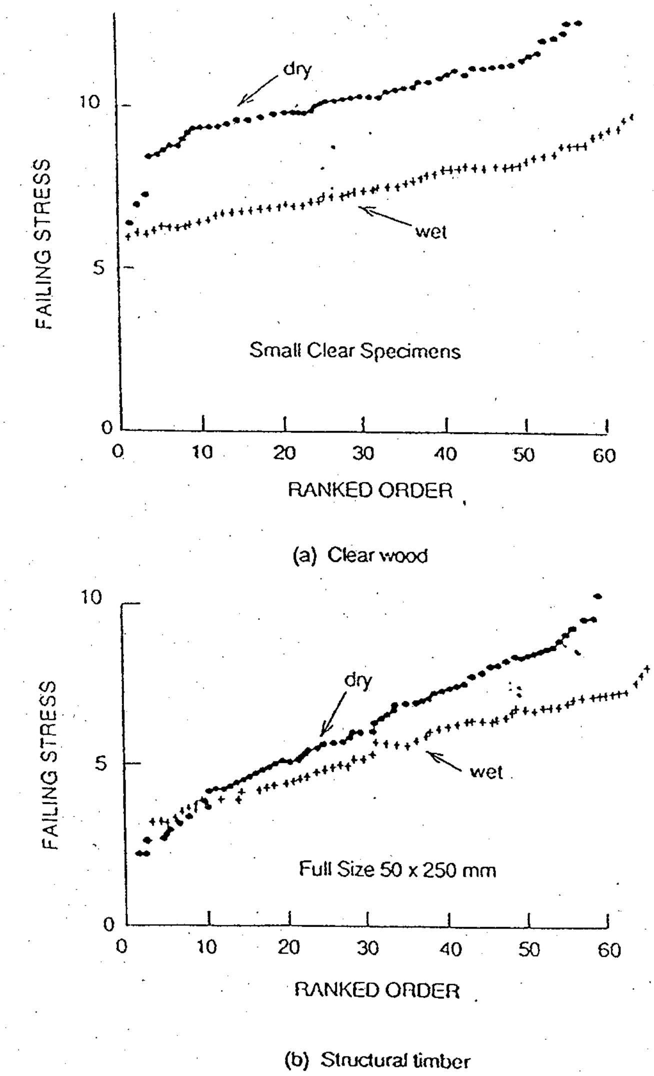


Figure 7. Effect of moisture on the bending strength of timber (after Madsen 1972).

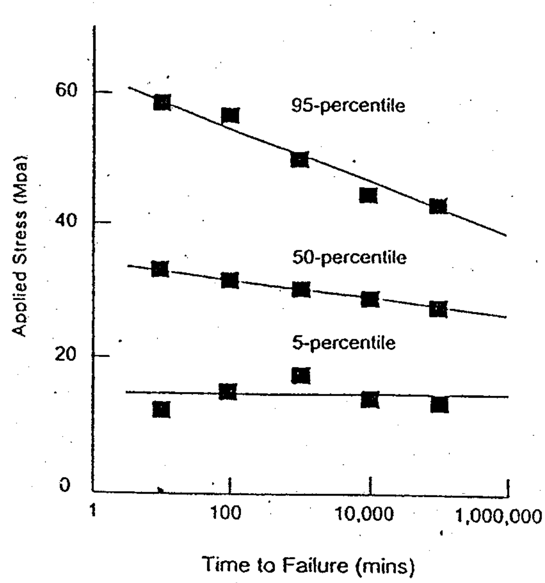


Figure 8. Effect of load duration on strength of dry timber (after Madsen 1971).

Special Connectors

The metal connector technology today is dominated by the fact that numerous metal connectors for special purposes are invented and applied each year. There is no time to undertake research to develop predictive models for each of these connectors. Accordingly, nearly all of these are evaluated from load testing; standards for such load testing is now a prime focus of much activity by various standardising agencies and research groups (Foliente & Leicester 1996).

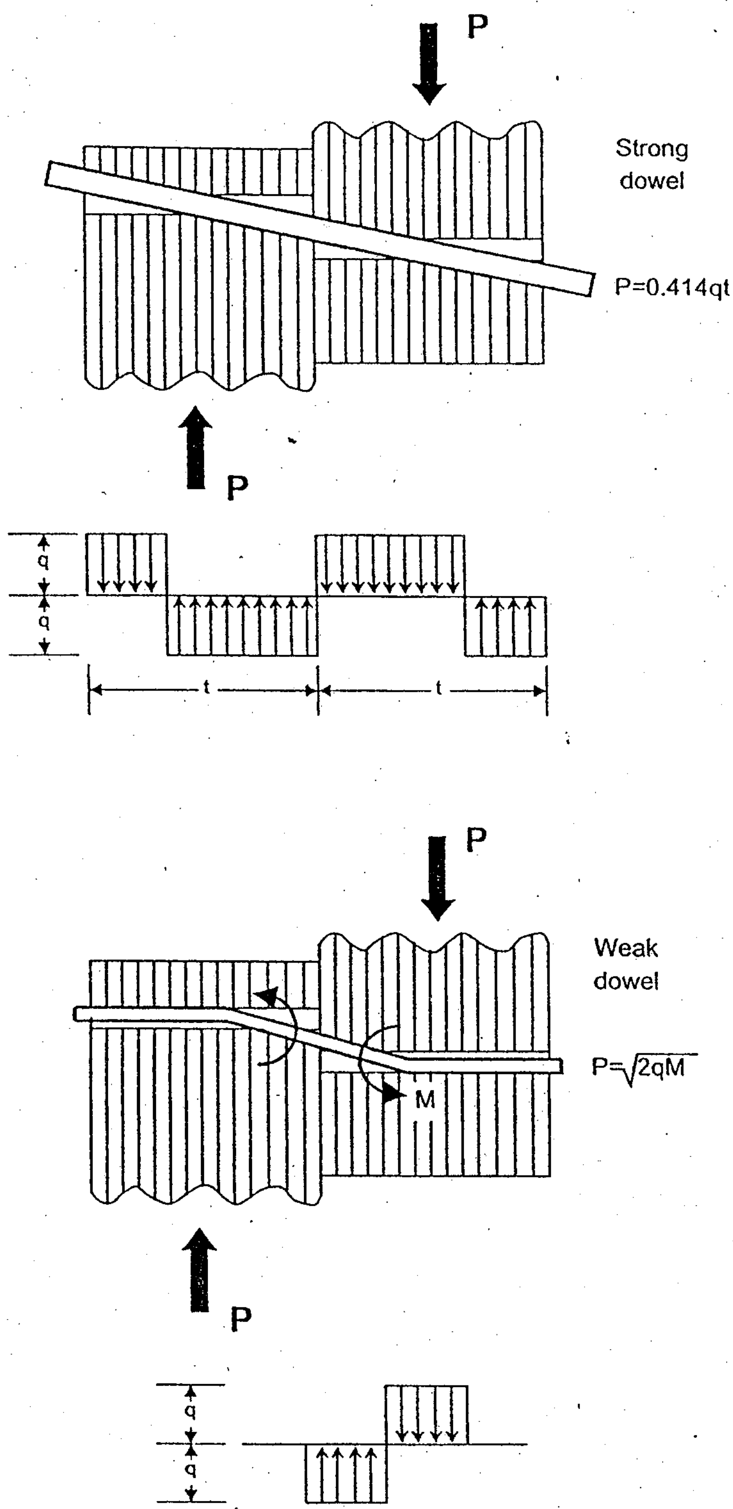
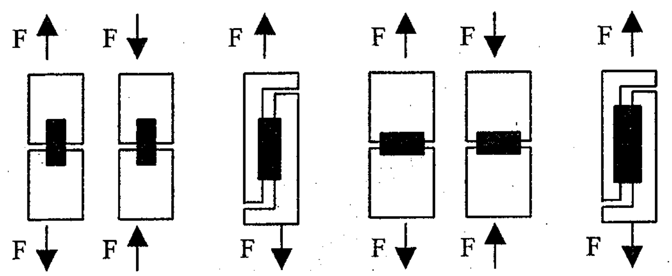
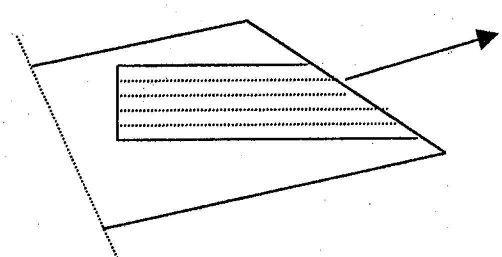


Figure 9. Examples of failure models for dowel connector.



(a) Load tests to obtain design properties



(b) Typical in-service load configuration

Figure 10. Load configurations for nail plates

Glued Joints

Durability

Glue can be used to make very effective joints. Immediately after fabrication, they are usually extremely strong; however, since their strength lies in chemical bonding, there is always a question about their long-term strength.

For some types of glues such as resorcinols and phenolics, it is well known that if the joint demonstrates a predominantly wood failure in a soak and chisel test, then the long-term strength will be excellent. However, for some other glues such as melamine fortified urea formaldehyde, there is a debate on the long term effects when used in an environment of tropical temperatures and humilities.

An interesting development during the past decade has been to form high capacity joints for connecting large members by using epoxy to glue embedded steel rods to these members (Buchanan & Deng 1996, Madsen 1996). The indications are that by selecting the correct formulation of epoxy, the joints will also have excellent long-term strength (Clorius *et al.* 1996).

Fabrication Quality

Laminates for glulam structures are often formed by end-jointing short pieces of timber by glued finger joints. This fabrication is done at high speeds and even when a great deal of care is taken, it may be expected that at least 1 in 10,000 joints will be effectively a non-joint. This joint then acts as a butt joint in the glulam and according to Equation (1) reduces the tension strength of the glulam to about a quarter of its strength without the but-joint effect. For small structures this may not matter. However, for large structures there may be something like 10,000 finger joints within the critically stressed zones and the chances of encountering a non-joint in the critical zone is too high to ignore; if the structure is such that failure of a single member would be catastrophic, then the only solution is to ensure that all laminates are proof tested in tension prior to fabrication into glulam beams. This procedure was followed in the fabrication of glulam for the large span dome and exhibition building erected for the coming 2000 Olympic Games in Sydney, Australia.

Structural Reliability

In-Service Risk

The most important target in structural design is to control the risk of failure. Hence, one of the most significant advances in structural engineering has been to develop computational procedures for assessing the probability of in-service failure.

The simplest problem of this type, illustrated in Figure 11, is to consider a single element of strength 'R' and a single loading that gives rise to a load effect 'Q'. Both 'R' and Q are random variables. The probability of failure p_F is then defined by

$$p_F = \Pr \{R<Q\} \qquad (5)$$

the probability that R will be less than Q, given a random choice of R and Q.

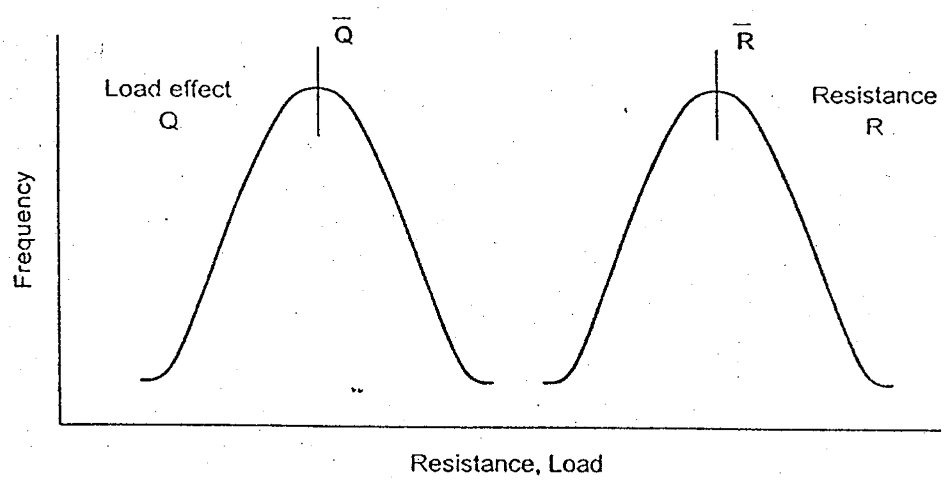


Figure 11. Representation of strength and load effect as random variables.

Procedures for computing P_F have been extensively researched. A basic procedure has been described in a previous paper (Leicester 1985). Quite involved problems can be solved, including problems that involve deteriorating structures, dynamic loads (such as earthquake or hurricanes) and load combinations.

For legal reasons, it is often preferable to discuss a safety index rather than a risk of failure. One useful definition of the safety index β is

$$\beta = -\log_{10} (P_F) \qquad (6)$$

So for example, a probability of failure $P_F = 10^{-4}$ will correspond to a safety index of $\beta = 4$. From Equation (6) it is seen that larger safety indices correspond to smaller probabilities of failure.

The selection of an appropriate risk level for design codes can be based on calibration to existing codes, or alternatively, to choosing risk levels that represent an optimised balance between the cost of structural elements and the effective cost of any failures. A procedure for optimising risk levels has been given in a previous paper (Leicester 1984).

Extensive studies have been undertaken in USA (Ellingwood *et at.* 1980), Canada (Foschi *et al.* 1989) and Australia (Leicester *et al.* 1986) to assess the safety of existing and proposed structural design codes. An example from the Australian study is shown in Figure 12; it indicates that at the time of the study the safety implied by the proposed timber engineering design codes was less than that given by the corresponding steel, concrete and composite material codes.

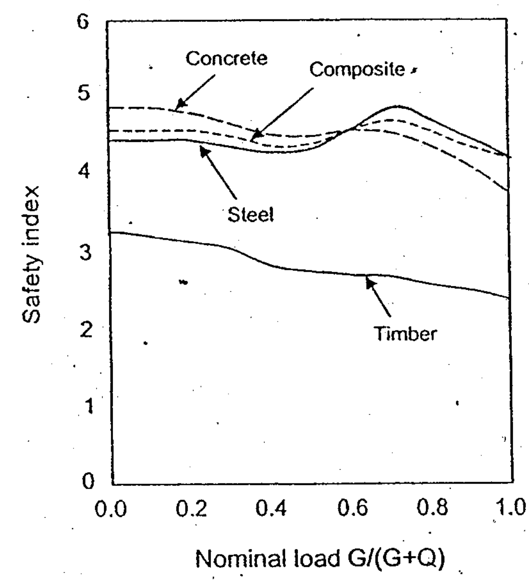


Figure 12. Comparison of safety levels for beams subjected to load effects due to dead weight G and floor live load Q (after Leicester et al. 1986).

Proof and Prototype Testing

Proof and prototype testing are two commonly used methods for the appraisal of product strength.

In proof testing every structural unit approved must first demonstrate its ability to sustain a specified proof load. In prototype testing, a whole population of units is accepted on the basis of tests on a limited sample of units.

One of the benefits of reliability theory is that it provides a rational procedure for deriving the test loads that should be used in proof and prototype testing (Leicester 1987, 1992). These procedures were used in the development of the Australian Timber Engineering Design Code AS 1720.1.

In-grade Testing

One of the special applications of prototype testing is the evaluation of the design properties of stress-graded structural size timber.

Prior to 1970, most assessments of the structural properties of timber were based on the measurement of the properties of small clear pieces of wood. However, Madsen (Madsen, 1992) showed that the use of clear wood properties could be quite misleading. For example, while the strength of the clear wood of Douglas fir is superior to that of a spruce-pine mix, the reverse is true for the structural size timber.

In-grade testing is applied to a particular size and grade of structural timber. The procedure that is used to grade the timber is irrelevant. In Australia, the procedure used is given in the standard AS/NZS 4063: Timber-Stress-graded-In-grade Strength and Stiffness Evaluation (Standards Australia 1997).

As an example, the test configuration specified in AS/NZS 4063 for evaluating the bending strength and modulus of elasticity is shown in Figure 13. In addition to the test configuration, the Standard specifies the method to be used for selecting the test specimen, i.e. as would occur in-service without any specific bias.

The Standard specifies that the sample shall comprise at least 30 test specimens; in practice, samples of 100-200 specimens are not unusual.

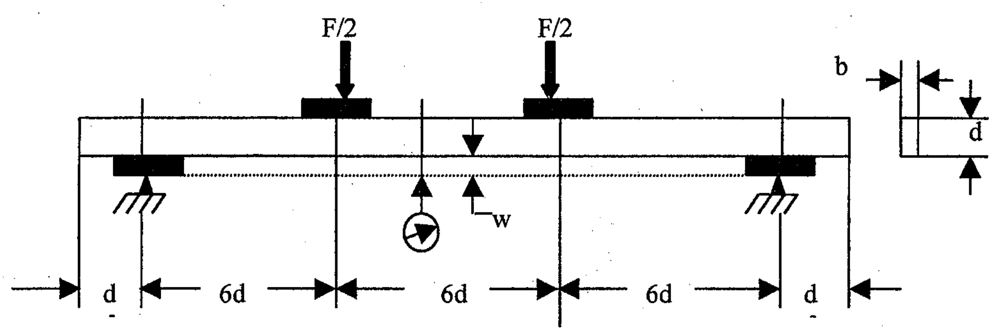


Figure 13. Configuration specified in AS/NZS 4063 for the measurement of bending strenth and modulus of elasticity

From the test data the characteristic bending strength R_k and characteristic modulus of elasticity E_k are given by

$$R_k = R_{0.05} \quad (7a)$$

$$E_k = E_{mean} \quad (7b)$$

where $R_{0.05}$ and E_{mean} denote 5-percentile and mean values respectively. These definitions of characteristic values are typical of those used in Limit States Design Codes. Methods for converting these characteristic values to basic working stresses are given in AS/NZS 4063.

Table 1 shows a comparison between the use of small clears and structural size specimens for the evaluation of the properties of structural timber. The data for the structural size evaluation refers to an evaluation for a full range of sizes, grades and structural properties; typically, 5,000-10,000 test specimens are required for this purpose. It is apparent that the small clears approach, while less accurate, is considerably cheaper than structural size testing. Hence, the small clears approach probably represents the best option in the utilisation of multiple species hardwood forests, when a penalty of 30% loss in strength can often be absorbed easily without affecting their end use.

Table 1: Comparison of two methods for evaluating the design properties of structural timber

Evaluation method	Cost for evaluating one species	Laboratory time	Typical error in 5 percentile strength estimate
Structural size timber	$1000000	1 year	±5%
Small clears	$1000	1 week	±30%

Stress Grading

Basic Concepts

The basic concepts associated with stress grading are shown schematically in Figure 14. An input resource is sorted by some procedure into an output comprising several grades of timber (possibly including a reject grade).

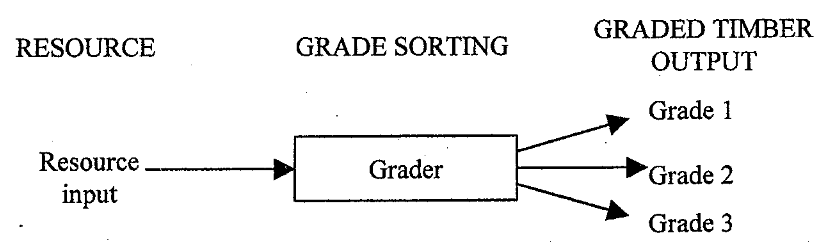


Figure 14. The basic elements of stress-grading

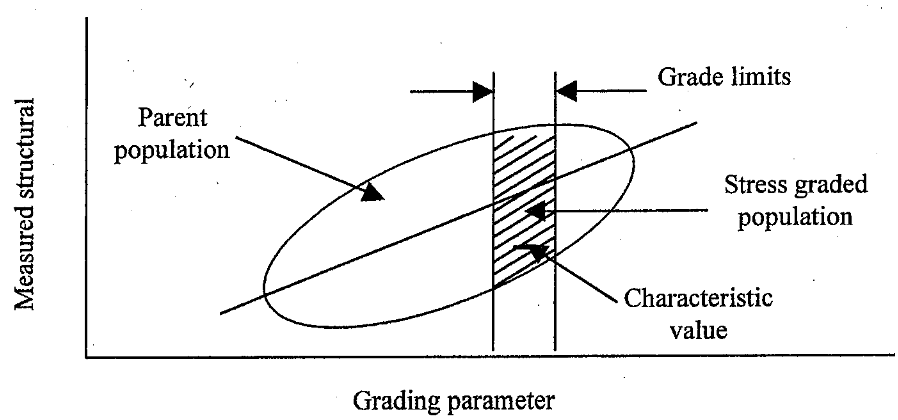


Figure 15. The concept of grade sorting

The effect of grade sorting on the structural properties is illustrated in Figure 15. Essentially a stress grade of material is obtained by selecting all timber between two limits of the grading parameter, the coefficient of variation of the stress-graded material V_g is related to the coefficient of variation of the input resource V_{ir} by:

$$V_g = V_{ir}\sqrt{1-r} \tag{8}$$

where 'r' denotes the correlation coefficient between the measured and predicted values of the structural parameters.

Figure 16 illustrates the influence of the coefficient of variation of stress-graded material on the efficiency of utilisation, i.e. the ratios of characteristic 5-percentile value to the mean value $R_{0.05}/R_{mean}$. An increase in the correlation coefficient 'r' leads to a decrease in coefficient of variation V_g and an increase in the efficiency of utilisation.

Apart from efficiency, a second important aspect of stress grading is control of the quality of the stress-graded material. To do this effectively it requires monitoring of the input resources, the sorting operation and the output resource.

The input resource is related to log species, source and silvicultural practices. Monitoring of the output is described in AS/NZS 4490: Timber-Stress-graded-Procedures for Monitoring Structural Properties (Standards Australia, 1997). This Standard specifies in-grade testing procedures for the initial evaluation, daily monitoring and the annual monitoring purposes. For daily monitoring, a conventional CUSUM procedure is suggested, this will pick up a change in mean values, but is unlikely to be effective for detecting a sudden change in 5 percentile values (Leicester 1994).

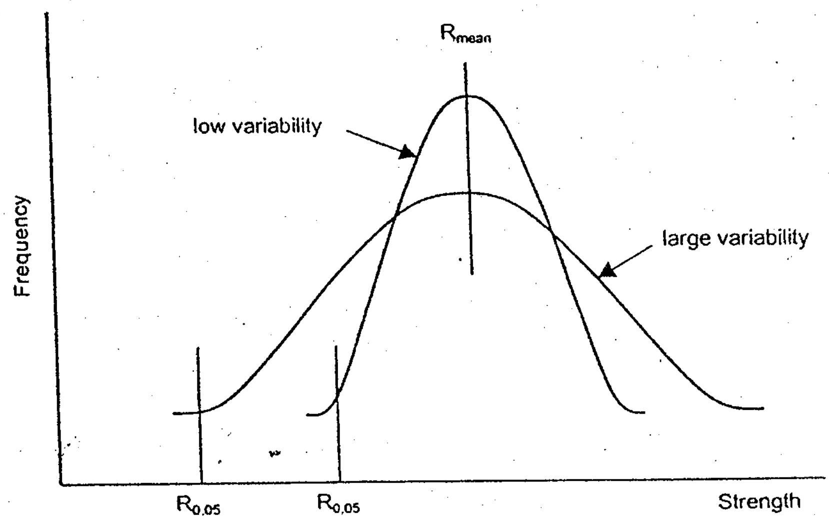


Figure 16. The effect of variability on the characteristic value $R_{0.05}$.

Visual Grading

Visual grading is based on limiting the size of natural features such as knot size, slope of grain etc. Examples are the Australian Standard AS 2082: Visually Stress-graded hardwood for Structural Purposes (Standards Association of Australia, 1979) and AS 2858: Timber-Softwood-Visually-Stress-graded for Structural Purposes (Standards Association of Australia 1986).

It should be noted that the output of visual grading could be quite sensitive to changes in the input resource. In addition, the concept of initial evaluation based on in-graded testing procedures is often omitted. If reliance is placed solely on testing small clear pieces of wood, then estimates of the characteristic strength R_k for structural size timber will frequently be up to 30% too high or 30% too low relative to the true value.

A difficult feature of visual grading is the size effect. This size effect refers to the fact that when defects of the same relative size are permitted within two sizes of timber of the same grade, then often the larger size will have the smaller strength, i.e. a smaller ultimate stress at failure. This size effect is considered to be so important that it has been standardised within an ASTM Standard D 1990-91: Establishing Allowable Properties for Visually Graded Dimension Lumber from In-Grade Tests of Full Size Specimens (ASTM, 1991).

For the case of the bending strength of beams, the ratio of strength values σ due to the size effect is given by:

$$\left(\frac{\sigma_2}{\sigma_1}\right) = \left(\frac{d_1}{d_2}\right)^{0.29} \left(\frac{\ell_1}{\ell_2}\right)^{0.14} \qquad (9)$$

where the subscripts 1 and 2 refer to sizes No. 1 and No. 2 respectively, d is the beam depth and ℓ is the beam span.

In the above it is assumed that a large beam has a lower strength. However, in some studies in Australia the reverse has been found to be true. For example, for Hoop Pine visually graded to Structural Grade No.4 according to AS 2858, the 5 percentile bending strength was found to be 18.5 Mpa and 20.1 Mpa for 140 x

35 mm and 240 x 45 mm respectively. A probable reason for this is that larger, more mature logs were used for cutting the larger sizes.

A recent innovation in the Australian scene is that with the introduction of in-grade testing to monitor characteristic values, it has now become worthwhile to develop special grading procedures for each particular structural material. These grading procedures are usually much simpler and more effective than those given in conventional visual grading standards such AS 2082 and AS 2858. Madsen (1992) has given some discussion on this topic.

Machine Grading

Currently within Australia, most structural hardwoods are visually graded. However, about 90% of structural softwood timber are mechanically stress-graded. This has occurred largely for reasons related to production efficiency. Some idea of the production benefits to be gained by using machine stress-graders can be obtained from the fact that current machines operate with speeds of 100-700 metres per second. However, there are so many other potential benefits related to machine grading that this is likely to be universally the preferred grading method in the near future.

One of the most obvious benefits of machine grading is the potential for increased efficiency due to the application of electronic scanning technology. The more information obtained from a scanning operation, the more improved will be the strength predictions; increase in the correlation coefficient then leads to reduced variability according to Equation (8) and improved efficiency. Electronic technology now being employed on a limited trial basis include microwave scanners (Leicester and Seath, 1996), x-ray scanners (Rouger *et al*, 1994). Sonic wave technology (Sato *et al*, 1994, Arima *et al.* 1994, Ross *et al.* 1996) and video imaging, Figure 17.

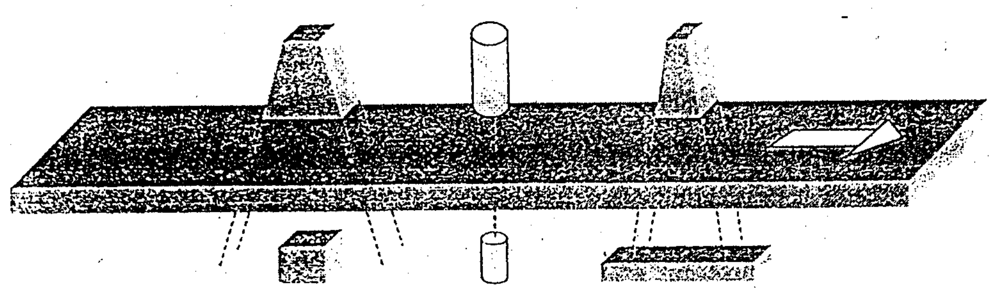
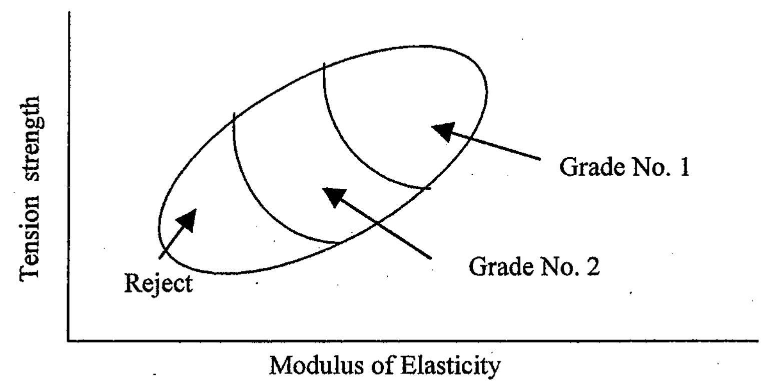


Figure 17 Examples of non-contact scanning devices.

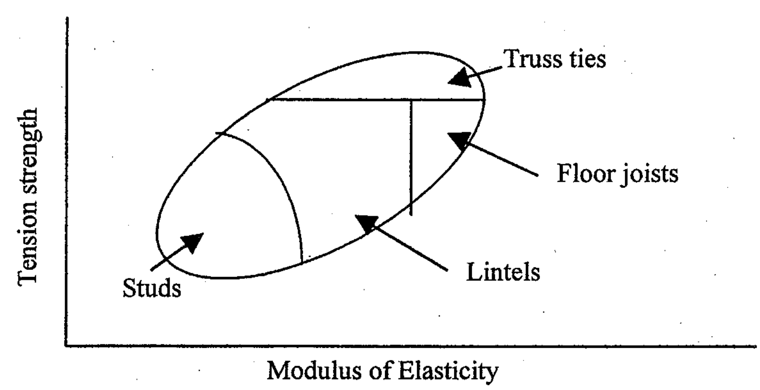
A second benefit from machine grading is that because multiple parameters are used, each structural property can be independently assessed. This then leads to the potential for grading for end-use, as illustrated in Figure 18, and accordingly a better optimisation of resource.

Finally, mention should be made of the fact that machine grading coupled with scanning provides the potential for quality control at high operational speeds. For example, the use of computers to obtain ensembled averages of graded timber forms a powerful diagnostic tool to assess the stability of a grading operation (Leicester & Seath, 1996). These methods are currently being used by Pine Australia during mechanical stress-grading operations.

Incidentally, it should be noted that machine grading, unlike visual grading, is easily manipulated to produce grades of any specified characteristic strength or stiffness values. In particular, the size effect for visual grades such as that given in Equation (9), may be built into the system, or may be removed altogether; thus the choice of stress-grade properties can be chosen to suit resource and market conditions.



(a) Conventional stress-grading



(b) Grading for end-use

Figure 18. Schematic illustration of the effects of conventional and end-use grading

Fire

Since 1990, there has been an Australian Standard to compute fire resistance of structural elements. This is AS 1720.4: Timber Structure - Part 4 - Fire-Resistance of Structural Timber Members (Standards Australia 1990). The Standard is applicable to large size members, typically glulam members, which are protected by a layer of char during the fire. However, for fire separation walls as used in light frame multi-residential construction, it was impossible for many years to use timber because the Building Code of Australia specified that separation walls had to be built of non combustible material. Under the evaluation procedures of the Australian Standard AS 1530.1 (Standards Association of Australia 1987) all timber, even timber impregnated with fire retardants, was deemed to be combustible.

To overcome this barrier to the use of timber, a case based on performance criteria was presented to the Australian Building Codes Board. Essentially a risk model, illustrated schematically in Figure 19, was applied to multi-storey buildings of the type illustrated in Figure 20. The building system and fire safety systems were varied from case to case.

The results of four such cases are presented in Table 2. The reference case is the reinforced concrete building without central alarm and sprinkler protection, which was considered acceptable within the Building Code of Australia. The analysis showed that the risk to life was less in the case of a building with separation walls comprising timber frame construction with a one hour fire rating and a central fire alarm system. On the basis of this analysis, it was successfully argued that such a system should be accepted.

Following several years of discussion, a special amendment in 1994 was made to the Building Code of Australia to enable it to accept the construction of 3-storey multi-residential buildings with fire separation walls and floors constructed with timber framing. Since then a major research project has been undertaken by the Fire Code Reform Centre to review all fire related regulations in the light of risk-based performance criteria (Fire Code Reform Centre 1996a, 1996b). The project is to a value of US$4 million over a 5-year period.

A general overview of these developments has been given in a previous paper (Leicester 1995). Predictive models for the fire resistance of timber framed wall systems have been developed by Clancy (Clancy *et al* 1994, Clancy & Young 1985).

Practical details for the design of multi-storey residential timber frame construction are given in the publications by National Association of Forest Industries (NAFI 1995).

Table 2: Computer model predictions for building shown in Figure 20.

Case No.	Structural frame material	Fire resistance (min)	Central fire alarm	Sprinkler protection	Relative expected risk to life	Relative expected fire cost
1	Concrete	90	No	No	1.00	1.00
9	Timber	20	No	No	2.27	0.71
14	Timber	60	Yes	No	0.90	1.87
15	Timber	60	No	Yes	0.67	2.54

Durability

As was the case with fire, most of the existing approaches to designing for durability are limited to the use of deemed-to-satisfy solutions. An example of this is in the application of the Australian Standard AS 1604: Timber-Preservative-Treated-Sawn and Round (Standards Australia, 1993) and the use of simple classification protocols (Australian Wood Preservation Committee, 1997). These solutions are limited in application and do not provide any method for estimating the risk involved.

To remedy this situation there is a major research project within Australia to develop engineering design procedures for design against decay, termites and corrosion (Leicester, 1997). These are generic procedures, which will be applicable to in-ground, exposed and protected structures. An example of the parameter considered in a prediction model of the type under study is illustrated in Figure 21. The project is expected to be to the value of US$3 million over a period of 3 years.

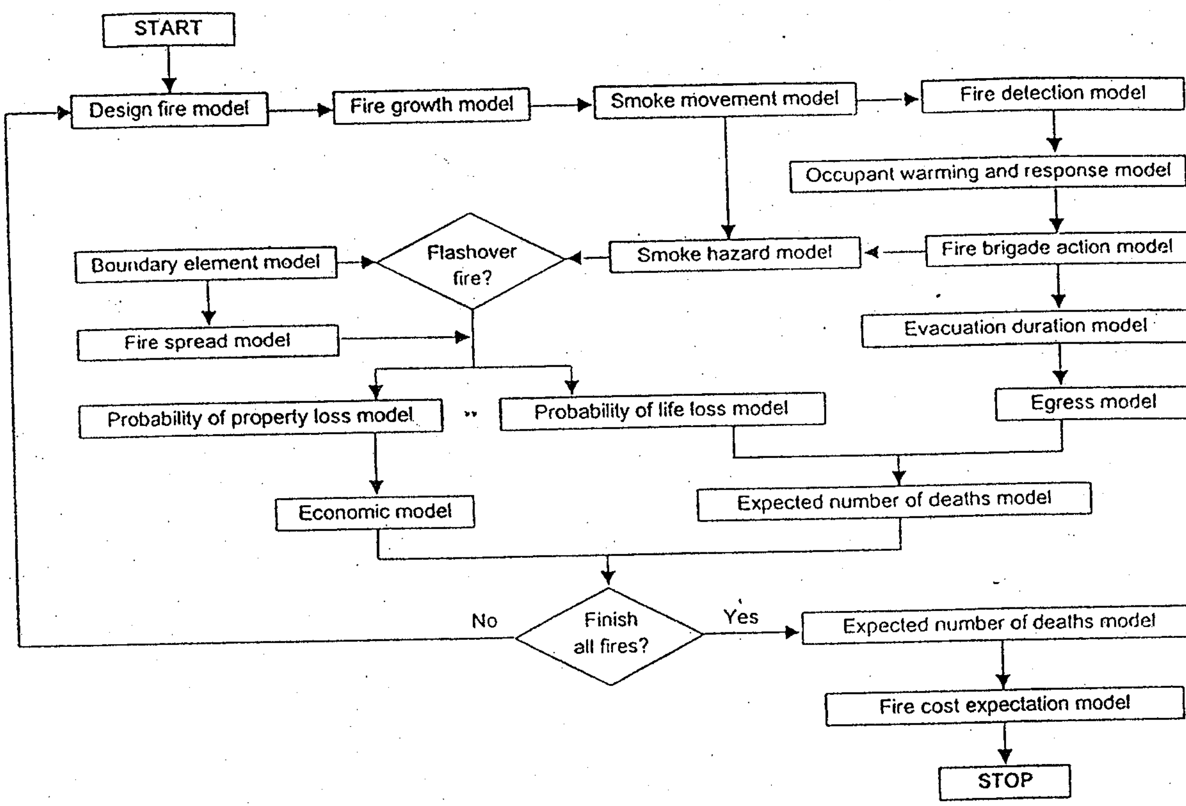


Figure 19. Risk model used for assessment of fire.

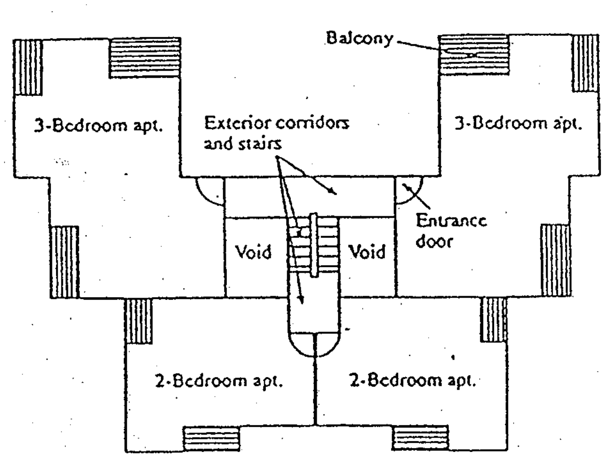


Figure 20. Plan of 3-storey apartment used for risk analysis.

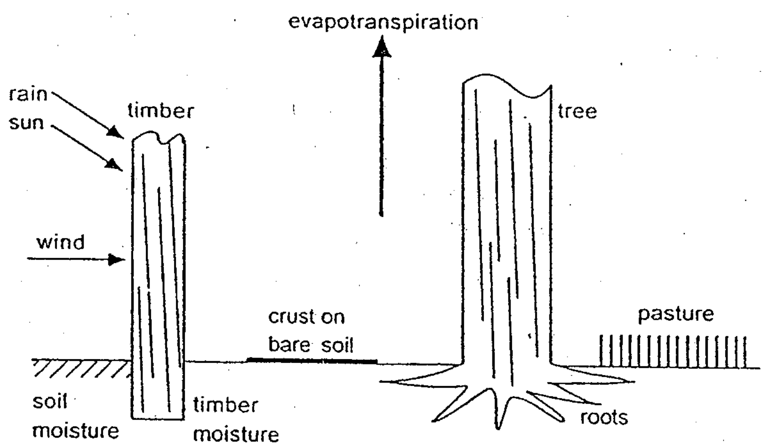


Figure 21. Illustration of parameters considered in modelling ground contact decay.

Utilisation of Australian Hardwoods

Because of a ban on the logging of rainforest species, almost all the hardwoods utilised in Australia are indigenous Eucalyptus timber. They cover a wide range of strengths and relative to the softwood species, they are generally stronger. However, on the negative side they are heavier, more difficult to saw due to growth stresses, difficult to season and to glue, difficult to nail (if seasoned), tend to split easily and tend to warp and twist during drying. Yet despite these disadvantages, until recently Eucalyptus timber, including unseasoned timber accounted for half the structural timber used in Australia.

Some of the methods used to overcome these difficulties have included edge sawing to mitigate the effects of growth stresses, the use of glued wrapping during seasoning to reduce drying stresses, increased edge distances for connectors to reduce splitting and special fixing techniques for attaching wall sheeting to unseasoned timber to reduce the effects of twisting during drying. End and edge distances for nailing are usually assessed by direct trial. However, for other types of connectors, appropriate recommendations are given in AS 1720.1, which contain a method for assessing the tendency to split.

Usually the clear wood of eucalyptus is very straight grained and so this wood is culled to be sold as timber for making furniture timber. Large size beams are formed by end or edge jointing 5-6 m lengths with metal connectors.

New Technologies

Materials

Probably the most exciting materials to become available to the structural engineer are Laminated Veneer Lumber, Parallam and other composite materials for replacing sawn timber. These materials are of high strength, very reliable, of large dimension cross-section and can be made in any length.

Almost as useful are elements fabricated from several types of material; usually these are of lightweight and may be fabricated in long lengths. Two popular examples of these are the I-beam (often fabricated with solid timber flanges and plywood webs) and the open web joist (often fabricated with solid timber flanges and light gauge steel web material). The latter is particularly favoured in domestic and light commercial construction, because the open web configuration facilitates the instalments of services.

Finally, mention must be made of the great variety of structural sheet material now being manufactured. Examples include Oriented Strand Board and Particle Board. They are very cost effective. However, from the engineering perspective they involve the difficulty that information on strength under long duration loads is often lacking, and interesting workshop on this topic was held in Toronto in 1993, and there were several interesting papers on this topic (e.g. Palka 1993).

Board Construction

Probably the optimum form of timber in terms of processing effort and structural quality is timber in seasoned planks or boards. In recent years, several attempts have been made to utilise this timber including pieces of low-grade timber. For two types of construction, this has proven to be highly successful.

One successful technology has been the development of stressed laminated decking for road bridges (Taylor & Keenan 1992, Crews & Walter 1996, Ritter & Hilbrich 1996). In this technology, decks are formed by pre-stressing timber boards with high strength steel bars, Figure 22. The other successful application of boards has been in the use of timber-concrete composite construction for heavy-duty floors (Natterer 1996). In this construction, the timber is nail laminated and used as a permanent framework for the concrete above (Figure 23). For both these applications, relative low quality timber may be used.

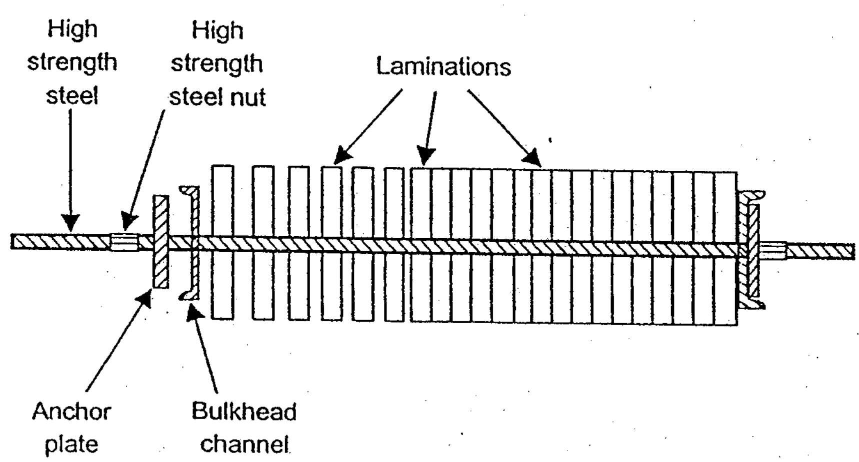


Figure 22. Stress laminated timber deck.

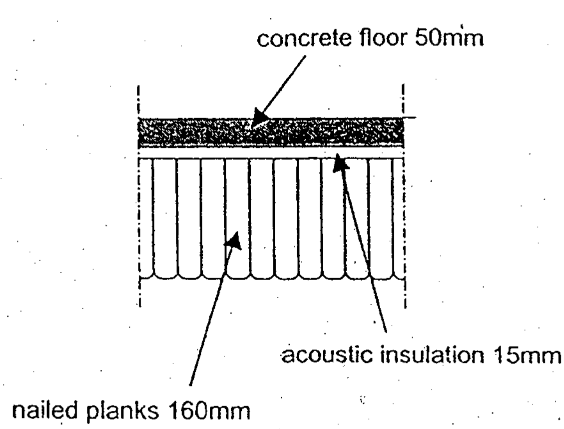


Figure 23. Example of nail laminated floor system.

Subsystems

There is an increasing trend towards the marketing of complete subsystems that are fabricated off-site in factory environments. These include floor systems, wall systems and roof systems. The advantage to the producer is that he can optimise the use of his resource, and perhaps produce systems that offer competitive advantages from the architectural view point, for example thin floor systems. For the end user, the availability of such systems reduces design and construction time, and reduces on-site quality control requirements.

A minor difficulty associated with the marketing of systems is that the testing regime required for a performance-based assessment of systems is often uncertain. Some attempts to develop suitable testing regimes are in progress (Foliente and Leicester 1996).

Whole Building Systems

Currently some engineer-architects, particularly in Europe, are designing whole building systems that are targeted at optimising the operation of the building from the point of view of space, thermal, acoustic and lighting requirements (Netterer 1991, Linkwitz 1996, Bruninghoff 1991). This is a difficult area to work in, but it is quite probable that in the long term, some of the concepts being developed will be systemised and so become more generally applicable.

Construction Techniques

Undoubtedly the greatest development in the construction area has been the development of hand held power tools for on-site work. This is particularly true for industrialised countries where labour costs are high. The benefits of such tools are obvious when consideration is given to the fact that joints for large portal frames may require hundreds, sometimes thousands, of nails in their fabrication (Yttrup & Evans 1996).

Hand held power tools are frequently used for driving nails, screws and staples. Some are driven by compressed air while others are totally self-contained explosive-driven units. Typically, nails up to 90 mm long can be driven not only into timber, but also through mild steel gusset plates up to 2.5 mm thick. The nailing rate for these operations is about one per second.

Another noticeable trend in construction practices is to develop special erection techniques for lifting large portions of the building that are fabricated on the ground. In particular, it is proving quite popular to use several cranes simultaneously to lift large sections of roof, which have been fabricated already complete with services.

Delivery Systems

It is notable that many countries that have sophisticated technologists and even reasonable product standards do not have technical quality in their buildings. This is because an appropriate network of technology must be in place to deliver this quality. The network must involve suppliers, designers, builders and regulatory systems. All aspects must in some sense be associated with registration, appraisal and audit; there must be a paper trail of action and responsibility between all stakeholders of the building industry. Figure 24 shows an example of marking that is used on structural timber, it identifies not only the claimed structural quality of the timber, but also the source of the timber and the certification agency.

A difficult but important aspect of quality systems is the communication of information. If it is too complex for the technology infrastructure, it will be ignored. The UNIDO Manual on house construction (UNIDO 1985) is an interesting example of an attempt to convey quite complex concepts in a simple and user friendly manner.

Software

Developments in computer software are progressing so rapidly that it is almost impossible to envisage the future. Already sophisticated companies have software packages that enable the rapid drawing of complex building shapes, the related timber engineering design of wall and roof structures and controls for the fabrication process.

Another type of development relates to information transfer. One form is the transfer of information related to building products. Another is the exchange of information related to technology; for example a recent web site set up in Melbourne for this purpose is http://www.dbce.csiro.au/res-cap/tinder.htm (Foliente & Woodward, 1997).

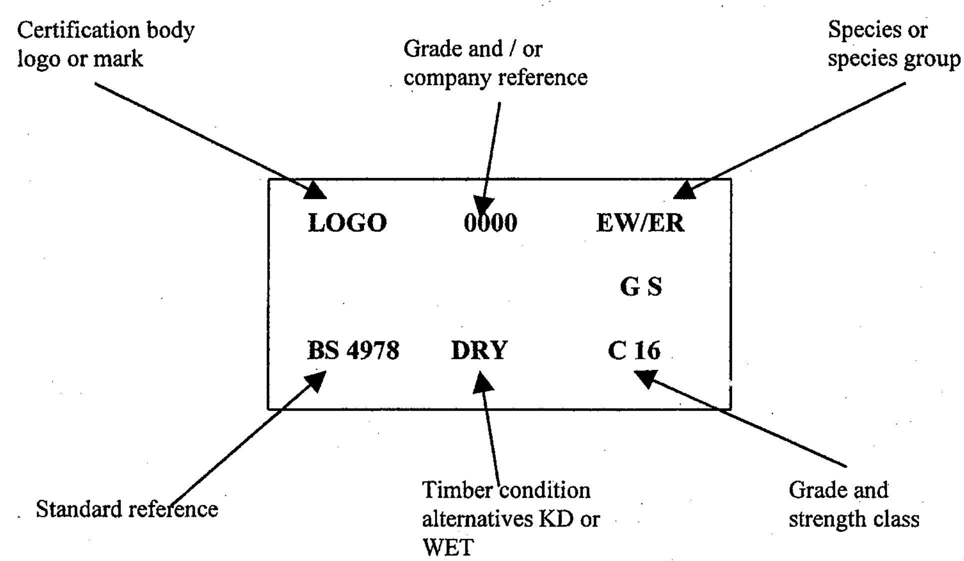


Figure 24. Example of information provided in branding structural timber.

International Trends

Performance Based Codes and Standards

One of the most significant trends for the building industry worldwide has been the trend towards the acceptance of performance-based codes, standards and procedures (Leicester *et al*, 1997). An example for this has been the recently published Building Code of Australia (Australian Building Codes Board 1996).

The concepts involved are illustrated by the application shown in Tables 3 and 4. The essential features of performance based codes and standards are the following:

1. There are at least two levels of specified performance, i.e. a level of product performance and a level of in-service performance.

2. Methods should be provided whereby target performances can be met either by (a) testing; (b) by computation; and (c) by deemed-to-satisfy criteria.

Table 3. Example of performance targets for use of composite I-beams

Performance control	Performance target
1. Specification of building objective	Probability of loss of life within the design life of the building is less than 10^{-6}.
2. Design for in-service performance	For a particular I-beam, the probability of failure in-service (during the design life) is given by $Pr(øR_k<S_k) = 10^{-4}$
3. Evaluation of characteristic values	
• structural element	$R_k = R_{0.05}$
• load	$S_k = S_{0.95}$

Notes:

$Ø$ = material factor

R_k = characteristics value of 1-beam strength

$R_{0.05}$ = 5-percentile value of 1-beam strength

S_k = characteristic value of load

$S_{0.95}$ = 95-percentile value of peak load within a design life

Table 4. Methods for achieving performance targets given in Table 3

Performance control	Method for achieving performance targets		
	Use of compliance criteria	Use of performance criteria	
		By computation	By test
1. Achieve building objectives	Specify the use of a specific set of design codes and standards	Undertake an assessment of risk to life	Survey of existing buildings for loss of life*
2. Obtain in-service performance	Use published span tables	Design using loading codes and engineering design codes	Survey of existing buildings for structural failures*
3. Evaluate characteristic values			
- structural element	I-beam accepted by description	Computation of strength of I-beam based on properties of components	Strength test of I-beams
- load effect	Load specified by law	Computation of loads (e.g. for wind loads, using computational fluid dynamics)*	Load survey

* *Not usual*

With respect to product appraisal, testing is usually a favoured option where possible, as it provides the most certainty. There are difficulties for assessing long duration effects via testing and there are often difficulties associated with selecting a testing configuration. However, within Australia it is now not uncommon to test subsystems such as floors, and there are even cases where testing has been applied to complete houses (Reardon 1989).

The benefits of the use of performance based criteria is that they provide a basis for developed optimised building practices. However, probably more importantly, they provide a basis for innovation (as illustrated earlier by the example related to design against fire), for trade and for technology transfer between countries.

ISO Standards

The existence of ISO (International Standards Organisation) Standards is potentially of considerable global benefit. They may be used for trade purpose, as model codes for countries that do not have any and as a common format for technology transfer purposes.

However, the existence and/or enforcement of ISO Standards also has the potential to create difficulties for both industrialised and emerging economies. This matter has been discussed at length in a previous paper (Leicester 1997). Tables 5 and 6 have been taken from that paper.

Currently TC 169, the ISO Technical Committee on Timber Engineering is involved in drafting standards related to stress-grading and structural evaluation of sawn timber and poles, the fabrication of finger jointed material and glulam, and the assessment of connector systems.

Table 5. Globalisation criteria for ideal ISO Codes and Standards

Codes and standards should be applicable to:

- all species
- all constructions
- all countries
  - loads
  - climate
  - biological hazards
  - environmental hazards
  - existing data
  - existing technology
  - existing infrastructure
  - existing culture

Table 6. Some possible procedures to assist in the globalisation of international codes and standards.

- Use performance-based criteria
- Establish equivalence with national product standards
- Accept trade-off between efficiency and quality control
- Draft tiered design codes
- Define multiple quality levels
- Use grouping methods for:
- timber species
  - loads
  - member sizes
  - building elements

Collaborative Research

The high cost of research and the generic nature of the information have encouraged the formation of large collaborative research networks. For example, within Europe a collaborative project on timber mechanics, titled 'COST-508', involves 77 research institutes from 17 European countries. The cost of the 5 year project has been estimated to be about US$30 m. Another large collaboration has involved Andean Pact countries in South America (Arbaiza, 1986). This project on wood technology involves 5 countries, 11 laboratories and 200 technicians.

Within the Australian region there are standards being developed jointly between Australia and New Zealand. Also, there are workshops in progress to harmonise the standards of APEC countries.

Environment

Undoubtedly one of the fastest growing areas of international interest in the timber engineering field is the interaction between building design and the environment. This may relate either to the impact on the environment by a building (e.g. Guymer and Bailey 1994) or the environmental impact due to the use of timber in building (Buchanan 1994, Bowyer 1990).

Utilisation of Lesser Used Species

The Problem

The difficulties of utilising LUS (lesser used species) timber are due to the fact that there are too many species, there are difficulties in species identification, and there is too small a volume of accessible timber if only one particular species is utilised. The extent of the difficulties associated with the occurrence of multiple species is indicated by the fact that there are some 4000 useable species in Indonesia, 2500 species in Malaysia, 4000 species in the Philippines and 2500 in the forests of South America (Tesoro, 1986; Arbaiza, 1986). In the mixed species rain forest, almost any species used will qualify as an LUS. In the following, some options for utilising LUS will be considered.

Option 1: Favoured Species

One option that is highly favoured by architects and engineers who are practising in relative isolation is to use only a limited set of favoured species. By placing such a limitation, it is not too difficult to acquire reliable information on the important properties of the timber such as for example, those related to structural, durability and supply aspects. Once the supply of these few species has been exhausted, then another set of species can be chosen.

Within Ghana, the species currently favoured are Essia, Kyenkyen, Esa, Onyina, Denya and O*haa*.

Option 2: Grouping Plus Visual Grading

Probably the most common strategy to cope with multiple species is to group them according to small clear wood properties and then to stress-grade them by visual methods. This concept is illustrated schematically in Figure 25 and 26. Within Australia, the grouping is done according to AS 2878: Timber-Classifications into Strength Groups (Standards Association of Australia, 1989) and the stress grading is undertaken in accordance with AS 2082 and AS 2558. This procedure has been applied to 600 Australian species.

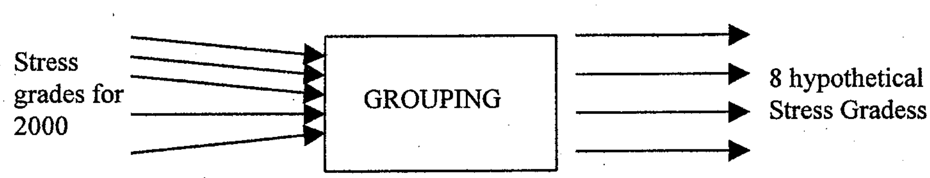


Figure 25. Concept of strength grouping.

The Australian strength grouping procedure has also been applied to 700 species of African timbers (Bolza & Keating, 1972), 500 species of South East Asian Timbers (Keating & Bolza, 1982) and 200 species of South American timbers (Berni *et al.*, 1979).

The other similar classification groups include those for species from Africa (Campbell & Malde 1970, Camben 1971, Okigbo 1966, Ward 1974), Malaysia (Burgess 1956, Engku Abdul Rahman bin Chik 1972), Singapore (Singapore Timber Standardisation Committee 1966), Philippines (Espiloy 1978), Indonesia (Suparman Karasudirdga *et al.* 1978, Iding Kartasujana & Abdurahim Marawijaya n.d.), Laos (Timber Research and Development Association 1976), Papua New Guinea (PNG Department of Forests 1972, Eddowes 1977, Bolza 1975), Fiji (Anon 1968, 1970), Solomon Islands (Forestry Division 1976, 1979).

Option 3: Machine Grading

Machine grading methods are not as sensitive to changes in the input resource as visual grading methods and hence machine grading is an ideal method of stress-grading mixtures of unidentified species. Application of this procedure has been made in a study of Malaysian timbers (Collins and Amin 1990). An example of the evaluation data is shown in Figure 27.

The efficiency of the method can be improved by pre-sorting according to species type (e.g. Eucalyptus) or according to wood type (e.g. mature or juvenile trees).

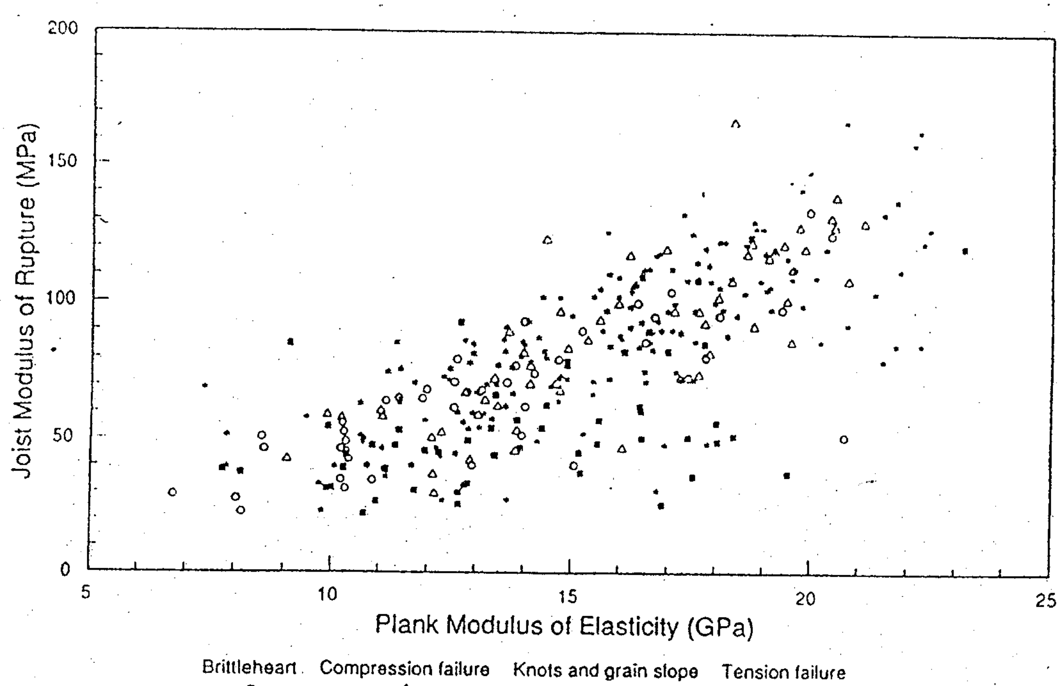


Figure 27. Relationship between stiffness and bending strength for Malaysian Mixed Hardwoods (after Collins and Amin 1990).

Option 4: Proof Grading

An interesting method of coping with multiple species is to use the technique of proof grading that was developed in Australia (Leicester 1984). An Australian Standard based on this technique has been published - AS 3519: Timber-machine Proof Grading (Standards Australia 1993).

Essentially the method comprises two steps. The first is to pre-sort the timber into a grade by any method desired. Next, the timber is passed through a proof testing machine that continuously stresses the timber in bending as it passes through. If the timber is below grade, the machine will break it and so it will be rejected.

The most obvious advantage of this procedure is that it does not require species identification, an impossible operation under mill conditions. In addition it does not require highly skilled grading personnel; if a mistake is made, the machine will break the timber and reject it.

A fairly simple machine, the Hilleng Proof Grader, was manufactured in Australia for this purpose. It was applied in about 20 small mills. At one particular mill the log intake comprised 150 species of rain-forest timbers and it was noted that on several occasions the graders made errors in species identification; these errors were noted only because the machine failed the timbers during proof testing. Without the benefit of the machine, major errors would have occurred during a conventional visual grading operation.

Conclusion

During the past 20 years, there has been a quantum leap in the quantity and quality of matters related to timber engineering. With this knowledge, and the availability of high quality technologists, it should be possible to avoid the current situation where a country with limited facilities will apply deemed-to-satisfy technology from other countries that may be quite inappropriate, it should now be possible to develop a timber engineering technology for each country that is suited to the timber availability, the climate, the technology infrastructure and the performance expectations of that country.

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ITTO-PROJECT 179/91 - Industrial Utilisation and Improved Marketing of some Ghanaian Lesser-Used Timber Species from Sustainably Managed Forests

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Project Leader

Overview

About four years ago the Forestry Research Institute of Ghana (FORIG) was awarded a research grant of US$985,273 by the International Tropical Timber Organisation (ITTO) to look at the possibilities of introducing some Lesser-Used Timber Species of Ghana to take care of the dwindling primary species.

The project, originally titled "*Industrial Utilisation and Improved Marketing of some Lesser-Used Ghanaian Timber Species from Sustainably Managed Forests*", is now popularly known as the LUS project.

The general aim of the LUS project was to encourage the forest products industry of Ghana and the sub-region to better utilise their forest resources in order to help aid the development of the Ghanaian society while also attaining ITTO's target 2000, i.e. to achieve complete sustainable forest management by the year 2000. Specifically, the overall objectives were to remove pressure from the over exploited primary species like the Mahoganies, Iroko etc. by increasing the use of available and sustainably managed wood whose characteristics are generally known but not utilised extensively, and using this wood more effectively by minimising waste and increasing value.

The complex nature of the project made it necessary to break down the activities of the project work into three main components.

1. Forest Ecology - To study the ecological impact on the forest after extracting the various species.
2. Wood Technology - which included the Physical and Mechanical properties of the wood, the wood processing characteristics, as well as the manufacturing and product developing expertise.
3. Forest Products Marketing - To study how best the species and their products can enter the local and International markets.

Originally, 14 Lesser-Used Species of Ghana were selected for the study, their selection was based mainly on their availability in the forest and aesthetic value. As results became available during the project, it was deemed necessary to focus attention on a few species rather than continue to work on the original 14 as stipulated in the project document. Eventually, six species were chosen for intensive study: Ceiba (*Ceiba pentandra*), Kyenkyen (*Antiaris toxicaria*), Celtis (*Celtis mildbraedii*), Essia (*Petersianthus macrocarpus*), Denya (*Cylicodiscus gabonensis*) and Ohaa (*Sterculia oblonga*). Once the fundamental information was collected and analysed, a plan was conceived and implemented to develop prototype manufactured products such as furniture pieces, deck boards, sun beds, etc. A set of outdoor furniture which has been called the "Ghana Collection", was manufactured from the LUS and given extensive exposure at several trade shows and training workshops for small and medium sized firms.

Of particular interest is to note that the President of the Republic of Ghana has a set of the Ghana Collection in his garden.

In addition, a state-of-the-art furniture testing device was acquired in the latter stages of the project and is being used to evaluate the performance of the furniture.

In a section of the city of Kumasi known as Sokoban, an industrial park is being developed for small to medium sized wood product manufacturing firms. The development is known as the Wood Village. The results of the LUS project has been presented in a special training workshop to some entrepreneurs who will be located in the wood village. Thus, the accomplishments of this project will be put to good use in the near future.

Summary of the Important Findings

Forest Ecology

The environmental component of the project focussed on damage to residual trees and the effects of logging on tree regeneration. The first part of this study examined the type and extent of physical damage caused to residual stands through tree felling, log extraction and road construction. The second part measured the effects of logging on pre-existing seedlings, assessed post-logging tree seedling recruitment and composition as well as the effect on tree biodiversity.

The study was conducted in one compartment each from three selected forest reserves, namely; Opro River in the Dry Semi-deciduous forest zone, Bura River in the Moist Evergreen forest zone and Draw River in the Wet Evergreen forest type (see Figure 1). These reserves cover the full environmental variation in timber producing forests in Ghana. All aspects of the studies in Bura and Draw Forest Reserves were completed within the project period. Delayed log extraction in Opro Forest Reserve made it impossible to carry out regeneration studies, within a period of 12 months after extraction.

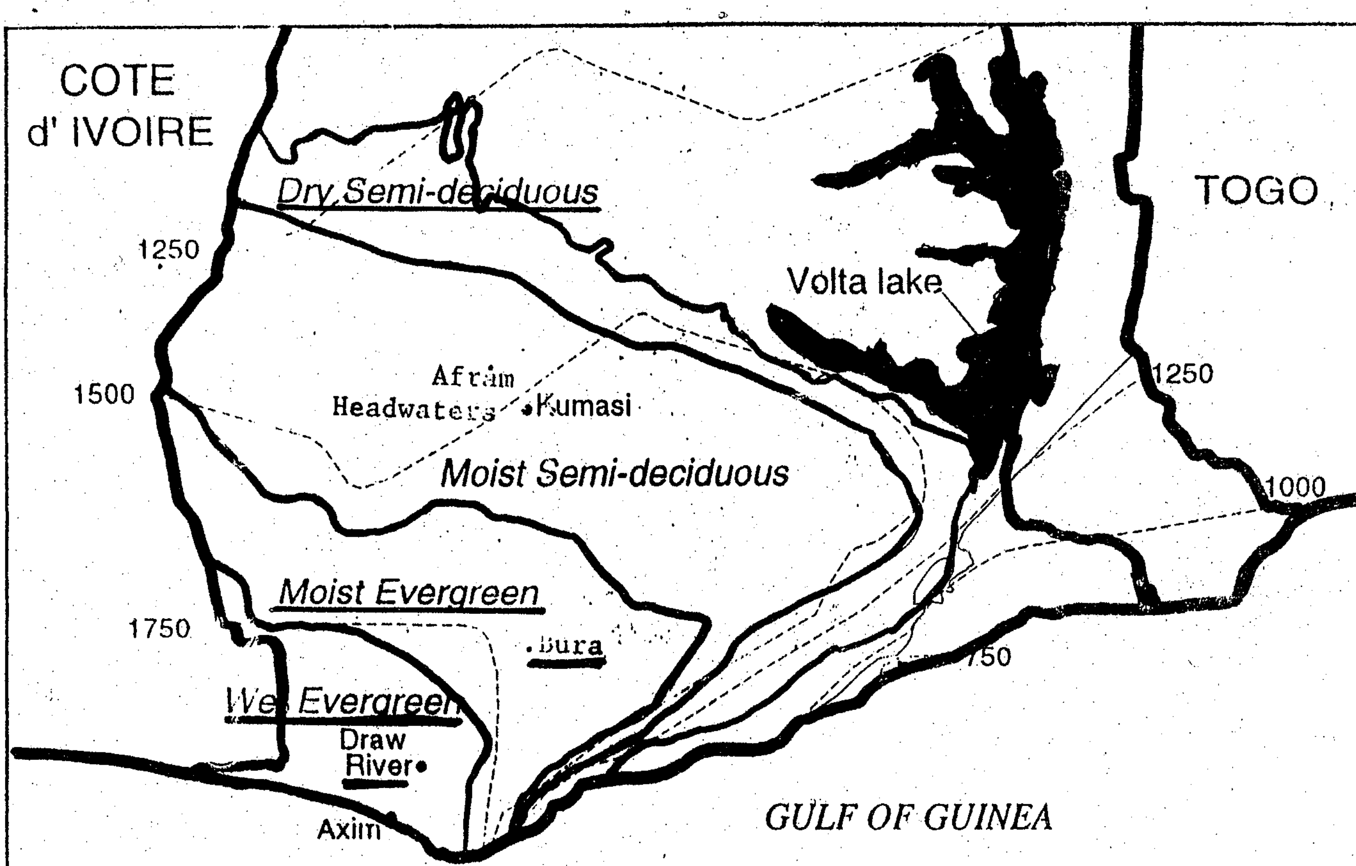

Figure 1. Forest ecological map of Ghana showing the study sites for the Ecological studies.

The felling damage assessment has indicated that the falling tree creates more opening per felled tree per hectare followed by skid trails and roads. For instance, the mean area of felling gap per hectare was 790m^2 in Draw where felled trees were bigger and 680 m^2 at Bura where trees were smaller in diameter. Total disturbed area was 13.4% and 12.7% at Draw and Bura respectively. This level of disturbance is considered low but this could rise if felling intensity is to be increased.

The regeneration studies indicated that disturbance due to logging markedly reduced pre-existing tree seedlings in felling gaps and skid trials but the stimulation of new seedling establishment significantly exceeds the losses.

Regeneration of all tree species is enhanced by the disturbance, although pioneer or light demanding species are more favoured. The regeneration also contains important timber species. However, patchiness in seedling densities is noticed in all species. This patchiness is attributed to patchiness in seed source and emphasises the need for seed retention in forest management. Tree biodiversity was noted to have increased in disturbed areas than undisturbed forest.

It is evident that the composition of the new regeneration after logging may not necessarily be the same as the present composition. The drift in forest composition whether logged or not logged is already evident in Ghana's forests. This should not pose any problem if a wider range of timber species can be marketed.

It is noted that the intensity of logging in these trials is low by international standards, affecting only 13% of the concession area. If a larger area is disturbed, we cannot safely assume that the benefits observed will be retained. There is the need to determine the optimum felling intensity in all the forest types in order to derive the optimum benefit from logging.

Wood Processing and Product Manufacture

Fundamental information on the 14 species initially selected for this study was acquired in the early stages of the study.

Information on physical and mechanical properties of the species was collected from the literature. Sawing characteristics, machining characteristics, drying characteristic, gluing, mortising etc. were also obtained through technical studies carried out by the project team at some sawmills. FABI Timbers in Kumasi, Swiss Lumber in Manso Amenfi, Bondplex in Kumasi, LLL in Kumasi and Ghana Primewood (GAP) in Takoradi need special mention. These firms allowed us access to their mills for the studies. Special thanks to these Companies.

Based on the information collected in the early stages of the project, as well as forest inventory data, indicating stocking levels of the LUS, and as the project progressed, the results of further technical studies along with the identification of pertinent marketing intelligence dictated a limitation of the species to six: *Ceiba, Celtis*, Kyenkyen, Essia, Okan and Ohaa, as mentioned above.

A brochure containing technical data has been developed for the promotion of the six species and a condensed version is being placed on the Internet.

Following up on the garden furniture marketing strategy, a group of several prototype chairs, tables and recliners has been manufactured under the project.

This set of furniture is termed "The Ghana Collection". The collection has been displayed at various trade shows, e.g.

- Indutech in Accra
- Gifex in Accra
- Gifex in Cotonou, Benin
- At the Mini-Exhibitions at FORIG
- At the Wood Industry Training Centre (WITC) and during the 20th Biennial meeting of the Ghana Science Association (1997), Kumasi.

In addition to the exhibitions three training workshops have been conducted in Kumasi, Takoradi and Accra in order to transfer the knowledge obtained during the course of the study.

Finally, a state of the art furniture-testing device has been acquired and is in the initial stages of testing the garden furniture.

Forest Products Marketing

Several aspects were considered in the marketing area. Both domestic and export markets received attention. Industrial raw material markets as well as consumer products were explored. The size and capabilities of the firms hoping to use LUS was taken into account with respect to the marketing studies. It was found that the same channels of distribution for the traditional well-known species can be used for LUS and the Internet may be a new way to establish more contacts within the distribution channel.

Wood production in Ghana is dominated by a relatively small number of large primary product producers. This production consists of lumber and veneer. It serves a lucrative export market and has traditionally involved small number of known species. For LUS to penetrate this market a suitable market strategy must be developed. A substitution strategy is recommended where knowledge of customers' preferences are used to identify and promote species which can satisfy the customers requirements. Implementing this strategy is not an easy task since end-users of traditional well-used species are reluctant to change.

Formal market research studies conducted by the project in the US and the UK revealed that the most important factor concerning potential buyers of LUS is availability of the LUS, followed by technical promotional information, availability of small trial volumes and low introductory prices (Table 1).

Table 1. Importance rating of different factors in promoting the introduction and acceptance of LUS

Factor	**Importance Rating***
Availability of a reliable supply of product	6.34
Availability of technical/promotional material	5.68
Availability of small trial volumes	5.38
Low trial price	4.86
Acceptance of the LUS by an influential firm	4.82
Risk-free trial period	4.48
Certification of the LUS	4.39

**Summary rating of Ghanaian and US responses (n = 120 firms)*

It was found that a reliable source of wood satisfying a given level of quality must be available before any interest in LUS will be taken seriously. Potential users also expressed a desire to have good technical data on the Lesser-Used species. This was the second most important factor. The first and second factors were more important than price. Introductory discount pricing and free trials of a limited quantity of LUS should be considered by producers as a way to stimulate the export flow of LUS.

Survey respondents in Ghana and the US were asked to rate the importance of different strategies for collecting market information (Figure 2).

Another area of importance relative to LUS is the domestic market in Ghana. Since the economics of the export flow of wood from Ghana basically determines the price of wood in Ghana, small to medium sized domestic producers of end-use products such as furniture have a difficult time acquiring first class wood. Access to reasonably priced raw material limits their growth. Moreover, without advances in technical capabilities, there is little hope that this industrial sector will be able to produce products of sufficient quality to enter export markets. After careful consideration, a marketing strategy for this sector was identified: garden furniture and decking panels.

The idea behind this plan is that the small to medium sized firm can begin to experiment with design concepts, production techniques, and distribution channels in the domestic market before moving on to exports.

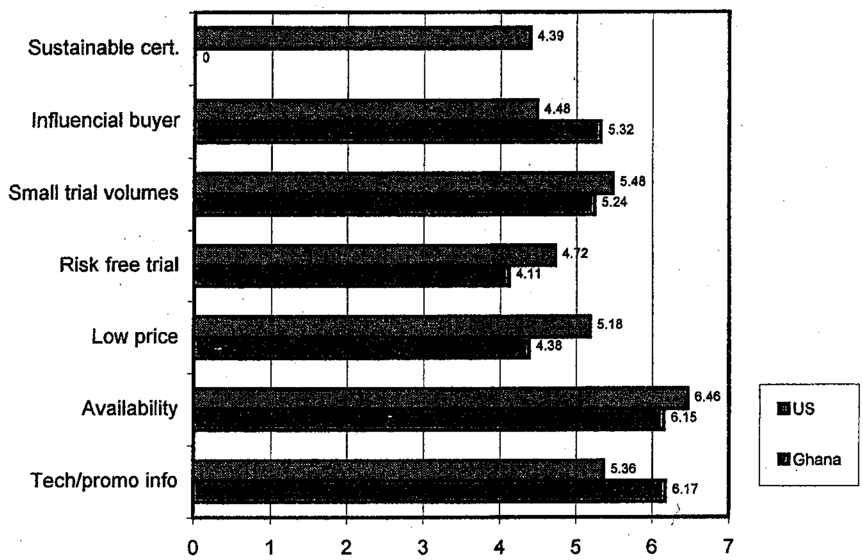

Figure 2. Importance of factors in promoting LUS. Ghana versus US.

Based on the information obtained in the surveys, a preliminary marketing strategy was developed to facilitate the introduction and acceptance of LUS from Ghana. The six factors that constitute the basis of the marketing strategy are:

1. Develop technical information
2. Develop promotional material
3. Develop a marketing strategy
4. Identify appropriate market niches
5. Recognise the importance of market information
6. Understand some important consideration.

The flow diagram in Figure 3 shows the various steps involved in introducing LUS.

The consultants for Ecology - Dr. Mike Swaine & Team; Marketing - Dr. Eastin/Appiah and Technology and Product Development - Messrs. Nilsson, Johnson and Prah will give more details on the achievements in their respective areas during this conference.

Linkages to Future Activities

While all of the stated outputs of the study have been accomplished there appears to be no natural ending to this project. The interaction of the ecology, marketing and wood processing components has led to a development of the various prototype products, and the marketing of these products is the next step. The exposure of these prototypes to the wood industry, and the general public has created a lot of interest. The training workshops have been instrumental in motivation and entrepreneurial involvement. This interest and involvement should be carried to many other ITTO sponsored projects.

We are very positive that the impact of the project results on the country's economy, as well as that of the sub-region, will be enormous.

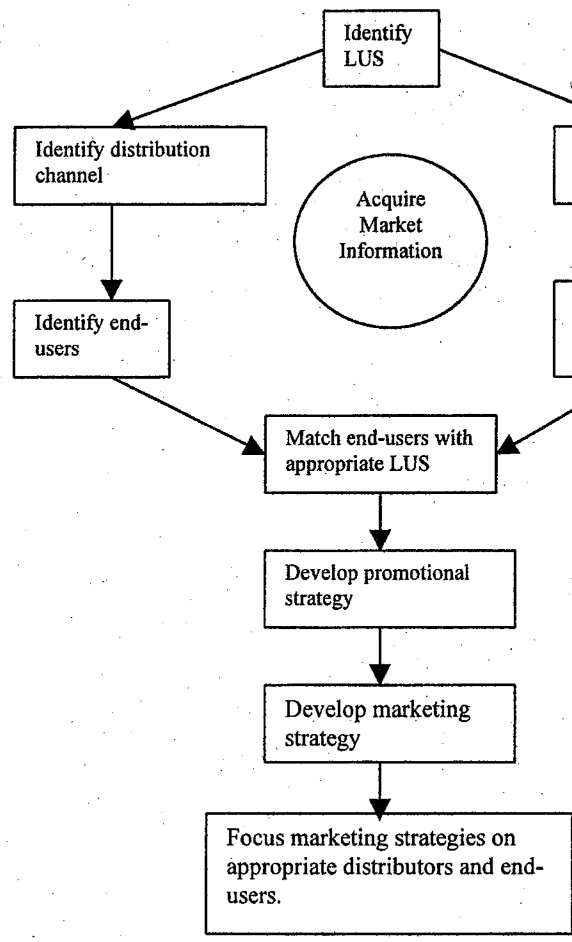

Figure 3. Flow diagram showing the various steps involved in introducing LUS.

Technical Session II: Ecology, hydrology and resource base

Technical Session II: Ecology, Hydrology and Resource Base

Chairperson: Mr. E.O. Nsenkyire, Chief Conservator of Forests

Ecological Impact of Increased Harvesting of Lesser-Used Species (LUS)

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[4] Forestry Consultant
[5] International Tropical Timber Organisation, Japan

Introduction

Tropical forests of Ghana is characterised by a rich and complex floristic composition. There are over 2,100 plant species, out of which 730 are tree species (Hall & Swaine 1981). 420 of these species are common and of wide distribution (Hawthorne 1989). Of these, 126 grow to timber size of which 50 are considered merchantable (Francois 1987).

The small number of species that are commercially exploited tends to make profitable logging and sustained yield management difficult to attain (FAO 1993). At present only about 7% of trees in the tropical forests of Ghana are being exploited. In addition, over 70% of timber exported in 1990 was from only two species (ITTO PD 179/91). A similar situation is found in Cameroun where 86% of timber harvested is from 15 species out of 56 commercially exploitable species (Evans 1990).

The dependence of tropical timber trade on a few species has resulted in the "creaming" of a few prime species, a reduction in the raw material base and an increase in the cost of sawmilling operations. Consequently the International Tropical Timber Organisation (ITTO) and Governments of some tropical countries have designed programmes to ensure both biodiversity conservation and expansion of the species base, as well as the greater utilisation of lesser used species (LUS)[1]. Within the last few years, ITTO alone has sponsored over 25 LUS-related projects, funding for which has totalled over US $5 million. These projects have aimed at prevention of creaming of the few traditional high value species; catering for increasing local demand and ensuring sustained production and supply of timber.

The restriction of exports to a relatively small number of species may be attributed to the fact that most importers from industrialised countries are reluctant to import Lesser-Known species from Africa probably because of the availability of adequate supplies of the more established species from a variety of African countries (Agyeman *et al.* 1997). Efforts are being made to utilise more species for both local and export markets. Governments of most tropical African countries are thus encouraging their timber industries to expand the species base in order to increase the net revenue (TEDB undated).

Presently, many of the LUS are being burnt or otherwise wasted after logging in the reserved forests and conversion of forest lands into agricultural use in off-reserve areas. There is the need to initiate programmes aimed at the sustained utilisation of LUS especially in countries where logging volumes or yield are low (Yeom 1984). It is in line with this objective that the ITTO commissioned the International Institute for Environment and Development (IIED) in 1991[2] to review knowledge in LUS and evaluate the

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[1] LUS are timber tree species that show promising market potential. Such species tend to be characterised by

- Flexibility in fitting today's rapidly changing markets i.e. the distribution and exploitable volume of the species are sufficient for market interest.
- (Often) strategically positioned as a substitute to prime commercial species and thus are potentially of high value. However, most of these species may have one or more undiserable characteristics (which may or may not be possible to overcome through improved processing techniques).
- A species for which marketing opportunities arise due to greater processing options, and thus a bulk market, relatively low value species, possibly in competion with plantation production.

Several terms that have similar meanings to LUS have been used extensively in the literature, namely; commercially less acceptable species ((CLAS) as defined by IUFRO), lesser known species (LKS), new species (NS) and previously unmarketable species (PUS). This project seeks to come out with broadly acceptable definitions of LUS and other synonyms.

[2] The IIED study was entitiled "*Conservation concerns relating to the diversification of species extracted for timber*". The study was undertaken in March 1991.

ecological impact of increased harvesting of LUS. The study noted that whereas industrial and marketing aspects of LUS have received considerable support, ecological, economic and social impacts of increased LUS utilisation have received little attention.

This project was therefore drawn up to review previous ITTO projects on LUS with particular reference to their effectiveness and impact on local communities, resource conservation and sustainable utilisation. The project also aimed at addressing information gaps arising out of the review and preparing guidelines for LUS.

The introduction of more Lesser-Used Species (LUS) and Lesser-Known Species (LKS) on the market will expand the resource base and make a lot more raw material available to the timber industry while taking some of the pressure off the few primary species. However, successful expansion of the timber industry through increased LUS and LKS supply will be dependent on adequate knowledge of the ecological and socio-economic impact of increased harvesting of LUS and LKS. Rietbergen & Poore (1995) have noted that even though numerous studies have been conducted into the effects of increased intensity of timber harvest from tropical forests, none has considered LUS extraction separately. Thus, it is difficult to draw definitive conclusions on the ecological, social and economic impacts of increased harvest of LUS alone. However, it is possible to explore the effects of increased LUS utilisation on the grounds of basic silvicultural reasoning such as:

- Increased utilisation will result in heavier harvesting which may lead to over-exploitation and increased damage to the forest stand. A longer than desired felling cycle may have to be used to restore the forest.
- Alternatively, an increase in LUS utilisation may help open the canopy and promote faster growth in forests with low harvesting intensity

According to Ahluwalia and Karnasudirdja (1995), ensuring that LUS are exploited without jeopardising the integrity of the forest ecosystem remains a challenge to foresters and conservationists.

Therefore, this Project was designed to look at the sustainability of the resource base of the LUS and LKS, establish their ecological and socio-economic impacts as well as the possibility of and trends in their marketing on the international market. Research questions that were addressed were as follows:

- To what extent will uncontrolled logging affect the dynamics of the forest?
- How can the forest resources be effectively and efficiently utilised in order to minimise ecological impacts?.
- What is the long-term impacts of increased LUS harvesting?
- Extent of disturbance resulting from uncontrolled logging i.e. extent, duration, occurrence and reversibility?

The objectives of the project were:

1. to review general African literature on LUS focusing on "grey" unpublished literature such as project documents
2. to review policy and legislation on LUS exploitation and management in Ghana
3. to review forest management practices, including collaborative forest management, which favour sustainable LUS exploitation in Ghana
4. To determine from the perspective of the forest service, timber contractors and local communities the
    - extent of damage arising from uncontrolled logging
    - ecological impact of increased LUS harvesting
    - mitigative actions necessary to restore the forest following harvesting.

Methodology

Literature review and review of ITTO projects on Lesser Used Species

A general African literature search focusing on "grey" unpublished literature such as project documents on Lesser Used Species (LUS) was undertaken before the field survey. Results from the literature search was used in formulating the questionnaire.

Additionally, 21 documents and reports of projects funded by International Tropical Timber Organisation (ITTO) on Lesser-Used Species (LUS) were reviewed. Results dealing with the ecology, utilisation and marketing of Lesser-Used Species (LUS) are discussed.

Results from three other ITTO projects, two on-going projects, namely; ITTO PD 179/91, and ITTO PD 33/95 and one completed project, ITTO PD 74/90 undertaken in Ghana and related to LUS utilisation and local community use of the forest were also reviewed in this project with the aim of drawing up comprehensive guidelines for LUS utilisation and management for Ghana.

Letters of enquiry and networking with specialists and institutions

An enquiry consisting of 22 questions on ecological, 24 on economic and 8 on social aspects of LUS management and utilisation were sent out to key scientists, specialists, managers, industrialists and non-governmental organisations (NGOs) for their comments. Unfortunately, the response to the letters of enquiry was very poor probably because of the detailed and extensive information requested. Future enquiries should be sent to targeted individuals and adequate remuneration given for work done.

Review of Policy, legislation and forest management practices

Policies and legislation which have a bearing on the exploitation and management of timber resources, especially LUS were reviewed. The history of forest management in the country was also reviewed. Current forest management systems and their impact on the harvest and utilisation of LUS are discussed.

Field Survey

Survey location and sampling units

The survey was conducted within forest reserves in the four broad forest types to assess whether the impact of uncontrolled logging differed within forest types. Logging operations were stratified into small[3] and large scale logging operations[4]. The activities of small/medium logging companies were assessed in three forest types, while those of the large companies were assessed in two forest types (Table 1). The major objective of this study was to assess the ecological impact of increased harvesting of timber. However, it was difficult to find sites which were harvested at different logging intensities at approximately the same time. Therefore, the activities of small and large companies using similar machinery but exploiting different volumes of timber were assessed.

Four forest reserves were selected because they were pilot sites for the development of collaborative forest management (CFM) initiatives. The CFM initiatives were supported and funded by the Forestry Department (FD), Ghana and the Department of International Development (DFID), UK. Individuals from communities involved in the collaborative forest management initiatives were interviewed in order to ascertain whether communities with a previous history of CFM had a different perception of forestry activities. Assessment of the impact of increased harvesting of LUS by local communities involved in CFM was compared to that of local communities not involved in CFM activities.

A total of 36 villages were used for the socio-economic survey while 15 compartments were assessed during the ecological study. A total of 39 questionnaires were administered mainly by FD staff who were involved in the CFM programme with the support of some staff of the Forestry Research Institute of Ghana (FORIG). The respondents were mainly FD staff (Forest Guards or Technical Officers) and local community leaders who were present during the time when the compartment was last exploited. The local community leaders were accompanied by a team of four specialists, including two ecologists, one

[3] Small scale logging operations are defined in this study as operations that results in the exploitation of up to 3 trees per ha within a felling coupe or compartment.

[4] Large scale logging operations removes more than 3 trees per ha within a felling coupe or compartment

sociologist and one economist whose responsibility was to undertake an independent assessment of the extent of damage and recovery following logging. Compartments which were exploited about 15-20 years ago were assessed because several studies in Ghana have looked at the ecological impact of timber exploitation after one year (ITTO PD 179/91, Swaine *et al.* 1998) and three years (Hawthorne 1993). However, none of the studies have considered the long term impacts of timber exploitation. Secondly, most of the studies have focused on the collection of quantitative data on logging disturbance and regeneration but none have looked at local community perception of logging activities and damage arising from logging activities. This study therefore focuses on local community perception of long term impacts of increased timber exploitation. The ecological survey was conducted between October and December 1997.

Pilot study

A pilot study was conducted in Bonkoni and Mpameso Forest Reserves at Mim in the Moist Semi-Deciduous Forest North-West Sub-type. These forest reserves were selected because they were logged by Mim Timber Company which has one of the most accessible data on logging and processing. The company is also one of the largest in the country with potentially greater impact than other companies.

The pilot study was conducted by three researchers over a period of one week. Five compartments in two forest reserves situated about 150 km apart were assessed during the pilot study. Field visits were arranged for the key informants in the morning and afternoons while the evenings were used for the unstructured interviews.

Table 1: Number of villages and respondents surveyed in different ecological zones in the country

Ecological Zone	Forest Reserves	No. of Villages	No. of Compartments	No. of Respondents	
				Area with small scale logging	Area with large scale logging
Wet Evergreen	Tano-Nimri	4	2	-	6
Moist Evergreen	Subri South-West	4	1	3	-
	Bura River	4	1	3	-
Moist Semi-Deciduous	Assin Fosu	4	2	6	-
	Bobiri	4	1	2	-
	Esuboni	4	2	4	
	Mpameso	4	1		3
	Bonkoni	4	1		2
Dry Semi-Deciduous	Opro River	4	2	6	-
	Afram Headwaters	4	2	4	-
Total		36	15	28	11

Data collection

Four key informants or opinion leaders from local communities including a staff of the Forestry Department close to the selected compartments in forest reserves were interviewed after arranging a trip to the compartments concerned. A small group of people was interviewed because it was observed during the pilot study that even though single people were targeted, community life was such that the interview ended with a lot of people contributing answers. Administration of the questionnaires almost always took the form of discussions. It took a lot of effort in ensuring that only one person was interviewed.

Secondly, most of the villages surrounding the forest reserves are small with between 20-50 households. Therefore, it was decided following the pilot study that a lot more villages and fewer people per village should be interviewed under this project to ensure that a lot more varied opinions are captured. In all cases, only one adult member from a household was interviewed.

Thirdly, the nature of the ecological survey is such that it was believed that a lot more compartments should be visited with a number of key people who were present before, during and after exploitation of the compartments. The emphasis of this study is on the collection of qualitative instead of quantitative data.

Structured questionnaires were used to collect information on ecological and socio-economic impact of increased LUS harvesting. Data collection focused on the effect of increased utilisation of LUS on forest structure, regeneration, biodiversity, forest health and soils. Unstructured interviews were also held with 16 individuals (mostly chiefs and elders) and organisations (especially Forestry Department and logging contractors) involved in logging to investigate attitudes towards forestry development and Government policy. Additionally, the unstructured interviews were used to assess local community knowledge of logging practices and their impact on the ecosystem and socio-economic environments.

A questionnaire was developed based on experiences gathered and results of a World Bank sponsored Environmental Impact Assessment of a proposed Natural Resource Management Project. The questionnaire also draws heavily on experiences of the CFM project. The questionnaires developed were tested in four selected pilot communities at Mim in October 1997 using Participatory Rapid Appraisal (PRA)[5] methods. Several informal meetings were held with local community representatives and individuals from villages near or inside forest reserves to find out and develop indigenous local community knowledge of forestry. The questionnaire was refined following the pilot study and administered in the other sites.

Ecological Impacts

Criteria for ecological impacts

Three criteria were considered for determining the significance of ecological impacts, namely; extent, duration and reversibility. These three criteria were selected based on a lessons learnt/reviewed from a World Bank sponsored Environmental Impact Assessment of a proposed Natural Resource Management Project. Four ranks or levels were identified for describing extent and duration criteria while three ranks were used for describing the reversibility criterion. A description of the ranks are presented below:

Extent criterion

Four ranks were chosen for this criterion, namely;

Very high: - Major losses. Ecosystem unable to function without major ameliorative action

High: - Substantial losses. Ecosystem function at a low level and mitigation would be required for restoration

Moderate: - Measurable losses. Ecosystem able to continue without ameliorative action but a lower level.

Low: - Small measurable charges

Duration Criterion

Four different ranks were selected, namely;

Long-term: - Duration of impact is greater than felling cycle (40 years)

Medium: - Duration of impact is between 20 and 40 years

Short term: - Duration of impact is between 5 and 20 years

Immediate: - Duration of impact is less than 5 years.

Reversibility Criterion

Three different reversibility ranks were chosen. These are:

Not reversible: - The scale of impact is so high that it is not likely that the impact can be reversed

Long term: - The impact can be reversed only after a long period of term, probably within a time limit equal to the felling cycle.

[5] Participatory Rapid Appraisal (PRA) is an intensive, systematic and semi-structured learning experience carried out in the community by a multi-disciplinary team including local community memebers

Short term: - The impact is minimal and can be reversed within a period shorter than the felling cycle.

Ecological Impacts of Increased Harvesting of LUS and Mitigative Actions Required

Micro-climate

Forest cover regulates local climate, determines the microclimate within which various lesser flora and fauna exits. Precipitation, humidity and temperatures are all affected by the existence of large contiguous tracts of forest cover. Therefore, any drastic changes in forest cover may result in changes in the micro-climatic condition of the forest stand. Generally, increased harvesting of LUS results in greater forest canopy cover removal which leads to temperature increases and possible wind speed increases within the forest. Increased harvesting of LUS resulting in greater canopy opening also leads to an increase in wind throwing of trees and increased competition from pioneers species and weeds. However, the majority of respondents in the pilot study were of the view that Polycyclic Selective Logging did not have a major impact on the microclimate. This is probably because the yield being allocated for felling (up to 3 trees ha^{-1}) under this system of forest management is relatively low. The duration of the impact of increased harvesting of LUS on the microclimate of the residual stand was viewed by respondents to be very minimal. Therefore, this environmental component was not included in the final questionnaire that was administered in the other study areas.

No mitigative actions are required for micro-climatic impacts.

Logging disturbance and tree damage

Damage to the residual stand was greater in the Wet and Moist Evergreen Forest Types compared to the other forest types. This is probably because of the relatively bigger trees that are felled in these two forest types. Felling gaps created as a result of logging are larger for bigger trees. Logging disturbance and tree damage were also much higher in the wetter forests. However, the general forest condition after logging indicated a more open forest stand in drier compared to wetter forests. This supports the policy of having reduced yields for drier forests in Ghana.

Respondents were of the view that the extent (Table 2) and duration of logging disturbance and tree damage (Table 3) of large logging companies were greater than that of small logging companies. Whereas up to 36.4% of respondents believed that extent of disturbance of large logging companies was long term, none of the respondents were of the view that small companies created long term disturbance to the forest stand (Table 2). It is important to note that the sample size used in this study was not large enough to determine the variation and levels of significance between the different responses. This is probably because the study focused mainly on the collection of qualitative information that is highly relevant for ecological impact studies.

Most respondents were of the view that logging operations did not disturb significantly the patterns of water flow. However, the majority of respondents believed that haulage roads and skid trail construction were not carefully done. Most of the roads become waterlogged and impassable during the rainy season.

The activities of large-scale logging companies should be regulated in other to reduce logging disturbance and tree damage. Staff of timber companies should be trained in the use of appropriate directional felling and road construction techniques. Additionally, road construction standards in the logging manual should be more rigorously enforced.

Flora and Fauna

The activities of large logging companies had a much greater impact on species composition following logging compared to smaller companies. This is probably because the large gaps created by the big companies result in a greater percentage of pioneers in the regeneration following logging. Results of ITTO PD 179/91 indicate that small gaps enhance natural regeneration but very large gaps result in a reduction of the quantity and quality of natural regeneration following logging.

The extent of disturbance on flora following logging by a large company was greater than that of a small company (Figures 1 & 2). However, the extent of disturbance on primary, LUS and NTFP's were similar for each company type.

Table 2: Extent of disturbance following logging by Small / Medium and Large Contractors.

Variable	Small / medium companies				Large company			
	Long Term	Medium	Short	Immediate	Long Term	Medium	Short	Immediate
Forest cover	-	72.7	27.3	-	18.2	63.3	18.2	-
Disturbance (Forest floor)	-	45.5	54.5	-	36.4	54.5	9.1	-
Tree damage	-	45.5	45.5	9.1	27.3	63.6	9.1	-
Rare and endangered spp.	18.2	45.5	27.3	9.1	45.5	45.5	9.1	-
Rare and endanged habitats	-	54.5	36.4	9.1	36.4	45.5	18.2	-
Birds	-	54.5	36.4	9.1	9.1	27.3	54.6	-
Mammals	9.1	27.3	54.5	9.1	18.2	36.4	45.5	9.1
Reptiles	9.1	18.2	45.5	27.3	9.1	18.2	63.6	-
Pest Infestation	18.2	27.3	9.1	45.5	9.1	36.4	45.5	18.2
Forest fires	9.1	27.3	9.1	54.5	27.3	54.5	9.1	9.1
Soils	9.1	-	63.6	27.3	18.2	27.3	45.5	9.1

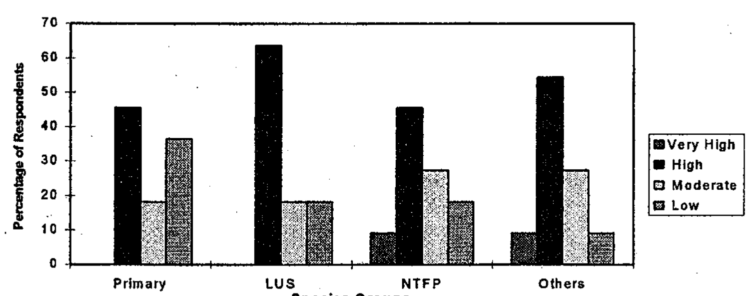

Figure 1: Extent of disturbance on different species groups due to exploitation by a small/medium sized logging company as perceived by respondents.

Table 3: Duration of disturbance following logging by Small / Medium and Large Contractor.

	Small / medium company				Large company			
Variable	Long Term	Medium	Short	Immediate	Long Term	Medium	Short	Immediate
Forest cover	36.4	45.5	18.2	-	54.5	36.4	9.1	-
Disturbance (Forest floor)	45.5	36.4	9.1	9.1	63.6	36.4	-	-
Tree damage	27.3	36.4	18.2	18.2	54.5	45.5	-	-
Rare and endangered spp.	45.5	27.3	27.3		63.6	36.4	-	-
Rare and endanged habitats	36.4	18.2	45.5	-	45.5	45.5	9.1	-
Birds	45.5	45.5	9.1	-	36.4	27.3	27.3	9.1
Mammals	45.5	45.5	9.1	-	54.5	36.4	9.1	-
Reptiles	36.4	27.3	36.4	-	36.4	27.3	18.2	18.2
Pest Infestation	45.5	18.2	27.3	9.1	45.5	45.5	-	9.1
Forest fires	27.3	27.3	45.5	-	54.5	27.3	18.3	-
Soils	9.1	27.3	63.6	-	36.4	45.5	9.1	9.1

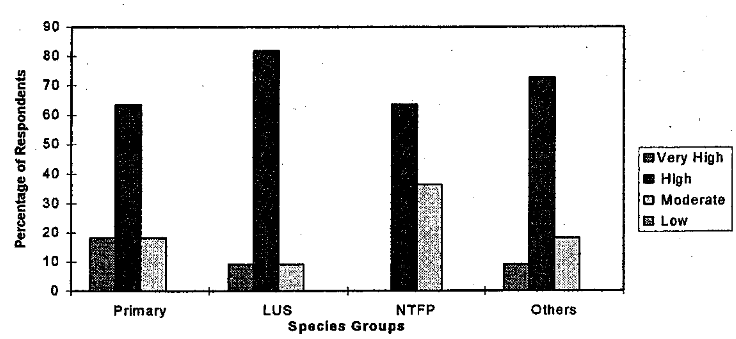

Figure 2: Extent of disturbance on different species groups due to exploitation by a large logging company as perceived by respondents.

Respondents indicated that the duration of the impact of logging primary and lesser used species was long-term but the duration of the impact of logging on non-timber forest products was short to medium term (Figures 3 & 4).

Most of the respondents stated that the effect of logging by small and large companies on the fauna, i.e. birds, mammals and reptiles were similar (Tables 2 & 3). This is because most of them believe that it is the noise of machinery more than the actual area disturbed that drives away birds, mammals and reptiles.

Large canopy gaps, created as a result of logging, should be avoided. Natural regeneration techniques should target species that are heavily exploited.

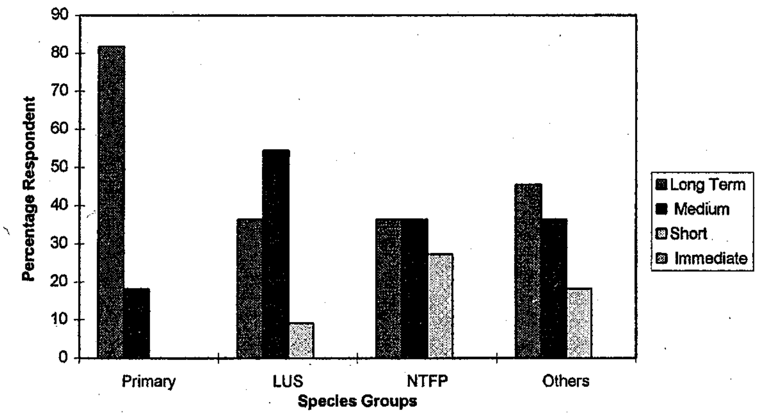

Figure 3: Duration of disturbance or period of recovery of different species groups due to exploitation by a large logging company as perceived by respondents.

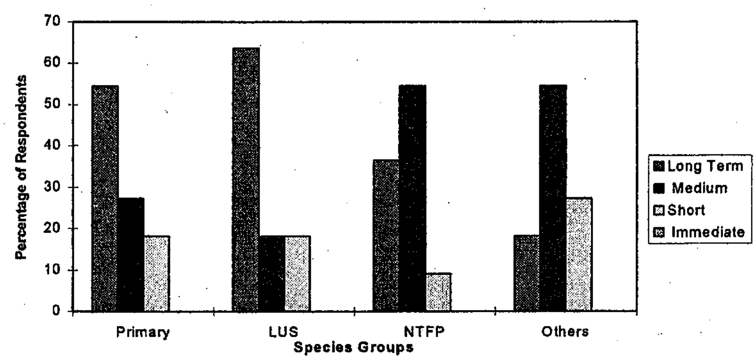

Figure 4: Duration of disturbance or period of recovery of different species groups due to exploitation by a large logging company as perceived by respondents.

Biodiversity

Respondents indicated that rare and endangered species and habitats are more affected more by large compared to small scale logging operations (Table 2). Whereas the duration of the impact of logging by large scale companies on rare and threatened species is mostly medium to long-term that for small companies is short to medium-term (Table 3).

Selective logging of mature or superior trees generally causes genetic depletion, consequent loss of potential food sources and disease control, reduction in the stability of ecosystems and a loss of resilience against catastrophes. The removal of seed trees also reduces the potential of the forest to regenerate after logging. Logging also alters the habitat of wildlife by changing or destroying nesting, feeding and breeding sites. The disappearance of species or the alteration of species compositions in ecosystems may cause irreversible losses of natural resources. The results of a reduction in biodiversity

Forest protection strategy should be enforced. The Biodiversity action plan should be widely disseminated, especially within the timber industry. Critical areas for conservation and rare and endangered species should be identified and protected in all forest reserves prior to exploitation (MLF 1997).

Soil

Respondents were of the view that the extent and impact of logging on the soil was greater for larger than smaller logging companies (Tables 2 & 3). Soil compaction was viewed as a greater problem following logging than soil erosion. This is probably because, with the exception of two compartments at Tano-Nimri Forest Reserve (WE) which were sloping, most of the compartments assessed had a generally flat topography. The low impact of logging on soil erosion may be due to relatively low yield allocated under the Polycyclic Selective Logging System and the rapid regrowth of vegetation on skid trails and felling gaps following logging. Another major impact of logging is the removal of the top soil during log dump, haulage road and large skid trail construction resulting in loss of soil fertility.

Logging roads and loading bays effectively remove a significant percentage (ca. 5-7%) of forest from production, but are rarely re-used on second rotation because their position is largely determined by the trees selected for felling. Logging concessions permit extraction only for three years, but their effects on forest regeneration are much more chronic because trees are very slow to re-invade the compacted road surfaces. There is a danger that road construction will cause a cumulative loss of production over several felling cycles.

Measures to return logging roads to productive use should be undertaken following logging (Table 4). On closing operations in a concession, the contractor should rip up the surfaces of all not permanent roads using tines, which will permit water infiltration and rapid vegetation regrowth.

Forest Health

Forest fires in Ghana may be linked to climatic changes, but one cannot simply dismiss current levels of fire damage as part of a natural cycle. This is because, the incidence of fire increases with forest disturbance. Logged forest areas suffer more heavily from fire damage than unlogged forests. Most respondents indicated that the activities of large scale logging operators were more likely to lead to greater forest fire risks. This is probably because the large canopy gaps created as a result of the activities of the large logging companies leads to the rapid colonisation of these gaps by the invasive weed, *Chromolaena odorata*, which is a fire risk.

Logging companies should include forest fire prevention and control programmes for the compartment to be harvested in their logging plans. Collaborative Forest Management (CFM) initiatives between Forestry Department and local communities should be initiated on forest fire management.

Table 4: Summary of impacts of increased logging and the mitigative actions required

	Impact		
Variable	*Small*	*Large*	*Mitigation*
Micro-climate	Low	Low	None
Hydrology / Water quality	Low	Low	Riparian forests and water sheds not to be logged
Soil			
Compaction	Moderate	High	Rehabilitation following logging
Fertility	Moderate	Moderate	
Biodiversity			
Flora	High	Very high	Biodiversity protection strategy implemented
Fauna	High	Very high	
Rare & Endanged habitats / spp	High	Very high	
Forest Stand			
Regeneration	High	Very High	Enhanced regeneration procedures

Impact of the Collaborative Forest Management Programme on Local Community Knowledge and Perception of Logging Operations

The design of the project was such that the impact of the on-going collaborative forest management (CFM) programme on the control of logging operations and damage following logging could not be assessed. This is because the study focused on compartments that were logged about 15 years ago, whereas the CFM programme was initiated only 6 years ago. However, a number of communities that have participated in CFM activities were visited in order to assess whether the CFM programme had changed the way local communities perceive logging activities and its impacts.

The assessment of the impact of logging of local communities participating in CFM was similar to those that had not participated in the programme (Table 5). However, the mitigative responses outlined by these two groups of communities were different. Communities participating in the CFM programme wanted an active role in the restoration of badly degraded sites through the Taungya system. They also wanted to be given the responsibility of protecting the forest resources in exchange for the initiation of development projects in their communities. However, most of the communities which are not involved in the CFM programme saw the problem of forest degradation as a direct result of the activities of the Forestry Department and timber contractors and therefore wanted them to take responsibility for any restoration programmes. They were willing to participate in programmes aimed at restoration of degraded sites provided they are adequately compensated.

Table 5: A summary of the asessment of the impact of increased logging by local communities. The mitigative actions suggested by them are also presented

Variable	Impact		Mitigation	
	CFM Communities	*Communities without CFM*	*CFM Communities*	*Communities without CFM*
Micro-climate	Low	Low	None	None
Hydrology / Water quality	Low	Low	Water sources of communities should be protected	Riparian forests and water sheds not to be logged. Taboo should be respected
Soil				
Compaction	Moderate	High	Rehabilitation by local communities using Taungya	Rehabilitation by Forestry Department (FD) and Timber contractors
Fertility	Moderate	Moderate		
Biodiversity				
Flora	High	Very high	Protection by local communities	Protection primarily by FD with support from the Local communities
Fauna	High	Very high		
Rare & Endanged habitats / spp	High	Very high		
Forest Stand				
Regeneration	High	Very High	Enhanced regeneration using Taungya	Enrichment planting by FD

General Discussion

Ecological Impacts of Increased LUS Harvesting

Uncontrolled logging in Ghana by small scale timber contractors generally results in moderate damage to the forest stand. Small scale logging operations resulted in the removal of up to 3 trees ha^{-1} in Ghana (Agyeman *et al.* 1995) and 2 trees ha^{-1} in Cameroun (Duiker & van Gemerden 1989) which affects up to 13% and 20% of the total area in Ghana (Hawthorne 1993, Agyeman *et al.* 1995) and Cameroun (Duiker & van Gemerden 1989) respectively. A higher logging disturbance was recorded in Cameroun compared to Ghana even though less trees were removed because of the larger diameters of the felled trees.

According to Planning Branch (1997) the present logging intensity in Ghana can presumably be somewhat increased if more species are used, without compromising sustainability. The annual allowable cut for reserved forests is estimated to be 0.5 million m^3 if all trees marked out for harvesting are removed (both primary and LUS). However, the majority of species that are currently harvested in the country are primary species and therefore an annual allowable cut of only 0.3 million m^3 is permitted from reserved forests. The timber industry's access to wood can be increased by about 40% by broadening the harvested species base to include LUS.

Logging disturbance and tree damage were found to be higher in the wetter forests. These differences may be attributed to the fact that larger trees were felled in the wetter forests as is evident from the larger gap sizes and larger mean volume of the felled trees observed from the results of ITTO PD 179/91. Another reason is that most areas in the wetter forests were logged once (first rotation felling) whereas most of the drier forests have been logged at least twice. Incidentally, the wetter forests are richer in floristic composition and have a greater percentage of fragile environments that needs to be protected. Since these areas also have greater logging disturbance and tree damage per unit volume of wood harvested, there is the need for stricter logging controls in the wetter forests compared to the drier forests. In practice, however, the manual of procedures of forest management in Ghana indicates that a higher felling intensity should be carried out in wet and moist forests (up to 3 trees ha^{-1}) compared to the drier forests (up to 2 trees ha^{-1}). This is probably because the drier forests are subject to annual fires that have degraded the forests and caused excessive canopy opening. A high felling intensity therefore, predisposes these drier forests to much more severe fire attacks in subsequent years.

Enhanced regeneration was observed in small gaps and skid trails in this study, even though results from a similar ITTO (PD 179/91) study which focused on damage immediately following timber exploitation show that disturbances due to logging markedly reduce the pre-existing tree seedlings in felling gaps and skid trails. This is probably because, the stimulation of new seedling establishment significantly exceeds these losses (Swaine *et al.* 1998) due primarily to the local enhancement of light, the principal limiting factor for plants in forest.

The impact of logging by small and large companies on the fauna, i.e. birds, mammals and reptiles were similar to their impact on forest flora. According to Myers (1988) forest disturbance affects animal populations even more than plant species, as animals often require large ranges. According to some local communities the noise of logging machinery chases away most mammals and birds. The impact of timber harvesting on forest flora depends on the ecology of particular species or group of species. Since different silvicultural systems produce forest stands with different forest structure, their impacts on animals varies depending on animal habitat requirements and ability to recognise logged forest (Gullison & Hardner 1993).

The main threats to biodiversity in Ghana are increased incidence of annual fires, increased exploitation, and clearing of forests for agriculture (Hawthorne 1994). Logging activities may result in the disappearance of species thus reducing the species diversity. Generally, the number of species and families in the logged-over stand are smaller than those in primary forest. Logging in a way reduces the potential of the forest itself (Abdulhadi *et al.* 1981). Uncontrolled logging has considerable impact on forest structure, species composition and biodiversity conservation and may lead to loss and fragmentation of forests (Foaham & Jonkers 1992). However, the current intensity of harvesting in Ghana (less than 3 trees ha^{-1}) results in an acceptable level of impact on biodiversity and the integrity of the forest in general (Hawthorne & Abu-Juam 1995).

Respondents were of the view that the extent and impact of logging on the soil was greater for larger than smaller logging companies. Soil compaction was viewed as a greater problem following logging than soil erosion, especially viewed against the background that current road construction activities of large companies tends to cause a cumulative loss of production over several felling cycles due to serious soil compaction.

Another major impact of logging is the removal of the topsoil during log dump, haulage road and large skid trail construction resulting in loss of soil fertility. Congdon and Herbohn (1993) observed that nutrient concentrations in felling gaps were depressed in wet tropical forests compared to unlogged forests even 25 years after selective felling. Conventionally, harvesting removes about 5-30% of the total nutrients taken up in the above grand stand (Stone 1968). There is a worldwide concern that increased removal of tree biomass with its nutrient content causes a decline in soil nutrient and forest productivity (Jordan 1985). Additionally, opening up the canopy through logging results in higher daytime temperatures and reduced daytime humidity on the forest floor (Schulz 1960) which invariably influences nutrient cycling.

Implications for Sustainable Harvesting and Forest Management

Current felling intensity by the majority of loggers (small/medium sized companies) in Ghana (0.33 m^3 ha^{-1}) is lower than that of most tropical countries in South East Asia and Latin America (0.8-1.1 m^3) (Gormley 1997). The effects of the operations in the country are therefore not too disruptive to the forest ecosystem (Hawthorne 1993). A study of the activities of large scale companies in this study also indicates that increased harvesting of LUS, if controlled i.e. within the framework of the annual allowable cut will lead to minimal negative impacts on the forest stand. However, uncontrolled harvesting of LUS by large operators in some study sites resulted in poor regeneration and forest stand condition even 15 years after logging. This is probably because the large canopy openings, especially logging roads and skid trails created following logging by large operators resulted in a high proportion of pioneers among the regeneration which are less valuable timber trees compared to light demanders and shade bearers. The results of this study together with other ITTO studies (PD 74/90 and PD 179/91) will provide the baseline information which together with other relevant information will lead to the determination and implementation of a sustainable level of harvest. This will include the volume of LUS that can be additionally harvested without jeopardising the ability of the forest stand to recover within the felling cycle.

It is well known that the future security of wood source from tropical forests depends on LUS. As trade continues to evolve, LUS will provide greater opportunity and incentive as well as income to forest managers leading to greater feasibility in silvicultural planning and responsibility towards maintaining SFM. Increased harvesting of LUS done on an economically and ecologically sound basis is firmly linked to SFM. This is probably because increased harvesting of LUS invariably leads to increased income part of which can be invested in the development and implementation of SFM techniques.

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Forest Degradation and Its Effect on Sustained Water Supply

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Introduction

Man exercises some influence on the hydrological cycle through the way he uses land. Through arable and pastoral farming activities as well as lumbering, man may exert some influence on the local and often regional hydrological cycle. Thus, water supply may be affected. However, there is uncertainty of the resulting hydrologic consequences of land use changes under tropical conditions, partly due to the fact that only very few field studies have been documented on the subject. Thus, a lot of room has been left for pure speculations that lack proper factual and scientific basis. On the other hand, encroachment on watersheds by farming activities, overgrazing by livestock, felling of trees for timber, fuel wood and biomass-burning is steadily increasing in Ghana according to the Ghana National Report on Environment and Development presented at UNCED in Rio in 1992. The Environmental Action Plan of Ghana (1991) also acknowledges that inappropriate land use may constitute a serious treat to water resources as well as serious land degradation inclusive of soil erosion.

The Forestry Research Institute of Ghana (FORIG) and the Timber Export Development Board (TEDB) with the support of the International Tropical Timber Organisation (ITTO) instituted a project "Industrial Utilisation of Lesser-Used Timber Species (LUS). The project is about enhancing the acceptability of some less known timber species on the international market. A number of issues were tackled of which one area is on the hydrological status of the catchments Bura, Draw and Opro forest reserves where the project was executed. It was envisaged that considerable logging of these less known timber species would take place after the project becomes a success. The then Water Resources Research Institute (WRRI), now Water Research Institute (WRI) of CSIR was requested to undertake the collection of baseline data on hydrology of the three forest catchments to enable the impact of logging on hydrology of the catchments to be assessed later when enough data have been acquired. The assessment aspect of this project was not part of the current study and therefore reporting of that has been left out. However, the baseline data collected has been documented in a report titled Hydrological Baseline Data Collection for Opro, Draw and Bura Forest Reserves by WRRI, April 1997 and could be found with FORIG and WRI.

This paper seeks to look in general at forests, namely our use and misuse of forests and its effects on the water resources of the areas. How these affect water supply is what this paper seeks to address. For the purposes of this article, water supply refers to potable water supply relevant to life in general. The forest plays a very vital role in the hydrologic/water cycle, as such some mention would be made of the cycle to assist with understanding.

Hydrologic cycle

Water for life goes through many processes before being utilised by life. A concept through which water is recycled is known as the water/hydrological cycle (Figure 1). This term is used to describe the endless interchange of water between the ocean, air and land. It consists of numerous storages and pathways through which water in nature circulates and is transformed from one state to another. The following; rain/precipitation, interception, evapotranspiration, infiltration, surface flow, subsurface flow, streams and oceans are some constituents of the cycle. Forests play a very vital role in this cycle because of the influence it has on interception, evapotranspiration, infiltration and others.

Forest and Water

Forest cover is desirable in catchments, especially in areas of high rainfall and rugged topography because it reduces high flows and subsequently reduces floods. The forest does this by intercepting some of the precipitation and delaying the period of the rain reaching the land surface which otherwise would have hit the land surface directly, subsequently causing erosion and high runoff. Among other things the forest protects: -

- soil against raindrop impact to safeguard erosion;
- encourages infiltration so that soil erosion is reduced;
- and stream flow is regulated as flood peaks are reduced, while
- dry period flows may be slightly increased.

Again, forest transpires a lot of water and because of their deep rooting systems, trees are able to tap water at considerable depths especially during the dry season. This encourages healthy tree growth and consequently improves leaf shade, which consequently hampers direct evaporation from soil surfaces. When forest is cleared, there is reduction in evapotranspiration, which may lead to a rise in the water table. This can cause problems in areas of saline groundwater as springs in such areas can destroy vegetation around. On the other hand chemicals transported up as a result of rise in water table could be leached into streams and rivers which might compromise their quality status. This results in high cost for water treatment for human use. Forest clearance can also result in a drop in the water table because of decrease in infiltration. This makes the hydrological characteristics of forested catchments as well as the hydrological consequences of replacing such forest with other land uses rather complex.

Therefore the benefits of forest cover, such as reduction in storm runoff and erosion must be weighted against its demerits such as high water use rates and reduction in total stream flow, which may be serious disadvantages in areas of water shortage.

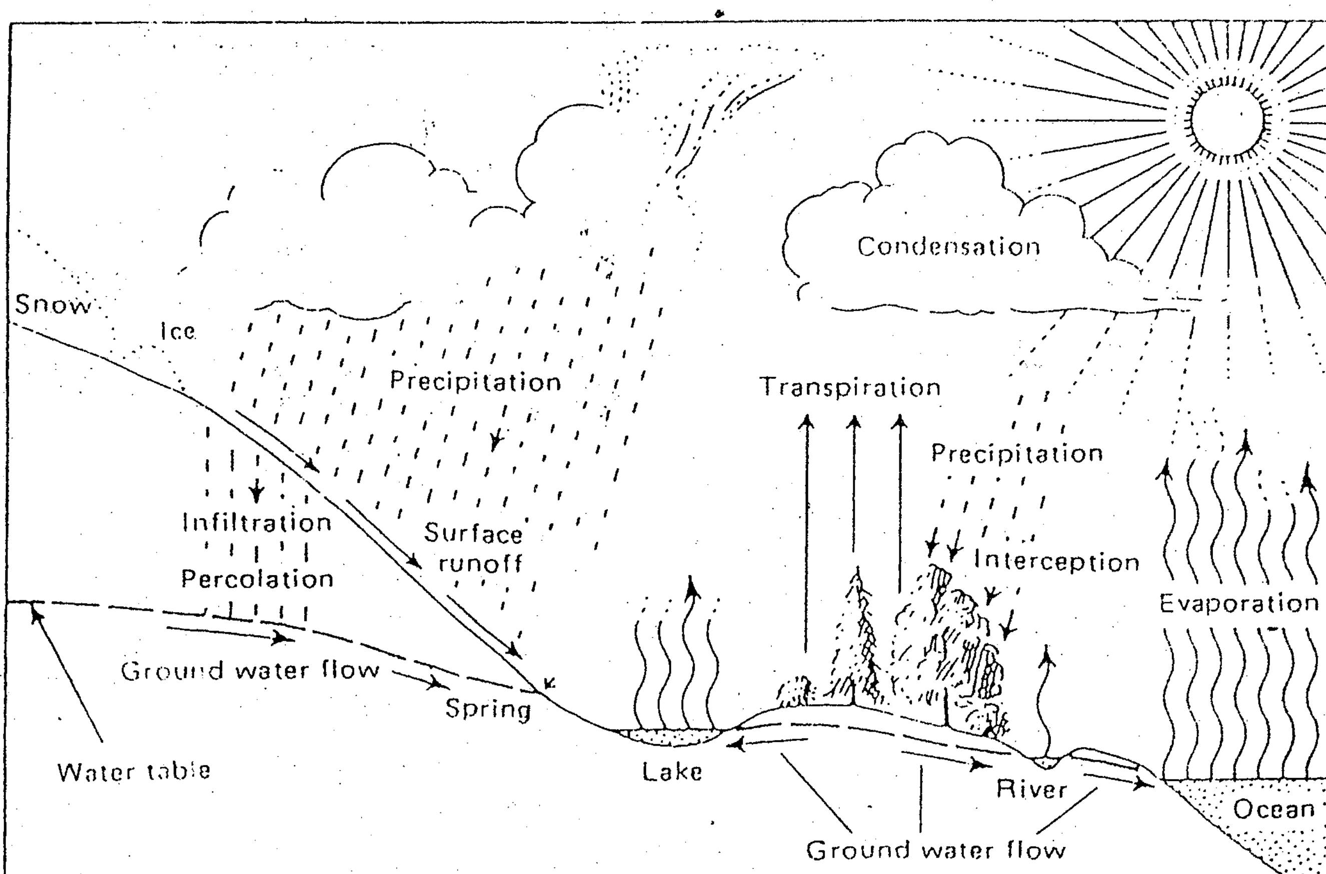

Figure 1. The hydrological cycle (Reproduced from A.D.M. Phillips & B.J. Turton (Eds.) (1975) Environment, Man and Economic Change, by permission of the Longman Group).

Practices that reduce forest covers

Deforestation is the process of clearing forest covers for other land uses like agricultural farming and human settlements. It is a phenomenon that is on the increase in Ghana. Two main operations of cutting trees are employed. They are the chainsaw operators' methods and the mechanised operator's method, which uses heavy equipment. The former process is known to be friendlier to the environment as it does little to disturb the natural ecology. On the other hand, the mechanised scheme is very detrimental to the ecology. This is because studies have shown that it disturbs the vegetation around, compacts soils during movement of tractors and loosens soil structures in certain instances when dragging of felled trees. These effects largely affect the quality of water that gets to the various water systems namely the lakes, rivers and oceans. Compaction of soil arising from trampling will result in dramatic reduction in the infiltration capacity. This will eventually have the following effects:

- Prevent the build-up of soil moisture reserves for use during the dry season by plants
- Adversely affect the recharge of groundwater systems with consequent fall in groundwater table.
- Lead to increase in overland flow which might cause flooding
- Create problems of silting of reservoirs downstream reducing water volumes in streams and rivers eventually creating flooding downstream.
- Increase rate of erosion of loosen soil and sediment yield of rivers.

Other modes of clearing forest cover are through burning of bush fires and overgrazing. Bush fires have also lately gained prominence in the country. By clearing through fires, unlike felling which is done selectively, this is done wholesale. This means every cover is gotten rid of and creates bare land surfaces and soot. Bare surfaces enhance quick runoff from the watersheds and infiltration for improving groundwater is reduced. On the other hand, soot from the burns find their way into the water systems and pollute them.

Effects of our forest on water supply in general

It is realised from the above that our water systems basically depends on whatever activities take place on land of which forest are a part. As is generally known, most life, be it plant or animal, depend on water for their existence. Thus, the quantity and quality of water available is always important for the day to day activities of man and life in general. The Table below shows the distribution of world water, which put the volume of the ocean as 94.2% of total available waters. The remaining which is normally termed fresh waters only occupies a total of 5.8%. These fresh waters are the concern of humanity as many human activities depend on this for survival.

Table: Estimates of the world's water

	Volume ($10^4 km^2$)	Percentage (%)	Rate of exchange (years)
Oceans	1370	94.2	3000
Groundwater	60	4.13	5000
Ice Sheets and glaciers	24	1.65	8000
Surface water on land	0.28	0.019	7
Soil moisture	0.08	0.0055	1
Rivers	0.0012	0.00008	0.031
Atmospheric vapour	0.014	0.00096	0.027

Source: Hydrology in practice by Elizabeth M. Shaw

Most experiments conducted in East Africa, Asia and South America (Lal & Russel, 1981) have shown that the annual yield of water in some forested catchment increases with deforestation. However this is normally attained during the rainy season and in a shorter period whilst during the dry period water is nearly non existent. When storage facilities are adequate water supply is improved. But in instances like in Ghana, where storage facilities are poor, such high water yields are not well utilised. Thus, this increased yield may then cause flooding downstream if not controlled. When the flooded area happens to be inhabited by humans or less water loving plants, disaster strikes and there is chaos. Meanwhile in the dry season of such deforested catchments, water shortage is encountered. On the other hand, it is known that forest reduces surface flows. What this means is that, some water infiltrates into the ground to recharge the groundwater and the same forest reduces evaporation, so that flow of water to the various systems are controlled sort of. This could be attested to in Ghana especially in the forest regions of this country. In this, most streams and rivers are perennial as compared to their counterparts in other regions like the Northern Regions with savannah vegetation where streams are seasonal. Whereas a high water table means more water for people in some areas that depend on hand-dug wells, a low water table creates drought in certain areas.

Since deforestation increases surface runoff with its attendant soil erosion, most rivers and streams around are silted up in the process loosing some capacity of their channel volume. What this means is that the volumes of water that they could have stored are reduced and as such water shortages are encountered in the lean seasons. Again, in instances where the water table rises with chemicals leaching into the water systems, the quality of water could degrade. This will affect the health of those who depend on it. This might affect farming, which is the main job for most rural dwellers.

Conclusions

When water table falls, water shortage is envisaged. In that situation, women and children will have to walk long distances in search of water. The destruction of the forests affects the poor. Apart from the loss of trees, fruits, fuel wood and fodder are also destroyed. The water quality is degraded and health of humans is threatened. Also, very important medicinal plants are lost. Rural incomes reduce and quality of life is greatly affected. Drought might put enormous pressures on the rural pollution to migrate to inland watersheds in search of arable land. In Ghana, most of the forests around our river banks of rivers Densu, Offin and Ankobra have been destroyed and water quality and volume have reduced (Barlertey Gormey 1997). Our previous experiences show that man must cease to regard water resources as an inexhaustible gift of nature. Our water resources can be preserved only if used with the greatest care and if proper attention is paid to its natural conservation. As a component of the environment, its utilisation and conservation must be guided by a technical policy that must be adhered to by all users of the resource.

Recommendations

Whether the effects discussed above are actually what pertain here in the country is not obvious although it could be assumed to apply. These call for localised studies to actually ascertain some of these findings.

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Forestry and Rural Development in Developing Countries

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Introduction

The rural areas harbour 60-70 percent of the population of most developing countries. The people are generally poor, unskilled, under employed, unorganised, and have very low access to goods and services, including shelter, nutrition and health. The rural areas have less than 10 percent of national skills and less than 20 percent of national investment finance needed for development in most developing countries. Despite the superior numbers, the rural people in developing countries lack the political clout to influence development the way they conceive and perceive it.

There is a good deal of rural-urban migration because of the yawning gaps of income, livelihood and employment opportunities. The movement from rural to urban areas is causing urban congestion, thereby exerting pressure on utilities and facilities and upsetting urban planning.

A majority of the rural people earn their living out of crop cultivation, animal herding, fishing, and forest product utilisation. In the past, most developing countries saw the challenge in rural development in terms of promoting agricultural growth. Bioresources, which play a dominant role in the industries and export trade of developing countries, were taken for granted as unlimited bounties. Now that 90 percent of the world's population growth is occurring in developing countries, the concept of bounty has proved false. Vegetation, soil and water resources have not only become degraded but have limited the sphere of agricultural activity, proving in no uncertain terms the inter dependence between agriculture and natural resources.

The need to maintain this linkage between agriculture and forestry to create positive synergies for sustainable rural development has now dawned on development planners and policy makers in developing countries. The main challenge is to develop biological and technical management systems and methods to transform peasant agriculture to satisfy the bulk of food, fibre and energy requirements, and provide surpluses for both domestic and export markets on a sustainable basis. Rural development should therefore be seen as an empowerment process leading to the sustainable management of soils, water, forests, grasslands, fisheries and wildlife resources by the rural dwellers. The need for unified extension rather than sectorial extension education in developing countries is therefore paramount if present sectorial conflicts are to be resolved to ensure sustainable rural development.

The other cause of the inability of the rural económics in developing countries to respond more robustly to various government interventions aimed at achieving higher rate of growth has mainly been due to lack of appropriate technologies. Methods and practices prescribed have either been unaffordable, ineffective under field conditions or too sophisticated for local skills. The technological challenge in rural development in developing countries is enormous and requires a systems approach which will ensure that research is participatory, demand driven, and capable of stimulating appropriate and affordable technical changes. These challenges can only be met if a national programme on research is properly funded by the public sector since there is still very little capacity and interest from the private sector.

Rural Development

Rural development has become a major approach to national development both in theory and practice of development in Third World countries. Rural development requirements are many and diverse, but mainly focus on finding effective ways of stimulating, helping, supporting and sharing rural production experiences in a bid to empower rural people to adopt new methods, learn new skills and adapt their ways of life to the changes that are continually occurring in the rural environment. No one process is a panacea, since addressing long term production issues simultaneously requires: reducing the rate of population growth; changing cultivation practices from extensive to systems that incorporate adequate soil conservation and soil fertility management measures; improved natural resources management, regulation, protection and conservation; and addressing deepening and persistent rural poverty.

The World Bank strategy for development directed at the poverty problem rightly emphasises rural development in terms of a broad and comprehensive process rather than a simple goal of increasing production. Forestry as a focus for rural development in developing countries must therefore face, rather than ignore the importance of positive synergies to be derived from sectorial linkages. In this connection, reducing the rate of population growth, making agricultural production sufficiently intensive, handing back forest property rights and forest stewardship duties to forest communities and recognising the basic forest product needs of forest dependent communities are essential areas of linkage to development to reduce sectorial conflict and enhance forest management.

Forestry for rural development should not be regarded as a sectorial step, on the contrary, it should be seen as a link to economic rural production, environmental management and ecology. It is impossible to implement a forestry action programme for development without participation by rural production interests in decision making at all levels. Forestry for rural development in developing countries would only be durable when cross-linked to agriculture, fisheries, wildlife and range management. The advantage is that linkages of this nature have better prospects of conserving land, soil, water, plants and animal genetic resources and can address cultural, traditional, ecological and socio-economic concerns in rural land use.

Forestry as a Tool for Rural Development

Since the publication of "Forestry for Local Community Development" by the FAO in 1978, many developing countries have realised the vital role of trees and forest resources in rural development. For rural communities, for whom forests provide livelihoods ranging from seasonal off-farm employment to daily needs such as food, fibre, construction wood, fuel wood and plant medicine, forests make the difference between being and not being. Of particular significance is the total dependence by nomadic tribes on forests and forest resources in most developing countries.

Forestry in rural development must have a strong focus on poverty alleviation, gender inequality, land and tree tenure, community participation in forestry decisions as well as social, economic and political forces which control or induce deforestation and thereby reduce incentives to practice sustainable forest management by forest communities. Other important areas of focus include pricing and marketing of forest products. It is only when forests survive and contribute to rural incomes and improve rural livelihoods that their management and renewal can contribute to rural development.

In developing countries where large tracts of unutilised forests still exist, they provide great opportunity for economic growth and rural poverty alleviation.

The importance of forestry for accelerating economic development has been led by Westoby (1963), who emphasised the importance of forest product linkage effects on development. According to him forest industries have a relatively high demand for labour and locally produced raw materials and generate multiplier effects, external economies, foreign exchange earnings and import substitutes that can combine to make significant contributions to economic development. Though Westoby's deductions were in respect of timber industries, they can be equally applied to general forest production for rural domestic consumption and other forest sector activities.

However, policy makers, forest economies and foresters in some developing countries still tend to view forests as source of national revenue with timber as the dominant product. In such countries forest control and forest management decisions have been wrestled from forest communities and this has not helped in promoting well-informed decisions in forest management. In these instances where Foresters' decisions have fallen short of community concerns and goals, community stewardship of their forests has been discouraged, and the rural incentive to practice sustainable forest management no longer exists.

Lack of local control and decision making in the management of the forests surrounding most communities in developing countries has therefore accounted for the reduction in the contribution of forestry to rural development. Current upsurge of recognition of the vital roles of forest dwellers in forest management is a positive turning point for forest based rural development decisions by communities and foresters in concert. The gradual return of authority over forest land to forest dwellers now make forestry a positive tool in rural development. Community stewardship of local forests is the best way to integrate environmental, economic, ecological, social and political concerns into forestry land use decision making, without which forest management cannot be addressed from the perspective of other land use interests to ensure conflict resolution and sectorial co-operation. Community participation in forest management is therefore a pre-requisite to the forestry sector contributing effectively and efficiently to rural development in developing countries. This is because community stewardship of their forests would successfully address current policy and market failures associated with existing forest tenures in developing countries and achieve better informed forest management decisions, including improved silviculture, conservation and protection for a wide spectrum of non-timber values.

We should now examine pertinent management and development activities in the forestry sector, which are consistent with rural development in developing countries.

Participatory Forest Management

Forest management is not new to forest communities. Communities have had their own management practices and conservation rules which have ensured forest survival and value down the ages. Pre-and post-colonial forest policies were responsible for community resignation from forest management. Now that the forest isolation or barrier concepts have proved unproductive, most developing countries have accepted the natural linkage between forest communities and their forests and the need for collaboration between the state and local communities for effective forest management.

Development of mechanisms to facilitate continuous dialogue and discussion with local communities is a critical requirement of collaborative forest management whether on-or off-reserves. Where the communities have their own institutions, organisations and ways of doing things, these should be adopted and developed for the planning, development, protection, regulation and sustainable utilisation of all forest resources including non-timber resources. The new collaborative forestry arrangements for sustainable forest management for rural development should ensure:

- Establishment of local authority for forest management decisions;
- Establishment of resource management and social boundaries;
- Mechanisms to define common objectives that accommodate different needs and interests;
- Harvesting rules based on sound silvicultural practices;
- Community ability to impose sanctions if required;
- Clear benefit and cost sharing arrangements;
- Establishment of efficient pricing and marketing mechanisms.

Once communities are supported to re-assert legitimate rights over their forest resources both on and off reserves and free access by outsiders is stopped, sustainable forest management would become a reality and contribute to community needs for rural development.

Collaborative forest management can also improve the quality and seasonality of rural water supplies through catchment management or rehabilitation where necessary. In the very dry areas forests constitute the first line of defence against desert extensions and desertification encroachment. In protecting and maintaining healthy environments, forests also contribute to eco-tourism, recreation, biodiversity maintenance and national energy supply, and offer effective protection to productive systems, including land and water, a situation which is quite critical for rural development in development countries.

Most rural people depend predominantly on wildlife and fisheries for their protein supply, which is critically required for a balanced diet, and this requirement can best be assured through sustainable forest management led by forest communities. In producing edible leaves, stems, roots tubers, fibre, honey, fruits, nuts and other range of products for the household menu, forests account in no small measure for rural food security. Forest contribution to food security is particularly obvious in times of famine and other emergencies. The rural areas have had a long history of plant medicine, which is the backbone of traditional healing for which the maintenance of bio-diversity is highly essential. The actual and potential contribution of forestry of rural development in developing countries ranges from the provision of shelter, nutrition and good drinking water to the maintenance of rural health and provision of employment and income.

In the Sahelian countries where national dependence on wood energy is as high as 95 percent of total national energy supply, deforestation is just as chaotic as oil crises in oil dependent countries. The need both to conserve wood resources through appropriate forest management mechanisms and regulatory measures where forest still exist and to develop such resources where they have been heavily eroded, cannot be overemphasised. Besides, the rural areas in developing countries almost wholly depend on forest energy for survival.

Plantation Forestry for National Wood Energy Development in Resource Poor Developing Countries

Traditionally, forest products including fuel wood, charcoal and non-timber products have been available and harvested from natural forests and woodlands.

In many developing countries, this is still the practical reality and there has not been much need to revert to artificial systems such as plantations to meet these needs. In such areas all that is required is the establishment of systems and methods, sufficiently regulatory and well managed to ensure sustainable production to meet community needs from their forests both on and off-reserves. Current development in the forestry sector, particularly community participation in forest management attest to a gradual beginning and a hopeful future, for the management of all forest goods and services for sustainable development in the rural areas in developing countries.

Where forest resources have not been well managed or have succumbed to population pressure, and the decline in forest product supply has created local or national deficits the need to rectify the situation has usually resulted in plantation forestry both by the public sector and the private sector to satisfy demand for wood and non-wood products. Wood energy supply is particularly critical where there is deficit supply since the tendency is to use agricultural residues with the consequent effect of upsetting farm ecology and creating a vicious cycle.

Hence, the best way to satisfy demand for wood energy as well as contribution to rural employment and poverty alleviation is to mobilise rural labour and land for plantation development. Where land is a constraint, government should make degraded forest reserves available to families, households and communities living near forest estates to enter and establish plantations. The final products should then be shred between the proprietors and government in proportions, predetermined and agreed, right from the start.

This kind of arrangement would give more incentive to citizens in the rural areas to plant trees both for their domestic needs and as an extra opportunity for income generation.

Private plantation owners and plantation owners in joint schemes with government would however need support from government in the form of grants and loans. Donor agencies could also play important roles in financing private sector and community plantation forests.

Retired foresters could contribute measurably to these schemes by supporting Donor agencies, government, the private sector and communities to formulate, plan and implement plantation projects as consultants.

Apart from raw materials for both rural and urban industries, plantation forestry in the rural areas would also produce a range of export products. Cutting, cross-cutting and transporting timber and fuelwood from private and community forests could improve rural employment and income opportunities to otherwise under-employed and poor rural youth. These would definitely help stem the tide of rural-urban migration for at times non-existent jobs.

Commercialisation of Tree Seedling Production

The cost of seedling production in government nurseries is too high. The centralised nature of the nurseries also makes the cost of seedling distribution a matter of concern. The best way for government to satisfy growing seedling demand in the rural areas is to cede production to the rural communities. Government should then intensify its efforts at improved seed production and distribution at cost recovery to the private sector, planting groups and communities.

Once there is a reliable and dependable source of seed supply, the rural communities can run tree seedling nurseries as rural business. Here again retired forester's consultancy support would be invaluable.

Government support to private nursery developers should not only involve short term loans and provision of nursery infrastructure but government itself should become a willing customer and buy private sector seedlings for government plantations in the rural areas. These nurseries are likely to be more efficient and better targeted at local needs. Seedling production and distribution can be an important source of employment in the rural areas.

Wood Supporting Industries

In many developing countries, wood is still the primary source of energy and the cheapest fuel available in the rural areas for cooking, processing and curing. It is also the main domestic energy in the urban areas. Wood energy is the mainstay for the running of rural industries including brickwork, distilleries, pottery, tiles and tobacco burns.

Wood is also an important raw material for carving artefacts, tools, utensils, and other domestic wooden products, including furniture. Wood therefore supports artisanal works from which considerable revenue is earned from urban sales and exports.

The Charcoal Industry

The charcoal industry provides employment for a sizeable number of rural dwellers, both men and women. Apart from labour for cutting and cross-cutting wood and stacking for carbonisation, charcoal production also offers employment in transportation, wholesale and retail distribution. The charcoal industry is quite labour intensive. The technology involves the use of either kiln or earth mounds to facilitate controlled chemical reduction of wood to charcoal.

As an upgraded wood product charcoal is sold mainly in the urban markets and used to provide secondary energy for cooking, baking, smelting and heating. Urban fuel users prefer charcoal to fuelwood because of its superior physical and chemical properties.

In developing countries where there are still large tracts of forests, woodlands and plantation resources, charcoal production is a reliable source of employment and an important source of income in the rural areas. Charcoal production may also be planned to support domestic industries such as iron smelting, lime and cement production. There is a growing market for charcoal export to European markets where it s very popular for making barbecue.

In small settlements of wood endowed areas, surplus wood can be used to generate electricity through boilers to serve the rural areas. In the highly degraded areas forestry can contribute to development through a range of farmer focused planting programmes within farm systems, fallow lands, degraded and derelict lands.

Agroforestry

In addition to establishing quick growing plantations, farmers may integrate trees into their farm holdings to support their domestic wood needs, conserve soil and water and improve farm production. The range of opportunities includes management of trees on range and fallow lands as well as establishment of woodlots. Other designs may take the form of dispersed planting on farms, farm boundary planting, windbreaks, shelterbelts and home gardens. When trees are well selected, apart from profitable financial returns from the sale of wood, farmers may also benefit from fodder production, soil fertility improvement and erosion control.

In situations where households are becoming more dependent on income from tree products, forests can contribute quite measurably to household income and rural welfare.

The Timber Industry

Westoby (1962) regards the timber industry sector as a propulsive sector, arguing that it has strong forward and backward linkages with other economic sectors and could induce spontaneous investment in many areas of production. Its primary conversion products form the raw materials for other industries. Therefore where timber industries have been sited in the rural areas, they have not only provided employment and training for the rural communities but they have opened up the country side with roads and given rise to occupational crafts and artisanal industries.

Some timber industries have established well-planned community settlements for their labour and provided modern social amenities otherwise woefully lacking in such areas.

Conclusion

Two decades back, it was difficult to convince donor countries to fund non-industrial forestry projects. Now donors realise that the real needs of developing countries to win their battles against dessertification, deforestation, soil erosion and severe shortages of food, fuel-wood, poles, fodder and fruits cannot be achieved without certain basic forestry interventions in the rural areas.

Unfortunately national accounting systems still lack behind in accounting properly for the contribution of forestry to national development. This has not only given a low profile to the forestry sector in the allocation of national resources for development, but has undermined the development role of forestry in national development policy decisions.

If forestry has to play its crucial role in rural development in the developing countries, it would have to be given a better recognition and a higher profile in national development planning.

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Technical Session III: Processing and product development

Technical Session III: Processing and Product Development

Chairperson: Dr. E.O. Bello, Director FPDRI, Philippines

Increased Utilisation of Lesser-Used Species - Social And Economic Impact

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Harvesting of trees for commercial and industrial purposes is 100 years old. One hundred years ago the axe and the platform were in use and it took days to fell a mahogany tree. There were no crawlers, skidders or wheeled tractors; no motorised chain saws; there were no sawmills, veneer mills, furniture and joinery outfits; no electricity and the road network was hardly developed. In short, our people looked to the forests for supply of dead wood as fire wood, and somehow manufactured small diameter trees and species into shingles, building members and household furniture.

From small beginnings involving the export of round logs of Mahogany and Edinam, Ghana now boasts of an export industry producing lumber and lumber products, sliced veneers, plywood, furniture and flooring parts. At the national level, we can claim that through proper allocation of logs, timber utilisation can be optimised. This means that sawlogs, logs for peeling and logs for slicing can be directed to appropriate processing plants. From two (2) to three (3) species, the Industry is now felling 60-65 species annually, with the sawmills taking in 30 to 40 species; slicers, 31 species, rotary or peeled veneers 18 species.

Dominance of Some Species

Professor Edward Ayensu, a prominent Ghanaian of Smithsonian Institute fame, has noted that Ghana has 3,600 species while, in a publication on biodiversity by the UK Department for International Development, it is stated that 250,000 species of higher plants are thought to exist.

Of the 60-64 Ghanaian species, we note that Odum, Mahogany, Ofram, Wawa, Koto, Niangon, Emire, Ceiba, Afzelia and Asanfona are dominant in terms of volume exported.

Growing Scarcity of Traditional Species

Ghanaian forestry reports in recent years indicate that the species for which Ghana is known in international markets are becoming very scarce. Species have been categorised into starts of various colours, from Green to Pink, Red, Scarlet and Black stars. This scarcity picture does not augur well for the timber industry and trade. Invariably, a species gains acceptance on the market and it deteriorates into a scarlet star species and even a permit species. Its place in the market is threatened.

Lesser Used Species to the Rescue

Current philosophy is that to reduce the pressures on the popular species, Industry must take a close look at the Lesser-Used Species (LUS). In order that a LUS does not get "promoted" to scarlet star, certain requirements will have to be met. Most so-called LUS have been known for a long time, at least, for fifty years. Their properties have been documented by British, French, Ghanaian, Belgium and German experts.

Relying on available knowledge, cooperation of major buyers and at high expense. Industry has been able to extend the range of species in demand up to 65. Species such as Bombax, Otie, Koto, Asanfona, Bompagya, Aprokuma, Dahoma, Akasa, Wawabima, *Canarium*, *Albizia*, Kyenkyen, Essa, *Ceiba*, Potrodom/Tali, Essia, Yaya (*Amphimas*), *Hannoa* etc, were once classified by the Forestry Department as secondary species.

Increased Utilisation of LUS Market Requirements

A successful promotion of use of LUS is always backed by full information on the species. On top of the list is the long-term availability of the species. This long-term availability should be buttressed on substantial investment in research into the regeneration of the species either in plantations or as natural forests.

The lack of investments in regeneration of indigenous species is one of the major causes of their scarcity and this ought to be avoided.

The second essential requirement is volume to justify long-term marketing efforts of the exporter and the buyer. To promote a species whose annual allowable cut is very low and insignificant is a waste of resources. The natural occurrence and availability ought to be improved by appropriate cultural operations. We have several examples of some species that gain market acceptance but whose natural occurrence is negligible.

Thirdly, it has been suggested that grouping species that have low natural availability may enhance their chances on the market. Unfortunately, very little success has been achieved. Even with Mahogany, buyers tend to insist on *Khaya ivorensis* as a separate product from the other species. Less sophisticated markets may accept mixed species but the problem of long-term supplies still remains.

Fourthly, milling or manufacturing based on limited volumes has its attendant shortcomings. Depending on the properties of the species, productivity is affected where saws to be changed to suit logs of a different species, where different species with different kilning schedules have to be tackled with kilning capacities under-utilised.

Technology, Finance and Knowledge

I have already alluded to these three factors but I need to dwell on each of them in some detail.

Firstly, technology. The totality of the industry including the small-scale carpenters is import-based. From logging right through to putting finished products on the domestic or international market, we depend heavily on imports. In terms of forest management equipment and accessories used in inventory, stock survey, mapping, field books, etc., are all imported. In logging, the road making equipment, felling, skidding, loading, hauling all requires inputs that are imported. At the milling stage all machines, cutters, band blades, glues, fuels, oils, lubricants, and even bundling wires have to be imported.

Second, the financial problem is obvious to all. The high cost of money at 40% and over interest, the deteriorating exchange rates and the hidden costs including unjustifiable deductions of 2% and 1% payable to FPIB and TEDB, all act as constraints when the issue of funding research and development of use of LUS has to be tackled.

Knowledge and its application in the promotion of increased utilisation of LUS ought to receive urgent attention. It is imperative that essential information or data is made public and accessible to those engaged in the Industry. Specifically, inventory data on both the well known and the LUS should be published. One cannot carry our promotion exercise without data on stocks, distribution throughout the country, annual net increases in stocks and other relevant information.

We also find that yield data taken out of stock maps do not cover all possible species. If stock surveys to not involve most of the LUS then there is a missing link in our quest to know more about our forests.

Incentive Package

Efforts by the Ghana Export Promotion Council in the promotion of non-traditional exports have been appreciated by all. The assistance the Council is giving to exporters of all types goes long way in enhancing Ghana's exports. We of the GTMO believe that LUS converted to any product ought to be treated as non-traditional export item to serve as incentive.

On the other hand, we find that the Tree and Timber (Amendment) Act which places levies on round logs and air-dried lumber of some species is a negative way of promoting value-added Production. The Act gives no incentive to a company that invests thousands of dollars in setting up kilns, boilers, and expertise to dry lumber for exports. All that the Act does is to punish those companies that continue to export only air-dried lumber. In the same manner, logging companies that try to find export markets for LUS are levied for their efforts.

There was a time in the 1960s when a bonus was paid to those who succeeded in finding markets for secondary species. In like manner, the GTMO believes that kiln dried lumber for all species should be treated as non-traditional exports. For LUS, national awards should be instituted by the Ghana Export Promotion Council.

Social and Economic Impact

In the light of what I have already stated, the increased utilisation of Lesser-Used species will yield a temporary relief. In the long run, our efforts at promoting increased utilisation will not be sustainable if attention is not paid to silvicultural research aimed at ensuring increasing supplies of the species involved. Industrial use of wood should be buttressed on regeneration of the species to ensure sustainable development and avoid environmental degradation.

The Identification of 14 Under Exploited Promotable Lesser-Used Timber Species of Ghana

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Introduction

Ghana's timber trade has been dominated for a long time by some 14 species which have been over-exploited with some of them estimated to have a resource life of about 10 to 25 years. To forestall possible extinction of these species and conserve their biodiversity, about 30 under-utilised species popularly known as the "promotable pink star species" are being promoted to replace the over-exploited species. Sustainable and efficient utilisation of these species will depend among others on correct identification and application of their technological end-use properties.

The objective of this study therefore was to describe the identification features of 14 under-exploited promotable species which are expected to form a significant portion of tomorrow's raw material for Ghana's wood industry. These anatomical, physical and miscellaneous features should assist the wood user to correctly identify the Lesser-Used species from each other, and as well from the over-exploited, sustainably exploited and the under-exploited Lesser-Known species.

Wood Identification Features

Wood features useful for identification purpose may be divided broadly into three groups:

- The anatomical (macro- and microscopic),
- The physical, and
- The miscellaneous features.

Whereas anatomical features may in most cases be used alone to positively identify a species, the use of physical and miscellaneous features are usually meant to complement the anatomical features.

Identification using Anatomical Features

The architectural designs formed by the four basic xylem elements of vessels, fibres, axial and ray parenchyma cells form the very basis for anatomical identification. These four elements which are made up of billions of dead cells form different patterns in the xylem. The patterns may be formed by the same elements such as those formed by vessels; or they may be formed by two or more elements such as paratracheal and apotrachael types formed by association of vessels and axial parenchyma cells. The ultimate shape, form and size of a pattern, depends on whether the elements are seen with the naked eye aided with a hand lens (macroscopic features) or whether they are viewed under a compound microscope (microscopic features). Whereas macroscopic features are easy and quick to discern, identification by microscopic means is more difficult and involves the use of relatively expensive compound microscope. However, because features seen at macroscopic level are limited in their magnification, (not more than 10 times) and resolution, some timber species which cannot be identified macroscopically can only be identified positively at microscopic level. (Oteng-Amoako 1990).

Physical Features

The physical features of wood including colour, odour, taste, weight, (or density) hardness, grain and texture are generally less useful for wood identification than anatomical features because of their greater variation within a species. However, their use with anatomical and other miscellaneous features help to identify a piece of wood. The physical features considered in this study are wood density, colour, lustre and odour.

Miscellaneous Features

The miscellaneous features include burning of splinter, fluorescence, colour of water extract, froth and chrome azurol tests. These features are neither physical nor anatomical but they are of some diagnostic importance. For the purpose of this study only burning of splinter test is included.

Materials and Methods

All samples for the study were cut from the stem of 14 species selected for an ITTO project on industrial utilisation of timber. All the 14 species occur in relative abundance, at a frequency of more than one tree per square kilometre.

Samples of a species measuring about 3 x 3 x 4 cm were sawn to true tangential, radial and transverse sections. All the samples were relatively dry and were hard to section with a knife, therefore sanding the transverse section with progressively smoother sandpapers was explored. A very smooth surface was achieved with the number 400 carbide-tipped sandpaper. Sanded surfaces were thoroughlly cleaned of their sawdusts with an air blower and by sticking and removing adhesive tape on the transverse surface, which removed sawdust entrapped in the small pores. The observation of the 87 standardised macroscopic anatomical features, selected from previous works of Brunner *et al.* (1994) and Oteng-Amoako, (1990) were measured using a transparent grid developed by Brunner *et al.* (1994). The grid was placed over the sanded wood surface and illuminated under a stereomicroscope or hand lens. Photomacrography of wood samples was prepared using an Olympus stereomacroscope with a photographic attachment. Development and printing of macrographs were done in the usual manner.

Relative density of species were determined using the method developed by Brunner *et al.* (1994) which is based on relative floatation or sinkage of 3 x 3 x 3 cm wood sample of the species in water soon after dipping. After the determination of density, match stick size from all samples were prepared and burned in still air to determine the colour of the residual ash and nature of the flame formed.

Results

The identification features compiled for each of the 14 species are as follows:

1. ***Albizia ferruginea.*** Benth. (Awiemfo-samina, Albizia) Mimosaceae
    - Vessels large, sparsely distributed, predominantly solitary, few short and radial multiples of different sizes, inclusions present.
    - Axial parenchyma vasicentric, aliform and confluent.
    - Fibre tissue proportion high
    - Rays indistinct,very numerous, less than 1/4 of vessel size.
    - Growth rings distinct, demarcated by thick wall fibres.
    - Wood density medium, brown, dull, no distinct odour.
    - Splinter burns to black ash with gritty feeling.

2. ***Amphimas pterocarpoides.*** Harms (Yaya). Papilionaceae
    - Vessels large, sparsely distributed, solitary and short radial multiples of same and different sizes, inclusions present.
    - Axial parenchyma broadly banded, wavy, regular, and widely spaced, about same size as fibre tissue.
    - Fibre tissue proportion average.
    - Rays indistinct, numerous, narrow, uniform size, less than 1/4 of vessel size.
    - Growth rings indistinct.
    - Wood density medium, brown, with shades of yellow, dull, no distinct odour.
    - Splinter burns to full black ash.

3. ***Antiaris toxicaria.*** Lesch (Kyenkyen) Moraceae
    - Vessels medium, sparsely distributed, solitary and few short radial multiples of one or different sizes, few clusters of 2 - 4, inclusions present.

- Axial parenchyma vasicentric, aliform and few confluent.
- Proportion of fibre tissue average.
- Rays of two types, very narrow and 1/4 to 1/2 size of vessels, moderate.
- Growth rings visible demarcated by thick wall fibres, band of parenchyma cells and small diameter vessels.
- Wood density low, brown with shades of yellow, dull, no distinct odour.
- Splinter burns to black ash and exudes coloured compounds.

4. ***Antrocaryon micraster***. A Chev & Guill (Aprokuma) Anacardiaceae

- Vessels medium, sparse, predominantly solitary, occasionally short radial multiples, diagonal arrangement; tyloses present.
- Axial parenchyma indistinct to naked eye, scanty paratracheal.
- Proportion of fibre tissue average.
- Rays moderate, two sizes of very narrow and wide, 1/4 to 1/2 of vessel size.
- Growth rings distinct demarcated by thick wall fibres, band of parenchyma cells and small diameter vessels.
- Density low, heartwood brown, white to grey, lustrous, no distinct odour.
- Splinter burns to white ash.

5. ***Bombax buonopozense.*** Sprague (Onyina- Koben, Akata). Bombacaceae.

- Vessels large, sparsely distributed, solitary and short radial multiples of equal size, diagonally arranged, few clusters of 2 - 4, inclusions present.
- Axial parenchyma indistinct, apotracheal diffuse-in-aggregate, smaller than fibre tissue.
- Proportion of fibre tissue low.
- Rays moderate, narrow and wide, 1/4 to 1/2 vessel size.
- Growth rings visible demarcated by thick wall fibres and absence of pores.
- Wood density low, white/grey, not distinct from sapwood, dull, no distinct odour.
- Splinter burns to full grey ash.

6. ***Canarium schweinfurthii*** Engl. (Canarium) Burseraceae

- Vessels medium, few, solitary and short radial multiples of same size, tyloses present.
- Axial parenchyma indistinct, scanty and sparsely vasicentric.
- Proportion of fibre tissue average.
- Rays moderate, very narrow and narrow, less than 1/4 to 1/2 of vessel size.
- Growth rings not visible.
- Wood density medium, brown, lustrous, no odour
- Splinter burns to white ash producing crackle and sparks.

7. ***Ceiba pentandra*** (Linn) Gaertn. (Ceiba) Bombacaceae

- Vessels large, few, solitary and few short radial multiples of one size, diagonal arrangement, tyloses present.
- Axial parenchyma indistinct, diffuse-in-aggregate, marginal, smaller than fibre tissue, irregularly spaced.
- Proportion of fibre tissue average.
- Rays few, narrow , two distinct size of broad and very narrow, 1/4 to 1/2 vessel size
- Growth ring boundaries distinct demarcated by thick wall fibres and marginal parenchyma.
- Wood density low, white to grey, not distinct from sapwood, non lustrous, no distinct odour.
- Splinter burns to full black ash exuding coloured compounds.

8. ***Celtis mildbraedii*** Engl. (Celtis, Esa) Ulmaceae

- Vessels small, numerous, indistinct, mostly solitary and few short radial multiples, inclusions present.
- Axial parenchyma few confluent, mostly narrow banded, smaller than fibre tissue bands, closely and regularly spaced.
- Proportion of ground tissue fibre high.
- Growth rings indistinct.
- Wood density medium, basically grey with shade of yellow, not distinct from sapwood.
- Splinter burns to white ash exuding coloured compounds.

9. ***Cylicodiscus gabunensis***. Harm (Denya) Mimosaceae

- Vessels medium to large, few, solitary and short radial multiples, diagonal pattern, brown inclusions present.
- Axial parenchyma vasicentric, aliform and confluent, narrow marginal, regularly banded, widely spaced.
- Proportion of ground tissue fibre high.
- Rays of two types, some distinct, very moderate, narrow, 1/4 - 1/2 vessel size.
- Growth rings distinct demarcated by marginal parenchyma bands and absence of pores.
- Wood density high, basically yellow, lustrous, no odour.
- Splinter burns to white ash, exuding coloured compounds.

10. ***Distemonanthus benthamianus***. Baill. (Ayan) Caesalpineaceae

- Vessels indistinct, few, inclusions present.
- Axial parenchyma, aliform, confluent, wavy with broken bands, narrow marginal, wide and regularly spaced, less than the size of fibre-tissue bands.
- Proportion of ground tissue fibre average.
- Rays numerous, very narrow, indistinct, less than 1/4 vessel size.
- Growth rings distinct demarcated by marginal parenchyma bands.
- Wood density medium, brown with shades of yellow, lustrous, no distinct odour.
- Splinter burns to white ash.

11. ***Petersianthus macrocarpu*** P. Beauv (Essia/Esia). Lecythidiaceae

- Vessel medium, solitary and short radial multiples, inclusions present.
- Axial parenchyma scanty paratracheal, few vasicentric, aliform and confluent, sometimes narrow, wavy, irregular bands smaller than fibre tissue.
- Proportion of ground tissue fibre high.
- Rays, two different sizes very narrow and narrow, indistinct and narrow, 1/4 - 1/2 size of vessels, numerous.
- Growth rings distinct demarcated by absence of vessels.
- Wood density medium, brown, dull, no distinct odour.
- Splinter burns to white ash producing cracks or bright sparks.

12. ***Pycnanthus angolensis*** (Welw.) Exell. (Otie) Myristicaceae

- Vessel medium, few, solitary and short radial multiples of different sizes, inclusions present.
- Axial parenchyma indistinct, fine bands.
- Proportion of ground tissue fibre average.
- Rays moderate, three sizes of very narrow, narrow and wide; the very narrow rays less than 1/4 of vessel size, narrow rays 1/4 of vessel size, and broad rays about 1/2 vessels size.
- Wood density low, white to grey; heartwood not differentiated from sapwood, lustrous, no distinct odour.

- Wood splinter burns to white ash, exudes coloured compounds.

13. ***Sterculia oblonga*** Mast (Ohaa, Yellow sterculia) Sterculiaceae.

- Vessel medium, few, solitary and short radial multiples, of different sizes, inclusions present.
- Axial parenchyma straight broad bands, regularly spaced, same size as fibre tissue bands.
- Proportion of fibre tissue average.
- Rays moderate, two distinct size, very narrow less than 1/4 of vessel size, and broad which is just less than full vessel size.
- Wood medium density, yellow, dull, no distinct odour.
- Wood splinter burns to grey ash exuding coloured compounds.

14. ***Strombosia glaucescens*** J. Leonard (Afina) Olacaceae

- Vessels indistinct, moderate, solitary and short radial multiples of same size.
- Axial parenchyma indistinct, apotracheal diffuse very fine tangential bands.
- Proportion of ground tissue fibre average
- Rays numerous, with two sizes of very narrow and narrow, 1/2 vessel size.
- Growth rings distinct demarcated by absence of pores and thick wall fibres.
- Wood density medium, brown with shades of red, lustrous, no distinct odour.
- Splinter burns to grey ash exuding coloured compounds with cracks and sparks.

Discussions

The 14 species can broadly be divided into two groups based on their axial parenchyma features. Eight of the species have distinct axial parenchyma whereas the remaining six have indistinct axial parenchyma.

Species with Distinct Axial Parenchyma

The axial parenchyma in this group can be divided into two subgroups depending on presence or absence of parenchyma bands. In *Albizia,* (Fig. 1), *Antiaris* (Fig. 2) and *Cylicodiscus* (Fig. 3), there are no axial parenchyma bands but *Albizia* has predomiantly aliform parenchyma, An*tiaris* is predominantly vasicentric while *Cylicodiscus* has vasicentric, aliform and confluent parenchyma types.

The five species in the subgroup with banded parenchyma are further divided into two species which have discontinuous or broken parenchyma bands as in *Distemonanthus benthamianus* (Fig.4), which also has marginal parenchyma, very small vessels and indistinct ray cells compare to small vessels with vasicentric and confluent parenchyma in *Petersianthus macrocarpus* (Fig. 5). For the three species with continuous parenchyma bands, *Celtis milbraedii* (Fig. 6) has narrow more or less wavy parenchyma bands, regularly spaced with indistinct vessels and ray cells but in *Amphimas* (Fig. 7) and *Sterculia* (Fig. 8) parenchyma bands are broad but the two species are differentiated from each other by the presence of wavy parenchyma bands with large vessels in the former and straight parenchyma bands with medium vessels in the latter.

Species with no Distinct Axial Parenchyma

All rays in this group are of two types except in *Canarium scheweinfurthii* (Fig. 9) which has only narrow rays with inclusions in medium solitary and short multiple vessels.

In *Strombosia glaucescens* (Fig. 10), the numerous rays are very narrow and narrow, and about 1/2 or less the size of indistinct vessels. Both *Antrocaryon micraster* (Fig. 11) and *Pycnanthus angolense* (Fig. 12*)* have very narrow and broad rays, large solitary and short radial multiples but the wood splinter of the latter burns to produce white ash with exudates whereas the former burns to produce white ash only. The wood of *Bombax buonopozense* (Fig. 13*)* and *Ceiba pentandra* (Fig. 14) are macroscopically similar both with very broad and narrow rays, but whereas splinter of *Bombax* burns to grey ash that of *Ceiba pentandra* burns to white ash with brown exudates.

All the species in this group have well demarcated growth rings except for *Canarium schweinfurthii* (fig. 9) and *Strombosia glaucescens* (fig. 10) but the latter is differentiated from the former by presence of two ray types and formation of white ash with crackle and sparks when its splinter burns in still air.

Conclusion

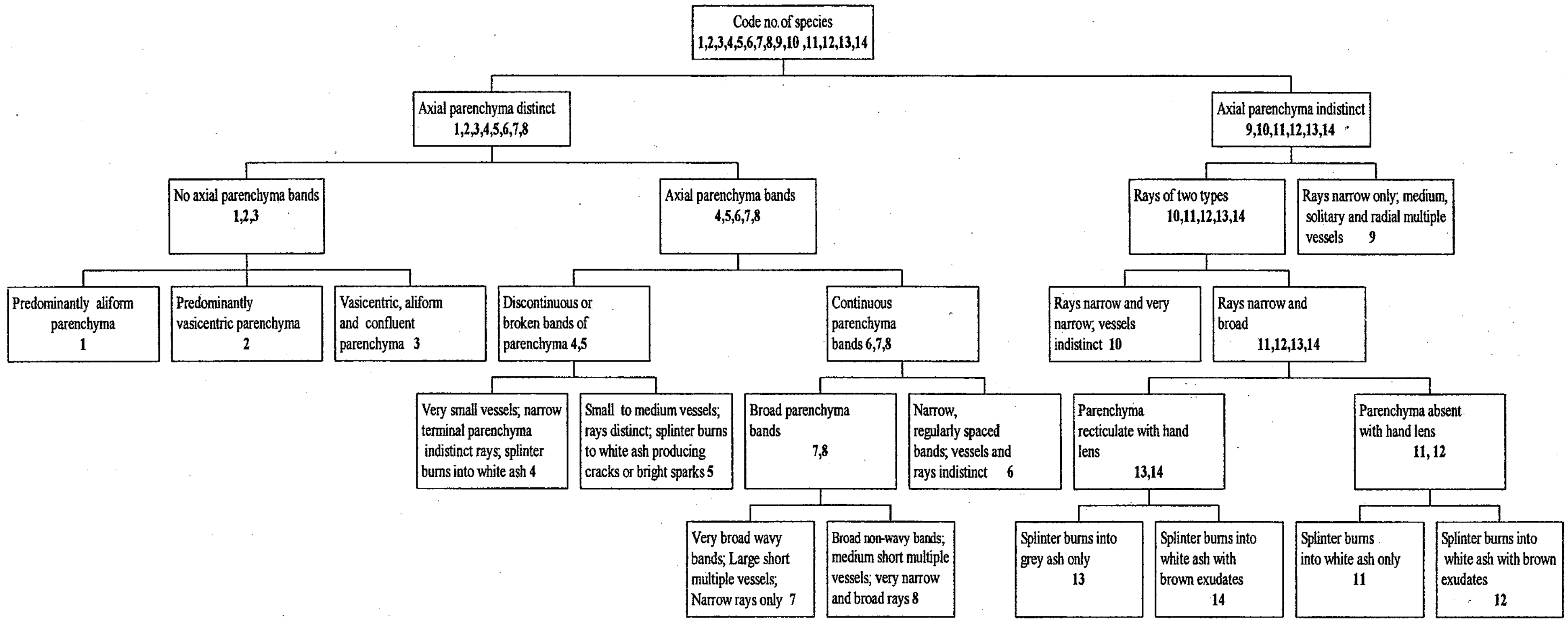
Based on the findings of macroscopic and other identification features a dichotomous identification table for the 14 species is presented in Table 1.

References

Brunner M; L.J. Kucera & E. Zurcher. 1994. Major Timber Trees of Guyana: A Lens Key. Trobenbos Series 10, Waegenigen, The Netherlands 183pp.

Oteng-Amoako, A. A. 1990. Macroscopic Wood Identification Manual for Papua New Guinea Timbers. Kristen Pres Inc. Madang, Papua New Guinea, 118pp.

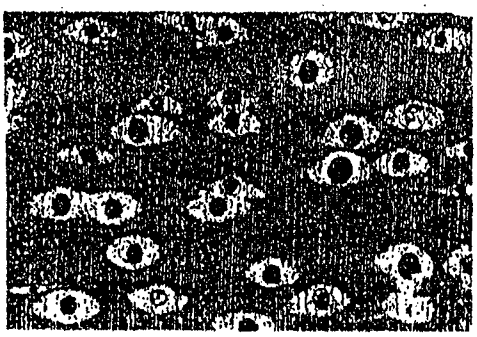
Table 1: A dichotomous identification table for fourteen Lesser-Used Species of Ghana



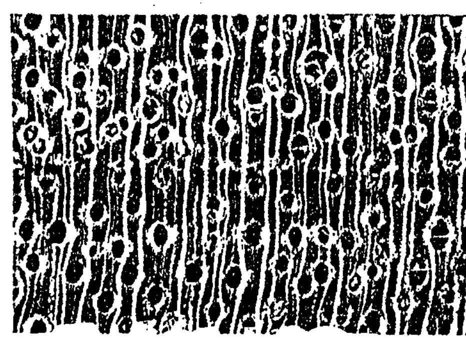
LEGEND

1. *Albizia ferrugenea*
2. *Antiaris toxicaria*
3. *Cylicodiscus gabunensis*
4. *Distemonanthus benthamianus*
5. *Petersianthus macrocarpus*
6. *Celtis mildbraedii*
7. *Amphimas pterocarpoides*
8. *Sterculia oblonga*
9. *Canarium schweinfurthii*
10. *Strombosia glaucescens*
11. *Antrocayon micraster*
12. *Pycnanthus angolense*
13. *Bombax buonopozense*
14. *Ceiba pentandra*

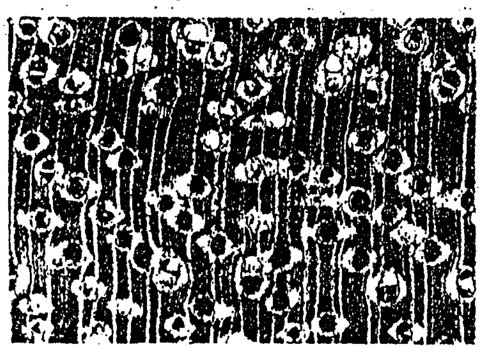
MACROGRAPHS OF FOURTEEN PROMOTABLE LESSER-USED SPECIES OF GHANA
(numbers refer to Figure numbers)



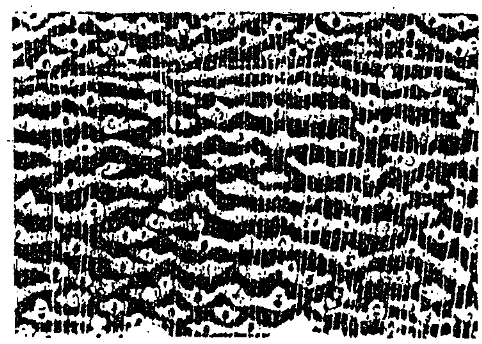
1. *Albizia ferruginea*



2. *Antiaris toxicaria*

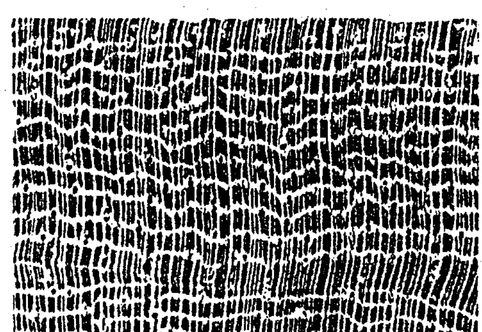


3. *Cylicodiscus gabunensis*

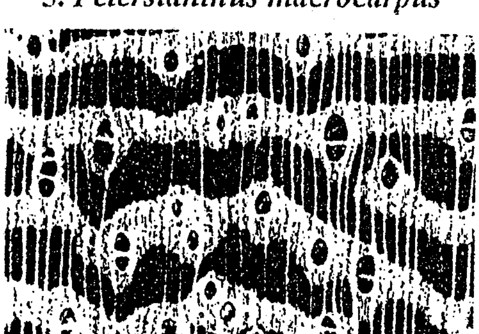


4. *Distemonanthus benthamianus*

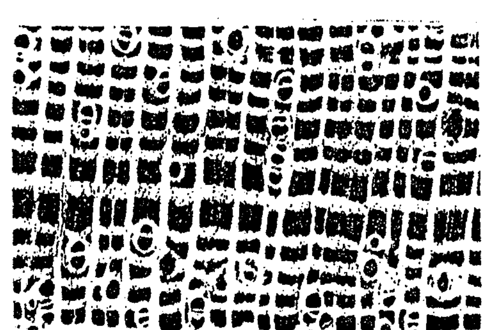
5. *Petersianthus macrocarpus*



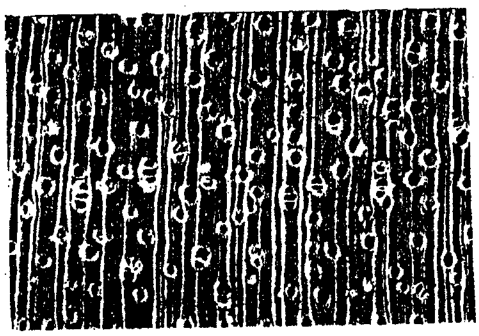
6. *Celtis mildbraedii*



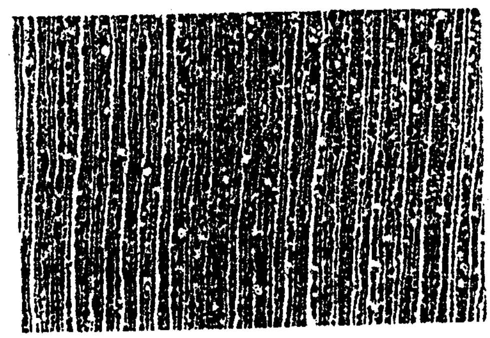
7. *Amphimas pterocarpoides*



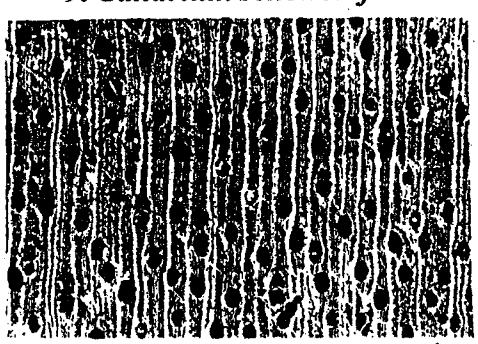
8. *Sterculia oblonga*



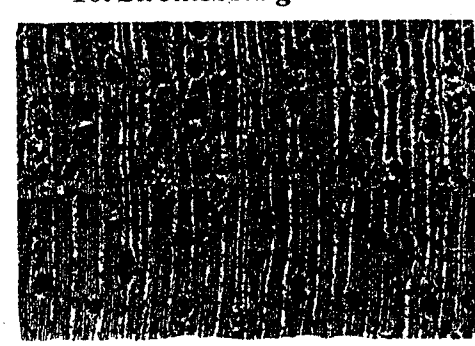
9. *Canarium scheweinfurthii*



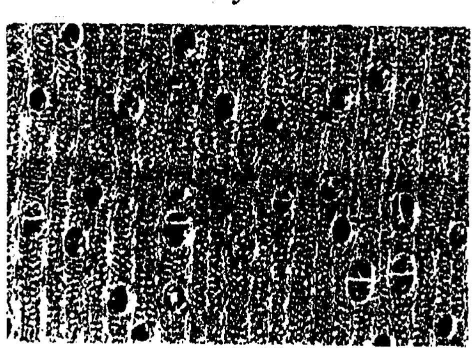
10. *Strombosia glaucescens*



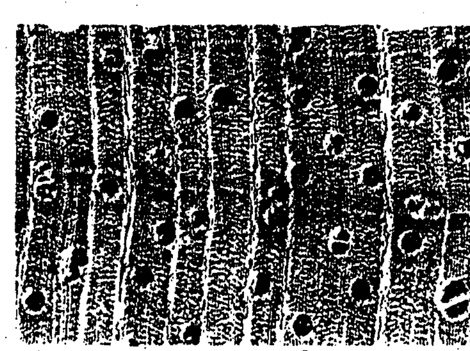
11. *Antrocaryon micraster*



12. *Pycnanthus angolenses*



13. *Bombax buonopozense*



14. *Ceiba pentandra*

Product Development and Processing of Lesser Used Timber Species

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Wood Industry Consultant

Introduction

This presentation is a concentrate of the experiences gained from the Product Development Segment in the ITTO-TEDB-FORIG Project "Industrial Utilisation of Selected Ghanaian Lesser Used Timber Species". The completed project segment is presented in three reports:

- Phase I: Furniture Production, April-May, 1996.
- Phase II: Product Development, August-September 1996.
- Phase III: Product Development Completion, July-September 1997.

In the beginning of the project, some 16 different Lesser-Used species were identified as potential useful species. During the progress of the project, this number was scaled down for a number of reasons, as we have heard and will hear more at this conference. When this segment of the project started in April 1996, the following species were selected for down-stream processing:

Species	Density
Ceiba (*Ceiba pentandra*)	304 kg m^3
Kyenkyen (*Antaris toxicaria*)	432 kg m^3
Celtis (*Celtis mildbraedii*)	751 kg m^3
Essia (*Petersianthus macrocarpus*)	814 kg m^3
Denya (*Cylicodiscus gabonensis*)	958 kg m^3

The Terms of References for this segment included the following areas:

- Manufacture of Furniture
- Manufacture of Parquet Flooring Panels
- Manufacture of Pallets; and should include:
  - Machining Characteristics
  - Gluing Properties
  - Finishing Properties

Product Development

Garden Furniture

At the start of this project segment, we identified garden furniture as the most suitable prototype furniture, for a number of reasons:

- The timber made available had a moisture content (MC) ranging from 15 to 25% while the production of indoor furniture requires a MC below 10%.
- Very few, if any, industry in Ghana has adequate resources in the form of management/personnel skills, drying capacity, machines or quality standards to embark export of indoor furniture.
- The knock-down concept, which is a prerequisite for furniture production for export, is not yet established within the furniture industry in Ghana.
- The international furniture market is extremely competitive and requires a thorough market intelligence on actual fashions, trends, designs etc. An introduction of LUS requires an extensive and professional marketing campaign. At this stage of the project this would be premature venture to undertake

- Garden furniture and related products on the other hand can be produced with less sophisticated equipment and quality standards are less stringent.
- Export of garden furniture, made from LUS, could be achieved within a relatively short period, approximately 1 to 2 years while export of indoor furniture would take considerable longer time due to the need of solid transfer of know-how to the industry.

In the production of prototype garden furniture it was our ambition to include as much as possible of industrial applications, such as:

- Production and Raw material Economy
- Aesthetic and Functional design, without compromising on comfortability and durability.
- Marketability

The collection of prototype garden furniture consist of the following items:

- Round and rectangular dining table
- Coffee table
- Armchair
- 3-seatee Sofa
- Sunbed

Various items of the garden furniture collection has been produced in four different LUS:

- *Ceiba*
- Kyenkyen
- *Celtis*
- Essia.

Some of the items have a mixture of LUS e.g. *Ceiba* for slats, Kyenkyen for frame (for lightweight reason) and *Celtis for legs* (for durability). From Product Development point of view the most beautiful and attractive prototype furniture produced in the project is an armchair made in Essia. No doubt, this LUS has a brilliant future as a raw material for furniture.

Garden Accessories

Deckboards, which is a huge consumption product throughout Europe with several millions of deckboards sold every year, have been produced in *Celtis*, Kyenkyen, Dahoma, Essia and Denya. This product is very easy to produce, compact in format with approximately 4000 boards to fill a 40' container. The samples of the deckboards have been impregnated, some with colourless protection to enhance wood texture, some impregnated with CCA. The result is a combination of beautiful deckboards, each species with is own beauty in colour and texture. Modelling with different species, or same species in different impregnation, is creating an additional attraction of the deckboards.

The most beautiful deckboards is made from Denya, which exceeds e.g. teak with its lively texture and attractive colour. The high density however makes it somewhat difficult to produce. Both machining and assembly is a bit complicated. With TCT tooling in the machines and pre-drilling for the nails, this problem is possible to overcome. Its solid weight in combination with appetising texture would make this deckboard highly attracted around the world. Another suitable species for deckboards is Essia, although not so durable as Denya but still attractive. The other species could be used as well but durability and wood texture makes them less attractive.

Parquet Flooring Panels

The project was fortunate to be allowed access to professional parquet producing machines at FABI Timber Ltd in Kumasi for the trial production of parquet strips. Three species were tested, Celtis, Essia and Denya. The other two were judged to be too light and soft to sustain the wear and tear of a flooring material. The test results indicate that Essia and Denya can be used for parquet strips while Celtis will be less economical attractive due to an abnormal reject percentage, mainly from a common discoloration (grey staining). Denya on the other hand might be difficult to produce due to its density and therefore might be rejected by the producers. The location of a parquet-moulding factory in Kumasi is a great advantage for continued trials with production of parquet panel made from LUS.

Pallets

Pallets have been produced in Kyenkyen and *Ceiba* according to the European standards plus one of the most commonly used in ASEAN and accordance with the ISO standard Serie 1: Information gathered about the use of pallets in Ghana reveals that pallets are used very sparsely. The industry appears not yet have started to appreciate the benefits of palletised handling. Large processing industries such as GHACEM (cement industry) have their production adopted to completely without pallets. Other production industries have some internal palletised transport but the pallets are made in various formats and mostly from scrap wood. In the dissemination of the LUS project to the industry it is therefore important that the benefits of the use of pallets for internal as well as for logistics is given a predominant role.

From material point of view, Kyenkyen appears to be durable enough, even to meet rigid EU standards. Celtis and Essia has been judged to be "too exclusive" to be used in such a low-grade product as pallets. Ceiba is yet to be tested as pallet material. Together with the pallet trial, some collapsible pallet collars, which are part of the European exchange system, were also produced. The price calculations shows that a Ghana made pallet can compete with Europallets produced in Europe from low grade spruce or pine, although those pallets are made in highly automated lines with a capacity of approximately 15 000 to 25 000 pallets per shift. The market price in Europe has for a long time been established around US$ 9. A similar pallet produced in Ghana could be landed in Europe for around US$ 7,50, including a 25% net profit for the producer. The major obstacle to overcome, however, is the very high standards, which in certain areas are more rigid than the BSI standards for furniture. All Europallets carries a burnt-in seal, which is a guarantee for its acceptance as an interchangeable pallet throughout Europe.

One possibility to get around this obstacle could be to make direct offers to mega-users of pallets such as the car industry (FIAT, VW, Opel, GM, FORD, VOLVO etc.) The only competing means would however be the price in combination with reliable deliveries in time and quantities.

More scientific testing of the pallets such as drop test or nail holding capacity has not been carried out for the simple reason that standards (ASTM-BSI-ISO) has not been available at FORIG. Nails of suitable quality for pallet production is not available on the local market and a pulling test machine is not yet installed at FORIG. The local available nail does not provide sufficient holding capacity compared with nails used in pallet production e.g. in Europe. Any testing of pallets assembled with local nails would therefore not reflect the actual durability of the wood species used in the pallet.

Dowel Production

By courtesy of Mr Simon Saoud, MD of A.E. Saoud Ltd., who had imported a new set of dowel making machines, some tests on dowel production from LUS were made. Counterparts at FORIG have taken part in the tests, including the machine technique, operations and maintenance.

Two species, Essia and Celtis were selected for the tests. The other species were judged on characteristics already known not to be suitable for dowels.

Part of the sticks was dried to approximately 6% MC before milling, while the remaining sticks were milled at Equilibrium Moisture Content (EMC) of approximately 15%.

Already at the first stage of milling, it became apparent that Celtis is not at all suitable for dowels. All test samples, both dried and EMC sticks broke into splinters when machined.

Also Essia showed the same tendency, although not so frequent but enough of breaking/splitting to discourage it from dowel production. The few dowel rods produced appeared with an unacceptable rough surface.

As a comparison, a third specie -Danta- was also used with some sticks dried to 6% MC and the rest at EMC. Noticeable better smoothness appeared on the dried sticks which confirms that extra dried wood results in better, and stronger, dowels and less breaking in the machine. The dowels made from Danta will now be used in the furniture samples that will be exposed to fatigue tests in the furniture testing rigs. It has also been introduced to the group of manufacturers tendering for the supply of school furniture to UST.

One more specie, Mansonia, was tested in a small volume. The sticks had been dried to an MC of 9% and the results came out even better than Danta. The dowels will be used in the prototypes made for fatigue testing in order to determine its strength in the joints.

Two more species, Teak and Koto, will also be tested for dowel production as soon as they have been made available and dried.

Continued Product Development

As some of the LUS has been identified as suitable for furniture, a more detailed product development towards different categories of furniture would be desirable. Such a differentiated product development would also assist the industry in their utilisation of LUS.

Apart from the garden furniture already made within the present project there are other categories of furniture that could be developed such as:

- Home furnishing, including sets for various uses e.g. bedroom, living and dining rooms, etc.
- Institutional furniture for Government, Hospitals, Day Care Centres, Schools etc.
- Office furniture for private as well as communal consumption
- Public furniture for hotel & restaurant, resorts etc.
- Kitchen cabinets and wardrobes, including doors made from LUS

Each category requires different quality standards and designs as well as marketing approaches. In future dissemination to the industry it will be necessary to combine the LUS as raw material with linkage to the above mentioned categories in order to encourage specialisation which in turn will promote efficiency, quality and competitiveness within the industry.

Other products where LUS could be used are for example wooden toys. Suitable species are *Celtis*, Essia as well as Kyenkyen.

Wooden toys are normally a "mass production" and divided into different categories such as:

- Push-pull toys, cars, trains, boats, animals, etc.
- Stacking toys, mostly made from turned parts
- Building/construction blocks = simple mass-production
- Educational toys, including puzzles in plywood
- Riding toys,
- Children's furniture

As the different categories requires different sizes of wood, toy production results normally in a quite high utilisation of the raw material. By using a combination of LUS, quite colourful and eye-catching toys in natural wood could be produced.

Wooden toys are "big business" with huge quantities exported from Asia to EU and US. Most of the wooden toys produced in Asia today is made from rubberwood (*Hevea Brasiliensis*), which has a major draw-back with customer repelling due to its initial toxic boron treatment. LUS would here, as raw material for wooden toys, have a natural advantage over rubberwood.

Production of wooden toys, contrary to plastic toys, is quite labour intensive due to its manual handling of each individual operation, in particular sanding and finishing operations. Many producers in EU, and US, have therefore due to high labour costs, turned to developing countries for their production. With a combined transfer of know-how in design, appropriate production technique and marketing, Ghana could become a dominant producer of wooden toys. The convenience of two harbours is an important advantage for overseas export.

One area dealt with only in a marginal way in this project is the joinery, mainly because dried timber has not been made available. However, the results from the furniture production give a clear indication that several LUS could be used for doors and frames, windows, skirting and mouldings. It would though be necessary to first establish some kind of standards in order to minimise the present waste occurring in the production (over-dimensioned frames, innumerable sizes etc.).

Industrial utilisation of LUS

Five species of LUS has been tested for industrial utilisation. A sixth species, Ohaa, was originally included but has not been made available in sufficient volumes during project period.

The tested species are:

- Ceiba (*Ceiba pentandra*)
- Kyenkyen (*Antaris toxicaria*)
- Celtis (*Celtis mildbraedii*)
- Essia (*Petersianthus macrocarpus*)
- Denya (*Cylicodiscus gabonensis*)

Individual Observations

Ceiba

This species has the lowest density of all LUS tested. Some prototype garden furniture has been produced. A few samples will be exposed to fatigue tests when the furniture testing equipment is in operation. In spite of its light density, garden furniture made from Ceiba has attracted the attention of international buyers who have requested samples with different finish applications, One set, plus finishing samples has been produced at FORIG's workshop and was Mid-September -97 shipped over to US for a market reaction survey.

With regard to pallet production, Ceiba could be used for one-way pallets, but it is doubtful if it would receive a certification as an interchangeable pallet, e.g. Europallet.

Ceiba has for a quite long time been used as middle core veneer in plywood. Its present use has led to the fact that today it is a species that is considered as "over exploited". Its sustainability appears however to include such large volumes that it will sustain also future harvesting.

Kyenkyen

This species has been used for prototype of garden furniture, pallets, deckboards and parquet strips. From texture and appearance point of view Kyenkyen is suitable for garden furniture. It takes stain and varnish fairly well if precaution is taken during application. Too generous application creates eye-catching spots with quite deep penetration. Fatigue tests will be the final determination with regard to its suitability as furniture raw material. As a pallet material, Kyenkyen is somewhat heavy and maybe too good to be used for such purpose.

As a flooring material, decking or parquet strips, Kyenkyen appears to be too soft and not enough durable for the wear and tear a floor is exposed to.

Celtis

This species has several advantages as furniture raw material. It is dense enough to create customer confidence with regard to weight. It has an appealing texture and colour. The apprehension so far by the local users regarding the grey/brown discoloration that appears short after sawing/drying can be turned into an advantage if a sorting procedure is applied. Such a sorting program is quite common in industries where clear wood is used for transparent varnish, while pieces with moderate discoloration are stained in to e.g. mahogany, teak or walnut colours making the discoloration to appear as a natural variation of the wood. Pieces with more dominant discoloration is coated with pigmented lacquer e.g. white, blue etc. This procedure is quite common in the industries as a measure to optimise the utilisation of the raw material. The finishing tests of Celtis along these lines have been overall satisfactory with appealing samples in clear varnish, mahogany and walnut stains as well as in white lacquer. Endurance and durability tests will be applied as soon as the testing equipment is installed.

As for other garden items such as deckboards, partitions etc., Celtis is useful but must be impregnated against termite and borer attacks if used in contact with the ground.

From durability point of view, Celtis can also be used for parquet strips but it is doubtful if it will receive acceptance by the producers because the discoloration would result in a high degree of rejects thus making it less economical. Before proper drying schedules and handling is established to avoid discoloration, Celtis is most likely to be rejected as flooring material.

Essia

This species has been used for prototype garden furniture, deck boards and parquet strips. Its red colour and texture makes it attractive as a furniture material as well as for decking and parquet strips. Other areas of use could be e.g. kitchen cabinet doors, which has a huge market in Europe where renovations/renewals is more a matter of changing doors rather than the cabinets. The high degree of standardisation limits the sizes to not more than four different widths, while the height is the same for both wall units as for the bench units. For high cabinets, there is normally only 3 different widths.

Essia is easy to machine with minimal wear on tools. Sanding with open coat results in minimal clogging of sanding belt. It takes finishing well and sapwood can be stained to match the heartwood. One disadvantage however is an unpleasant smell during machine operations. When coated with sealer and varnish the smell is not at all noticeable.

One major drawback in this project segment has, very unfortunately, been the limited volumes made available. The small volumes at hand have been dried together with other species, resulting in considerable degrading in form of checking and internal cracking. Before any promotion of Essia can take place, proper drying schedules must been worked out as there otherwise is a risk that potential users will reject it due to abnormal wastage from drying defects.

Denya

The high density (958 kg/m^3) restricts the utilisation of this species. Within the project Denya has been tested for deck boards, parquet strips and turnings. It has the most beautiful and attractive texture of all LUS. Machining is somewhat difficult and requires very sharp tools. Tungsten carbide, or stellite tipped tools is recommended. Joining with nails or screws requires pre-drilled holes. Sanding requires precaution as excessive pressure results in clogging of the sandpaper and burning of the woods surface. Denya is easy to bond with PVAC glue and takes lacquer very well. A final sanding before finishing with grit 120, extra open coat, and a sanding of the sealer with grit 240 gives an excellent end finish.

The natural resistance against fungi and insect attacks makes Denya ideal for decking and flooring. No impregnation is necessary, which could be used as a promotional advantage over other wood species that requires impregnation to sustain out-door use.

Conclusions and Recommendations

This segment of the project included research towards industrial utilisation of six Lesser-Used Species. Five of the LUS has been used in an industrial scale to determine its suitability as raw material for a number of products. Three species, Kyenkyen, *Celtis* and Essia has turned out o be the most suitable for furniture and similar products, while Denya, due to its high density, could be used for decking and other garden accessories including flooring. Ceiba is already widely used in the industry for core veneer and even mouldings. A positive development outside the ToR has been the interest shown by the small-scale wood-workers about the LUS and its potentials in a new range of products.

The product development so far has been done within the LUS project, which now is ending. The result, and the spontaneous positive reactions from the industry and the market, gives a clear and solid indication that the LUS has a future as raw material for a wide range of products.

The introduction of new production techniques, e.g. dowel joints instead of tenons / mortising deserves also a continued dissemination to educational centres as well as the industry and small-scale entrepreneurs. Transfer to dowel joints would result in a tremendous saving of raw materials (15-25%) and increase productivity enormously (e.g. from present 3-4 doors per day in a typical small scale carpenter shop to 25-30 per day). Dowel joints are also a prerequisite for export both to the region and overseas.

The results obtained during the project is judged to be of immense value for the industry in Ghana but the continued dissemination is an area of pronounced worry as there is no qualified counterparts left to carry out the information to the industry. The project leader is about to retire and the second in command is leaving for a three year Ph.D. training overseas. The most experienced Technician, and carpenter, is planning to leave the Institute for computer training at the UST. The remaining counter-parts are junior technicians with little or no aptitude to disseminate project results. It would be a pity if the LUS project potential would be only a paper work left on a shelf to collect dust instead of being used to elevate the industry into exporters of products made from LUS.

It is the Consultant's sincere hope that the achievements from this project is carried forward by FORIG, together with organisations with a commercial approach, e.g. TEDB, FAWAG or KWEL to continue the dissemination of the LUS results. It would most likely result in a faster introduction of LUS as raw material as these organisations have direct links with the majority of the established industries in the country.

WOOD SPECIES						
Operational characteristics	Ceiba Density 304 kg/m³	Kyenkyen Density 432 kg/m³	Celtis Density 751 kg/m³	Ohaa Density 755 kg/m³	Essia Density 814 kg/m³	Denya Density 958 kg/m³
Cross-cutting Saw-blade ∅ 350 mm $Z = 80$ Rake angle 10° Clearance angle 15° Teeth top level R+L 10°	Very smooth. Slight sanding required.	Smooth. Only slight sanding required.	Very smooth. No sanding required. Powdered sawdust very irritating. Nose mask recommended.		Very smooth. No sanding required.	Smooth. No sanding required.
Rip-sawing Saw-blade ∅ 350 mm $Z = 24$ Rake angle 15° Clearance angle 15°	Easy	Satisfactory	Satisfactory		Satisfactory	Difficult due to hardness. Sharp tools required.
Planing SCM Thicknesser Model 250. HSS knives Feed speed 7m/min	Easy, but very porous surface.	Planes smoothly, no tendency to split.	Satisfactory, but slight tendency to chip if planed against the grain. Nose mask recommended.		Smooth, but surface checks from drying defects may be present.	Smooth, if sharp knives are used.
Drilling/Boring Spindle speed 1400/600 rpm for 8mm/28mm drill bits	Satisfactory, but dust might block holes. Very sharp bits recommended. Gentle boring to avoid compressing of wood fibres.	Satisfactory. Smooth holes. Little or no off-sizes.	Satisfactory, producing smooth holes with little or no off-sizes.		Satisfactory, producing smooth holes.	Difficult. CTC drill bits recommended.
Routing HSS routerbits	Easy and satisfactory in all directions.	Easy and satisfactory in all directions.	Satisfactory in all directions. Slight tendency to split. No chipping.		Satisfactory.	Requires extra power. Chipping may result if dull tools are used.
Moulding Spindle spped 6000 rpm	Satisfactory, but surface porous. Sharp tools required.	Satisfactory across and along the grain. Raised grains occur as angles inclined to the grain. Sharp tools recommended to avoid chipping.	Satisfactory along the grain. At 45° and across the grain, chipping may occur. Sharp tools recommended to avoid chipping.		Satisfactory.	Satisfactory. CTC tools recommended.

WOOD SPECIES						
Operational characteristics	Ceiba Density 304 kg/m^3	Kyenkyen Density 432 kg/m^3	Celtis Density 751 kg/m^3	Ohaa Density 755 kg/m^3	Essia Density 814 kg/m^3	Denya Density 958 kg/m^3
Round-over of edges	Moderately smooth. High feed speed causes rough edge. Must be done gently/slowly.	Moderately smooth. High speed causes tearing of edges.	Smooth in all directions.		Smooth in all directions.	Smooth along grain, but tearing across.
Bending Cold process	Poor.	Fair bending radius achieved.	Satisfactory bending radius achieved.		Difficult.	Impossible.
Turning	Poor results.	Acceptable quality pieces.	High quality pieces.		High quality pieces.	Good quality pieces.
Wear on tools	No wear.	No wear.	Minimal wear.		Minimal wear.	High wear. CTC or Stellite tools recommended.
Gluing PU and PVAC glue	Poor bonding due to porous nature.	Excellent both with PU and PVAC glue.	Excellent both with PU and PVAC glue.		Glues well with both PU and PVAC glue.	Glues well, but requires high pressure.
Sanding Orbital beltsander Belt speed 14m/sec Grit 100, 120, 150 Open resp. closed coat	Easy to sand. Gentle pressure required to avoid excessive removal of wood. Grit 120 along grain and grit 100 for across sanding. No clogging of belt.	Along grain smooth surface with grit 120, open or closed coat. Grit 100 for across grain sufficient. Light to moderate clogging.	Along grain smooth surface with grit 120. Across grain grit 100 sufficient. Moderate clogging.	Along grain smooth surface with grit 120. Across grain grit 100 sufficient. Moderate clogging	Along fibre no noticeable difference between open or closed coat. Grit 150 for along grain and grit 100 for across. Light to moderate clogging.	Long grain extra with open coat grit 150. Across grain grit 120 sufficient. Heavy clogging. Burns easily on across sanding.
Finishing Stain in white spirit, mahogany and walnut colour. Sealer sanded with grit 240 before final coat with clear varnish or white lacquer.	Porous wood results in blemish appearance of stain. Lacquered surface of acceptable finish with 2 coats of sealer + final coat.	Takes stain and sealer well. Lean application of stain recommended to avoid "bleeding" spots. Acceptable finish with 1 coat of sealer + final coat.	Takes stain and sealer well. Lean application of stain recommended to avoid "bleeding" spots. High quality surface with 1 coat of sealer + final coat.		Takes stain fairly well on sapwood. Excellent surface with 1 coat of sealer + final coat.	Takes sealer and varnish well. Beautiful natural wood texture does not require stain. Excellent surface with 1 coat of sealer + final coat

Recent Advances in the Machining of Lesser-Used Species

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Abstract

Over exploitation of the commercial wood species has led to a fast decline or degradation of the tropical forest. It is expected that efficient utilization of the lesser-used wood species would improve sustainability of the tropical timber resources and reduce negative ecological impacts. These objectives can be achieved if appropriate technologies for processing the lesser-used wood species are developed. It is also expected that some of the recent advances in machining of the commercial wood species would be applicable to the lesser-used wood species. This paper highlights some of the recent advances in wood machining with emphasis on sawing and planing.

Introduction

In recent years, considerable interest has been generated towards efficient wood machining practices as a result of the high cost of raw material and labour. Until recently, much attention was focused on processing of the commercial wood species thus neglecting the so-called lesser-used wood species.

Over exploitation of the commercial wood species, has led to a fast decline or degradation of the tropical forest. It is expected that efficient utilisation of the lesser-used wood species would improve sustainability of the tropical timber resources and reduce negative ecological impacts. These objectives can be achieved if appropriate technologies for processing the lesser-used wood species are developed. It is also expected that some of the recent advances in machining of the commercial wood species would be applicable to the Lesser-Used wood species.In this paper, some recent advances in wood machining with emphasis on sawing and planing is discussed.

A Review of Recent Advances in Wood Machining

Sawing

In the conversion of logs to sawn lumber, pit sawing was once practiced extensively in some parts of the world. This crude method of sawing using obsolete and inefficient saws resulted in wood waste and low productivity. Recent technology, however, shows tremendous improvement in the conversion processes. Automated band-mill and twin band-mill with which logs are automatically sawn into lumber have been developed. This has resulted in reduction of operator's work, and an upgrade in machining efficiency.

Productivity, recovery and quality

It is well known that three factors compete for attention during the specification of a sawing process. These factors are productivity (workpiece feed rate), recovery (amount of sawdust production), and quality (wood surface finish and dimensional accuracy). These three factors are closely interconnected, and to a large extent are mutually exclusive. It must be emphasized that an improvement in one factor can be achieved only at the expense of one or both of the other two. For example, reductions in saw plate thickness and kerf reduce sawdust production and increases recovery of solid wood. However, this change can also impair sawcut quality and can require a reduction in workpiece feed speed. Saw tensioning provides an important exception to the above mutually exclusive pattern. Tensioning increases the stiffness and critical speed of saw blades through the deliberate induction of in-plane membrane stresses typically by hammering or rolling (Szymani & Mote, 1977; Schajer, 1984, 1992; Hutton, 1991). The increased saw stiffness and critical speed allow any of the three factors to be improved without impairing the other two. A thinner circular saw blade with a narrow kerf tends to lower the critical rotation speed owing to its low natural frequency (Angelo & Mote, 1988). The cutting operation cannot be continued when the critical rotation speed is lower than the operating speed because the stiffness against the lateral deflection disappears. The relationship between the natural frequency and rotation speed of a circular saw blade is shown in Figure 1.

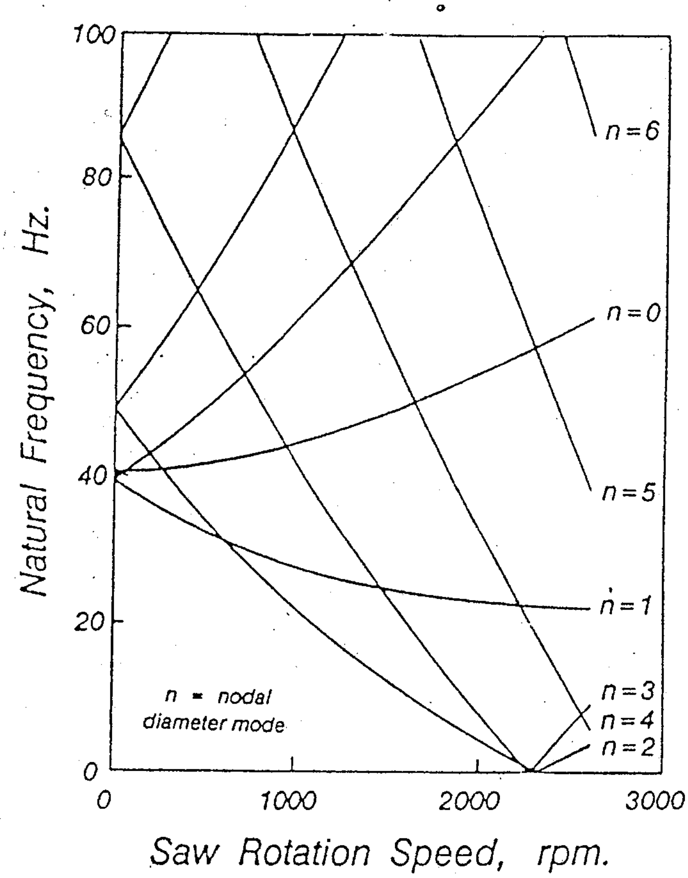

Figure 1. Natural frequencies of an unguided circular saw vrs. Rotation speed.

Vibration of Saw Blades

There are many different causes for the vibration in bandsaw blades and circular saws during machine operation. Once vibration is induced in saw blades, whatever the cause may be, it results in an increase in saw kerf losses, wood losses from cutting inaccuracies and poor surface finish. Vibration is moreover considered to be an indirect source of the increase in cutting force, a decrease in tooth life, the generation of gullet cracking and excessive noise levels. To prevent the lateral vibration and the whistling noise of circular saw blades, some techniques have been introduced such as tensioning (Schajer & Mote, 1984), the use of high damping alloy (Hattori *et al.,* 1993), vibration damping due to air film (Trochidis, 1989), stiffening by thermal membrane stresses (Mote et *al.,* 1981), and guided saw blades (Hutton *et al.,* 1987). In the actual woodworking field, an asymmetric circular saw blade is frequently used, in which several slots are made on the circular saw blade from the periphery of the blade towards its center. Such a blade is useful to prevent the lateral vibration both in idling and cutting operation (Dugdale, 1979; Mote & Yu, 1987).

The literature on bandsaw vibration can be divided into two general categories. The first is concerned with resonance vibration of a saw blade between two guides or wheels (Mote 1965, Alspaugh 1967, Ulsoy & Mote 1980). These analyses are based upon the model of an axially moving beam or plate subjected to fixed support boundaries at the guide or wheel. The second category focuses on the static or divergence buckling associated with edge cutting forces (Mote, 1980; Foschi & Porter, 1970, Pahlitzsch & Puttkammer, 1974; Garlicki & Mirza, 1978). Fixed support boundaries are imposed at ends of a saw blade in these analyses as well. A basic assumption in all previous research has been that the cutting span between the guides can be examined independent of the band outside the cutting region. The implied assumption is that the guides or wheels isolate the band in the cutting region from the remainder of the system. Research has shown that vibration of the span between the saw guides and spans which include the remainder of the bandsaw blade are coupled together (Wu & Mote 1982). These band regions can never be designed and analysed as independent systems as long as the bending stiffness of the band blade is significant.

Dynamic stability of tools: self-excited vibration

The bandsaw vibration is affected by the system dynamics, which is important in determining the sawing accuracy of the bandsaw. If the system is dynamically unstable, even the finely constructed and most accurately aligned machined will not produce the desired products considering accuracy and productivity. Operating a system close to an unstable condition is very hazardous from safety point of view as well. Typical results of saw instability are undulating sawcuts such as washboards, poor surface finish and sawcut width several times wider than the saw tooth thickness.

Recent studies have demonstrated that self-excited vibration and washboarding are induced during cutting with a bandsaw under a tooth passage frequency slightly greater than the natural frequency of the bandsaw (Okai *et al.*, 1996, 1997). The relationships between the wheel rotation speed of a 410mm bandmill and the natural frequencies of the saw blade when self-excited vibration and washboarding are induced is shown in Figure 2. If the unstable regions for sawing overlap each other, then one has to select rotation speeds lower than the minimum rotation speed under which self-excited vibrations and washboarding are induced, neglecting efficiency of production. Fortunately, the rotation speed ranges under which self-excited vibrations and washboarding were induced do not overlap. Then the self-excited vibration and washboarding can be controlled when the wheel rotation speeds are in the stable region considering efficiency of production. A computer simulation and experimental results for self-excited vibration and washboarding are shown in Figure 3. It can be seen that the bandsaw vibrations are excited only under tooth passage frequencies slightly greater than the natural frequencies of the bandsaw. It also can be seen that self-excited vibration and washboarding are not induced when the tooth passage frequency is equal to the natural frequency of the bandsaw. This result can be explained as follows: when the tooth passage frequency is equal to the natural frequency, no lateral cutting resistance is induced on the side of a tooth, and consequently, energy is not given to the bandsaw vibration to grow (Okai 1997). The relationships between the wheel rotation speeds and the workpiece thickness when self-excited vibration and washboarding are induced under a fixed height of the feed table is shown in Figure 4. The shaded area is the unstable region for sawing, and the unshaded areas represent the stable regions for sawing. It can be seen that as the workpiece thickness increased under a self-excited vibration, the wheel rotation speed range within which sawing becomes unstable, increases. Figure 4 can be used as a stability diagram to control self-excited vibration and washboarding by considering the trend line for the minimum and the maximum wheel rotation speed when self-excited vibrations and washboarding are induced.

Sawing Tropical Woods: Characteristics and Difficulties

The tropical forest is characterised by:

- A mixed species forest with a large range of properties (from 200 up to 1200 kg/m3 density).
- A large distribution of log sizes with a large proportion of big trees.
- Problems of forest accessibility and logging which favours the development of small sawmills with poor performance.
- A tremendous variability of sawing equipment.
- Difficult maintenance (especially sharpening and tensioning) through lack of qualified sawdoctors and equipment.

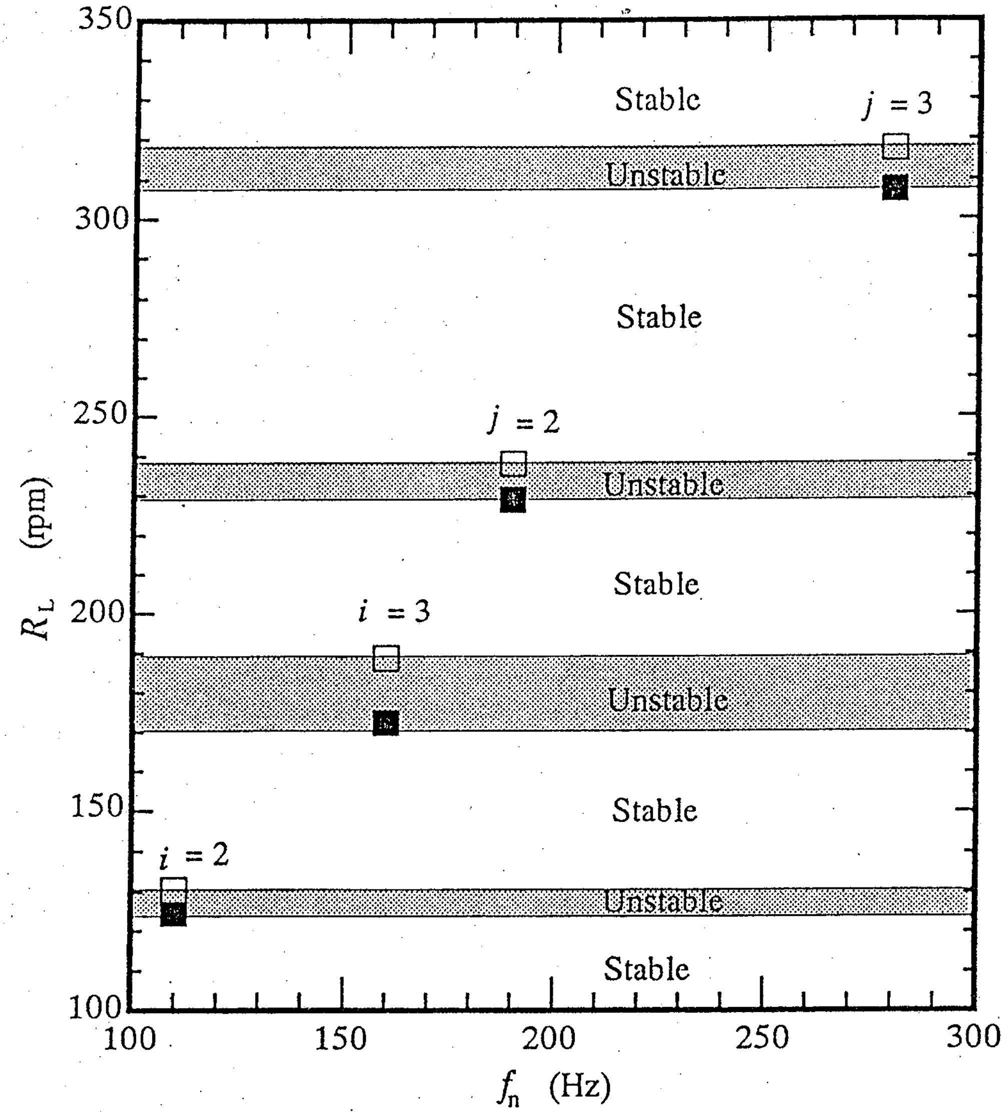

Figure 2. Relationships between the wheel rotation speeds during sawing R_L and the natural frequencies of the bandsaw f_n when self-excited vibrations and washboarding are induced under a constant free length of the saw blade.

Legend:

- ■ *Minimum wheel rotation when self-excited vibrations and washboarding are induced.*
- □ *Maximum wheel rotation when self-excited vibrations and washboarding are induced.*
- *i* *transverse vibration mode.*
- *j* *torsional vibration mode.*

Note: Workpiece thickness = 35 mm constant.

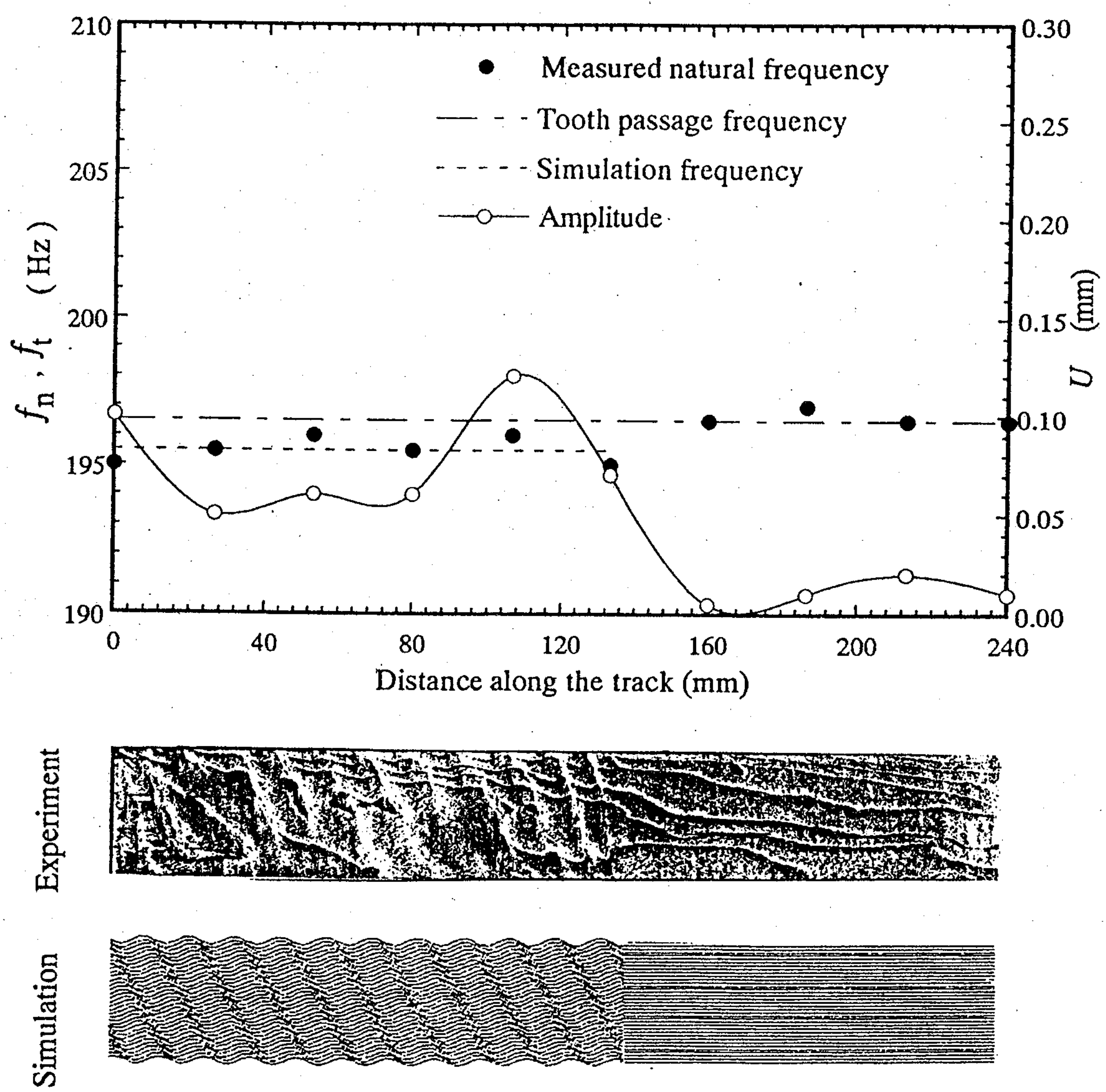

Figure 3. Self-excited vibration and washboarding during sawing with a bandsaw under a tooth passage frequency slightly higher than the 2nd torsional natural frequency.

Legend:

fn	*Measured natural frequency*
ft	*Tooth passage frequency slightly*
U	*Amplitude*

Notes: Set-up wheel rotation speed – 229 rpm; Feed speed – 11.97 mm s^{-1}

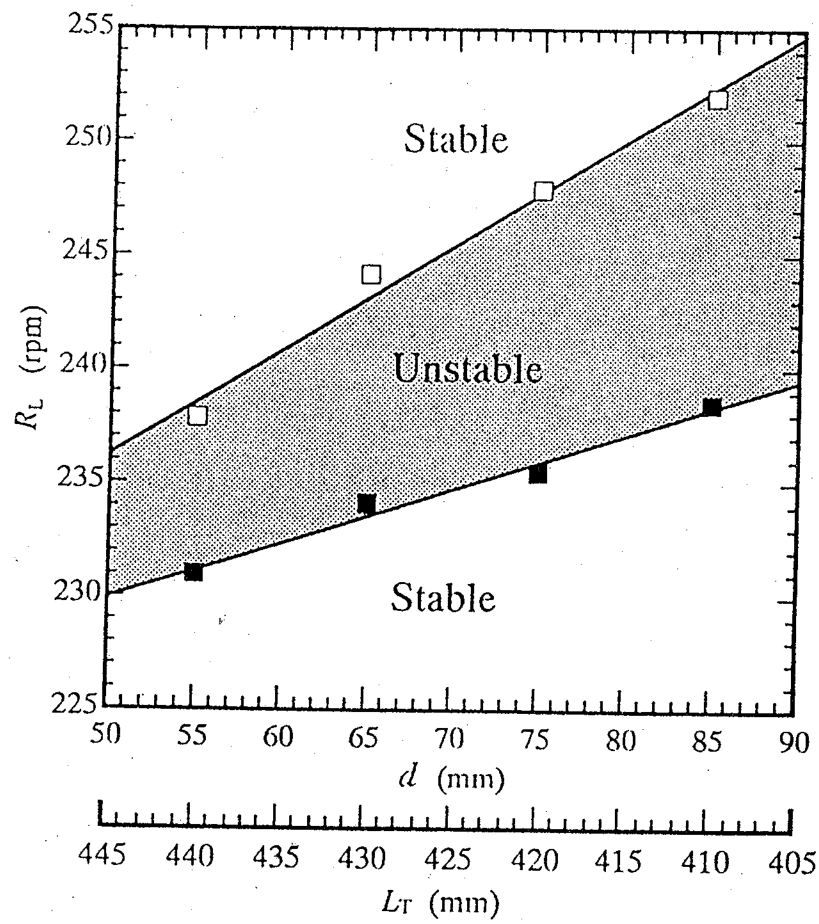

Figure 4. Relationship between the wheelrotation speeds during sawing R_L and the workpiece thickness d, or the free length of the bandsaw blade L_T from the top of the workpiece to the band/top wheel contact point when self-excited vibration and washboarding are induced under a fixed height of the feed table.

Legend:

■ *Minimum wheel rotation when self-excited vibrations and washboarding are induced.*
□ *Maximum wheel rotation when self-excited vibrations and washboarding are induced.*

Two main difficulties in sawing tropical woods are:

- High cutting force due to density and sawing depth. In Africa and south America, more than 50% of the logs sawn have a diameter greater than 60 cm and a dry wood density higher than 700 kg/m3 (Sales *et al.*, 1988).
- Fast tooth wear due to density gravity which gives high cutting force thus increasing friction, mechanical and thermal wear. High proportionate of silica content in certain species also contributes to fast tooth wear.

Fast tooth wear: solutions

For ripsawing, tungsten carbide is commonly used on circular saws, and for bandsaw blades, stellite tipping remains the most efficient solution.

Effect of temperature during sawing and its action on bandsaw blade stability

During sawing, the friction of the blade on the wheels and wood induces uniform overheating. The thermal expansion of the blade caused by this overheating is equilibrated by the elasticity of the mechanism for maintaining tension between the wheels. On the other hand, the cutting process, especially for tropical hardwoods, heats the tooth edge which can rise several hundred degrees inducing thermal gradient from the front to the back of the blade. This causes a displacement of the blade from back to front and a loss of tensioning thus reducing the mechanical performance of the blade. Fortunately, although the temperature can be very high, the surface concerned is very small and located near the tooth edge. The thermal input is limited and the tooth body acts as a very good radiator, limiting the temperature gradient even for heavy woods. To balance this effect, the sawdoctor can give an additional tension on the front of the blade by introducing a back-crown.

Blade stability on the wheels: Effect of wheel design

Recent studies have demonstrated that the apparent change in the wheel diameter near the tooth side or the rear side of the blade influences the running stability of the bandsaw blade (Okai *et al.*, 1996). Figure 5 shows the effects of sawdust or the wheel design on the running stability of the bandsaw blade. It can be seen that when sawdust adheres on the bottom wheel near the tooth side of the blade, there is an apparent change in the wheel diameter near the tooth side, and the bandsaw moves to the region of increasing wheel diameter, or the counter feed direction. Increases in the movement of the saw blade in the counter-feed direction increased the projection of saw teeth from the end of band wheel, and sawing becomes unstable. As depicted in Figure 5(b), when a sawdust collector was positioned under the workpiece to collect the sawdust produced, the wheel design remains unchanged and the running position of the bandsaw is stabilised.

The lesser-Used Wood Species

The following wood species in Ghana are classified as lesser-used wood species: Canarium *(Canarium schweinfurthii)*, Ceiba (*Ceiba pentandra*), Celtis (*Celtis mildbraedii),* Okan *(Cylicodiscus gabunensis*), Ayan (*Distemonanthus benthamianus*), Essia (*Petersianthus macrocarpus*), Sterculia (*Sterculia rhinopetala*), Bombax (*Bombax brevicuspe*), Albizia (*Albizia ferruginea*), Aprokuma (*Antrocaryon micraster*), and Akasa (*Chrysophyllum albidum*), (Ayarkwa *et al,* 1993).

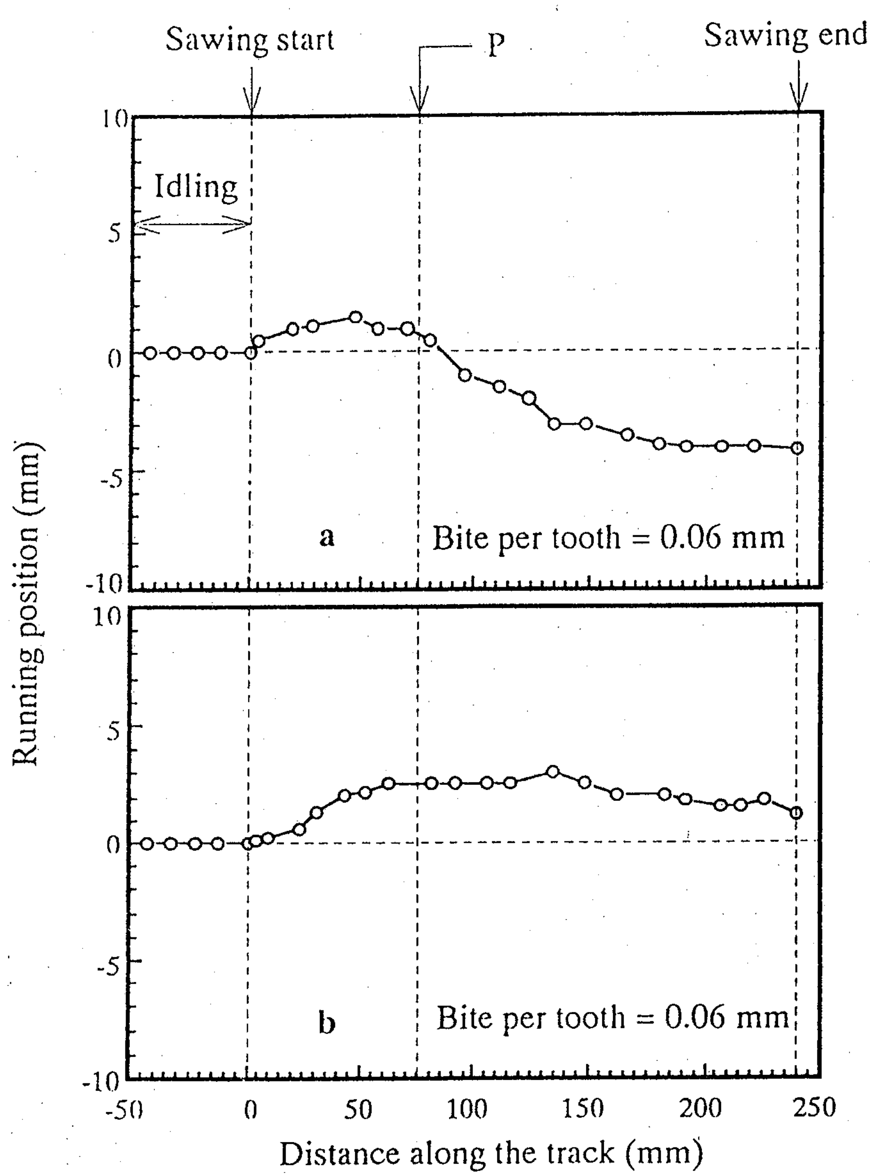

Figure 5. Relationships between the running positions of the bandsaw and the distances along the track of the bandsaw teeth under identical bites per tooth.

Legend:

a: The sawdust produced adhered to the bottom wheel.

b: The sawdust produced was collected by a sawdust collector.

P: Distance along the track of the tooth sides of the saw blade at the instant the rear side of the saw blade entered the workpiece.

Note: Setup wheel rotation speed: 235 rpm

Some of the above species are characterised by high wood density, interlocked grains, high silica content, severe blunting effect, and woolly surface, thus restricting the use of the timber of these species in the past. However, recent studies have demonstrated that the lesser-used wood species can be sawn or planed if the appropriate machinery and tools are selected. (Sales 1985) studied the wear of different materials such as speed steel, high speed steel, stellite, and tungsten carbide during planing of Makore (*Tieghemella africana*) at 15% moisture content and silica content of 0.3%. For the same planing length on makore, the following results were obtained:

Tools	***Number of sharpening***
Tungsten carbide	1
Stellite	2
High speed steel	3-4
Speed steel	12-15

It can be seen that tungsten carbide and stellite have the less number of sharpening, and these results indicate that when planing lesser-used wood species containing silica (eg. *Canarium* and Ayan), tungsten carbide or stellite are the appropriate tools to select since these species have a severe blunting effect on tools.

Studies have shown that when planing Albizia (*Albizia ferruginea*), a reduction of cutting angle of 15° is necessary to prevent tearing of interlocked and irregular grains, and a cutting angle of 10° is required for satisfactory planing of quater sawn material of Okan (*Cylicodiscus gabunensis*). When planing Canarium (*Canarium schweinfurthii*), a reduction in cutting angle to 20° gives improved finish on interlocked grains provided the cutters are kept sharp. Otherwise, a woolly finish is obtained. A reduction in cutting angle of 15° is necessary to prevent tearing of interlocked and irregular grain when planing Celtis (*Celtis mildbraedii*).

Conclusion

The machining characteristics of the commercial wood species and that of the lesser-used wood species are almost the same. Thus, there should be no difficulty in machining the lesser-used wood species as substitute to the commercial wood species once a machining knowledge of the latter is known.

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Durability of Solvent Based Wood Finishes on Wood Furniture Components

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Abstract

Furniture components are finished with chemicals to enhance their beauty and durability. Suitable finishing systems may improve colour and figure of the wood, as well as provide smooth, mirror-like surfaces. Appropriate finishing operations and chemicals are required to add valve to the wood products. In Ghana, furniture components usually exported include, chair parts, broomsticks, toys, flooring, parquest, T & G, and profile boards. Preferred species are Koto, Teak, Avodire, Black Hyedua, Apa, Odum, Mahogany and Asanfena. Preferred finishing chemicals used by a number of producers are the Sanding Sealers (Nitrocellulose), Semi-matt and Matt Lacquers, Standard Lacquers, Epoxy esters and Polyurethanes. These are mostly solvent-based finishes. The paper investigates the factors of species, tooling, finishes and application that influence the durability of the chemicals on the finished surfaces of the furniture and the ability of the wood components to resist imprinting, scarring, damage from spilled water, beverages, cleaning agents and hot dishes on the finishing system.

Introduction

Finishes protect and decorate manufactured wood products (Martens 1968). Decorative finishes have appearance as a dominant requirement and protection secondary.

Finishes constitute a complex field because of the continued growth and availability of:

- New pigments
- Vehicle solvents
- Additive vehicles
- Solvent and additives which can be used by the formulator.

Achieving a finish on wood involves a combination of two factors

1. Surface condition of the wood
2. The finishing treatment applied to the wood.

Furniture finishes may be one of two types:

1. Transparent or clear finishes
2. Opaque finishes or paint

Most of the coating materials are lacquers. A clear finish system usually modifies the colours and appearance by stains.

Properties desired in finishes are:

1. Quick drying
2. Easy sanding
3. Good build
4. Durability

Stains may be dissolved in alcohol, aromatic hydrocarbons or water, or a mixture of alcohol, aromatic hydrocarbons and glycol ethers (non-grain releasing type).

Clear gloss lacquers are similar in composition to a clear base in sanding sealers at 21% to 27% solids. Flat lacquers are gloss lacquers to which a flatting agent such as Colloidal Silica has been added.

Properties desired in topcoat lacquers include:

1. Quick drying
2. Good levelling
3. Build
4. Rubbing
5. Resistance to painting, checking or cracking

Since it is difficult to obtain the optimum in all properties, lacquer formations vary depending on the properties the user wants stressed (Appendix I).

Durability Factors

To obtain a better durability of a wood coating system, the influence of species anatomy must be known (Rour & Podgoriski, 1995). A non-porous surface is better, e.g. Pine is better than Oak. The influence of toolings and the wettability of the surface is very important for adhesion and penetration of chemicals. Other factors include the influence of application, application devices, laid quantities, number of coats, penetration and regularity of the coats. Addition of additives like UV absorbers can modify the finish and improve their durability.

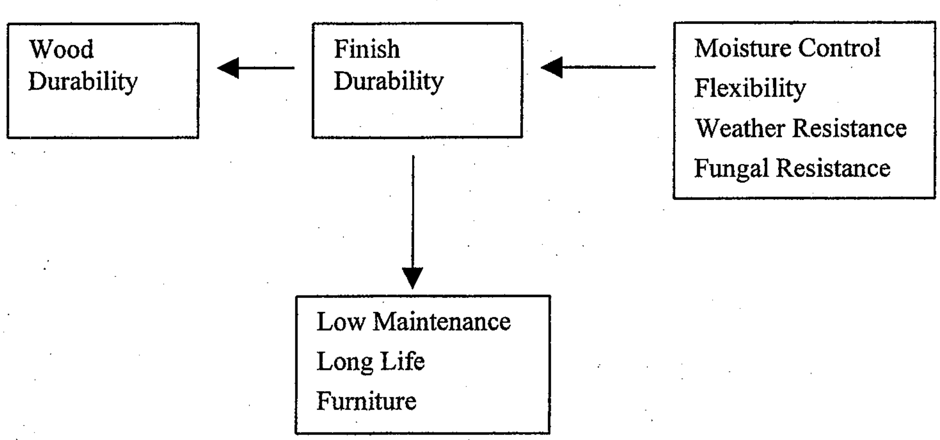

Figure 1. Integrated System of Surface Finish Protection

Finish durability is related to wood cracking and flaking on some wood species.

There are some reservations among furniture manufacturers about water-borne finishes. They are difficult to apply by spraying. Long maintenance finishing periods are achieved with polyurethane and amino resin finishes, but the refinishing of those finishes with hard surfaces is poorer than with softer water-borne surfaces and they should be sanded carefully before finishing.

Some tropical species (Tables 1 & 2) contain agents that can make their surface finishing difficult. For example, they can prevent an alkyd lacquer from drying. Even when the lacquer has dried over a long period, adhesion will occur very soon. Before such species can be finished, their surfaces must be washed with a solvent such as Xylene or a thinner or nitro-cellulose lacquer. These treatments ensure good drying and adhesion. However, the agents remain within the wood and may emerge to the surface and attack the finish film. Investigations have shown that the best results can be achieved by priming the surface with products that prevent these agents from coming into contact with the surface finish. Polyurethane products and some special acid-catalysed lacquers are useful for this purpose. After the priming, the final finish can be done with urethane or acid-catalysed lacquers.

When freshly cut, or of planned, wood surface, oxidation occurs (Nussbaum, 1992). The dominating factor is the enrichment of inherent oleophilic components, at a rate that depends on the wood species. These components may consist of Resin and fatty acids, waxes and terpenes. Beside the low energy surface they create, they are also likely to reduce the adhesion of an applied coating due to their short chain length, which prevents anchorage to the wood substance.

To reverse this trend, a process of surface activation involving techniques of acid etching, corona discharge, UV radiation and flame treatment have been investigated. Such processes sterilise the wood components, since microbiological activity significantly reduces the lifetime of stained wood panels. Flame treatment of wood surfaces results in a decrease in microbiological activity (Nussbaum, 1992).

This fungicidal action of flame treatment may be an important contribution to increasing the durability of stained outdoor panels.

Wood surface quality also deteriorates when wood is exposed to ultraviolet light and acid rain (Hon, 1993). When wood surfaces are exposed to UV light, carbonyl groups increase and lignin content decrease simultaneously. Although UV light is a major element in degrading wood polymers, it is to be expected that for lignocellulosic biopolymers where hydrolytic breakdown can be an important mode of deterioration, acid rain will have a catalytic effect.

In addition to oxygen, sulphur dioxide and nitric oxide (NO) are important gasses.

Table 1: Chemical Composition of Species

Wood Species	Polysaccharide Content (%)	Cellulose (%)	Lignin (%)
Wawa	63.1	41.5	34.3
Odum	59.0	42.3	29.0
Utile	62.9	43.8	36.9

Based of their high reactivity, these gases are likely to have ill effects on the surface quality of wood when it is exposed to them.

Photodegradation of wood surfaces has been known to occur via numerous free radical chain reactions. Several types of free radicals, with different reactivity generated in cellulose, hemicellulose and lignin that are distributed on the wood surfaces have been recognised. Some of these free radicals are active toward oxygen to produce hydroperoxide (Hon., 1995).

Basically, finishing of furniture components must take into account all factors that influence the durability of the surfaces. The importance of finishing (which incorporates durability by protecting the wood, as well as aesthetic beauty) cannot be over emphasised.

Table 2: Chemical Composition

Species	B.A. Extraction (%)	Hotwater Extraction	Lignin (%)	Cellulose (%)	Pentosan (%)
Otie	1.1	2.4	23.8	53.5	18.7
Ceiba	5.6	14.6	22.4	33.0	18.7
Emire	9.6	3.9	30.5	42.0	11.9
Wawa	1.4	1.4	34.3	41.5	17.4

Methodology

Case studies of industrial production for export of profile boards, broomsticks, flooring in selected furniture factories were carried out. Species preferred for these products included Teak (*Tectona grandis*), Koto (*Pterygota macrocarpa*), Odum (*Milicia excelsa*), Asanfena (*Anigeria spp*), Avodire (*Pycnanthus angolensis),* Ceiba (*Ceiba pentandra*), Emire and Wawa (*Triplochiton scleroxylon*).

Wood preparation was done for accurate dimension and improved surface characteristics, through carefully controlled drying, sawing, surfacing and shaping, moulding, sanding and sorting for quality.

Profile boards of durable species i.e. Ofram and *Ceiba*, were laminated with veneers of the highly durable decorative species i.e. Asanfena and Odum with thermoplastic glue.

The final finishing was through sanding, staining, drying, sealing and coating integrated heating and dust extraction systems. In top coating, mixtures of hardeners, acetone, thinner and polyurethane were applied, based on international standards. Tests included surface quality for smoothness and evenness. Durability tests were carried out based on B.S. 3692 for:

1. Resistance to marking by liquids (spirits, soap, tea, coffee).
2. Resistance to dry heat form lacquers to thermosetting lacquer and amines.

Surfacing and Finishing, Case Studies

A. Akuaba Company Ltd.

Raw Materials:

- Hyedua
- Avodire
- Odum
- Emire
- Dahoma
- Walnut
- Wawa

Finishing operations:

1. Sanding I. (after dimension sawing)
   Rough sanding and sand paper 80 grit
   Staining (strin mixed with sanding scaler)
2. Sanding sealer application
3. Drying
4. Sanding II (with 320 grit and paper).
5. Lacquer application (gloss or matt)
6. Drying
7. Sanding III
8. Top coat application (lacquer)

B. Company Habitat

Finishing Operation:

Equipment:

- Spray guns
- Turn tables
- Metal stands
- Trolleys
- Fume Chamber

Chemical:

- ❑ Sanding sealer
- ❑ Lacquers
- ❑ Stains

Procedure:

1. Sanding hand (Sandpaper grit 120)
2. Dust removal
3. Sealer application (sanding sealer)
4. Sanding (smooth sand paper, grit 320)
5. Sealer application (sanding sealer)
6. Sanding
7. First top coating
8. 2nd top coating

C. Trassacco Company

<u>Outline of finishing process</u>:

1. Hand sand components with 120 grit aluminium oxide sandpaper
2. Apply two coats of sanding sealer
3. Sand with No. 00 glass paper
4. Apply two coats of cellulose lacquer (matt), available lacquers, clear lacquers, high build cellulose lacquer, SPL lacquers

Population preferred SPL lacquers (Matt).

D Case Study Co. D.

<u>Chemicals used:</u>

1. Sanding sealer
2. Semi-matt & matt lacquers
3. Stains (Rosewood, Mahogany Mansonia, Walnut)

<u>Procedure of finishing:</u>

1. Sanding with 60 grit sand paper
2. Sanding with 100 grit sand paper
3. Dust blowing with air hose
4. Sanding sealer application (smooth sandpaper)
5. Sanding with 280 or 320 grit
6. Sanding sealer application
7. Lacquer application II spraying along grain of wood
8. Drying
9. Lacquer application II (Either matt or gloss)

NB: Matt lacquers more durable than gloss lacquers Lacquer sealers are supplied ready from spray of 18 to 21 per cent non-volatile matter.

Table 3: Furniture Species Characteristics

Species	Characteristics
Mahogany	Typical red-brown heartwood with pale sapwood grain straight or interlocked
Asanfena (T & G for local market)	Heartwood and sapwood red-brown to pink. Grain rather silky or wavy/straight. Dries easily but some risk of stain when freshly cut.
Dahoma (Outdoor furniture)	Yellowish brown streaky heartwood. Sapwood pale. Coarse interlocked grain. Fresh wood corrodes iron.
Emire (Joinery, Moulding, Flooring)	Pale creamy yellow heartwood and sapwood. Medium coarse texture. Grain straight/interlocked, sometimes with irregular stripes.
Ceiba	Wood is light. Very difficult to saw clearly and finish with wide spores. It machines easily but sharp cutting edges are necessary to severe the fibres clearly.
Koto (Joinery, T & G for local market, Ceiling)	Creamy white heartwood and sapwood slightly interlocked.
Hyedua (Flooring)	Attractive olive brown, dark striped, pale. Straight interlocked grain with striped figures.
Kusia (Flooring)	Characteristic yellow/gold heartwood and sapwood. Often strongly streaked with black. Grain straight or interlocked.
Wawa (Interior moulding, Profile boards, battens, antisapstain chemical Bumper EC)	Creamy white heartwood and sapwood. Interlocked grain.
Utile (Flooring, Profile boards)	Has considerable amount of hard deposits like calcium carbonate and silica grains, which have pronounced dulling effect on all cutting edges, reducing the surface quality of the wood. Grains and resins have adverse effect because of the tendency for these to adhere to the tool, thereby causing overheating.

Summary and Conclusion

Tooling Effects on Wood Species Survey Quality

Sawing

Quality of finish depends mainly on the accuracy of machining. Spring set teeth not recommended for cutting Makore and Asanfina. Saws were easily dulled resulting in rough surfaces of wood. Smooth sawing was achieved with saws having straight teeth tipped with stellite Tungsten Carbide Tipping (TCT) and diamond for all species.

Most of the furniture species (Table 3) have interlocked grains and soft fibrous texture, which affects many machining operations. A cutting angle of 20° is found to minimise tearing of interlocked grain.

Chemistry

Teak contains agents (Resin, fatty acids, waxes, terpenes and oleophilic components) that can mar the surface finish. Polyurethane and acid-catalysed lacquers are useful to prevent these agents from coming into contact with the surface finish.

Finishing

The most hardwearing surfaces were those provided by the many varieties of hard seals (Oleo-resinous, epoxy ester and Polyurethanes).

The ability of the wood components to resist imprinting, starring, damage from water, beverages, cleaning agents, and hot dishes depends on the finishing system.

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Appendix I

History Perspective, Trades and Developments of the EU Finishing Market.

Sweden

Nordic Concept:

1. Highly efficient industrial surface treatment.
2. Short production lines with multiple benefits of:
   - acid-curing paint and lacquers,
   - rapid drying systems with
   - a good build.
3. Products can be stacked directly after finishing and curing.
4. The problem of fairly substantial solvent emissions.

Research and Development has resulted in the production of:

1. Low-emission two peak high solids system.
2. Solvent-free UV curing systems.
3. Waterborne lacquers and stains.
4. Most recently and water borne UV curing lacquers.

<u>Acid Curing Lacquers</u>

Acid-curing pigmented and clear lacquers to replace the traditional low-solid cellulose lacquers.

- Fast drying
- Easily applied in any climate
- Inexpensive
- Easy to stack and with
- High solid control
- Environmentally friendly.
- Attractive, High Quality finish

<u>Disadvantages</u>

1. Solvent-based
2. Contain formaldehyde, whose emissions can irritate the skin.

Germany and other European markets, traditional with emphasis on:

1. Cellulose-based finishes (> 50%).
2. Style of furniture that involves more craftsmanship and normally multiple coats of lacquer.

Alternative to cellulose thin R&D leads to:

1. Polyurethane and Isocyanide (Two-pack) paint system - main features of EU market.
2. More painted and styled furniture.
3. Greater use of special-effect finishes (rustic-effect stains and high gloss finishes).

Italy

(With large numbers of small factories individualised pieces of furniture as lifetime investment).

Furniture makers choose:

1. Polyester (containing the solvent styrene) and
2. Polyurethane coatings, which have
   - a lot of body
   - eradicating the natural effects of the wood substrate which prefers clear lacquers and pigmented stains to enhance and highlight the natural qualities of wood.

France

(Interest in environmentally, more advantaged products)

- Resistant coatings for wooden flooring
- Modern water borne or UV curing systems (public interest lukewarm).

U.K.

Traditional and conservative widespread use of:

- Pre-catalysed one pack systems (70%)
- Trend towards AGID CURING HIGH SOLID
- Systems offering a dramatic reduction in solvent emissions
- UV curing products (10%)

<u>Modern Finishing Trends</u>

1. Application of less paint or to reduce volume by 5-10%
2. Instead of two coatings of a 120g acid-curing lacquer, the same is now with
3. 50g of UV curing lacquer reducing the amount of lacquer required.
4. UV curing lacquer requires no thinner applied in a 4-stage process. It is environmentally friendly because it has no solvents.
5. Introduction of substitutes, such as foil and similar laminates, to replace wood finishes to some extent. Foils, however, once damaged, cannot be repaired. They also mask the natural qualities of wood substrates.

<u>Different Finishes</u>

Polyurethne/polyester lacquers (Italy), Cellulose-based lacquers (Germany) one-pack acid curing lacquers (U.K.).

Now convert to UV curing and waterborne lacquers.

ADVS: Short Drying schedule

Any Oversprayed lacquers can be recycled after spraying

Source: Backlund Leif, 1997: Creative relationships for a creative finish. Becker Acroma. Furniture manufacturer, April 1997. The Int. Journal for the Furniture Production Industry, Publex International Ltd.

The Quality of Mouldings, Cabinets and Furniture Manufactured from Lesser Utilised Tropical Hardwood Species

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Abstract

The Lesser-Used tropical hardwood species are now being specified widely for mouldings (flooring parquet, and tongue and groove profiles), cabinet and furniture. These items are selected for shops and kitchen fitting, and for living room and office furniture. The familiar tropical species, which were usually specified for these items, are now very expensive and difficult to come by these days.

Some of the problems associated with the processing of the lesser-utilised species, which have led to poor product image, include: inadequate supply, erratic royalty regulations, inappropriately developed grading rules, and inefficient manufacturing processes.

The quality of products obtained after the manufacturing processes and finishing do not compete favourably with similar products from the Asian and North American countries on the international market. Some European countries like Germany, Italy and the U.K. patronised wood products such as flooring and parquet manufactured from tropical hardwood species.

In this paper, attempt has been made to present the quality control procedures utilised in the manufacturing of flooring from Afena (Strombosia glauscescens); cabinet, office and living room furniture from Avodire (Turreanthus africanus), and Tongue and Groove profiles from Ofram (Terminalia superba). These three species are among, the numerous lesser utilised tropical species found in the tropical high forest including Ghana and are presently under exploitation.

Proper monitoring and control of the manufacturing processes could improve appreciably, the surface quality of the products fabricated for export.

Keywords: Quality control, manufacturing processes, lesser-utilised hardwoods, International Market.

Background

In recent years, there has been considerable demand for woody items such as furniture, cabinets, and mouldings, although there is stiff competition with similar items made from man-made materials such as plastics. This could be because some wooden items have ubique aesthetic values. The advance in computer manufacturing technology has aided the design and production of more sophisticated wooden items. Manufacturers are in constant search for designs, which could offer the best price, and of course are very attractive to the customer both domestic and international.

The competition among producers has also become intensive with regards to quality assurance of the commodities being produced. The manufacturing processes that a piece of factory lumber passes through before being converted into a piece of furniture are now very efficient. This is because of availability of a wide range of innovative workshop equipment, which have been made to ISO 9001 quality standards.

The quality of sofas for example can be examined by testing their reliability and comfortability. Mouldings such as flooring and tongue and groove profiles must be processed from durable timber, which can withstand the abrasion and stresses imposed on them while in use. Both the wood selected and the product must be of good quality. There is usually no problem with the selection of a particular species with knowledge of its physical, chemical and mechanical properties for a specific item. However, without the basic information on their properties, problems that impair quality may develop after a product is made.

Of particular interest to the wood technologist is in the wood before processing. It has been observed that some commodities including living room furniture, cabinets, kitchen fitting, bar and bank counters are being manufactured in Ghana from some selected "new" species including Avodire. There is little information on the technical properties, which is so important in considering a species for a particular use. Customers purchase these products and later complain about defective size and shape, which may not be observed at the time of manufacturing and purchasing. Some customers are unable to explain their requirements to the manufacturers, thus contributing to poor quality work.

Of the new species that grow to good sizes to be exploited and processed into factor lumber in Ghana, the species listed in Table 1 (pink star species) are among others presently exploited below the annual allowable cut (AAC). Research and development are presently being carried out on some of these species in order that they will be promoted on the niche market. Among the species listed are three species currently widely specified for some of the products mentioned earlier. These are Afena, Avodire, and Ofram. In this paper, the quality control measures in the manufacture of wooden items for the domestic market will be described

Value-Addition

Many value-added products can range from low to high capital cost items depending one or more factors; for example:

- Products that require substantial amount of equipment to be added to either a new facility or an existing mill may require a fairly large investment such as A.G. Timbers (finger jointing plant) and FABI Timbers Ltd (moulding plant).
- "Low" cost items - dimension lumber (knotty material) from branches and tops of trees or veneer.
- "High" cost items: - laminated veneer lumber (LVL), Oriented strand board (OSB), Medium density fibreboard (MDF), Composite I beams, Furniture, Mouldings, Cabinets

Also, LUS are now widely specified for living and bedroom furniture (these require preservation treatment), cabinets, kitchen fittings, and mouldings, e.g. floorings, parquets and T & G profiles.

Poor Quality Products on Market

A. Wood raw material

1. Wood structure defects (condition of log/lumber) visible

2. Moisture movement:

- Internal stresses
- Surface checks
- Splits/crack

B. Manufacturing Proces

1. Efficiency of mill/workshop equipment and machinery

- poor measurements - cutting defective sizes and shapes
- obsolescence - frequent breakdowns of machinery

2. Improper design and jointing of members adhesive.

- wood adhesive wood members
- wood/hardware members
- wood/connectors:
- nails, screws
- hardward/adhesive/dowel joints

The lack of machinery spare parts contributes significantly to poor product quality, improviced replacement are made locally which also aids in defective processing.

Natural defects of wood include reaction wood, checks (surface). The development of internal stress weakens plane of growth rings.

Remedy

*Total Quality Management

- Log yard sorting
- Optimisation in the sawmills
- Process control technology
- Waste recycling (integrated)
- Producing to order/control
- Integrated process planning
- Information technology
- Market data

Recommendations

1. The Forest Products Inspection Bureau and presently GSB provide the wood industry with the means of tackling national problems relating to standardisation and specification. Standard dimensions of wood products, which are checked before export, depend on highly skilled personnel. This is vital for new products. Frequent training programmes for these personnel is very necessary in view of the dynamic nature of the technologies involved in wood products manufacturing.

2. Quality should be tested and check by millers and manufactures at all stages of production.

3. Goods inspection. Materials required for production and bought-in-components (for example hardware) must be inspected on arrival at the factor to ensure that they are of the right quality.

4. Furniture, mouldings and cabinets.

Conclusion

To utilise fully the state-of-the-art technologies now available, wood products industries need to complement their investment in equipment with investment in human resource. The rapid pace of technological change and automation within the wood products industry worldwide has led to continuous increase in the skilled workers for the industry. Within the industry, recognition is growing that adequate training is key to productivity and quality and training must match technology for its effective implementation.

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Wood Residues Densification Technologies, their Applications, Prospects and Problems in Developing Countries

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Abstract

Wood densification technologies have provided a great boost to the usage of waste biomass materials for domestic and industrial fuels in the developing countries. The technologies are well favoured especially in those countries confronted with massive deforestation problems. Conversion of wood residues to solid fuels through densification is not simple and straightforward. The most serious problem being the low bulk density of wood which initiate a chain of other constraints such as low heat release rate per unit volume of product, as well as high production and storage costs. This paper aims at evaluating the existing choices of densification technologies currently in use in the developing countries. It also discusses prospects and problems of these technologies in these countries.

Apart from improving the combustion characteristics of wood for both industrial and domestic consumption, densification technologies can aid rural development through judicious usage of products manufactured from the systems. The limitation in the range of densified fuel production technologies which provides little consideration for the local production environment; the high cost of products manufactured with the systems; as well as the combustion characteristics of the products are the basic problems influencing the development of wood residue densification technologies in the developing countries.

Introduction

The past few decades have witnessed, in the developing countries, a tremendous increase in the demand for energy caused by increased population growth. The increased demand for energy has resulted in massive depletion of the forests, especially those located in the zones of these countries.

Current programmes aimed at reducing the rates of densification, and forest exploitation in these countries have resulted in efforts engineered towards increased utilisation of wood aid agricultural residues generated in the countries through the application of densification technologies.

Densification is the physico-mechanical conversion with or without an additive of a dry loose woody material of fine particle size, into a solid state characterised by a regular shape and a high density. Products produced through this process include fuel logs, pellets and briquets.

Within the last decade, various densification technologies have been introduced to the developing countries for producing densified products from biomass materials generated in the countries. Most of these technologies have their origins in the developed countries and are used basically for densifying biomass prevalent to the countries.

Despite the great potentials of these technologies for providing the much needed solution to the energy problems currently confronting the rural population of the developing countries, their applications have brought along a mammoth of problems that have made the up grading and utilisation of the woody materials in these countries difficult.

This paper aims at evaluating the various technologies involved in the conversion of wood residue materials to densified solid fuels. The application, prospects and the problems limiting their successful introduction in the developing countries are discussed.

The Principles of densification

Densification involves the bulk reduction of woody particles through pressure application to a point where products of various forms are obtained. In a typical densification process, the application of low to moderate pressure (0.20 - 5.0 MPa) to compact the loose material reduces the space between the particles. Pressure increases to beyond 5.0 MPa cause a collapse of the cell walls - of the cellulose constituent, thus approaching the physical or dry mass of the material (Dada 1989, Anon 1985).

The major cementing material that prevents springback in the densified product can either be the lignin, a thermoplastic polymer, which is a major component of most plant tissues; or a natural/synthetic binder. At high temperature and pressure, lignin begins to soften. This fluidisation of lignin and its subsequent cooling while the material is still under pressure is an important factor in high pressure densification process.

The densification process can be classified into three major groups (Sebra, 1988; Lequeux *et al.*, 1988) depending on whether the material is compacted with pressure application only; pressure and external binder application; or by special systems involving prior biochemical degradation of woody material before pressure application.

The amount of pressure applied determines the quality of the products produced. In low pressure systems such as baling and manual pressure, applied pressures of 0.2 - 5 MPa (30-800 psi) are only able to eliminate the voids between particles but incapable of raising the temperature or collapse the cells within the particles. Pressures ranging from 20 to 500 Mpa (3,000 - 75,000 psi), combined with friction, raise the temperature of the feedstock to 200-300°C, and cause collapse of the cellulose cells eliminating the voids (Lequeux *et al.*, 1988). The lignin binds the cellulose in its collapse state as it cools, causing the cellulose from springing back to its original density.

Existing Choices of Densification Technologies

The existing technologies currently used for densifying biomass in developing countries are varied and very numerous. Most of the technologies are basically of European and American origins.

The choice of a technology is influenced by a magnitude of complex interrelated factors which include mainly the characteristics and end-use of the densified product; the desired production capacity of the plant; the quality and availability of raw material. Other factors include skilled/unskilled personnel; the infrastructural set-up of the system; and the socio-economic factors at play in and around the environment of the briquetting plant. In general, the major categories of compaction plants employed in the developing countries for producing densified biomass products include the following: piston, screw, pelletizer and roll briquettor.

The piston press compresses the material with a ram driver, either by mechanical means from a flywheel via a crankshaft or hydraulically. The machines are usually larger, ranging in size from 450 to 3,000 kg/hr., whilst hydraulic machines are usually of the order of 250 kg/hr. for most materials, briquettes produced with the mechanical presses are generally harder and denser than those with hydraulic presses, the reason being the high speed with which the mechanical presses operate. The capacity of the piston presses range from 50 kg to 10 m tonnes per hour (Kollocn, 1980), with an energy requirement of 25-30 kwh/tonne (Joseph & Hislop, 1986).

The screw press forces the material to flow continuously along the passage way of a screw revolving with a cylinder. Two major types of screw presses (conical and heated die) are available. In the conical screw press; the friction generated by the movement of the particles against the metal heats the material (180°C – 220°C) and renders it more plastic. The pressure exerted by the pressing head of the screw causes the material to be extruded through a matrix perforated with 8 dies of 2.5cm in diameter. With a single-die matrix, it is possible to produce briquet rolls of 100 mm in diameter. In the conical screw press, the die is often heated with either electric elements or charcoal fire to facilitate densification.

In certain cases, a cheap locally sourced binding material such as molasses, starch or some cheap organic material may have to be added.

The major difference between a conical screw press and a heated die screw press is the presence of a heating mantle on the latter. The heating mantle is employed to apply heat to the die and to raise its temperature to about 300 to 310°C; and that of the feedstock to about 200°C.

Screw presses have low production capacities usually in the range of 75-250 kg/hr and require 70-80 kwh of energy/tonne of products (Joseph & Hislop, 1986). This results in high labour and capital costs per tonne of output. A significant advantage of these-presses is the allowance of a wider limit of moisture content to feedstocks.

The pellet presses produce granules or pellets (about 1cm) from biomass materials through extrusion. The extruding mechanism consists of a perforated, cylindried or disc-shaped steel die press roller. The compressed biomass (pellets) are forced out of the array of holes (5-15 mm diameter) on the steel died by the moving action of the press roller inside the steel die. As the pellets are extruded out of the holes, they may be cut off the specific lengths, usually not more than 30mm. Pelletizing mills have high through-puts of 5-20 tonnes/hr for a single unit and energy requirements of 2-16 kwh/tonne (Joseph and Hislop, 1986). Although pellet presses were originally developed for annual feeds and mineral-ore pellet production (Sebra 1988), quite a limited number of energy applications of these presses have surfaced in Europe, North Amercia and in a few developing countries such as Kenya, Zimbabwe and Zambia.

Along with the above presses, a number of simple presses are also being used to produce various forms of products ranging from cubes to rolls and bales. In general, these fuel products are of low density and durability than the extruded forms (Anon 1935). Apart from the cubing presses which make use of perforated dies similar to those for pelletising, the presses in this category produce low quality products from biomass, and require binders to hold the feedstock together during pressing.

Each of systems described above demands an appropriate preparation of the material. In general, the material must be reduced in size, dried and homogenised before being introduced into the press. The moisture contents and chop length of material before being fed into the machines are usually set by the press manufacturers. For most press systems the moisture content has to be within the range of 10 to 18 percent, while the size of the material may be between 3 to 15mm (Anon 1985).

Prospects of Densification Technologies in the Developing Countries

The development and application of densification technologies for producing densified solid fuels from biomass have great potentials in the developing countries. The technologies can aid in improving the characteristics of biomass for both industrial and domestic combustion purposes. It can aid in providing materials for rural electrification projects through gasification processes. The development of the technologies in these countries can also help in improving the processes of transportation and handling of biomass currently unused in distant location and their distribution to various locations of use. The potentials of densification technologies in the developing countries are discussed below:

Improvement in combustion characteristics of biomass

Densifying biomass enhances the combustion characteristics of the biomass by reducing the boiler and fuel handling equipment costs. When considering the substitution of biomass in coal fired boilers, densification can reduce the cost of conversion (Anon 1985). The low sulphur content in densified biomass often eliminates the need for fuel gas scrubbers and reduces boiler surface corrosion (Hathaway 1980). The flame temperature of densified fuels is lower than that of coal, hence the reduction in the nitrous oxide produced. Densified biomass also produces lower fly-ash emissions, and lower ash volume that are easier to dispose of than that resulting from coal combustion (Hathaway 1980).

Densified biomass reduces both the mass and volume of fuel required per unit of boiler output. This fact makes possible, the direct substitution of densified products such as pellets for coal in stocker-fired boilers with the only modification being increasing the spreader of chain grate speed and adjusting the air supply. Although densified biomass can substitute for coal in stocker-fired boilers, several factors have to be taken into consideration before use. For example, the use of briquettes or pellets in boilers designed for hard coals with high fixed carbon content may cause a large drop in efficiency due to inadequate convective heat transfer surface.

Another important advantage in using densified fuels is the improvement in boiler control. Raw biomass from the same source often exhibits widely varying moisture content and calorific value, resulting in unpredictable fuel which necessitates constant readjustment of fuel and air flow rates. Briquettes or pellets have more uniform properties which allow finer control, better response to load swings, and higher turn down ratios (Anon 1985).

Gasification

Although gasification places a higher quality demands on densified biomass fuels than does direct combustion of raw biomass; there are a number of important advantages of using briquettes instead of, for example, chipped wood for gasification.

- briquettes are dried, thereby increasing the efficiency of the process and increasing the calorific value of the gas produced;
- the bulk density is improved thus increasing the residence time in the gasifier and the gas conversion rate;
- the size of the briquettes can be chosen to fit together with the size of the gasifier and the gasifier grate.

The gas obtained from the gasification process, after proper cleaning, can be used to generate electricity for industrial or domestic uses in the rural areas of the developing countries. In some developing countries, densified biomass fuels are already being used to provide electrical energy in small installations (Anon 1982). With the recent developments in the technology of gasifier units and steam engines (Anon 1982), greater use of densified biomass fuels in the developing countries would be expected.

Fuel energy supply to rural communities

Per capital consumption of fuel-wood in developing countries is presently around 1-2 m^3 per year. This would equal a consumption of 0.5-1.0 metric tonne of densified biomass fuel per year per capita, which is equivalent to 200-450 kg oil consumption per year. In the developing countries facing deforestation problems due to uncontrolled use of the forests for firewood and charcoal for household cooking, densified biomass has great prospects of being substituted for the traditional energy supply. Besides household use for energy, densified fuels can also be applied in small-scale industries such as bakeries, brickworks, and potteries.

Problems influencing the development of biomass densification technologies in the developing countries

Although biomass densification technologies have great potentials for the rural populations in the developing countries, a magnitude of problems are inhibiting their successful introduction and performance in these countries. The problems are not of raw material availability, but of the process technology and product end usage.

Densification equipment used in most of the developing countries are usually designed in and for developed countries (Joseph & Hislop, 1986). In general, the range of process equipment is very limited, and provide very little consideration for the local production environment, such as the energy supply situation, post installation maintenance facilities, and the target local markets for the plants are expected to serve.

Energy requirements for densification are very high and complex. The complexity of factors influencing the energy requirements presents problems in prediction of the actual energy consumption requirements for a particular feedstock and densifying equipment. Even when the energy requirements have been determined, their production has been affected by the lack of high cost of diesel or electrical power.

Another problem influencing the development of biomass technologies in the developing countries is the high maintenance costs of processing equipment. The maintenance costs can be divided into two principal components; dye replacement, which is highly dependent on feedstock properties; and the general mechanical maintenance, which is not as variable. The presence of sand, dirt or tramp materials in feedstock cause rapid wear of dye. This problem is more pronounced with the use of tropical hardwoods, most of which contain high proportions of silica. The poor machine maintenance culture, not resulting from skilled personnel to carry out the maintenance operations but due to lack of spare parts is another major problem.

Although densified biomass fuels are suitable for industrial uses, they are often very inefficient and inconvenient in domestic stoves. Experience in some developing countries (UNSO 1983a; Louvel 1987; Joseph & Hislop 1986) has shown that the marketing of the products for domestic fuel can be difficult.

Densified biomass fuels cannot be burned efficiently in stoves designed for wood or charcoal. Thus, the introduction of this technology in any locality must be accompanied by an appropriate stove design for its combustion. The difficulties associated with developing an optimum stoves, a new fuel as well as the level of investment required for marketing the combined stove-fuel project can not be under-estimated (Hislop, 1984).

Other problems hindering the utilisation of densified biomass at the household level include the difficulty of ignition; the problem of extinguishing combustion after use; the vulnerability of wet weather; and the high market prices which make use at the household level very uneconomical.

All the above mentioned problems would have to be resolved before viable densification projects can be developed in the developing countries.

Thermal Stimulated Moisture Desorption and Drying Characteristics of Tropical Hardwood

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Abstract

The processes of thermal stimulated moisture de-sorption and drying characteristics of selected species of tropical hardwoods have been investigated. Empirical equations representing the desorption by sun drying and oven drying were established. The sun-drying occurred in two phases, the constant rate period and falling rate period. For each phase the drying constants were evaluated and the values range from 0.74 to 1.39h^{-1} for the constant rate period and from 0.0 to 0.191^{-1} for the falling rate period. The moisture diffusion coefficients for sun-drying were determined and the values ranged from 5.0 x 10^{-10} to 1.6 x 10^{-8} $m^{-1}s^{-1}$. During the oven-drying process, three stages of desorption with different amount of shrinkage levels were identified the values of shrinkage factor calculated range between 0.43 to 2.17. Obeche was found to possess the highest value of shrinkage in confirmation with the high void fraction.

Introduction

Timber is seasoned or partially dried to attain equilibrium moisture content with the surrounding ambient conditions. Unfortunately, large quantities of timber species are used immediately after conversion form logs, leading to insect infestation and attack by fungi, shrinkage and warping in drying out. This practice has perhaps been responsible for the poor reputation of timber as building material. To utilise the full potential of different wood species, the response to thermal stimulated environment and the accompanying moisture flow rates, moisture gradient and temperature gradients existing in wood during drying must be known.

For the selection and use of wood as building material, the general physical process governing desorption of moisture must be investigated thoroughly since desorption is one of the major processes which control durability. Studies on water movement, moisture diffusional flow experimental and numerical solution of non-steady state flow in local wood species has been reported. It is generally accepted that the two basic phenomena involved in drying processes are evaporation of moisture from the surface and migration of moisture from the interior. The present study is intended to investigate thermal stimulated moisture desorption by imposed temperature ramps from sinusoidal variation of solar radiation and step-wise change of oven temperature and the associated drying characteristics.

Desorption Process

In drying, diffusivities are often activated by thermal fields and consequently become strong functions of temperature and time. When a solid of initial moisture concentration M_1 is subjected to thermal fields at selected temperatures and timbers for desorption to occur the kinetics of the desorption process can be described as essentially the decay of the adsorbed moisture concentration, M(t). Such a process yields insight into the forces binding water molecules to the wood structure as the dehydration takes place by removal of free and chemically bound water. These phenomena involved in the drying can be described as evaporation of moisture from the surface and migration of moisture from the interior to the surface, and each of these phenomena is affected by external factors which control the drying process.

The rate equation of the desorption process can be described by:

$$\frac{dM}{dt} = -kM^{v} \qquad (1)$$

with $M(0) = M_1$, where k and v are the rate constants and order of the desorption reaction respectively. The desorption equation (1) is separable so long as k does not depend on concentration, and if k is also time independent, the solutions become:

$$kt = \ln\left(\frac{M_I}{M}\right) \text{ if } \nu = 1 \qquad (2)$$

$$kt = (\nu - 1)^{-1}[M^{(1-\nu)} - M_I^{(1-\nu)}] \text{ if } \nu \neq 1 \qquad (3)$$

If k is also any function of temperature T, and if the temperature is programmed to change linearly at a ramp rate α such that

$$T(t) = T_I = \alpha t \qquad (4)$$

Then the left hand side of kinetic equations (2) and (3) can be expressed as

$$\int_0^t K[T(t)]dt$$

Thermally Stimulated Desorption

In thermally stimulated processes of drying, the ramp rate, α is considered positive. The two competing forces are such that the temperature ramp tends to increase k and with it the rate of desorption and the natural isothermal tendency of dM/dt to decrease with time according to equation (1). Therefore the desorption rate must exhibit a transition which can be analysed to provide information on adsorbed and structurally bound water in wood.

For thermal stimulated desorption of moisture in wood, the usual source of irradiation. F(t), which may be used to induce phase change or structural modification is either solar flux or heat flux form a radiator. Thermal stimulation offers the means to study the interactions between external sources of heat and wood, on the assumption that the wood is semi-infinite and bounded by a planar surface. Assuming that the thermal flux, $F_0(t)(W/m^2)$, is of infinite lateral extent with arbitrary time dependence, and that not all impinging power is effective, and if R is the reflection coefficient of wood, then a fraction RF_0 is reflected and the remainder $(1-R)F_0$ is transmitted into the wood where it is dissipated such that at a depth x, the change in dissipated power, P(%) can be expressed as:

$$P(x) = P_0 e^{-\lambda x} \qquad (5)$$

where P_0 is the power dissipated at the surface (x = 0) or $P_0 = (1-R)F_0$ as power input, and λ is the decay constant.

Equation (5) is a source term of the diffusion equation:

$$\frac{dM(x,t)}{dt} = D\frac{d^2M(x,t)}{dx^2} \qquad (6)$$

and for cases of constant coefficient, the equation (6) can be written as:

$$\frac{dM(x,t)}{dt} = D\frac{d^2M(x,t)}{dx^2} + (1 - R)F_0(t)e^{-\lambda x} \qquad (7)$$

Equation (7) shows that a change in moisture content with time is controlled by the moisture gradient and the imposed thermal field.

If it is assumed that the solid was initially at a constant temperature, T_α = 30°C, which is maintained constant far from the surface, and the ambient surface temperature change prior to experimentation is also considered small enough so that radiation into the surrounding medium is negligible compared to stimulation effect of the imposed thermal flux, the boundary conditions then become:

$$T(x, 0) = T_\alpha$$
$$T(0, t) = T_\alpha, \; dT/dx\,]_{x=0} = 0$$

Experiments

In desorption studies, the moisture content of the sample at any time is defined on dry basis (db) by:

$$M(t) = \frac{W_m(t) - W_D}{W_D} \quad (8)$$

where $W_m(t)$ is the weight of moist sample at t and W_D is the weight of dry sample. The bulk desorption was investigated for sun-drying and oven drying and hence anisotropic characteristics were neglected. The wood species were cut into rectangular blocks of 5 x 2 x 20cm. The species of hardwoods selected for the experimental investigation are shown in Table 1. Diurnal variation of ambient relative humidity and temperature for drying has been reported.

Table 1: Timber species selected for experimental investigation

Species	Local name	Bulk density ρ_b(kg/m^3)	*Void fraction V_f
Afrormosia (*Afrormosia elata*)	Kokrodua	720	0.54
Iroko (*Terminalia ivorensis*)	Odum	690	0.56
Utile (*Entandrophragma utile*)	Utile	660	0.58
Sapele (*Entandrophragma cylindricum*)	Sapele	630	0.60
Obeche (*Triplochiton scleroxylon*)	Wawa	380	0.76

* The density of wood cellulose material, $\rho_w = 1.56 \times 10^3$ kg/m^3. $V_f = 1 - (\rho_b/\rho_w)$

During sun drying, the specimens were exposed to ambient atmospheric conditions and the results obtained for variation of moisture content (db) with time for constant exposure time of one hour at an initial ambient temperature of 30^{0}C and relative humidity of 81% are shown in Figure 1. At an hourly interval, the samples were recovered and weighed until a constant weight was obtained. The hourly variation of solar radiation provided different energy input for the drying and hence different temperature ranges for the thermal stimulation.

The oven-drying method was used to investigate the variation of moisture content (db) with temperature. The samples were placed in an oven for one hour at a temperature of 30^{0}C and the weight at the end of each period was recorded. The temperature was increased in steps of 10^{0}C up to 150^{0}C to obtain a series of data as shown in Figure 2; whereby the temperature ramp rate was 10t. The samples showed signs of thermal cracking and deterioration at 150^{0}C due to decomposition of organic matter.

Results

Sun-drying processes

During drying, water evaporated slowly from the wood until equilibrium was reached with the surrounding air, at an equilibrium moisture content of about 2% of dry weight. The drying curve in Figure 1 shows the variation of moisture content with drying time. The data for Obeche and Sapele are re-plotted in Fig.3 as a log-linear graph of moisture loss with time, which illustrates that drying takes place by two sequential mechanisms over the periods AC and CE. This confirms the existence of transition in the drying process. From an initial moisture content M(1) the transition in desorption occurs at the critical moisture M_C and thereafter the desorption continues until the equilibrium moisture content M_E is reached.

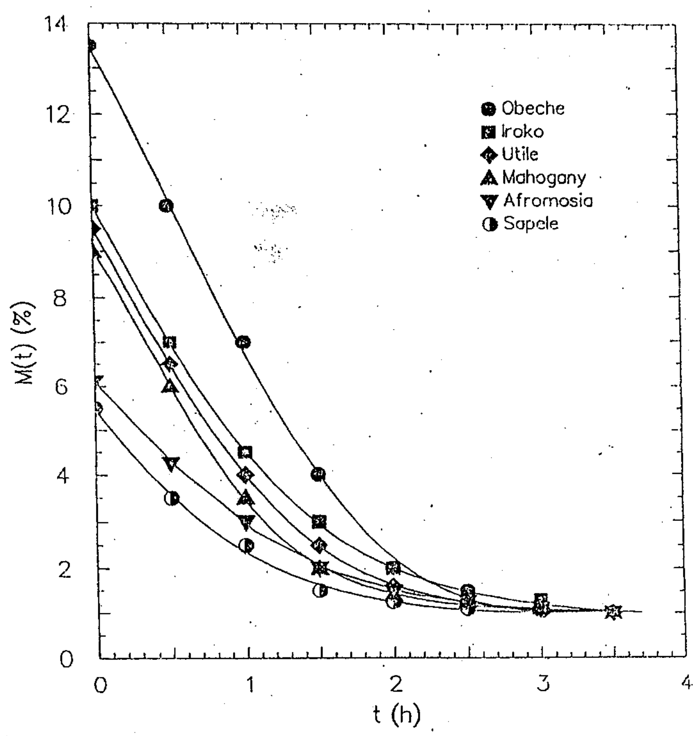

Figure 1. Moisture content change with time of exposure to atmosphere

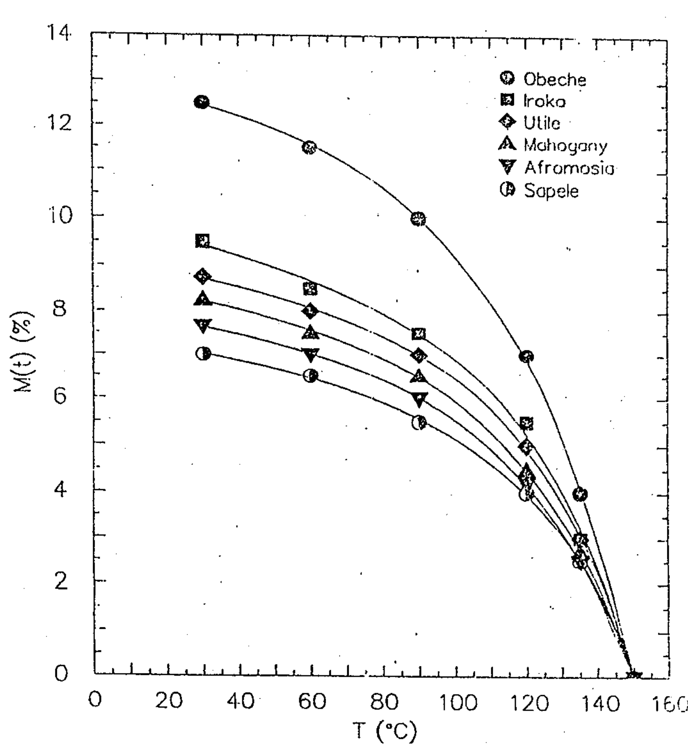

Figure 2. Moisture content change with temperature

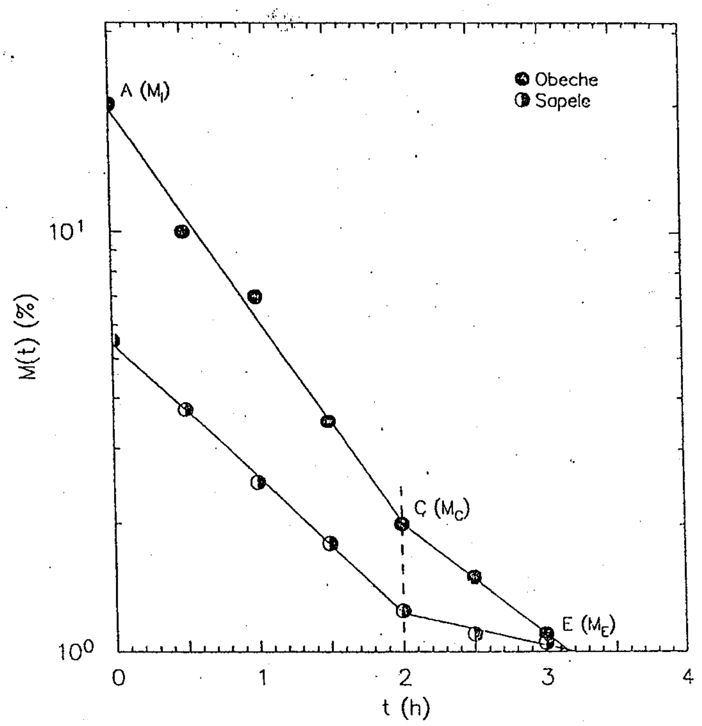

Figure 3. Log-linear plot of moisture loss with time of exposure of Obeche and Sapele to atmosphere.

The most appropriate means of illustrating information on drying mechanisms is by drying rate curves rather than the drying curves (Figure 1). The drying rate curve is a plot of change in moisture content with time against either time (Figure 4) or against moisture content (Figure 5). With reference to Figures 4 and 5, the regime BC is a constant rate period of drying where the rate controlling mechanism is evaporation of moisture from the surface, which is controlled by the condition of air adjacent to the surface. The point C at which the drying rate starts to decrease is termed the critical moisture content. Below the critical moisture content the rate of drying decreases, leading to zero at the equilibrium moisture content. This period is termed the falling rate period. As shown in Figures 4 and 5, some of the species did not exhibit constant rate period because the initial moisture constant was less than the critical moisture content as a result of previous conditioning. The change in drying mechanism illustrated at the point E is attributed to diffusion controlled drying, whereby the removal of water vapour is largely the rate controlling process.

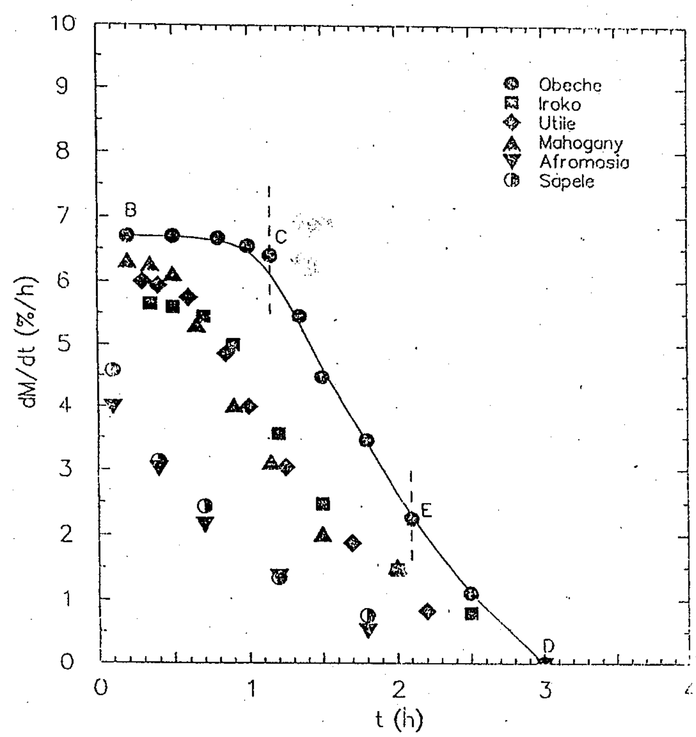

Figure 4. Plot of time rate of change of moisture content versus time.

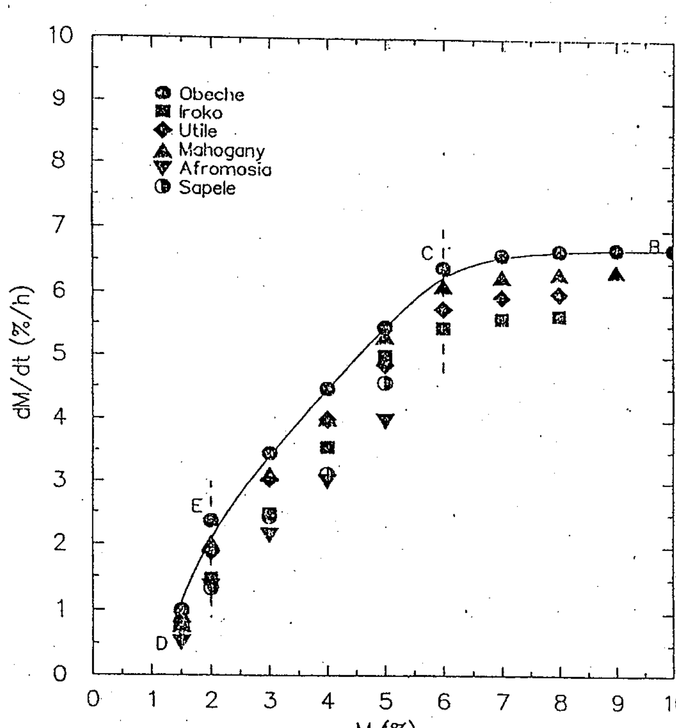

Figure 5. Plot of time rate of moisture content versus residual moisture content.

For each drying regime the moisture loss can be described by the expression $M = M_{exp}(-kt)$ or $dM/dt = -kM$, where k is a drying parameter.

$$\frac{dM}{dt} = \frac{\pi^2 D}{4L^2}(M - M_E) \tag{9}$$

and therefore k is related to the moisture diffusion coefficient D, of the appropriate regime by an equation of the form:

$$k = \frac{\pi^2 D}{4L^2} \tag{10}$$

For the constant rate period, the drying is proportional to the free moisture content, or $dM/dt = -k(M-M_C)$ and the empirical drying equation can be written as:

$$\frac{M(t) - M_C}{M_I - M_C} = \exp(-k_1 t_C) \tag{11}$$

Similarly, the drying equation for the falling rate period can be expressed as:

$$\frac{M(t) - M_E}{M_C - M_E} = \exp(-k_2 t_E) \tag{12}$$

The drying constants, k_1 and k_2 were evaluated to determine the corresponding diffusion coefficients D_1 and D_2 as shown in Table 2. The diffusion coefficient ranges from 5.0×10^{-10} m^2/s to 1.6×10^{-8} m^2/s, and the specimens with high drying rates possess high k values.

The drying characteristics were also examined by plotting the drying rate against residual moisture content. A plot of drying rate (dM/dt) against residual moisture content, M, shown in Figure 5 for two wood species confirms that drying takes place in phases with the transition at about 2% moisture content. That is, above 2% moisture content, drying process involves the removal of free water, while below 2% moisture content, the drying process involves the removal of bound water. In addition, the transition shows that much of the water in wood species consists of free water, which can be easily removed by application of low thermal fluxes.

Table 2: Drying parameters and shrinkage factors for timber species

Species	Moisture content (%)			Drying constant (h^{-1})		Bulk diffusion coefficient x 10^{-8} m^2/s		*Shrinkage factor S x 10^{-3}% (°C)^2		
	M_I	M_C	M_E	k_1	k_2	D_1	D_2	PS	SS	TS
Obeche	10.0	2.0	0.25	1.39	0.19	1.56	0.21	0.63	1.57	2.17
Utile	11.5	1.7	0.20	1.29	0.14	1.29	0.15	0.57	0.70	1.57
Afrormosia	5.5	1.0	0.11	0.74	0.04	0.83	0.06	0.47	0.43	1.30
Iroko	7.0	1.4	0.14	0.87	0.05	0.98	0.05	-	-	-

* PS = Primary stage, SS = Secondary stage, TS = Tertiary stage.

Oven-drying Method

The oven-drying method was used to investigate the moisture loss with imposed temperature ramp as shown I Figure 3. The temperature rate of change of moisture content. [dM/dT] is plotted against T in Figure 6, and it is observed that loss of moisture takes place in three stages. The low thermal activated rate occurs between 30°C to 90°C, the intermediate rate occurs between 90°C and the high activated phase occurs between 130°C to 150°C. The level of thermal activation is significant, as the primary stage consists of free water removal, which requires minimum thermal activation while the intermediate stage involves bound water removal and with significant level of thermal activation. The tertiary stage is the result of structural disintegration, which is of no significance to seasoning mechanisms.

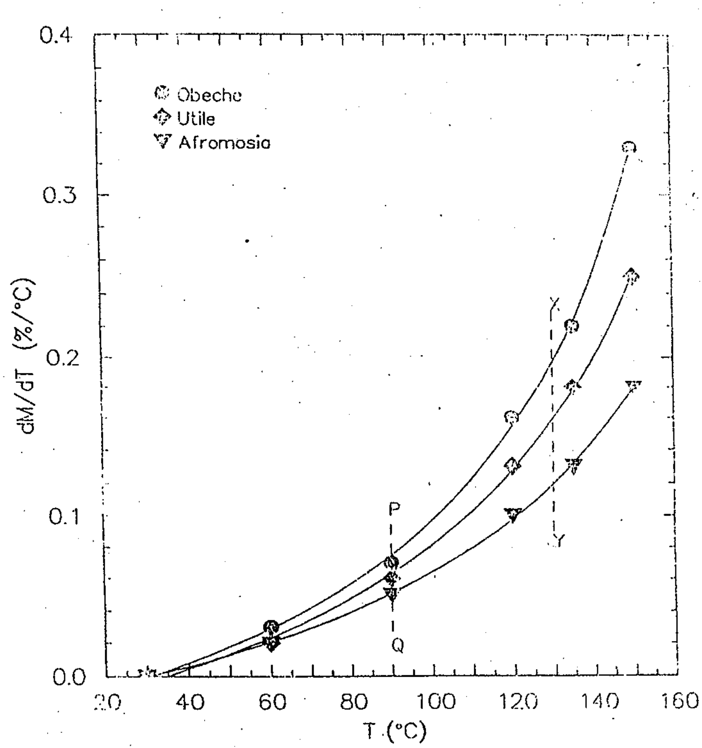

Figure 6. Plot of temperature rate of change of moisture content versus temperature.

The variation of moisture desorption with temperature resulted in dimensional changes which were evaluated by the shrinkage factor, S. From Figure 6, an empirical relation [dM/dT] = ST was deduced to describe the stages of desorption which has a general solution of the form:

$$M(t) - M_I = 05S[T_I^2 - T^2] \qquad (13)$$

where M_1 and T_1 represent the initial conditions of desorpton.

The shrinkage factors determined are shown in Table 2 and Obeche has the highest rate of moisture movement and shrinkage level as a result of the high void fraction. Shrinkage usually occurs when combined water absorbed to the cell walls diffuse to the surrounding air with subsequent collapse of the voids. A 1% change of absorbed water corresponds to about 0.5% change in dimension lateral to the grain such that a maximum strain of over 10% is possible.

Discussion

The oven drying temperature was programmed to vary linearly at a temperature ramp of 10°C such that

$$T(t) = 30 + \sum_{0}^{12} 10t \tag{14}$$

While for sun drying, the imposed thermal field results from the sinusoidal variation of diurnal solar radiation expressed as:

$$I(t) = I_{\max} \sin\left(\frac{\pi t}{N}\right) \tag{15}$$

where I(t) is the radiation intensity at t hours after sunrise, I_{max} is the maximum value at solar noon and n is the day length in hours.

The linear desorption problems considered involve variable diffusivities and the programmed temperature changes induce additional driving forces. It was also observed that diffusivities were activated and for the oven drying, the diffusion coefficient has an Arrhenius dependence on T given by the expression:

$$D(T) = D_{\infty} \exp\left[-\frac{E}{R\left(30 + \sum_{1}^{12} 10t\right)}\right] \tag{16}$$

where E is the activation energy, R is the gas constant and D_{∞} is a pre-exponential term which represents D at infinite temperature.

Since the temperature results have shown that there are two competing forces, a temperature ramp which tends to increase k and the rate of desorption, and the natural isothermal tendency of [dM/dt] to decrease with time. Therefore, the desorption rates exhibit transition which has confirmed the existence of free and bound water in the wood structure. In addition, according to equation (16), the diffusion coefficient rises with temperature and causes larger fluxes. On the other hand, the amount of diffusant in any finite sample decreases with time and tends to decrease the surface flux. From the above analysis, the mechanism of drying is a complicated process which requires further investigation to develop the mathematical relations.

Conclusion

Species of tropical wood of commercial values have been subjected to two modes of thermal stimulated desorption to investigate the drying characteristics.

1. The sun-drying process could be described by a general empirical relation of the form M M_1exp(-kt), for which the k values and diffusion coefficient were evaluated for the constant and falling rate periods of desorption.

2. The oven-drying method confirmed that drying takes place in stages with different diffusivities and shrinkage levels. The shrinkage factor ranges from 0.63 to 1.3 x 10^{-3}%(°C)$^{-2}$

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Technical Session IV: Marketing and socio-economic issues

Technical Session IV: Marketing and Socio-Economic Issues

Chairperson: Mr. Johnny François, Forestry Consultant, Accra

Administrative and Institutional Structures for ensuring Sustainability of Forest Ecosystems

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Introduction

Ghana is a signatory to several important international agreements and is an active member of the International Tropical Timber Organisation (ITTO) all of which lead to various commitments and structures that have to be put into place.

Agenda 21 (UNCED, 1992) and the associated Forest Principles have set the direction for a number of important timber producing countries, including Ghana. Agenda 21 was developed as an action plan for the period 1993-2000 and sets out a balanced programme covering the four priority areas of sustaining the multiple roles and functions of the forests; enhancing the protection, sustainable management and conservation of all forests and the rehabilitation of degraded areas; promotion of efficient utilisation and realisation of the full value of forest products; and finally, establishing and strengthening the capacities for assessing forest data.

The Government by signalling its determination to respect other international agreements such as CITES and ITTO is fully endorsing the need for the rational use of the country's forest resources and the need to move quickly towards the sustainable forest management as directed under the ITTO Year 2000 objective.

In line with the international obligations and national and local aspirations, the country has promulgated a national forest and wildlife policy and recently a National Forestry Development Plan, which reflects its full commitment to the policies of sustainable forestry management. On the local front, the Government is desirous of supporting community initiatives towards the preservation and conservation of forest ecosystems.

This short paper will attempt to address the question of what administrative and institutional systems need to be in place for sustainable forest management to take place and the direction that Ghana is making in this aspect. This year is one of major change for the forest sector in Ghana with the formation of the Forest Service from the present Forestry Department.

Guiding principles

The guiding principles that emerge when considering the move towards the kind of forest management that will ensure sustainability of forest ecosystems have a direct bearing on the administrative and institutional structures that need to be in place.

1. A commitment towards the sustainable management of the forest resources.
2. Identification of distinct blocks of forest whose boundaries have been defined and are protected under law.
3. Regular collection of pertinent information on the state of the forest resource.
4. Formulation of a silviculture management system linked to forest growth and a defined acceptable yield.
5. Adoption of an approved code of harvesting and forest practice that can be endorsed by recognised international standards/organisations.
6. Empowerment of all stakeholders in the management process.
7. Formation of a controlling body separate from the direct interests of timber harvesters.
8. The need to incorporate performance indicators for the organisation over-seeing forest management and control.

9. Award of timber harvesting rights/agreements in accordance with open reporting so that the potential for malpractice is minimised.
10. Realisation of the wide value of the forests and the need that true resource and environmental costs should be incorporated into all production and consumption decisions.

Present systems

Let us look at the present systems and the level of commitment that has been made towards the guiding principles. The present Forestry Department, although undoubtedly having weaknesses in the business sense, does have strength with respect to the management systems that have been put into practice for the forests.

The government has accepted the principle of sustainable forest management at an international level through its commitment to the ITTO programme and has framed its commitment within the 1994 Forest and Wildlife Policy.

Reservation

The country long ago accepted the importance of forest reservation, initially as a means of preserving a suitable microclimate for the agricultural sector, but later to ensure adequate timber and non-timber forest resources for the nation and for preservation of watersheds. Ghana currently has 252 legally constituted forest reserves within the High Forest Zone covering 20% of the total area. The principle of the need for forest conservation from the standpoint of the maintenance of biodiversity and protection of watersheds has been fully endorsed with the adoption of the Forest Protection Strategy. This comprehensive strategy requires that some 350,000 ha of the forest reserves are taken out of normal production under the rules of "coarse-grained" protection.

Conservation is seen to be required at two levels - the so-called coarse-grained protection rules which identify major protection zones within the reserve; and the fine-grained protection rules which relate to small patches of forest identified at the time of pre-felling inventory.

Course-grained Protection

Those zones that are identified at the time of forest management plan preparation include the following: -

1. *Hill Sanctuaries*: All land over 30% slope will automatically be defined as Hill Sanctuaries. All such land can not be logged using normal means without causing an unnecessarily amount of site deterioration. The identification of such areas is made by reference to the Survey of Ghana 1:50,000 scale maps.
2. *Swamp Sanctuaries*: Areas dominated by perennial swamps are not suitable for logging and are excluded from timber production.
3. *Provenance Protection Areas*: In order to ensure that an adequate genetic base is retained for the over-logged commercial species, the conservation policy allows for the retention of 5% of the flat land area of the Moist Semi-deciduous, Dry Semi-deciduous and the Moist Evergreen forest within those reserves with forest still in good condition and providing a good breeding population.
4. *Special Biological Protected Areas*: These are areas, which should be provided with full protection. They are areas where the forest has been identified to have a high Genetic Heat Index (an index that has been derived to signify the range of tree species within a particular area). These areas attract wide scientific interest and will be registered with the international community.
5. *Intact Forest Areas*: In order to ensure that there is an adequate representation of intact forest (unlogged) of all the main types, this extra zone has been suggested.

The guidelines for the application of the course-grained protection criteria extend to fire susceptible areas. Opening the canopy in fire-susceptible areas will expand the danger of the damage as a result of vigorous grass growth. Consequently, forest reserves are being zoned with respect to their need for fire control, with for example shelterbelts of unlogged forest being left along the perimeter of areas likely to be subjected to wildfires. The attached table indicates the various protection and production zones that are recognised and are now being used in the forest management planning process.

Fine-grained Protection

Within those areas that have been defined as belonging to the Timber Production Zone - (essentially the forest remaining after all the course grained protection areas have been identified) - 100% pre-felling inventory is carried out on a compartment by compartment basis. It is at that time that further areas requiring protection are excluded from the concession areas. Such areas will include buffer zones close to streams, and exclusion areas around the so-called black star species; trees of such importance that no felling is tolerated within their immediate locality.

Silvicultural Management Systems

The Forestry Department has adopted a silvicultural system utilising a polycyclic regime on a harvesting cycle of 40 years. A system of yield control has been developed which necessitates the 100% sampling of forest prior to logging and the fixing of an approved level of cut in accordance with the principle of sustainable forest production.

Rules have been defined to set the appropriate yield for the main forest types. The approved yield is calculated on a species by species basis for each compartment due for felling. In order to minimise the effects of the excessive openings within the canopy, guidelines have been derived to limit the total number of trees that can be removed on a per hectare basis.

The forest management system that has evolved therefore attempts to take account of both the conservation requirements of the forest as well as the silvicultural aspects. In order for the new Forest Service to be confident that the management system is being fully followed it will be necessary to strengthen the control procedures and in particular ensure that a more rigorous process of management planning is undertaken by the timber concessionaires. Information flows on timber harvesting are not always adequate and the level of record keeping sometimes weak. In the first year of the Forest Service, a determined effort will be made to ensure that the information system is adequate to the task, and the forest manager has all the information he needs at his fingertips. At the same time, key information must always be available to Headquarters staff, as it is not always the case today.

The forest management system is being made a standard - "A System of Quality Management for Ghana's Forests"- for international creditation and for eco-labelling. The system will be further strengthened by the inclusion of a bar coding system for the complete tracking of the log from the forest to the mill. An extensive paper system is already in place, backed up by the maintenance of a series of linked computer databases.

Collection of Growth Data

The Forestry Department embarked in 1986 on a comprehensive national inventory of the forest reserves within the High Forest Zone. Over a period of about 8 years, information was collected on the composition of the forest both on and off reserve and the plantations. In addition, information is gradually being put together on the growth of the natural forest through the re-measurement of permanent sample plots. The national inventory was initiated more than 10 years ago and there is a constant need to revise information on the state of the reserves. Fire, which is the most serious factor with respect to the loss of forest cover, has had its effect and there is a realisation that much of the information held on individual reserves is not now fully accurate. The use of satellite imagery enables some revision to be undertaken, especially monitoring the effects of fire and over-cutting.

Participation

The importance of the forest-user groups and the local communities is emphasised in UNCED policy documents. This has particular relevance to Ghana, where the communities own the forest themselves. Currently, the level of involvement of the communities within the management process is not adequate. However in moving towards a more integrated forest management system the needs of the forest users will be fully taken into account and they will be encouraged to make their wishes known at the beginning of the forest reserve planning cycle.

It is important that the forest owners are made aware of the value of their resource and agree to the proposed long-term management to be undertaken on their behalf by the Forest Service. Consequently, future forest management plans and the timber utilisation contracts (concession agreements) will spell out the projected benefits to the community and set targets for the Forest Service. In addition, by putting as much of the responsibility for the management and protection of the reserves on to the communities themselves, there should be a better awareness of the value of the forests and the need for good forest protection. The intention will be to promote the use of local contracts to forest-user groups to undertaken routine maintenance.

Controlling body

Ghana's Forestry Department was formed in 1907 and set out on an ambitious programme of forest reservation. The Department is represented in all regions of the country. Following the passage of the new Forest Act, the Forestry Department will become a Forest Service, autonomous from the Civil Service, with the intention that it should be operated in a more business-like manner and more fully aware of the needs of its clients - the forest owners. The creation of the new Forest Service is expected to lead to a reduction (by about one-third) of the present work force. This will provide the opportunity to review current staff and ensure that the new service is staffed with the most technically competent workers. By moving away from the current restrictions of working within the Civil Service, it is hoped that the Forest Service will not be constantly constrained by inadequate funding, since operating funds will be directly linked to the income generated through retained income.

It is important that the Forest Service provides markers to ensure that its own performance can be rated. Following the strengthening of the District Assemblies, community leaders will be expected to be briefed on how well the Forest Service is managing its resources against agreed indicators of achievement. These will feature in all future forest management plans.

Control of Timber Harvesting Concessions

An essential role of the Forestry Department has been the issue and control of timber licences and harvesting concessions. Initially, the role of the Department was restricted to the forest reserves; but this was extended to all forest resources both on and off reserve. There is in place, a strong system of checks and counter-checks, but it has been realised that improvements are still required. Following the passage of the new Timber Resources Management Bill towards the end of last year, timber utilisation contracts (TUCs) will become operational. These strengthen the rights of the forest owners and require their agreement before they can be issued. The process of consultation will be a major component of the TUC system. The issuing of licences or timber concessions has in the past been undertaken in a less than open manner, often with no consultation with the local communities. This is fully realised to be unacceptable and non-conducive to the practices of good forest management.

The TUC system provides a clear set of guidelines and professional standards that interested companies will need to conform to. It is therefore a central theme of the TUC system that only those companies that have demonstrated their professional competence will be eligible to be considered for future contracts.

Resource Valuation

A greater effort will be needed in this respect. It has been appreciated for some years that the level of the royalties does not reflect an adequate percentage of the commercial value of the timber. Following the passage of the Timber Rights Bill, the level of the royalty will be fixed as three percentage bands linked to the FOB value of the timber - the allocation to a particular band dependant on the scarcity of the particular species. In addition, the process of returning revenue to the forest owners is too slow and over-bureaucratic and leads to communities downgrading the real commercial value of the forest to themselves. The financial structures within the New Forest Service will therefore need to address this concern.

Calculation of the total economic value of the forest has not featured in current practice, though future development projects that effect forestland are likely to be subjected to the EIA. More attention needs to be given to ensuring that land use decisions are made in the full awareness of the complete value of the forest.

Administrative structures and needs

In Ghana, we are in a process of major change with respect to the controlling organisation of forest resources. The present Forest Department will become the new Forest Service, giving autonomy from the Civil Service and a more business-like attitude to forest management; whilst ensuring the need to be more responsive to the client - the forest owning communities.

Looking in more detail at the administrative needs that the controlling organisation (i.e. the Forest Service) will need in order to ensure that the principle of sustainable forest management is put into practice, first, there will need to be an effective information system in place. Information is the keystone of all organisations and a system has already been active within the Forestry Department, but it will need to be extended and improved in order to ensure that the management processes are fully effective. The type of information that is required for a good forest management includes: -

- Information on the state of the forest, its composition in terms of species and utilisable volume;
- The suitability of the forest for either timber production, conservation, NTFP production;
- Its growth and the level of an acceptable cut in terms of sustainability;
- Current and historical use - availability of timber production areas for the future, and
- Production levels and the revenue generation.

Separately, but linked to the above is the need for an effective financial recording system. The Forest Service is determined to be seen as an efficient business with a close control on the flow of capital and revenue. Managers need to know what resources are tied up, what costs are being incurred for particular administrative units, what particular activities are costing and importantly, that the revenues generated are being quickly returned to the clients - whether that be the Government or the forest communities. As has been mentioned above, this has been a weakness of the present Forest Department and needs to be addressed.

An effective administration needs well trained, motivated manpower, each member of the team having a clear role and provided with annual targets. The Forest Service overall needs to demonstrate accountability and accept the principles of working towards agreed performance levels both on an institutional and an individual level. As part of the Government move towards strengthening the role of the District Assemblies, the forest managers at the district level will need to be fully aware of the needs and aspirations of the local communities and ensure that the revenue and benefits of the forests go some way in meeting those needs without compromising the long-term sustainability of the forest ecosystems.

Table 1: Forest Management Categories to be used for Forest Reserve Zonation

Area Category	Characteristics	Objectives of Management	Mean of Identification
Protection			
Hill Sanctuaries	All land within the reserve where the slope is > = 30%.	To provide environmental protection of steep slopes that would be subject to erosion if logged. To ensure maintenance of the watersheds. To also provide wide scale protection for undefined flora and fauna resources.	Identified by FMSC using the Survey of Ghana 1:50,000 scale contoured maps. All areas above the slope criterion are included. Compartments with at least 65% steep land are designated as protected.
Swamp Sanctuaries	Perennial wet areas	Maintenance of water sources, flora and fauna preservation.	Coarse-grained areas identified by FMSC from base maps. Smaller areas identified as part of the fine-grain protection activities undertaken during stock survey.
Provenance Protection Area	Area with high populations of key economic species.	Act as gene banks for exploited species.	Areas initially identified by the Botanical Unit of FMSC. Additional areas may be identified in the course of Part 1 preparation.
Special Biological Protection Area	Areas of high plant GH1 or presence of rare fauna species.	Full protection of areas of high biodiversity and therefore of both national and international value.	Botanical surveys undertaken by FMSC.
Intact Forest Area	Areas with the highest basal areas and species diversity for a particular ecological zone of forest reserve. Areas which were designated as nature reserves in the 1970s.	High level of protection to ensure maintenance of representative forest of each ecological zone.	Botanical and production inventories undertaken by FMSC. Additional sites may be identified at the time of compartment inspection, prior to stock surveys.
Cultural sites	Culturally important areas identified during the settlement procedure or in special cases areas identified since and archaeological sites.	Preservation of the sites of traditional or historic value for the benefit of the local community and the nation. Promotion of tourism where acceptable.	As demarcated on existing base maps and reinforced by local knowledge during community discussions.

Table 1 (*continued*)

Area Category	Characteristics	Objectives of Management	Mean of Identification
Protection Research Area	Research Working Circles.	Provide scientific and technical knowledge of use both by the Forest Service and the wider scientific community.	Demarcated and mapped by the research organisation. Information to be combined by FMSC.
Fauna Protection Area	Areas identified by the Wildlife Department as being critical to the preservation of the habitat required for rare or important species.	Maintenance of natural habitat for critical species.	
Semi-protection Fire Buffer Zones	Intact areas surrounding 'valuable' forest in fire prone areas.	Provide a buffer from fire from outside the reserve reaching valuable forest considered to be fire-susceptible.	Areas to be recommended by Ecology Unit, FMSC and modified as appropriate following field inspections.
Shelter belts	Areas with a larger boundary to area ratio which are therefore particularly vulnerable.	Maintenance of forest cover and hence restrict spread of fire and provide continuing shelter for agricultural crops.	Original areas demarcated as shelter belts for protection from desiccating winds. Located from existing forest reserve maps.
Convalescence forest	Forest which due to either the effects of past logging or fire is now at stage where it can not be logged in the present management cycle. A guide of $15m^2$ basal area or less is indicative in this case.	Area left to regenerate until commercially sized timber available for felling.	Satellite imagery or air photography supported by ground reconnaissance.

Table 1 (*continued*)

Area Category	Characteristics	Objectives of Management	Mean of Identification
Protection			
NTFP Production Areas	Areas identified by rights holders as important NTFP collecting grounds that do not fall into the protection designations.	Production of NTFPs for local and commercial use.	NTFP survey (FMSC) but extended and modified by local knowledge.
Timber Production Areas	Healthy productive forest > $15m^2$ ha basal areas which does not fall into protection, research or NTFP area designation.	Sustainable timber production.	Residual areas on the zonation map after the other zones have been identified.
Others			
Conversion	Areas where forest cover and regeneration is minimal and might be suitable for conversion to plantations. A guide of 5m basal area or less would suggest this condition.	To act as a land bank for possible conversion to forest plantations if site conditions are suitable.	Satellite imagery, forest inventory data and ground reconnaissance.
Enclosed Farms	Farmland which has been legally recognised.	Legitimate agricultural practices that do not lead to further forest damage.	Existing forest boundary maps.

Marketing of Lesser-Used Species to Make an Impact on the Timber Industry

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Introduction

The natural tropical forest resource in several tropical timber producing countries are becoming exhausted, and the desire to put forest management on a sustainable basis has led several major countries to reduce their allowable cut significantly, resulting in the decline in availability and quality of the preferred primary/traditional species, which are mostly affected. This situation has compelled many timber companies in tropical timber producing countries to seriously consider the potential in utilising and marketing of the lesser known/used species (LUS) and this is noted to be more pronounced in several tropical timber producing countries whose forests are becoming impoverished either in terms of area or quality.

For most tropical timber producing countries, the promotion, utilisation and marketing of the LUS is primarily aimed at supporting sustainable forest management and in particular, the aspirations of the International Tropical Timber Organisation (ITTO) to ensure that by the year 2000 all tropical timber traded must have come from sustainably managed forests (Objective 2000).

Also as an immediate objective, most countries are promoting the utilisation and marketing of the LUS to ensure continuity of trade in tropical timbers, in the face of dwindling forest resources and non-readiness for plantation development.

This paper will highlight the market structure for the sale of tropical timber products in some major markets, conditions and opportunities culminating in the best possible approach for promoting and marketing the LUS, to actually make an impact on the tropical timber trade and industry.

Factors Influential in the Promotion and Marketing of LUS

The following factors are influential in effectively promoting the utilisation and marketing acceptability of LUS:

i. Species availability
ii. Natural durability of species
iii. Physical properties;
iv. Working qualities;
v. End-use range;
vi. Trail volumes;
vii. Price range.

These factors are of utmost importance to buyers and end-users, and therefore concrete information and details on these must be well documented and made readily available. These factors may be prioritised depending on the conditions and opportunities in the market place.

This can be related to surveys done under the ITTO Project PD 179/91, to evaluate the importance of different factors connected with the introduction and acceptance of LUS. The surveys involved Ghanaian sawmill and value-added wood processing industries and US importers/wholesalers of tropical hardwood lumber and veneer, respectively. The results of the surveys are indicted separately in Appendices 1 and 2.

The results reveal that the most important factors influencing the introduction and acceptance of LUS are:

1. The availability of an adequate resource supply;
2. The availability of technical and promotional information;
3. The ability to import small trial volumes of LUS; and
4. Low introductory prices to encourage trial use.

However, the increased utilisation and marketing of the LUS calls for the following actions;

- improved research and development;
- improved technology for the processing of various wood products, particularly made from the LUS;
- effective marketing strategy to be able to sell LUS products.

Processed or downstream wood products, in my opinion, are the more likely option to effectively utilise and market the LUS, both locally and externally.

Factors Influential in the Promotion and Marketing of LUS

The following factors are influential in effectively promoting the utilisation and market acceptability of LUS:

1. species availability, distribution and stocking;
2. natural durability of species.

Conditions and Opportunities for Marketing the LUS

Tropical timber products suppliers, manufacturers and exporters have to assess market conditions and take advantage of opportunities existing therein. In this case, they must have good sources of market intelligence information.

Market Conditions

Ideally, the most effective way of marketing the LUS is to manufacture products; more particularly, machined wood products, semi-finished or finished, like toys, furniture components and builders woodwork. Thus, any attempt at promoting or marketing of the LUS should be product oriented rather than species-led. For most tropical timber producing countries, there is therefore no better option than to develop the processing capabilities of local wood products manufacturing companies to effectively and efficiently process the LUS.

I now wish to discuss some of the opportunities of marketing the LUS, by taking a few examples relating to various possible types of products.

Dimension Stock for Furniture and Joinery

This constitutes seasoned and graded timber cut to standard widths and thickness to be used for furniture and joinery. Presently the LUS in this form affords an opportunity to conveniently, develop products.

Manufacturing of Semi-Finished or Finished Products

As discussed, one of the most viable approaches to clinch a niche in the market place is to use the LUS in value-added wood products.

Here, the case of rubber tree (*Heavea brasiliensis*) can be used as an illustration. Until the beginning of the last decade, the rubber tree was virtually unknown or used as a timber tree. Today, however, *Hevea* is one of the most extensively used in Southeast Asia after Meranti. Particularly, Malaysia exports furniture, turnery products, toys and several other manufactured products made of this (*Hevea*).

It is also worth-mentioning that the rubber tree now accounts for 80% of total raw materials used in furniture manufacturing in Malaysia.

Grouping/Mixing of Timber Species

This practice involves an assortment of several species with similar characteristics, instead of a single species, for example, mixed white species, mixed red species, light density timber etc, or the shorea species of the Far East countries.

This form of marketing although good, has its limitations. For example, marketing of a particular colour of species may be difficult, if the colour is not in vogue at the material moment in time or season.

Production of Wood Based Panels

Most LUS perform well in the production of wood based panels which presents a good product avenue for more efficient utilisation, particularly for those LUS which pose difficulties for their use as solid timber and generally timbers which are prone to checks and shrinkage.

Processing such timbers into wood-based panels not only provides end users with a stable material, but also allows suppression of certain defects, as well as producing decorative panels by mixing different species.

Suggested Strategies for Marketing LUS to Make an Impact

Domestic market

For the domestic market in most African countries, government is the largest investor in construction and could therefore influence the choice of wood in construction, i.e. specifiers, architects, etc could be educated and encouraged to specify and use the LUS.

In the same vein, government needs to promote the development of viable timber processing companies, with the realisation that the most effective way of marketing the LUS is to manufacture wood products. This is what has been fostered in Malaysia and Indonesia through both market and government-led initiatives to create a significant shift to more finished wood products and furniture, which provides opportunities for LUS processing.

Some of the methods used include fiscal means such as punitive taxes on raw exports, banning exports of logs or of certain species, education and training, technical assistance, etc.

Export Market

(a) Co-operation with distributors and end-users

There might be the need initially to use the services of major distributors or importers of tropical hardwood in developing markets for the LUS. In doing so, one will have to be familiar with distribution channels in various markets.

The traditional distribution channel is from the exporters, to agent, to importer or industrial user or manufacturer who may in-turn sell to distributor/retailer, to artisans and DIY shops. Similarly, that is a traditional probable routing for seeking market information. This distribution channel, however, varies slightly from country to country.

The basic distribution channel for getting the various LUS wood products are through sales representatives, distributors and company sales staff. Sales representatives or agents are the most common and receive a commission. In trying to promote or market the LUS, it is important to take advantage of these distribution channels.

(b) Trade promotion offices

Trade Promotion Offices, Overseas Sales Offices or Joint Venture with foreign marketing companies can be a means of establishing the LUS in target markets.

In our case, the Timber Export Development Board's London Office has been operating in recent times as a sales office, and has been instrumental in the marketing of Ghanaian LUS in the European market and this is already yielding good results for the LUS in wood based panels.

These suggested systems are in themselves a source of good market intelligence information since it implies a presence in the market place.

Strategic Framework for Sustainable Marketing of LUS

(a) Identify available resource

- be sure LUS being marketed is available in abundance
- build good relationship with potential suppliers

(b) Develop and disseminate publicity material

- catalogue comprehensive technical information

- produce brochures, pamphlets, posters etc.
- display relevant information/brochures at Fairs, for example
- make publications available to important clients in the marketing chain.

(c) Develop processing capability

- use appropriate machinery and equipment
- employ qualified and experienced production managers
- produce quality products to meet exact needs of consumer
- be sure products can be sustained
- season LUS to be durable when necessary
- use appropriate packaging

(d) Identify Market Opportunities

- look for areas in which the LUS can be suitably promoted
- concentrate on markets which are are innovative in their attitude towards new species

(e) Develop Marketing Strategy

- use an experienced marketing manager
- deliver on time
- take advantage of market opportunities
- recognise the important role of market information
- use a sales representative if you can
- identify and make use of available trade promotion offices
- provide adequate technical information on product and species for the benefit of consumer
- quote reasonable prices to encourage market penetration
- be ready to export small volumes of LUS for trial
- ensure to monitor performance of supplies
- use domestic market to develop LUS for export.

Possible Impacts in Marketing LUS

The marketing of the LUS in recent times is gaining much attention in most tropical timber producing countries. This has become necessary for most of these countries in order to sustain their trade in tropical timbers, in the face of dwindling timber resources, particularly, the primary timber species.

Producing countries necessarily have to go through stages of good promotion and utilisation of the LUS in order to successfully market the LUS.

Having developed and implemented a strategic framework for marketing of the LUS, producing countries are likely to experience impacts that will benefit their timber industries.

Some likely impacts are:

- provision of support for sustainable forest management;
- substitute primary species which are becoming extinct;
- increased investments in new technologies to facilitate local processing of the LUS;
- contribute to timber and timber products export to sustain foreign exchange earnings;
- wood product diversification;
- increased research and development, etc.

Generally, the marketing of the LUS can be seen to impact on the socio-economic conditions of producing countries.

Constraints in LUS Marketing

Problems which constrain the promotion and marketing of LUS include:

Attitude of markets

The tropical timber markets (both domestic and foreign) seem to be very conservative in its choice of species, and demands commitment of much resources to change this attitude.

Also, the attitude of markets in accepting species but keeping price depressed is not encouraging the sale of LUS. Profit levels for processing LUS is marginal because the prices are depressed.

Environmental Concerns

Campaigns and calls for boycott of trade in tropical timber will not help the promotion and sale of LUS. The difficulty is that some conservation groups appear to be satisfied with nothing less than a complete abandonment of tropical forests in particular, by trade. This will of course affect the trade and sale of the LUS.

Competition from Substitute Products

There is competition from substitute products and temperate hardwoods. For instance in respect of declined availability of tropical logs, Japanese log consumers are looking to alternate timbers.

Technology and Management

Most wood processing companies in tropical timber producing countries lack the requisite technology and skills to process or utilise the LUS, to be able to compete favourably on the world market. This situation is largely due to inadequate financial resources.

Conclusion

Some tropical timber producing countries, particularly Malaysia and Indonesia have made great strides in promoting the utilisation and market acceptability of the LUS.

The case of rubber tree (*Hevea*) can be cited as an example for Malaysia. In spite of some adverse qualities with the rubber tree, it has made its mark especially in the South East Asian market for the reason that the colour, density, supply and price were right for end-users.

Tropical timber producing countries must observe and take advantage of market opportunities to market LUS products. The use of sales representatives and trade promotion offices is a good means of marketing the LUS and exporting companies must take advantage of this.

A strategic framework for marketing the LUS well implemented will definitely make an impact on timber industries in tropical timber producing countries.

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Appendix 1

Importance rating of different factors in promoting the introduction and acceptance of LUS.

Factor	Importance rating*
Availability of a reliable supply of product	6.34
Availability of technical, promotion material	5.68
Availability of small trial volumes	5.38
Low trial price	4.86
Acceptance of the LUS by an influential firm	4.82
Risk-free trial period	4.48
Certification of the LUS	4.39

*Summary rating of Ghanaian and US responses (n = 120 firms)
Scale: "1 = Not important" to "7 = very important"

Technical Session V: Timber engineering and re-constituted wood

Technical Session V: Timber Engineering and Re-constituted Wood

Chairperson: Prof. Robert Youngs, Wood Scientist, VPI, USA

Lesser-Used Timber Species in Construction

D L Jayanetti
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Introduction: The significance of Lesser-Used timber species for construction

The merits of timber as a building material are first and foremost technical. Timber in its natural state without any complex processing can be used in many forms of construction. Timber is relatively easy to work and handle and secondary processing for basic use can be undertaken with fairly rudimentary equipment. Basic timber technology is ancient and an almost world-wide traditional construction practice. In almost every settlement basic carpentry skills are available so that unlike other building materials one is not faced with the challenge of aggressive promotion of entirely new skills in construction. Timber has a unique combination of both thermal efficiency and superb sound insulation qualities. Timber is a structurally sound material and compares favourably with concrete, steel, stone, fired-clay bricks and a variety of other materials. Moreover the natural composition of timber could prove an added advantage in structural uniformity, compared to the hazards of bonding technology in concrete, brickwork, blockwork or stone, together with its light weight and resilience. Due to technological innovations, the durability of timber is no longer questionable and indeed, there are low-cost techniques to ensure resistance of timber against bio-degradation. Similarly, design techniques can permit adequate resistance of timber against fire much in the same way, as other materials will survive a fire attack.

One special technical merit of timber as a material for construction is that in most developing countries there already exists some basic local infrastructure. There is already a history of chainsaw operators felling timber, saw millers dealing in primary processing and joinery workshops dealing in secondary processing albeit with rudimentary equipment and techniques but non the less yielding valuable components for timber construction. What matters in all these is that there is a useful starting point, which could be built upon. There is also some local knowledge on seasoning of timber and treatment of timber components against bio-degradation, even though one could observe gross inefficiencies in this sub-sector.

The merit of timber as a construction material from the economic or financial point of view is based on three principles. In the first place, timber can be promoted as a building material if in developing countries the raw material is widely available and an entire structure could be built with minimal dependence on foreign exchange. For most developing countries any building materials technology that could be promoted with local inputs could lead to considerable savings in foreign exchange to the national economy. In the second place, there are proven small-scale and sometimes rudimentary cottage-scale technologies for timber processing. One example of this concept is with regard to roofing technology. Materials such as sawn timber can only be produced using large-scale imported technologies, whereas timber poles, preservative treated against insect and fungal attack by a boron diffusion process, can be produced locally on a small-scale.

The most important factor, which predetermines timber as an environmentally friendly material, is the fact that it is a renewable building material. Other raw materials such as limestone, clay, sand and stone are all exhaustible and indeed, there are numerous examples where large-scale cement or fired-clay bricks factories are facing closure due to depletion of proven raw material reserves.

A merit of timber construction which is probably more economic than technical is the time-scale within which a timber construction could be erected when compared with other materials such as concrete or brickwork. This whole concept fits into the potential for mass production of timber components such as bridge and roof trusses, beams and columns, door and window frames. There are examples of countries where labour is simply too costly and where labour on construction sites alone could account for half of the cost of inputs. Under these circumstances, especially where the countries fall into the category of newly industrialised countries, there should be a clear economic advantage in promotion of timber as an industrialised low cost building material.

Within the framework of timber as a construction material, a distinction is made between primary or commercially accepted species and Lesser-Used or less accepted species. For several reasons, the viability of timber in the context of construction is dependent on Lesser-Used timber species rather than commercially accepted species. It is important to stress that the term Lesser-Used timber species does not connote inferiority; many Lesser-Used timber species have as yet not been characterised and may as well be comparable to the commercial species. In fact, the focus of this paper is on those Lesser-Used timber species that are almost indistinguishable in log size and form to the commercially known species. In many developing countries the forests are currently being logged for only a few selected species, with many species and grades left unharvested. In South East Asia, there are about 600 commercial species and 460 Lesser-Used species; in West Africa, there are about 125 commercial species and 111 lesser known species, while in South America there are about 240 commercial species and 260 Lesser-Used species. The issue here is that timber is still an abundant resource considering the large stocks of Lesser-Used timber species. For example, in South America, out of 470 timber species classified for international trade, only 28 are of significant production out of which only five species represented over 50% of total production; only these five species were exported. Thus the progressive reduction in the supply of popular species on its own call for promotion of Lesser-Used timber species in the timber industry.

If Lesser-Used species of timber are to be promoted for use in construction, then the secondary processing required to transform logs into structural components will all contribute to employment and skill generation. In addition to secondary processing leading to production of components for prefabricated elements, there will be need for treatment of the raw material. In this regard, the demands for local chemicals and utilisation or repair of basic machinery required for the timber industry should all influence local economic growth. Invariably, any strategic promotion of Lesser-Used timber species in the construction sector will promote national economic growth.

Most developing countries are pursuing or will be pursuing structural economic reforms and almost invariably, these are based on principles of local industrialisation and development of viable local markets as opposed to strictly export of raw materials. The timber industry thus affords one of the opportunities for promoting industrial growth through a combination of processing for local markets as well as for exports. However, the development of local markets in the timber industry will imply production of a wider range of higher value-added products than for the export market. If Lesser-Used species of timber were to be promoted as a construction material, the implications on industrial expansion could be tremendous. Some developing countries with relatively viable industrial bases could achieve high economic gains by promoting small-scale processing of chipboards and similar composite industrial products using Lesser-Used timber species as the principal raw material. Moreover, if developing countries are to slowly shift into an affordable-scale industrialisation in the construction of buildings then the most viable starting point it seems is the use of timber in construction.

In some developing countries, Lesser-Used timber species could be promoted for use in construction both for the local market and for export to other developing countries where the raw material base may be inadequate. This strategy would, first and foremost, require a good local industrial base for secondary processing of Lesser-Used timber species, based on standardised products and prefabricated components. The advantage with such a strategy is that the exporting countries have the advantage of satisfying domestic needs and at the same time gaining foreign exchange earnings. The viability of this concept is based on three main issues. First of all there are few timber growing developing countries with a relatively advanced local infrastructure for small-scale industrialisation and also potential for processing of primary timber species for export. Secondly, there are some developing countries which are deficient in their resource base for supply of timber and who in the short term could be better off with imports from timber surplus developing countries. Thirdly, timber unlike materials such as concrete blocks and fired-clay bricks has a superior strength to weight ratio as well as value to weight ratio so that transport costs could be tolerable.

State of the art: The economic and technical viability of Lesser-Used timber species for construction

Reasons for Lesser-Used timber species not being used

Largely, the reasons why Lesser-Used timber species are not being used in construction are mainly the same reasons why timber in general is not used as a building material. In most developing countries, the available timber species that are predominantly the commercial species are used for roofing, door and window frames or for purely aesthetic functions such as use of plywood for wall and ceiling panelling. The choice for structures has always been a variety of industrially processed materials notably steel and concrete. Even in circumstances where timber products are abundant on the market in the midst of scarcity or high cost of other materials, the preference has never been timber.

There are obvious social biases against the use of timber. Clients of the construction industry are yet to see timber as a durable and fire-resistant material, which incidentally are the most significant factors that could influence the choice of timber. In fact, it is likely that most clients of the industry do not know of any of the technical qualities of timber. However, the underlying reason is that the acclaimed qualities of timber have not been demonstrated effectively. The construction industry is easily one of the most conservative sectors and effecting change in practices or acceptability of products is usually a mammoth task; it requires efforts which transcend beyond what is currently offered in promotion of timber for construction. Unfortunately, the bias against use of timber affects the entire spectrum of the construction industry i.e. professionals, contractors, artisans, clients, policy makers and finance institutions.

The lack of regulations, codes of practice and technical manuals in support of timber construction is yet another factor hindering efforts to promote the use of Lesser-Used timber species in construction. Experience has proved that lack of regulatory procedures precipitates any biases against a specific building material and worse of all this leads to low quality of products, faulty construction practices and unnecessarily high cost of end product. Design guidelines and codes of practice, which normally could influence architects, engineers and contractors to opt for use of timber, are non-existent. There are design manuals and codes of practice from countries in Europe and America but these are usually for coniferous timber species rather than tropical timbers and thus not relevant to the needs of most developing countries.

It is estimated that there are more than five thousand timber species in the tropical forests and the limited knowledge available suggests that fifteen hundred species are suitable for construction purposes. This can be contrasted with industrialised countries where timber has a long tradition as a construction material yet there are only twenty coniferous timber species in use. There is very little investigational work to characterise and understand the botanical and engineering properties of Lesser-Used timber species. In a few countries some basic data exists but this covers only a small proportion of the total stock of species and moreover the data is not comprehensive enough to lead to any strategic planning.

The general scenario in most developing countries is whereas there are several proven research findings on production and use of local building materials there is hardly any mechanism to translate research into viable commercial production. This phenomenon applies to undue variety of building materials including timber and most certainly lesser used timber species. In timber-rich countries such as Côte d'Ivoire, Nigeria and Gabon, so much effort is put in local research into forest products and in several instances very innovative findings remain stuck at the research laboratories with no opportunity of ever being implemented. This gap between research findings and actual commercial use of research results is easily one of the most important factors hindering prospects for wide adoption of Lesser-Used timber species in construction.

Identification of current practices of use of Lesser-Used timber species in construction

There are currently no significant examples of the use of Lesser-Used timber species as a construction material in developing countries. There are examples of use of residual timber such as the bark of trees and poles for construction of houses but these are in predominantly rural areas. The images created by use of timber in these circumstances are rather negative. There are isolated examples where lesser used timber species have been used in construction in a modern and improved context but again these are too limited to have any meaningful impact.

The use of Lesser-Used timber species for construction is slowly showing potential in industrially processed timber products. The use of wood chips for composite boards in some countries dwells on timber species that are less suitable as sawn timber due mainly to their irregular form. There is potential to use chips from Lesser-Used timber species to manufacture wood-cement boards. In some countries where these products are on commercial scale, there is an unfavourable market trend due mainly to the unattractiveness of the finish of the boards.

The economic advantage of Lesser-Used timber species as a construction material

Most of the problems that currently predetermine the high cost of Lesser-Used timber species can actually be tackled and eliminated. Most Lesser-Used timber species have an inherent botanical advantage which is of economic significance; many of them have more than average density and have strength commensurate with any known commercially popular species. Several Lesser-Used timber species may not possess the aesthetic qualities of the primary species but nonetheless can meet the functional requirements for use in construction. Construction technology using timber in general offers particular ease of and speed of erection and moreover, requires little investment in heavy plant on site. Timber has a good strength-to-weight ratio and it is easy and quick to cut and join using basic hand tools; erection in timber can proceed very fast and thus lead to worthwhile savings in the otherwise long gestation periods which are characteristic of fixed asset investment.

Technical merits of Lesser-Used timber species as a construction material

As indicated earlier on, there are some timber species currently classified as Lesser-Used purely for the fact that they have no traditional value on either the international or local timber markets but certainly not because of their technical inferiority. For this reason, it could be argued that the technical merits of a number of Lesser-Used timber species are similar to those of the commercially adopted timber species. For the purposes of construction the functional requirements of materials in terms of structural soundness, durability and water resistance can all be fulfilled by several Lesser-Used timber species. In principle the strength properties of timber correlate with the density and it is precisely in this respect that some Lesser-Used timber species have an advantage over the primary species.

The two areas that pose a threat to wide adoption of Lesser-Used timber species are:

- fire resistance
- durability against bio-degradation.

Fire resistance of timber members is also largely a function of density of the timber. Timbers in structural dimensions, which have high densities, are particularly difficult to ignite. Durability of Lesser-Used timber species against fungal or termite attack is also not a problem since there are established methods of preservation, ensuring longevity of timber as a structural material.

Selected small-scale technologies for treatment and preservation of Lesser-Used timber species

Timber preservation and treatment against bio-degradation employs a range of technologies from rudimentary through small-scale to sophisticated high-cost technologies. Of particular interest to promotion of Lesser-Used timber species for construction are the available rudimentary or small-scale technologies. Apart from short-term treatment of logs and lumber to protect timber from stain and insect attack, there are proven methods for protection from insect attack, especially protection of timber in ground contact or exposed to the weather.

Dip diffusion treatment with borates is relatively cheap and at the same time effective as first time treatment. Dip diffusion requires little capital investment, copes with impermeable species since diffusion is through the water in the green timber, and is environmentally attractive. For timber components prone to more hazardous attacks, waterborne copper/chrome/arsenic could be applied by means of a double diffusion process that is equally cheap. Drying of sawn timber is feasible in tropical climates without reliance on artificial methods. The equilibrium moisture content of timber in service in naturally ventilated buildings is in the region of 15 % but this can further be reduced to acceptable limits by simple natural processes over a longer period of time. For large volume treatment of Lesser-Used timber species there are small to medium-scale drying methods available, namely low-temperature kiln drying, dehumidification and solar drying. Depending on local circumstances one method may prove better than the others. However, a combination of these methods is also feasible.

Case studies: Examples of successful case studies in economic and technical viability of Lesser-Used timber species

Bridge building in Cameroon

The aim of this project was to develop the capability for the manufacture and erection of modular wooden bridges, capable of carrying rural feeder road traffic, using local skills and materials. The bridge consists of simple, identical prefabricated triangular wooden panels joined top and bottom to make up trusses. These trusses are in turn joined together side by side in pairs and are braced to one another to create a girder construction. The main span of 24m was constructed by a launching procedure using derricks, cables and pulleys. The timber deck is carried on top of the girders and is made using a nailed laminated timber construction, laid transversely. Longitudinal running boards direct the wheel loads of vehicles using the bridge. It has been shown that local unskilled labour can be employed in building the bridge, with a core of technicians and personnel who learn the system by being involved in each site in the country concerned. Various forms of abutments and approach spans are possible, and depending upon their design, these can also provide opportunities for local employment.

The bridge was designed for the HS 20 highway loading of the U.S. (AASHTO) design code. This is equivalent to a tractor truck with a semi-trailer of 32 tons total. Design tables are provided for spans from 9 to 27m. The tables also provide for AASHTO H 20 loading.

An important concept was the use of a local Lesser-Used timber, Dahoma (*Piptadeniastrum africanum*), for the majority of the structure. Dahoma is a tough, hard, heavy species, suitable for exterior work if adequately protected. The timbers for the bridge were treated with creosote using the hot and cold treatment method. A recent study by the Building Research Establishment in the UK showed Dahoma to have strength properties comparable with or slightly lower than European beech. BRE found that on drying, some material had a marked tendency to collapse and distort, and that the interlocked grain affected machining properties.

Rubberwood in Asia

Rubber trees have a limited productive life and are regularly replaced; Rubberwood is consequently a large and regular resource available to any country with substantial plantations; these include Indonesia, Thailand, India, Malaysia and Sri Lanka. The total area of Rubberwood plantations in Asia is estimated at around 8 million hectares. Rubberwood is not a timber plantation species and there was no reason to presume that it had potential as a commercial timber. In Malaysia and Sri Lanka especially, it was described in the past as being soft, of low quality and fit only for firewood and it was used by industries as fuel-wood and for producing charcoal. In fact it is moderately hard though not very strong with problems of low quality. Today there is strong competition between its use as commercial timber for construction as against its use as fuel-wood.

Rubberwood logs are likely to be up to 10 metres in length with a diameter of up to 0.5 metres; they have a marked taper. There are two main problems:

- Rubberwood is perishable
- It is prone to distortion on drying

Its perishability results in staining, decay and insect attack; the distortion results in the sawn timber being generally limited to 2 metres in length with widths up to 150mm. The relevance of Rubberwood to this paper is therefore not so much its use for building construction but the way in which the problems restricting its utilisation were identified and solved, and how a ‘new’ species can take the place of another in short supply. In Malaysia today, Rubberwood is used mainly for light coloured furniture, which is filling some gaps created by the decreasing availability of Ramin. It has however been used for roof trusses, laminated timber, flooring, cement board and joinery, and a recent development in Thailand has seen the setting up of a mill for Rubberwood plywood production using machinery from Finland.

The perishability of Rubberwood is balanced by its permeability, which makes it very amenable to preservative treatment. As a result of much well directed research, the log and green lumber can now be protected against stain and insect attack, and the dry timber can be promoted as having the requisite durability for construction purposes. Drying problems have been traced largely to the presence of tension wood as well as to the high ratio between tangential and radial shrinkage. Currently there is a well-directed research programme in Sri Lanka and India as well as Malaysia on use of Rubberwood. A notable feature of the development of Rubberwood as a very important timber species has been the insistence on good production and quality control and the acceptance by industry of technical advice.

Gaps between research efforts and the commercial application of Lesser-Used timber species in construction

The extent to which the gap between research efforts and commercial application of research results poses a limitation to wide adoption of a host of local construction materials has been a matter of concern to several national governments in developing countries and the international community at large.

If efforts at bridging the gap between research and commercialisation are demonstrated, it is likely to be of high significance with regard to Lesser-Used timber species mainly because timber is a renewable material and there are vast resources yet to be tapped. Currently not many developing countries have embarked on those types of research innovations which for lack of proven methodologies have not had any impact on the actual needs of the construction market. However, it is likely that once a few innovations become commercially viable the scene would be set for other countries to either replicate the results directly or embark on commercially attractive research undertakings. The main constraints, which widen the gap between research efforts and commercialisation of research results, can be summarised as follows:

Inadequacies in research efforts

Unlike the industrialised countries where timber construction is widely adopted, research efforts in timber-growing developing countries often have no relationship with the actual needs of the industry. The actual needs of building professionals, artisans, contractors, timber component producers and clients of construction products are often ignored in research practice. Funding is often a limitation but again experience from Europe and America and to some extent Asia suggest that once the needs of the construction industry, especially the research needs of the private sector, are catered for, there will be adequate funding to carry out the respective research. The value of research to product promotion in a developing country is amply demonstrated by the example of Rubberwood in Malaysia that was developed from a source of fuel-wood to a competitive material for construction. Investigations into detailed properties of a variety of Lesser-Used timber species are lacking; grouping and nomenclature will for example be of interest to the industry and so will research on stress grading and other specifications be of commercial interest.

The extent to which efforts in research and development activity in primary timber species has helped to promote export-oriented timber species in some developing countries should serve as a clear lesson of how research remains at the foundation of any meaningful progress. Demonstration activities have also played a role in promoting primary timber species. However, the few demonstration projects on use of Lesser-Used timber species suffer from the general lack of thrust and a rather non-aggressive dissemination of technology.

Lack of Access to Appropriate Technologies

Although an array of small-scale technologies exists for treatment and preservation of Lesser-Used timber species, the same could not be said of secondary processing technology. In advanced levels of secondary processing such as for composite materials i.e. wood-chip boards and wood-cement panels, the existing machinery are almost invariably at a scale which may not be commensurate with the size and effective demand of the local market.

Lack of standards, codes of practice, and other regulatory instruments

In countries where research and demonstration work have led to a near breakthrough in the use of Lesser-Used timber species, the lack of standards and codes of practice and schedules for bills of quantities specific to the Lesser-Used timber species could pose a severe limitation to any prospects for commercial adoption of the findings. In the first place, the reluctance of finance institutions to provide credit for potential investors in timber processing ventures and contractors alike could jeopardise any dreams of wide adoption of Lesser-Used timber species. In the second place and even more importantly, the competition form other materials such as concrete and steel which are covered with ample regulatory instruments puts

Lesser-Used timber species in an unduly uncompetitive situation. In this way, the already existing bias by both contractors and customers is aggravated.

Options for promoting Lesser-Used timber species in construction

Technology transfer from industrialised timber technology countries

If developing countries are to achieve any break through in promoting Lesser-Used timber species for construction, then the logical first step and probably the most cost effective approach should be based on a system of transferring existing proven technologies rather than initiating entirely new technologies. Analysis of industrial timber product consumption since 1980 indicates that there is a world-wide increase in the use of timber largely in the developed countries but also in some developing countries. In fact, in some developed countries there is a noticeable increase in the use of timber in construction to the extent that currently financial institutions and insurance companies deal with timber construction in much the same way as other materials when negotiating with clients. All these point to the fact that there is an established and growing technological base for timber products in construction, which could facilitate any settlements.

The botanical differences between the timber species of the tropical forests compared to the coniferous timbers of the developed countries poses a severe limitation to technology transfer from developed countries to developing countries. However, the concept is still valid. Unlike the concrete and steel industries where similarities between developed and developing countries permit relatively straight forward approach to technology transfer, the timber sub-sector, especially Lesser-Used timber species, is under-developed in most developing countries, thus requiring an entirely different strategy to technology transfer. The issues at stake in promoting Lesser-Used timber species are rather basic; first and foremost to ensure the existence of a general culture in timber technology and then more importantly, to identify, classify and understand the operational characteristics of existing Lesser-Used timber species. In this regard, what is transferable is the methodology or software for assessment of stock, classification of stock and biological and engineering characteristics of stock.

In most developing countries that could be classified as timber growing or timber surplus economies, there is still a deficiency in basic expertise even on the primary timber species. Issues such as stress grading and dimensions have still not been dealt with adequately. The transfer of methodologies from industrialised countries could initially aim at ensuring rapid improvement in primary timber species technology so that once the basic infrastructure is in place the recipient countries could adapt the know-how to Lesser-Used timber species. In countries such as Sweden, Norway and Finland to name a few, much work has been done on timber resources assessment, nomenclature, grading rules and standardisation of dimensions which could all be of benefit to developing countries. Another area, which is ripe for transfer from developed countries to developing countries, is with regard to preservation of timber. Again, here the techniques or simple tools for seasoning and preservation against fungi and termites should form the basis for technology transfer. Design and construction techniques are often ignored or understated in any programme for promotion of local building materials. In timber technology, design and construction considerations are probably even more important than timber treatment and such botanical considerations. In this respect the experiences of the industrialised countries become relevant. However, the principle of technology transfer should aim at careful adaptation rather than outright replication because of the obvious differences in the factors which predetermine design and construction details.

The differences in levels of timber technology and general resource profiles of developing countries should come into prominence in any system of technology transfer from the industrial countries. Ultimately, the technology transfer would only be effective if the exact deficiencies of the recipient countries are taken into consideration. In some countries, the emphasis may be on the very basics of primary timber species, i.e. stress grading, classification and dimensioning. Emphasis may even have to shift to strengthening of secondary processing of primary timber species so as to consolidate any little gains in local timber technology culture. However, in some countries the emphasis on technology transfer would go beyond assistance in strengthening the promotion of primary species, and overlap into basic issue of Lesser-Used timber species especially classification and grading methods.

Establishing a timber technology culture

Most developing countries where strategies for promotion of Lesser-Used timber species are feasible would by definition already have an existing timber construction practice based on popular timber species. Thus there is already an existing basis for promoting the use of timber in construction. However, in most of these countries there is hardly any local timber technology culture. One of the fundamental prerequisites in ensuring a successful promotion of Lesser-Used timber species is to ensure that there is local acceptance of timber in general, regardless of the species. Currently, even in timber exporting developing countries, there is limited use of knowledge of timber as a material for construction.

Establishing a local promotional exercise which should focus initially on popular adopted species once the use of popularly adopted species has been widely accepted, the scene is then set for introducing Lesser-Used timber species. The promotional exercise should not be targeted at the consumers alone. In fact, more important than the end-user are those at the production end of the sector i.e. those engaged in primary and secondary processing. Perhaps, the most strategic component in the range of activities required for securing a local timber technology culture is the design and construction component. Ultimately, it is the carpenters, architects, foremen, structural/civil engineers, quantity surveyors and contracting personnel who would influence the wide adoption of timber in construction. In order to facilitate the intervention of skilled labour and professional work force, a deliberate effort should aim at promoting availability of structural timber components.

Technology transfer between developing countries

The technology gap between developing countries in the area of timber technology, i.e. timber production and utilisation in construction, should be seen as an opportunity for promoting technology transfer between developing countries. Even though there are no remarkable achievements in the major timber producing developing countries, the isolated successful experiences in a few countries are worth transferring to the others. Unlike the technologies from the developed countries, which often cannot be replicated directly in developing countries, experiences from one developing country can be replicated in another with relative ease. In this way, technology transfer becomes more readily affordable. Developing countries from the same ecological zones are likely to have similar timber species so that the concept of replicating experiences and achievements becomes meaningful. Similarly, developing countries with the same level of basic industrial and timber technology infrastructure are likely to benefit effectively if a successful country transfers its experiences to the needy.

One area in which a few developing countries have made reasonable progress in Lesser-Used timber species is in primary research. Countries such as Malaysia, India, Thailand and the Philippines all have basic research centres and laboratories dealing specifically with timber and timber products. The experience acquired by the countries so far could form the basis of research expertise that could be transferred to the remaining countries that are yet to make a start in investigations on Lesser-Used timber species. In Malaysia, the use of Rubberwood as a construction material has been demonstrated yet other rubber producing countries such as Liberia and Nigeria have not made such progress in this area. Another area of concern, where disparities exist between developing countries in the level of know-how and local initiative, is with regard to timber preservation technology. Advances have been made by a few developing countries in simple methods for timber preservation including developments in solar drying techniques for timber seasoning, timber impregnation technology and above all initiatives in treatment for termite protection. All these initiatives are directly applicable to Lesser-Used timber species and could thus form the basis for technology transfer between developing countries.

The concept of technology transfer between developing countries at least in the area of building materials is relatively new and untested. At the same time there are some basic limitations facing developing countries for which reason only a limited scope of technology transfer could be feasible. In isolated cases, technology transfer between developing countries could take the form of supply of simple tools, training of personnel in tool fabrication, training of personnel in a variety of skills related to production, aspects of Lesser-Used timber processing, training of personnel in a variety of research and laboratory test methods and installation of laboratory equipment. However, in a majority of cases technology transfer could be pitched at the most rudimentary level, i.e. exchange of information pertaining to Lesser-Used timber species could be sent from those countries pursuing active programmes to the recipient countries.

Secondary processing of Lesser-Used timber species

One of the most viable strategies for promoting use of the timber in construction is for timber growing developing countries to embark on intensified secondary processing of Lesser-Used timber species. The merits of secondary processing need not be over emphasised. The strategy fits well into the overall economies. The superiority of the building materials sector as a viable sector for industrial gains is based mainly on the multiple linkages to the national economy in both outputs and ability to stimulate a parallel growth in the input sectors. In the first place, the abundant reserves of Lesser-Used timber species plus the fact that timber is a renewable resource could all serve as a solid base for continuous supply of raw materials required in secondary processing plants. In the second place, the promotion of secondary processing could lead to the availability of a multitude of products that could then satisfy the rather complex market for construction. Thirdly, there are relatively simple tools and technologies available on the market for secondary processing of timber and this on its own will enhance prospects for the strategy to prove feasible to both potential producers and consumers of end product. In the final analysis an intensive use of timber in construction is only feasible if processed or prefabricated components or composites of timber are widely available on the market.

Some timber growing developing countries have come a long way in a relatively short period regarding timber processing. From the initial stages where focus was strictly on harvesting sawn logs for export and for sawmills, there is now a shift into secondary processing to increase added value but mainly to generate foreign exchange. A few developing countries have now moved into production of prefabricated door frames, window frames, roof trusses and panels for wall framing. There is scope for further diversification of products through secondary processing of timber, utilising Lesser-Used species strictly for the construction market. Fortunately most developing countries already have an established technological infrastructure for primary processing of timber and to some extent some rudiments for secondary processing which could be consolidated upon to intensify and diversify secondary processing of timber. Opportunities exist to embark on chipboards and other structural composites using chips from Lesser-Used timber species and cement and other additives to form a monolithic composite material.

Joint programmes: Sub-regional joint demonstration projects adaptation of internationally sponsored technology transfer

Despite the fact that a few developing countries have made some progress in timber technology, the general picture is that of a total lack of direction and focus on the actual task of promoting Lesser-Used timber species for construction. One way to overcome this problem is to optimise the use of the available resources by undertaking communal programmes amongst a group of developing countries.

The merits of a joint sub regional project of Lesser-Used timber species are several. First, the resource requirements for each timber for construction are massive compared to what is normally available from international support sources; the resources requirements will normally comprise assistance in technical expertise, supply of information and software, laboratory equipment, machinery and training of local experts. In the second place, most developing countries requiring assistance to promote Lesser-Used timber species for construction will tend to have identical problems such as in raw material assessment, classification, treatment, processing and design techniques so that economies will be achieved by intervening in their problems on a communal basis. Thirdly, a strategy of joint projects takes account of the contribution that the recipient countries could make to project success; the little expertise and facilities available in some of the recipient countries could all be mobilised into the project to secure some saving and ensure efficient use of all available resources.

Programme of Action

National Governments

Some of the solutions required to make Lesser-Used timber species affordable, technically appealing and above all available in large quantities are already unknowingly being pursued by national governments. There are on-going general policy reforms and programmes to promote wide adoption of local construction materials which if sustained would have an impact on the use of Lesser-Used timber species. However, the peculiar requirements of Lesser-Used timber species would in addition to general policy reforms benefit from the following specific interventions of national governments.

Strategic programme of assured supply base

The primary task of national governments if Lesser-Used timber species are to be widely adopted for construction is to embark on a strategic programme of an assured supply base. The unique advantage of timber over other materials is its renewability; if timber is treated as a depletable raw material just like limestone, clay or sand than its versatility as a potentially viable low-cost material is threatened. For this reason, governments should outline a vigorous policy of afforestation for any exploitable Lesser-Used timber species as a fundamental pre-requisite to any other policy interventions aimed at promoting Lesser-Used timber species as a construction material.

Promotion of standards, specifications, building regulations, codes of practice and contractual reforms

By definition, regulatory instruments for governing the operations of the construction industry have legal implications so that it is the unique task of national governments to undertake any reforms of this nature. Like other construction materials, the strategy for promotion of standards should first and foremost aim at incorporating the use of Lesser-Used timber species into existing building regulations. However in order to facilitate the fast adoption of Lesser-Used timber species, requisite standards and specifications should be formulated and effectively disseminated. Similarly, codes of practice and simplified manuals should be prepared to guide operations in secondary processing as well as in design and construction. In this regard, governments need not search for new methodologies to achieve this target. There is sufficient experience and proven methodologies that can be directly applied or adapted. Unfortunately, Lesser-Used timber species are characterised by such a variety of groups with almost every group requiring specific considerations in codes of practice and specifications which would require some additional efforts.

Strengthening research capacity, curriculum revision and provision of specific skill requirements

To the extent that governments are directly in charge of most institutions dealing with timber research in developing countries, it must be seen as their prime responsibility to first bring about reforms in research programming, and secondly to take positive steps towards strengthening the resource base of the institutions. Again here, governments need not devote additional resources to carry out the reform but simply reorient the approach and set-up of the research institution to link them up with the private sector producers of timber products and the construction industry. The target should be research into areas of direct benefit to specifiers, architects, engineers and contractors. Apart from general topics of investigation requiring immediate attention such as raw material assessment, identification, grouping and nomenclature, there is also the need for specific studies into items such as:

- strength and durability
- density characteristics
- stress grading
- low-cost techniques for seasoning and protection against bio-degradation
- field tests for brittleness, vulnerability to splitting, grain, level of distortion

If timber construction technology is to become a priority issue in national strategies, then governments must address themselves to the manpower requirements of this strategic sub-sector. The training programme should cover a vast range of skills in the timber industry; operatives for secondary processing, machine and equipment installation plus maintenance specialists, forestry management personnel, timber treatment and preservation expertise and then timber design and construction technology. In all these endeavours, there must be a focus on training of skills specifically geared towards the promotion of Lesser-Used timber species. The training programme need not lead to setting up of entirely new institutions. One useful strategy is to strengthen existing institutions through programme reform and most of all curriculum revision. The curriculum revision should prove most useful to institutions training high-level artisans or technicians for the construction industry as well as professionals such as architects, building technologists, civil/structural engineers, quantity surveyors and mechanical engineers.

Effective dissemination of research and development of innovations

The few examples of demonstration projects aimed at popularising research initiatives in the building materials sector have failed in several developing countries. However, the concept of demonstration projects is still valid and remains a vital tool for linking up research to practice. Timber construction technology would require particularly effective demonstration projects considering the unfavourable position that timber occupies relative to other building materials. Governments should take advantage of the fact that they are, in most instances, the single largest client of the building industry and use this position to demonstrate the viability of Lesser-Used timber species as a material for construction. Apart from the physical erection of structures, there are other modes of research dissemination that the government can manipulate to achieve the desired results. Governments can for example take full advantage of their television and radio broadcast network as well as informal systems using agricultural extension officers, health officials and teachers.

Fiscal policy reform and investment incentives

There is need to review existing fiscal policies and incentive strategies not only for the timber industry, but also for the entire construction materials sector. It is likely that most timber exporting developing countries would have put in place fiscal policies and related incentive strategies to boost production for export. The danger in such a strategy is that it could serve as a disincentive to investments in exploitation and processing of Lesser-Used timber species. If the timber industry is treated as a sub-sector of the economy with uniform tax incentives and equalisation of reductions in import levy then there is every chance that the exportable timber species would attract all the local and foreign private-sector investment. In this regard there is need for tax and similar fiscal incentives to be targeted so the promotion of Lesser-Used timber species, especially the secondary processing of species for construction; the incentives should be covering entrepreneurs at the production end of timber as well as those investing in the use of timber components for construction. The extent to which timber is disadvantaged in relation to other competing building materials should also be reviewed so that corresponding adjustments are made on existing fiscal policies to reflect any peculiar requirements of Lesser-Used timber species.

The lack of standardisation of timber components for use in construction poses a problem with several negative consequences, in particular the high incidence of wastage of timber which eventually makes timber seemingly costly. The lack of standardisation also leads to delays in construction time and the quality of finish. Governments bear the responsibility for promoting standardisation of measurements of timber components. Once standardisation has been accomplished for simple components, the process of industrialisation could be initiated.

There are two distinct advantages of industrialisation utilising Lesser-Used timber species. The first is of immediate national consequence in terms of improving delivery and stimulating national growth. The second is that governments could explore possibilities of exporting industrial components to other developing countries that may be facing a deficit in supply of Lesser-Used timber species. In this way timber serves a dual market and sustains the foreign exchange earning capacity of the timber industry.

International support

Information flow

The rich experiences of some developed countries in the use of timber for construction plus relevant research projects undertaken by specialised international agencies could all prove useful to the needs of some developing countries who may wish to promote Lesser-Used timber species for construction. In this regard, the international community could support efforts of national governments through supply of relevant information to selected focal points in the recipient countries. If information flow of this nature is to be effective, the information must as much as possible be targeted to the needs of the recipient countries, implying that information must be further refined or processed before being disseminated. For example, in the area of grouping of species and similar areas, what may be required is only the methodology or concept. Similarly what may be of interest to local architects in developing countries is the design guidelines rather than detailed drawings.

Joint research and demonstration projects

The international community could support the efforts of national governments through bilateral programmes in research and demonstration covering a variety of aspects for promotion of Lesser-Used timber species. The possible areas of co-operation include raw material assessment, species identification, grouping and nomenclature, treatment and preservation techniques, field tests for classifications, secondary processing and construction techniques. Depending on the particular focus of the joint project and also depending on local infrastructure and other variables of the recipient country, the project could be hosted by the recipient country with specific components being hosted by the donor country. There could also be twinning arrangements whereby expertise from individual developing countries are attached to selected specialist companies or research institutions in the developed countries to undertake joint research programmes.

Equipment and machinery

Perhaps the most obvious support that the international community could give to the developing countries is in supply of equipment and machinery. The range of equipment and machinery required is extensive, broadly covering equipment for research laboratories, tools for treatment and preservation of Lesser-Used timber species, for species identification and most of all for secondary processing. It is important for donor countries or multi-lateral agencies taking up this challenge to aim at technologies which can be sustained by the recipient countries. This may call for some adjustments on the part of the donor countries - adaptation of existing technologies rather than outright technology replication. Donors of machinery and equipment may also explore possibilities of assisting the recipient countries in local fabrication of rather simple tools.

Manpower development

In the end, developing countries will only achieve the target of adequate local capacity in the promotion of Lesser-Used timber species if the gaps in available manpower are dealt with in a comprehensive manner. The international community's support in this area is vital and should more importantly prove a cost-effective approach to development. Manpower development should cover both professionals and middle-level technicians and the entire range of activities required to effectively promote Lesser-Used timber species should be considered. The training programme to be offered should as much as possible be specific to the subject with adequate balance between classroom academic oriented courses and on-the-job practical training schemes. With regard to the latter, an attachment to private sector ventures for on-the-job training has always proven beneficial to be potential entrepreneurs from recipient countries.

Support for co-operation between developing countries

The responsible international agencies could initiate collaborative research and demonstration projects involving joint efforts of a few developing countries from one sub-region with logistics support from the international community. The concept of such collaborative projects has been rehearsed by agencies such as UNIDO and this should not prove too difficult to adapt to the task of promoting Lesser-Used timber species. The main areas of support from the international community are for equipment, machinery, and assistance in expertise. The concept entails single a group of developing countries being hosed by a single collaborating country for the purpose of undertaking a project of mutual benefit to the group. After the successful demonstration stage, the international community could provide a lower margin of logistics support to replicate the initiatives to the remaining participating countries.

Plywood Mechanical Design: Predictive Modelling and Characterisation

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Abstract

During the last decade, important progress has been realized in the fields of wood rheology, the design of composite materials and in the domain of experimental characterization of anisotropic solids. In particular, plywoods represent a class of wooden materials with which mechanical design, according to desired technical performances, can be accomplished with high accuracy. This statement seems to be paradoxical, due to the great variability of wood mechanical properties generally described in the literature.

The main objective of this paper is to give evidence of the excellent fit between experimental and predicted elastic characteristics, such as bending or torsional stiffnesses of plywood panels. The panel is an equilibrated, seven cross plies 0/90/0/.../0, tropical wood (okume) plywood. The success of the demonstration is of course partly due to the good technological peeling properties of this species, with no large knots, no localised reaction wood, straight grain, etc.

Elastic characteristics of a given plywood are computed using a quite classical multilayer mechanical modelling, taking into account the orientation and the anisotropy of each ply. According to Lowe Kirchhoff and plane stresses assumptions, predicted values of supplenesses are available for small deflections. The modelling is original in that it uses the specific gravity of the wood and the moisture content as predictive parameters of the tridimensional elastic behaviour of the constitutive wood.

Bending and torsional supplenesses are measured using two specific testing machines, a four-point bending test and a torsion test. Because of technical originalities concerning the support's shape, the experimental devices were well adapted to very wide test samples cut off an anisotropic panel.

Introduction

Due to the recent improvement in knowledge about wood rheology and the use of efficient methods for the mechanical design of multilayered materials, plywoods represent a class of wooden composites where design can be relalively accurately accomplished, according to the desired technical properties. The main goal of this paper is to give evidence of the very good fit between predicted values of elastic characteristics, such as bending or torsion rigidities, and experimental results. It will be shown that the quality of this fit depends both on the efficiency of the modelling and on the pertinency of the experimental process. The power of the methodology will be illustrated with the problem of shape effects of samples during creep experiments in bending. Which is not a problem!

Mechanical design of the plywood.

The mechanical elastic design of plywood is perform using a classical model of multilayerer material, with anisotropic oriented plies, under the hypothesis of small deflection, and plane stresses (Hearmon 1948, Laroze 1988).

The specificity of the modelling is in the utilisation of two material indicators, specific gravity ρ and moisture content H, as predictors of the elastic anisotropy of the solid wood, from which the plies are peeled (Guitard 1987).

The models are different for softwoods or hardwoods. As we are concerned with hardwood, the elastic compliances of the standard wood correspond to a specific gravity $\rho = 0.65$ g/cm3, and a moisture content $H = 12\%$. For a given wood, the standard model is to be corrected using a power law of the specific gravity.

In the same way, to take into account the exact value of moisture content H, when it is close to 12%, a linear adjustment is performed.

The elastic behaviour law of multilayered materials is built on the basis of thin plates theory, including perfectly glued plies. Under such conditions, for an equilibrated n plies panel, flexure and torsion rigidities D_{ij} are calculated

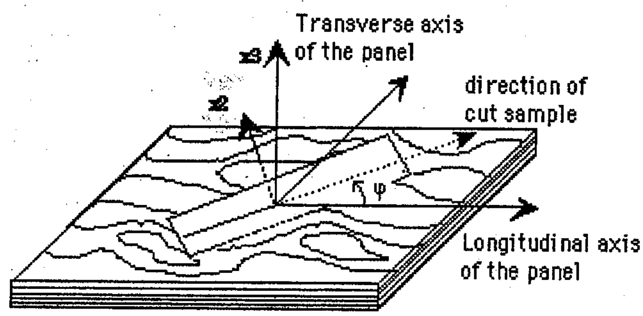

Figure 1: Angle giving the orientation of samples versus pannel axis

Materials and sampling

For the demonstration, the chosen material was an okume plywood. This tropical wood is considered in France as a reference specie for plywood. The specific gravity was ρ = 0.41 g/cm3 at a moisture content H=11%, (see elastic properties in table 1).

The material was an equilibrated seven plies plywood, with the crossing sequence 0/90/0/.../0, rough from manufacturing, i.e. with neither sandpapering nor surface treatment. Panels were manufactured by the research centre of ROL TECH Company, in production size 2.50 x 1.20m^2.

The ply peeling thickness was 2.1 mm. 200 grams of phenol-formol glue were used for each square metre of joint. The temperature of polymerisation was 140°c, under a pressure of 1.4 MPa. Under such conditions, the final product was densified, with a total thickness of 14 mm and a specific gravity of ρ = 0,44 g/cm^3, while the moisture content was close to H = 11 %.

The samples submitted to flexure or torsion tests, were 500 mm long, 100 mm wide and 14 mm thick. They were cut off plywood panels with respect to various orientations characterized by the angle made by the long axis of the sample and the longitudinal axis of the panel. For each angle value, among 0,5,10,20,30,45,60,70,80,85,90 degrees, five samples were cut off and tested (Figure 1).

Results and comments

During the test a bending (or a torsion) momentum was applied. Measuring the resulting deflections, curvature or twisting, the mechanical characteristics experimentally evaluated are supplenesses in bending-torsion $d^{i;ij}$. The theoretical estimation of which must be deduced by inverting the rigidity tensor $D^{i;ij}$, itself resulting from the D_{ij} after a rotation of angle, corresponding to the orientation of the given sample.

For the purpose of comparison, each suppleness $d^{j;ij}$ is converted into an elastic modulus E_{ij}, which is a characteristic supposed to be independant of the thickness h of the panel.

The essential conclusion is that the fit between prediction and measurements is excellent, the maximum gap is less than 10%.

For off-axis measurements, the quality of the fit is also very good. As an example, figure 2 represents the variation of the flexure modulus $E^{j;11}$ according to the orientation the sample was cut off the panel. Each experimental result corresponds to the tests achieved on 5 samples; the mean values the standard deviation is plotted versus angle. Figure 3 shows the torsion modulus results. In both cases the same quality of fit is obtained.

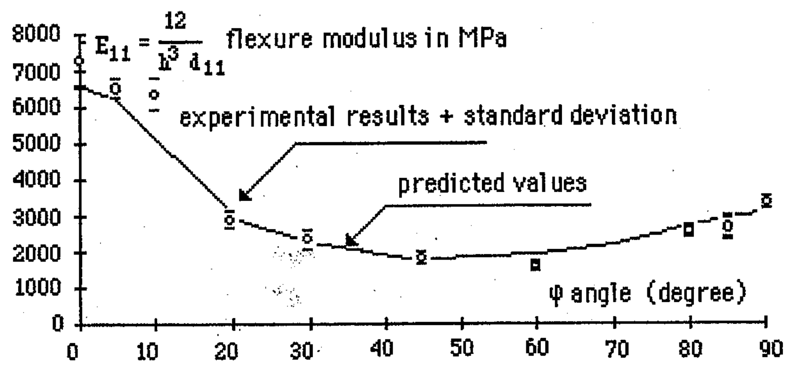

Figure 2: Off-axis flexure modulus versus the longitudinal axis orientation

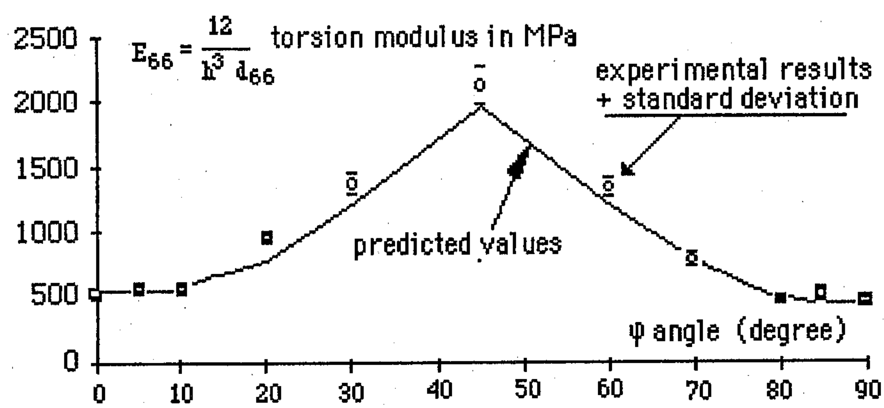

Figure 3: Off-axis torsion modulus versus the longitudinal axis orientation

When the comparison between predicted values and experimental data leads to a good fit, the conclusion can be that both the theoretical modelling and the experimental process are performing well. However some specificities of the experimental devices need to be shown.

Particularities of the testing machines

During a static four points bending test, as shown in figure 4, a pure bending momentum induces the main curvature k_1. In the general case, secondary deformations occur and are superimposed to the main curvature k_1. Because of Poisson effects, an antielastic curvature, k_2, appears, and the sample takes a saddle shape as indicated schematically on Figure 5. For off-axis tests, due to a non-zero value of d_{61} suppleness, a coupling effect can introduce a complementary torsion k_6. For the sample to be submitted to a pure bending momentum, it is necessary that those secondary deformations should be free to develop. The associated displacements must be kinematically compatible with external linkages.

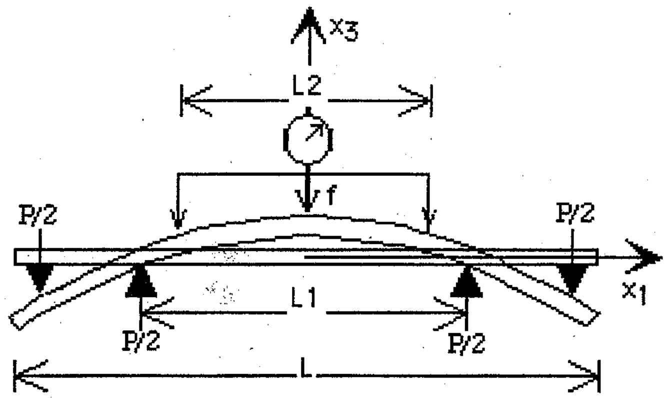

Figure 4: Principle of the static four points bending test

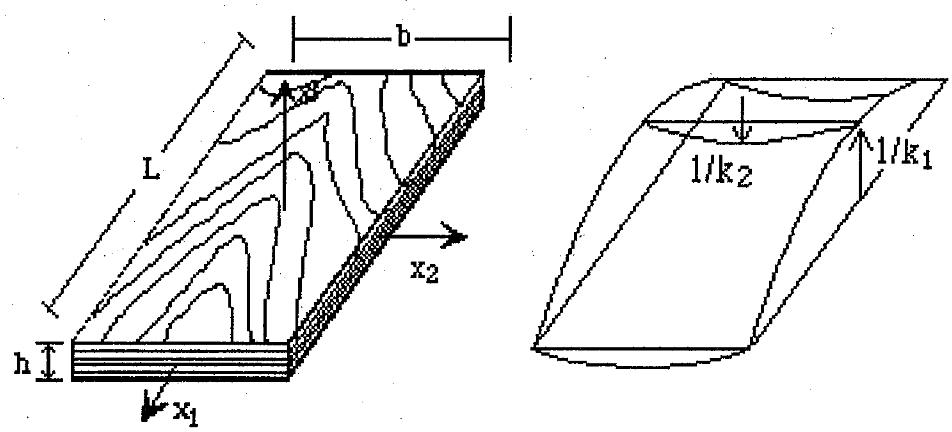

Figure 5: General shape of the deformed sample submitted to pure bending

Most standardized bending tests, such as ASTM, CEN or AFNOR standards recommend linear supports. These kinds of supports do not allow for the development of the anticlastic curvature, k_2, close to each support, mainly in very wide samples. Thus, unexpected secondary moments are induced and the test is no more a pure bending test. The consequence is an apparent rigidification. The wider the sample, the higher the rigidification is. These results agree with those of McNatt, Wellwood and Bach (1990) who showwed that large-panel tests yielded higher modulus of elasticity (MOE) values and lower modulus of rupture (MOR) than small-specimen tests. These authors suggest regression equations to accurately predict MOE and MOR. Post (1983) also studied specimen sizes and concluded that the most reliable data for use in engineering design are obtained from test panel sizes comparable to those in practical use.

As a first specificity of our technical device to avoid this kind of shape effect is, instead of using linear supports, we suggest pin supports as shown in Figure 6, so that the anticlastic flexure is free to develop.

The second specificity of our device is the introduction of a ball bearing with a large diameter, allowing a free rotation of each support around the x_1-axis. In such conditions, no secondary torsion momentum is induced during off-axis bending tests. To be noted that the ASTM standard recommends allowing free rotation, around longitudinal axis, of both external supports, we suggest that rotation of both internal supports must also be free.

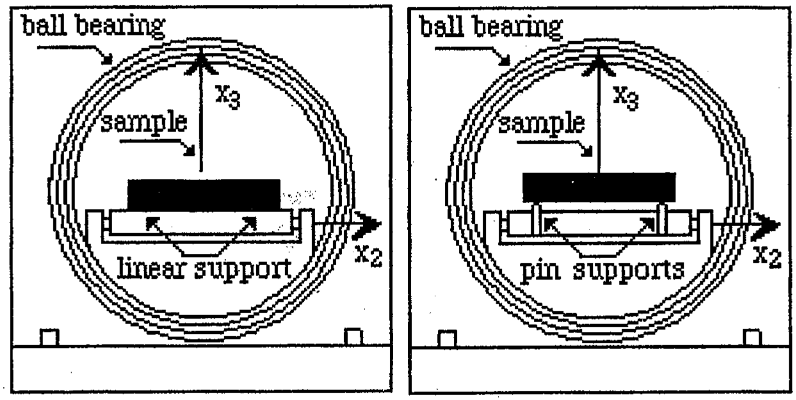

Figure 6: Utilisation of pin supports instead of linear supports allows the development of the anticlastic curvature. The free rotation of each support is possible around the x_1 axis, because of the large diameter ball bearing

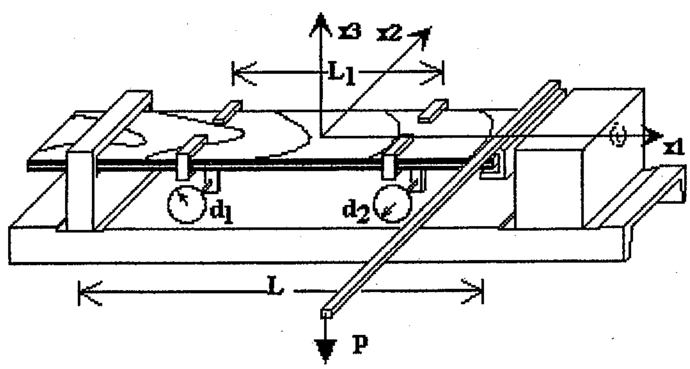

Figure 7: Torsion test machine with pin supports.

For torsion tests, similar particularities are introduced in the design of a very simple, but efficient, torsion testing machine represented in Figure 7.

Application to the shape effect on plywood creep bending tests.

Four point bending creep tests were performed, with linear supports, on plywood samples with the same length (L = 50 cm) and thickness (h = 1.4 cm), but with three different widths (b = 5cm, 10cm and 25cm). The cross section shape factor thus varied from b/h = 3.6 to b/h = 18.

For every sample, the level of loading corresponded to 20% of ultimate short term strength. Tests were made under constant climatic conditions: 20°C and 65%RH.

The flexure momentum M was kept constant, and the evolution of the curvature C(t) was registered versus time t. The experimental results shown in figure 8 are the compliances J(t) = C(t)/M.

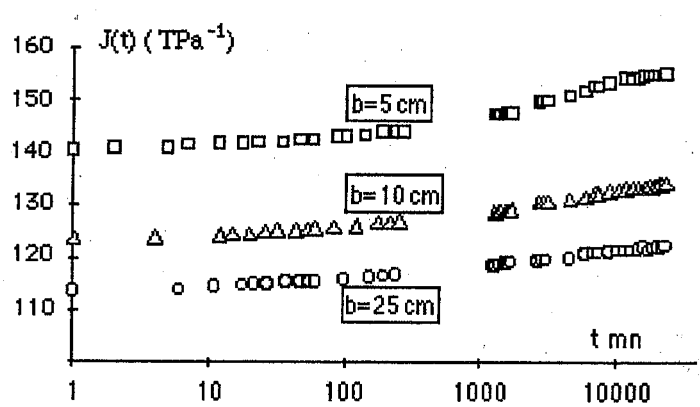

Figure 8: Observed creep compliances,on samples with different widths, using linear supports.

It appears that, for any time t, the larger the specimen is, the smaller the creep compliance:

$$J(t)_{25cm} < J(t)_{10cm} < J(t)_{5cm}$$

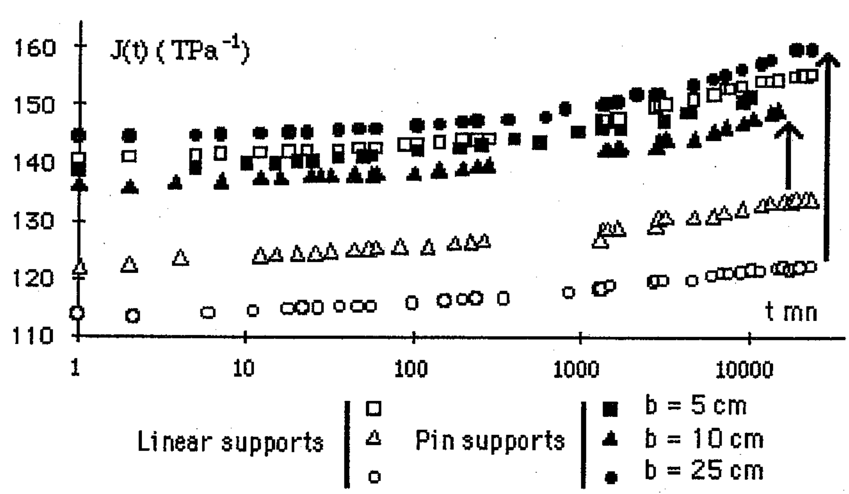

Figure 9: Comparison of creep curves for samples with different widths, using linear supports or pin supports.

As the material used for the three tests was the same, and since the geometry of the specimens and the external loading were taken into account in the compliance definition, J(t), it appears that we have actually shown a cross section shape effect.

To avoid this shape effect we suggest the use of pin supports. The results obtained in these conditions, compared to previous results, are shown in Figure 9.

The influence of the utilization of pin supports is spectacular on the creep curve corresponding to the larger sample ($b=25$ cm and $b/h = 18$). Compared to previous results, the increment of short-term compliance is about 40%. This increment is only about 10% for 10cm width samples. There is no significant effect on samples with a smaller width (5 cm and $b/h = 3.6$).

As a partial conclusion, using pin supports, instead of linear supports, eliminates the shape effect observed on creep curves, obtained with linear supports on wide samples. There is no more shape effect with linear supports when using samples with a cross section shape factor smaller than 4. CEN standard recommends, and DINWOODIE uses samples with 5cm width. Experimental data obtained in such conditions can be used with no doubt, unless the samples are thicker than 1 cm.

Conclusion

As a general conclusion, we can say that the design of plywood can be performed with a high accuracy, according to desired properties, using the multilayer thin plane plates theory. It has been shown that the elastic properties of the wood can be well estimated by predictive rheological models using the specific gravity and the moisture content as predictors.

The design of flexure (and torsion) testing machines, and also the interpretation of experimental results ought to be achieved taking into account the dimensions and the orientation of samples cut off the plywood panel. For cross section shape factor less than 4, the elastic beam theory is valid. For a higher shape factor, the Elastic Thin Plates Theory must be considered.

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Re-cycling of Wood Wastes for the Manufacture of Structural Laminated Cement-bonded Particle Boards

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Abstract

This report highlights the achievements of the Forestry Research Institute of Nigeria, Ibadan in the past five years on the re-cycling of wood wastes for production of cement-bonded particle boards and subsequent lamination of the boards with veneers and strips of wood. Specifically contained in this report is the result of one such investigation carried out at the Institute. Cement-bonded particle boards, which were 12mm thick, were initially fabricated from mixed sawdust and flake particles of Nigerian hardwood species. The boards were three-layered and were formed with three production variables of board density at levels of 1,000, 1,100 and 1,200 kg/m^3; and cement to wood mixing ratio at three levels of 2.00, 2.50 and 3.00. Following subsequent drying to a moisture content level of 12%, the panels were subsequently surface laminated with veneers at three glue spread levels of 0 (serving as control), 25 and 32 kg/92.90m^2 double glueline of veneer. From the results obtained, the levels at which the panel density, mixing ratio and glue spread were applied in the study experiment had significant effect at 1% level of probability on strength and stiffness of the experimental panels. MOR values ranges from 25.56 or 41.64 N/mm^2 for the laminated panels as against the values of 5.40 to 13.88 N/mm^2 for the natural non-laminated panels. Similarly, the MOE values increased from a range of 1143 to 2648 N/mm^2 (non-laminated) to a range of 3274 to 5482 N/mm^2 following lamination. In view of the initial lamination success achieved, considerable increase in the panels strength and other attendant advantages such as production of thin-size boards which may subsequently be laminated to provide acceptable panels for structural purposes, panelling, ceiling and partitioning, more research studies on surface lamination of cement-bonded particleboard are recommended.

Introduction

By its general classification, wood-cement boards include the wood-wool cement slabs; cement-bonded particleboard; wood flakeboards; wood shavings boards; and gypsumbonded fibreboards (Simatupang *et al.* 1978). While woodwool cement slabs are more often used in Germany and other parts of Europe, cement-bonded particle boards are more popular in Japan. Recently, pilot wood-wool cement slabs production lines have been established in Malawi and Zambia in Africa (Hawkes and Cox, 1992). As a result of its breakthrough on research into sawmill wood wastes utilisation, the Forestry Research Institute of Nigeria, Ibadan established a small-scale pilot commercial plant in 1991 for production of sawdust-cement floor and wall tiles; decorative face cement-bonded particle boards for purpose of ceiling and partitioning; and corrugated cement-bonded particle boards for roofing. Two important factors might have contributed to the increased tempo of research and commercial production of wood-cement boards in many countries within the last decade. These are the ease of sourcing of the basic raw materials used in many localities and the inherent admirable properties of the products.

As reported in literature, wood-cement boards are generally accepted as reliable panels of considerable merit for building construction uses such as wall panels, roof, decking, ceiling, cladding, flooring and shuttering (Sandermann, 1970, Chitterden *et al.* 1975, Simatupang *et. al.* 1978; Bison-werke, 1981; Elten, 1981; Canali, 1981 and Lee, 1984). The inherent admirable properties of the panels that enabled them to be so embraced include:

(i) Very low dimensional stability values under prolonged exposure to moisture and fluctuating relative humidity changes.
(ii) Impressive durability resulting from excellent resistance to insects, fungi and mould attack. The alkalinity nature of the cement-binder has probably contributed to this resistance.
(iii) Impressive thermal, sound and low combustibility values.
(iv) Excellent speed of construction when assembled for low-cost house construction.

Generally, wood-cement panels are used in the developed countries in most areas where moisture uptake, decay and unsatisfactory combustion performance will not permit the use of solid wood and other wood-based panels.

These admirable properties notwithstanding however, cement-bonded particleboards are weaker and inferior to resin-bonded particleboards and chipboards in relation to strength and impact resistance; even though they are superior in terms of other essential properties such as dimensional stability, durability, insulation, inflammability when in contact with fire and stiffness (Dinwoodie, 1978, Bison-werke, 1981).

In view of this inherent poor strength of wood-cement boards, the Forestry Research Institute of Nigeria (FRIN), Ibadan initiated research into finding ways and means by which the surfaces of cement-bonded particleboards can be laminated with veneers and other wood laminates with a view to increasing the strength values measured from the panels. For the research investigations, the cement-bonded particleboards used as the core or substrate materials are made from sawdust and flakes generated from the country's sawmills. When the laminates have to be wood strips, they are also made from wood wastes generated in sawmills, furniture and wood-working factories. The strip laminates are also processed from small size logs such as thinnings from plantation forests. Two factors motivated research interests in this new area of wood products development. These are:

(i) The need to ensure close utilisation of Nigerian Tropical Hardwood Timbers through appropriate re-cycling processes.

(ii) The need to foster value-added in the manufacturing of wood-based panels from Nigerian, hardwood timbers.

Incidentally, the objectives of FRIN, Ibadan seem to coincide with objectives and scope of this International Conference planned by the Forestry Research Institute of Ghana, Kumasi. This paper therefore highlights the achievements to date on the possibility of surface lamination of cement-bonded particleboards with a view to upgrading its strength properties as investigated at FRIN, Ibadan.

Laboratory Work Done

Production of the substrate cement-bonded particleboard

The cement-bonded particle boards which were used as the core or substrate materials for producing the laminated panels were usually made 3-layered with saw-dust-cement blended materials forming the face layers and flake-cement blended materials forming the core layers. Both the sawdust and flake particles used were mixed from different hardwood timbers based on current research achievements at FRIN, Ibadan. Also based on pilot commercial practices going on at the Institute, the following standard specifications were used for laboratory production of the cement-bonded particle boards which were subsequently laminated:

1. 2mm grade sawdust obtained through sieving of the raw sawdust collected from sawmills and plank re-saw processing centres.
2. 50 to 70mm long and 0.125 to 0.250mm thick flakes obtained from slab wastes collected from sawmills as well as trims and edgings collected from furniture and woodworking processing mills.
3. Both flakes and sawdust pre-treated with hot water at a temperature of 50°C to 80°C and maintained in such hot water for a length of soak of 60 minutes.
4. Both flakes and sawdust air dried to a moisture content of 12% immediately following pre-treatment.
5. Panel layer characteristics of sawdust-cement mix accounting for 60% of the board thickness and flake-cement mix accounting for 40% of the panel thickness during board spreading and forming. This technique ensures production of very smooth surfaces which can be conveniently overlaid with veneers. In some cases however, 100% sawdust fibre input is used.
6. Use of calcium chloride at 1 to 3% of the cement weight in board during material mixing.
7. Use of standard cement/water ratio of 0.60 based on the cement weight in board.
8. Use of cement/wood (whether sawdust or lake) ratio of 2.0 to 1.0 up to a maximum of 3.0 to 1.0.
9. Use of panel density of 1,000 to 1,200 kg/m^3 based on oven dry weight of board.

Following forming and subsequent pressing, the cement-bonded particleboards, when demoulded were generally air dried to moisture content levels of 8 to 12% in order to provide a suitable moisture content level ideal for gluing.

Production of the laminates

Two types of lamination are generally done. These are single surface lamination with veneers and multi-surface lamination with wood strips. Since the Institute has no facilities for rotary peeling of veneers from small size logs, the single surface lamination is generally done with commercial grade veneers, or sometimes sawn and plained veneers produced at the Institute's woodwork hop. The commercial grade veneers are about 0.500mm thick while the sawn and plained veneers are generally 3.0 to 4.0mm thick.

When wood strips are used to laminate the surface, the strips are also generally 3.0 to 4.0mm thick. When sawn and plained veneers or wood strips are to be used as laminates, properly air seasoned timbers, usually to moisture contents of 12% are used. Sometimes too, they are kiln seasoned to this same moisture content level at the Institute timber seasoning unit.

Preparation of the Resin Adhesive

A special resin adhesive is formulated to provide an appropriate gluing medium for wood and cement products. Powdered urea formaldehyde resin, sold under the trade name cascamite forms the base component of adhesive synthesis. To it are added extenders and fillers. The extender used is Portland grey cement. The formulation of the adhesive used from these component raw materials are as follows: -

(i) UF glue - 50-60 parts

(ii) Portland grey cement - 35-25 "

(iii) Fillers - 15 "

The formulation is sometimes adjusted for a particular wood species in order to achieve the desired results. Water is finally added to mix the adhesive to the desired viscosity level.

Assessment of static bending strength and stiffness properties of the laminated panels

For this particular report, 12mm thick, three-layered cement-bonded particleboards were made with the following production variables at the indicated levels:

(i) Panel density at three levels of 1000 kg/m^3; 1100 kg/m^3; and 1200 kg/m^3 based on over dry weight of board.

(ii) Cement to wood mixing ratio at three levels of 2.0:1.0, 2.5:1.0 and 3.0:1.0.

(iii) Following production and subsequent drying, the three-layered cement-bonded particleboards were surface laminated with commercial grade Mahogany veneers at three glue spread levels of 0 (serving as furniture and woodworking processing mills control), 25.0 and 32.0 $kg/92.90m^2$ double glueling of veneer. After glue application, the laminated panels were cold pressed for 12 hours. They were handled just like the conventional laminated resin-bonded particleboards. In view of this therefore, they were cut into test specimens, conditioned and tested in accordance with the ASTM standard D. 1937 - 78. All tests were carried out on a Housefield Tensometer Type W.

Results and Discussion

Results

The average Moduli of Rupture and Elasticity (MOR and MOE) for the 27 experimental treatment combinations used in the study are listed in Table 1. MOR values ranged between 25.56 N/mm^2 and 41.64 N/mm^2 for the 18 treatment of the study for which their experimental cement-bonded particleboards were surface laminated with veneers. Corresponding stiffness (MOE) values ranged between 3274 N/mm^2 and 5482 N/mm^2. For the other 9 treatment combinations which served as control for the experiment, i.e. cement-bonded particleboards which were not surface laminated, measured strength values (MOR) ranged from 5.40 N/mm^2 to 13.88 N/mm^2. The values exhibited by the control boards conform favourably with those earlier reported in literature on cement-bonded particleboard production from different wood raw materials (Prestemon, 1976, Dinwoodie, 1978, Bison-Werke, 1981, Denisov et al. 1985, Badejo, 1987, 1988 and 1989).

Table 1: Compiled average[1] for static bending strength (MOR) and stiffness (MOE) of veneer laminated 3-layered cement-bonded particle boards made from mixed tropical hardwoods.

Treatment Combinations				
Density of cored board (kg/m^3)	Cement of Mixing ratio of core board	Glue spread for surface lamination kg/92.9m^2 of veneer	Modulus of rupture (MOR) N/mm^3	Modulus of elasticity (MOE) N/mm^3
1000	2.00:1.0	0.0	5.40	1143
1000	2.00:1.0	25.0	25.56	3274
1000	2.00:1.0	32.0	25.98	3542
1000	2.50:1.0	0.0	7.05	1355
1000	2.50:1.0	25.0	25.71	3456
1000	2.50:1.0	32.0	26.97	3617
1000	3.00:1.0	0.0	7.46	1400
1000	3.00:1.0	25.0	25.99	3568
1000	3.00:1.0	32.0	27.41	3779
1100	2.00:1.0	0.0	8.02	1565
1100	2.00:1.0	25.0	27.27	3745
1100	2.00:1.0	32.0	30.02	4024
1100	2.50:1.0	0.0	8.87	1693
1100	2.50:1.0	25.0	27.76	3885
1100	2.50:1.0	32.0	30.97	4126
1100	3.00:1.0	0.0	9.72	1979
1100	3.00:1.0	25.0	28.57	4167
1100	3.00:1.0	32.0	33.86	4578
1200	2.00:1.0	0.0	10.96	2235
1200	2.00:1.0	25.0	30.38	4362
1200	2.00:1.0	32.0	34.48	4726
1200	2.50:1.0	0.0	12.07	2448
1200	2.50:1.0	25.0	31.98	4448
1200	2.50:1.0	32.0	39.65	5166
1200	3.00:1.0	0.0	13.88	2648
1200	3.00:1.0	25.0	33.96	4635
1200	3.00:1.0	32.0	41.64	5482

1 Based on 4 observations per each treatment combination.

Following surface lamination with veneers, the cement-bonded particle boards became considerably stronger and stiffer in building. For these laminated panels, the increase in strength over the control boards ranged from 145% to 381%. Similarly, the increase in stiffness of the laminated panels over the control boards ranged from 75% to 210%.

Scouting through literature, it appears that studies on surface lamination of cement-bonded particleboards with veneers is completely a new area of research. Unlike the case with the manufacture of wood-wool cement slabs, cement-bonded particleboards and flakeboards for which published studies abound (Namioka *et al*, 1972, Vermass 1973, Prestemon, 1976, Kawamura et al., 1979, Xia, 1982, Lee, 1984, Lange and Simatupang, 1985, Kavvouras, 1987, Badejo, 1987, 1988 and 1989) no reported literature has been found on surface lamination studies of cement-board particleblards. Similarly, no technical literature has been found on similar subject. The range MOR values of 25.56 to 41.64 N/mm^2 obtained for the laminated panels however compare more favourably and in many instances more than double the figures of 13.8 N/mm^2, and 19.0 N/mm^2 reported for 18mm thick chipboard bonded with Urea Formaldehyde (UF) and Melamine Formaldehyde (MF) glue respectively in Bison-Werke Technical Literature.

Table 2: Factorial analysis of variance for testing the effects of core layer cement-bonded particle-board density, cement to wood mixing ratio and lamination glue spread on strength and stiffness of laminated cement-bonded particleboard.

Source of variation	Degrees of freedom	Mean square (MS) values	
		MOR	MOE
Core board density (D)	2	577.53***	13.599**
Core board mixing ratio (R)	2	66.34	1.464**
Surface lamination glue spread (GS)	2	5511.74**	65.604**
D X R	4	8.97	0.065
D X GS	4	34.21	0.081
R X GS	4	4.95	0.033
D X R X GS	8	2.43	0.069
Error	81	16.52	0.058

**Significant at 1% level of probability.

For purposes of factorial analysis, the MOE data in Table 1 were reduced by a factor of 1,000 in order to reduce the magnitudes of MS values shown above.

The MOR and MOE data as evaluated in a 3 x 3 x 3 factorial analysis of variance with four replications are presented in Table 2. As the table shows, the levels at which the density of the core layer cement-bonded particleboards, the mixing ratio between the cement and wood used to fabricate them and the spread of the UF glue used for lamination were applied in the study experiment had significant effect at 1% level of probability on strength (MOR) and stiffness (MOE) of the panels. No two-way or three-way interactions were found between and among these three variables used for the experiment. MOR and MOE significantly increased as the density at which the core cement-bonded particleboard were produced increased. Similarly, production of this core substrate panels with increasing cement binder content manifested in production of significantly stronger and stiffer panels in static bending. The increasing strength and stiffness means values obtained as panels density increased, conform with previously published studies on cement-bonded particleboards and flakeboards (Dennisov *et al.* 1985, Kavvouras, 1987, Badejo, 1988). Similarly, strength and stiffness increase of the panels at increasing binder content level (as indicated by the mixing ratio levels between cement and wood) conform with previously published studies on cement-bonded particleboards (Prestemon, 1976; Xia, 1982) and resin-bonded particleboards (Post 1958, 1961).

Furthermore, stronger and stiffer panels in static bending were produced with increase in the quantity of spread of the resin adhesive used for lamination. The mean MOR and MOE values of 32.33 N/mm^2 and 4338 N/mm^2 respectively obtained at the glue spread level of 32 $kg/92.90m^2$ double glueline of veneer were significantly higher than the mean values of 28.5 N/mm^2 and 3949 N/mm^2 respectively obtained at the lower level of 25 $kg/92.90m^2$ double glueline of veneer. From the results obtained in this study, the highest MOR and MOE values of 41.64 N/mm^2 and 5482 N/mm^2 respectively originated from cement-bonded particleboards initially fabricated with a density of 1200 kg/m^3 and cement to wood mixing ratio of 3.00 to 1.0 and which, following drying to a moisture content level of 1%, were subsequently surface laminated with Mahogany veneers at a glue spread level of 32 $kg/92.90m^2$ double glueline.

Summary and Conclusion

In view of its inherent low strength, this study has clearly demonstrated that it is possible to increase the strength or cement-bonded particleboards from three-fold to four-fold through surface lamination by the use of appropriately formulated resin adhesive. From work done to date at the Forestry Research Institute of Nigeria, Ibadan successful lamination with veneers or strips of wood has been achieved with a number of Tropical Hardwood Timbers which include *Khaya* species (the Mahoganies), *Nesogordonia papaverifera* (Danta), *Nauclea diderrichii* (Opepe), *Gmelina arborea* (*Gmelina* - an exotic plantation - grown timber), *Terminalia* *ivorensis* (Idigbo), *Terminalia superba* (Afara), *Tectona grandis* (Teak: an exotic plantation-grown timber), *Mansonia altissima* (Mansonia), *Afzelia africana* (Afzelia) and Pines (Plantation-grown exotic timbers). Apart from ensuring re-cycling of wood wastes for production of value - added quality wood products, surface lamination of cement-bonded particleboards will increase the inherent strength and stiffness of the boards. It may also contribute to solving of the weight problems of the products as they may now be produced in thinner thicknesses and thereafter surface laminated to produce decorative face wood products for structural uses, panelling ceiling and possibly production of immovable furniture items. In view of these envisaged advantages, more research studies in this area are recommended. It is hoped that the results presented in this paper will stimulate all enquiring minds into the development of laminated cement-bonded particleboards.

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Effect of Under-water Storage on the Utilisation Value of Rubber Wood

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Abstract

Rubber wood is highly susceptible to the attack of biological organisms. The processing industries may need to store the wood at least for a few months. The present study investigated the effect of under-water storage on the strength properties of rubber wood. Rubber wood sizes stored under water for 3, 4, 5 and 6 months were subjected to static bending and compression parallel to grain tests. The strength data were corrected to 12% moisture content and compared with the strength data of non-ponded air-dried wood. It was found that the properties like modulus of rupture (MOR), modulus of elasticity (MOE), and fibre stress at limit of proportionality (FSLP) and density decreased with the storage period. But the percentage reduction in properties of wood stored under water for various lengths of time does not show any uniform trend. Test of significance by the ANOVA technique showed that the decrease was not statistically significant up to a storage period of 3-4 months. The study has shown that rubber wood stored under water up to a period of 3-4 months can be used safely for all end-use applications, except in cases where maximum compressive stress (MCS) is critical. Under-water storage of rubber wood beyond a period of 4 months is not recommended as far as its mechanical properties are concerned.

Key words: Rubber wood, under-water storage, strength properties.

Introduction

Rubber plantations are an important non-conventional and Lesser-Used source of timber. Rubber plantations ensure a sustained supply of wood as the plantations are managed on a rotation of 25-30 years. Utilisation of this resource can indirectly contribute to the conservation of natural forests. The major rubber growing ASEAN countries have the potential of producing 19 million m^3 of rubber wood logs per annum based on an annual replanting rate of 3% and an estimated yield of 100 m^3 per hectare (Ser 1990).

India is among the leading rubber growing countries in the world. According to the estimates of the Rubber Board of India (RRII 1992), the total annual rubber wood production in India is about 1.27 million m^3, out of which 60% is stem wood and the rest branch wood. Kerala State alone accounts for about 86% of the total area under rubber cultivation in India.

It is estimated that about 50% of the demand-supply imbalance of wood in India can be resolved by rubber wood. Thus, rubber wood can play a very important role in the timber scenario. Conversion of this perishable wood into value added products through chemical treatments warrants attention since it is available at comparatively low cost and the plantations are likely to become one of the most promising sources of wood. Because of the acute timber scarcity, the stem wood of rubber trees now finds many applications. Effective utilisation of this wood will relieve pressure on our forests to a significant extent.

The perishable nature of rubber wood - its susceptibility to fungal and insect attack - limits its wider utilisation. Rubber wood will continue to be under-utilised if it is not treated with preservative chemicals for protection against fungi and insects. It is for this reason that rubber wood has been traditionally used for firewood, packing cases and match veneers. Only through developing appropriate techniques for the protection can wood from rubber trees be effectively and efficiently utilised. Dhamodaran (1996) is one of the most recent works undertaken in India in this respect.

Storage of raw material for a few months is most likely required for running a medium to large-scale rubber wood processing unit, as the availability of this timber may not be regular throughout the year. Because of its acute susceptibility to biodegradation, the method of storage of rubber wood is very important. Under-water storage is an effective way to protect timber from the attack of biological organisms. This method of storage needs to be evaluated in the case of rubber wood. Tan *et al.* (1980) showed that under-water storage is an effective way to protect wood from immediate fungal attack. They tried under-water storage up to a period of one month only. They found that this method of storage of raw material was superior to the application of end coats to prevent sap stain development during the storage period. It is important to assess the effect of under-water-storage on the physical and mechanical properties of rubber wood, as much data on this aspect is not reported so far.

Materials and methods

Fresh green rubber wood billets of 500-700 mm girth and 1 m length from slaughter tapped trees of age 30-35 years, collected from felling areas in central Kerala, India, were used in the study. Eighteen billets were kept in round form with bark intact and 18 billets were squared. Some more billets were converted to planks of 150-mm width and 25, 50 and 75 mm thickness. There were 30 planks for each thickness. Squared billets and sawn planks were kept under water (tap water) in one tank and the round billets with bark were kept in another. Both the tanks were in the open (outside). Water was replaced every 10 days.

At the end of 45, 60, 90, 120 and 180 days, 5 planks each of 25, 50 and 75 mm thickness, 3 squared billets and 3 round billets were removed. The billets and sizes were sawn to look for the extent of sap stain.

Evaluation of physical and mechanical properties of rubber wood stored under-water

The main mechanical properties investigated in the study are the bending and compression strengths. Tests were limited to these two as modulus of rupture (MOR) and modulus of elasticity (MOE) and maximum crushing stress (MCS) will give a fairly good indication of the utilisation potential.

Rubber wood stored under water for 3, 4, 5 and 6 months were subjected to testing for their physical and mechanical properties. Defect-free specimens of size 20 x 20 x 300 mm for static bending test and 20 x 20 x 80 mm for compression parallel to grain test were prepared from the ponded air-dried wood. Tests were carried out in an 'Amsler' Universal Testing Machine. Density of the samples was determined by water-displacement method and moisture content by oven-drying. The physical and mechanical properties were determined according to Indian Standard IS 1708-1986 (BIS, 1986). All strength data were corrected to 12% moisture content for comparison purposes, using the formula suggested by Sekhar and Rajput (1968).

All the tests were repeated on samples prepared from non-ponded, air-dried control material for comparison (Gnanaharan and Dhamodaran, 1993).

Results and discussion

Optimum under-water storage conditions

No sap stain development was observed in billets, either with intact bark or without bark, kept under water for a period of up to 6 months. Beyond 3 months algal growth was observed on the samples causing a greenish colour on the surface of the samples. However, this was found limited only to the surface and the wood inside was clean as found from sawn samples. Bacterial activity was noticed after 4 months causing foul smell. This was in spite of the fact that water was changed frequently (every ten days) to reduce algal and bacterial growth.

To avoid extractives from the bark polluting the water, it is advisable to store wood under water in squared billet form. This will further help to accommodate more volume. Sawn sizes can also be stored under water.

Effect of under-water storage on physical and mechanical properties

Table 1 shows the effect of under-water storage on the physical and mechanical properties of rubber wood in air-dried condition (MC 12%). For comparison purposes, the physical and mechanical properties data of non-ponded, air-dried rubber wood at 12% MC were extracted from an earlier report of Gnanaharan and Dhamodaran (1993). It can be seen that from an under-water storage period of 3 months onwards up to 6 months, values of physical and mechanical properties show a decreasing trend (Figure 1). The slightly high value of MOR for wood stored under water for 3 months may be due to the sampling errors. Except this, the values of all other mechanical properties of under-water stored wood are lower than the non-ponded, air-dried wood.

Table 1: Effect of under-water storage on the physical and mechanical properties of rubber wood (CV (%) values are given in brackets).

Property	Under-water storage period (months)				
	0**	3	4	5	6
FSLP (N/mm^2)	60.45 (24.4)	53.47 (19.0)	48.70 (19.3)	45.83 (5.6)	38.49 (24.0)
MOR (N/mm^2)	98.35 (4.2)	107.90 (13.2)	96.83 (9.4)	87.55 (12.4)	70.16 (22.3)
MOE (kN/mm^2)	15.67 (37.8)	14.77 (34.9)	11.69 (22.6)	9.06 (27.1)	7.23 (32.4)
MCS (N/mm^2)	52.73 (9.5)	44.01 (7.1)	50.12 (11.8)	45.01 (14.1)	36.75 (15.7)
Density* (kg/m^3)	580.0 (5.5)	557.9 (5.9)	551.3 (3.4)	513.9 (6.7)	473.3 (8.3)

* *Mean of 12 samples, all other parameters, mean of 6 samples.*
** *Values of the mechanical properties of non-ponded air-dried rubber wood at 2% MC (extracted from Gnanaharan and Dhamodaran (1993)).*

Table 2. Analysis of variance (ANOVA) of the data on the effect of under-water storage on physical and mechanical properties of rubber wood. Test of significance.

Property	Between non-ponded and 3 months ponded			Between non-ponded and 4 months ponded			Between non-ponded and 5 months ponded		
	D.F	M.S	F. ratio	D.F	M.S	F. ratio	D.F	M.S	F. ratio
FSLP	1	146.091	0.913^{ns}	1	320.333	2.543^{ns}	1	641.526	5.722*
MOR	1	245.708	2.318^{ns}	1	6.871	0.137^{ns}	1	352.242	7.379*
MOE	1	2.493	0.081^{ns}	1	46.138	2.216^{ns}	1	131.209	6.389*
MCS	1	228.202	13.045**	1	20.384	0.681^{ns}	1	178.641	5.471*
Density	1	3037.500	2.854^{ns}	1	5075.042	7.388*	1	26467.042	24.038**

ns = *Not significant*
* = *Significant at 5% P level*
** = *Significant at 1% P level*

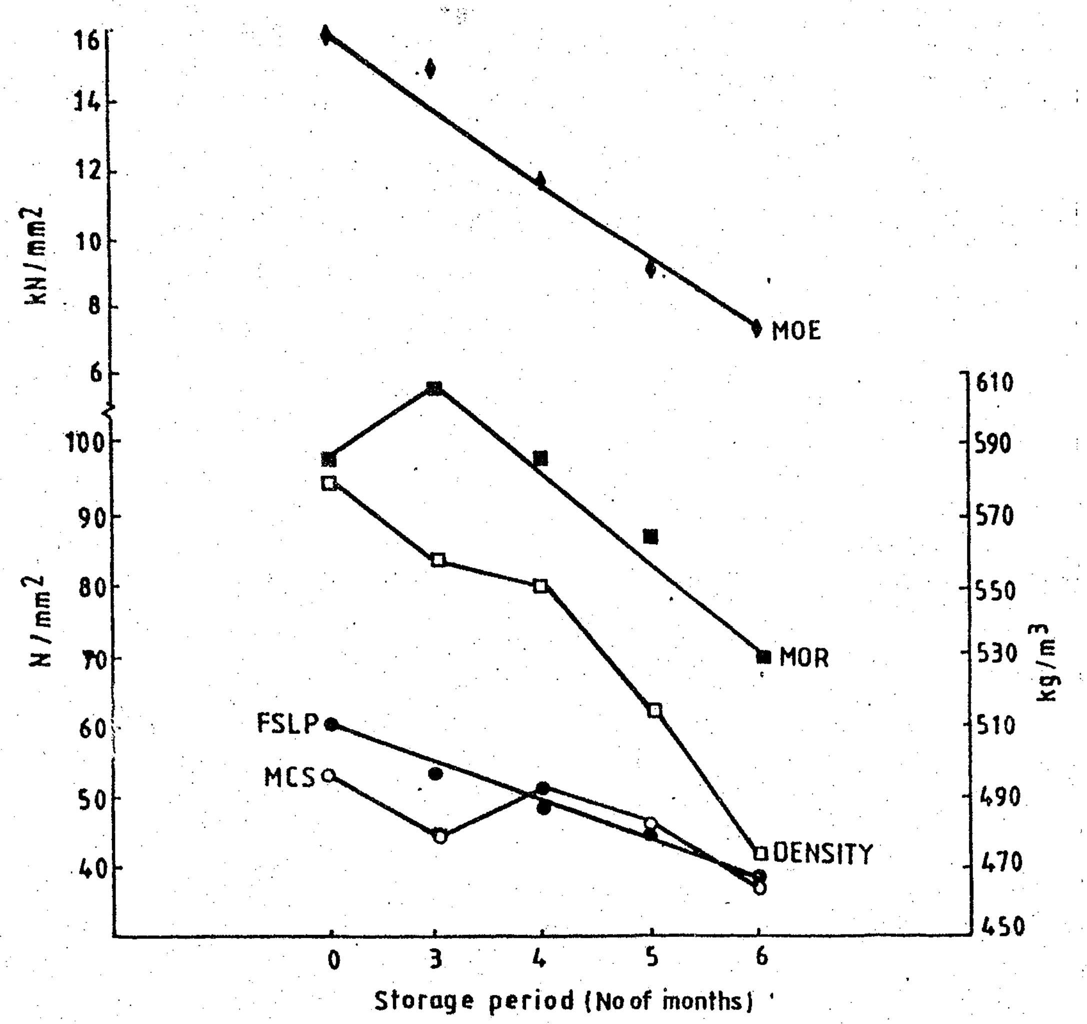

Figure 1. Effect of under-water storage period on the physical and mechanical properties of rubber wood.

Liese (1984), in his review of the wet storage of wind-blown conifers in Germany, observed a reduction of up to 10-15% in impact bending and compression strength after 3 years of wet sprinkler storage of pine wood. He did not observe further reduction after five years' wet storage. MOR and MOE after 4 years sprinkling were sufficiently high to satisfy the standard requirements of marine (boat) timber for which the level is higher than the construction timber. He found no significant strength reduction affecting later utilisation due to prolonged wet storage. The findings of this study, which are contrary to the above findings, may be due to the difference in nature of the timber species.

The percentage reduction in properties of wood stored under water for various lengths of time does not show any uniform trend. The data were subjected to test of significance by the ANOVA technique and Table 2 gives the results of the test. Pair-wise comparison was made between non-ponded, air-dried wood and 3, 4 and 5 months ponded wood. It can be seen that the reduction in values of FSLP, MOR and MOE due to under-water storage is not significant up to a storage period of 3-4 months. The reduction in wood density is also not significant for 3 months, but significant at 5% level for wood stored for 4 months and highly significant (1% level) for wood stored for a period of 5 months. Naturally, storage beyond 5 months will adversely affect all the mechanical properties.

In the case of MCS, 3 months under-water stored wood is significantly different (at 1% level) from the non-ponded air-dried material. However, for 4 months under-water stored wood it was found non-significant. For 5 months under-water stored wood, it is again found significant. To clarify the situation, wood stored under water for a period of 1 and 2 months were subjected to compression parallel to grain test at air-dried condition.

The mean values of MCS were 38.39 and 41.66 N/mm^2 respectively (mean of 6 samples each). The mean MCS for non-ponded air-dried rubber wood is 52.73 N/mm^2. This clearly shows that the higher values obtained for the MCS of 4 months under-water stored air-dried wood material may be due to sampling problems.

Conclusion

Rubber wood can be stored under water without any problem of sap stain development. To accommodate more volume and to avoid the problem of polluting water with the extractives from bark, it is advisable to store wood under water in squared billet form. Sawn sizes can also be stored under water. If the storage is in an artificial pond, the water needs to be changed once in a week or ten days to avoid foul smell.

Under-water storage reduces all the physical and mechanical properties of rubber wood. Up to three months under water, storage does not significantly affect the wood density; up to four months, the reduction is significant at 5% level. Whereas fibre stress at the limit of proportionality (FSLP), modulus of rupture (MOR) and modulus of elasticity (MOE) are not significantly affected up to a storage period of four months. MCS is significantly lowered due to under-water storage, even for a period of one month. Hence, for all other end-uses except in cases where MCS is important, a storage period of 3-4 months does not significantly affect the utilisation value of the timber. For end-uses where MCS is critical, it is advisable to avoid the use of under-water stored wood.

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The Distribution, Density, and Estimates of Carbon and Inorganic Nutrients in some Lesser-Used Species

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Introduction

Timber is the third foreign exchange earner for Ghana and timber exports had for some time now been based on the so-called prime timber species (Table 1) with little attention being paid to other species called secondary species or Lesser-Used species (LUS). This is with the result that prime species have been exploited, most of them are currently threatened, and their harvesting either reduced or banned.

To sustain the timber industry therefore attention has been focused on the promotion of the Lesser-Used species.

Currently however, many international initiatives have focused on sustainable management of forests, and this has resulted in the establishment of Forest Stewardship Council (FSC) which has the ambition of setting world-wide standards for good forest management (FSC, 1992). The FSC is currently drawing up the principles and criteria for forest management which they hope will be used by organisations for forest monitoring and certification, consumers of forest products and policy makers. The FSC is also proposing to become an independent non-governmental international organisation, which will evaluate, accredit and monitor forest certification programmes. Certification of forest products will be one way to promote sustainable forest management practices. They propose that this should be market driven. Certification initiative that will provide economic rewards to forestry operations which will ascribe to management practices that are ecologically sustainable, socially beneficial and economically viable. By complying with certifying standards, the forest products will be granted access to the burgeoning worldwide 'green' market. The implications are that unless forestry activities are sustainable and environmentally acceptable, access to market will be difficult. Thus, sustainable forest management is necessary if the marketing of LUS is to succeed.

Sustainable forestry as recently defined means "the stewardship and use of forests and forest land in such a way and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil now and in the future, relevant ecological, economic and social functions at local, national and global levels, and that does not cause damage to other ecosystems" (Helsinki Ministerial Conference, 1994).

Maintenance of productivity is an essential factor for sustainable forest management. However, one of the most important factors for productivity is nutrient availability. Thus in assessing the ecological sustainability of forest activities, the impact on nutrient availability should be determined. Many studies have however shown that in tropical forests between 60-90% of nutrients are stored in the above-ground biomass (Jordan 1985, Ruhiyat 1989). Thus, estimation of nutrients in the above-ground biomass of any species is a good indicator of the contribution of the species to nutrient availability in the ecosystem. Also among current global environmental problem that is of most concern is the accumulation of green house gases in the atmosphere which has begun to change the global climate (IPCC 1990).

Reports suggest that managed forests and agroforestry systems have the potential to sequester and conserve about 10GT of carbon annually. Thus one of ecologically functions of the forest that is of global interest and which should be part of sustainable forest management practices is the sequestration and conservation of carbon.

However, the contribution of LUS in Ghana to nutrient availability and sequestration of carbon is not known. However, these contributions to ecological sustainability cannot be discussed without reference to the resource base. This paper therefore provides estimates nutrient and carbon storage of some Lesser-Used species as well as distribution and density.

Distribution and density

The LUS considered in this paper are shown in Table 1. Concerning distribution, *Ceiba pentandra* and *Antiaris toxicaria* were the two species that had the widest distribution with distribution in all the forest ecological zones. *Celtis mildbraedii* and *Sterculia rhinopetala* were distributed in all the forest ecological zones except the Wet Evergreen Forest Zone.

Petersianthus macrocarpus and *Cylicodiscus gabunensis* were however restricted mainly to the Moist Evergreen and Moist Semi-Deciduous Zone.

Table 1: Some Lesser-Used species with the total volume and above felling limit

Timber	Local	Species	Stocking above felling limit (CU.M)
Ceiba	Onyina	*Ceiba pentandra*	3,240
Albizia	Awiemfosamina	*Albizia ferruginea*	5,371
Antiaris	Kyenkyen	*Antiaris toxicaria*	10,134
	Bonsamdua	*Distemonanthus benthamianus*	3,885
Yellow Sterculia	Wawabima	*Sterculia rhinopetala*	5,308
	Esia	*Petersianthus macrocarpa*	23,665
Celtis	Esa	*Celtis mildbraedii*	67,709
	Denyau	*Cylicodiscus gabunensis*	16,209

This distribution might be related to the soil fertility, pH and rainfall in the different ecological zones. Thus *Ceiba* and *Antiaris* are widely distributed because they can tolerate the acidic soils as well as nutrient rich and poor soils.

Celtis mildbraedii and *Sterculia rhinopetala* on the other hand may be sensitive to low pH and nutrient soils, while *Petersianthus macrocarpa* and *Cycliodiscus gabunensis* had the highest total stocking i.e. for all species >5cm dbh as well as the highest stocking for trees above the felling limit. *Sterculia rhinopetala* had the next highest total stocking, but had the lowest stocking above felling limit.

Petersianthus macrocarpa had the next highest total stocking. However, the stocking above felling limit was almost equal to that of *Ceiba pentandra*, which also had almost equal total stocking to that of *Antiaris toxicaria.*

Ceiba pentandra however had almost twice stocking above felling limit as *Antiaris toxicaria.*

Cyclicodiscus gabunensis had the lowest total stocking but the stocking limit was higher than that of *Sterculia rhinopetala.*

Carbon and nutrient content

The carbon and nutrient content for the LUS in the Moist Evergreen and Moist semi-Deciduous Forest Ecological Zones are shown in Tables 2 and 3.

In the Moist Evergreen Zone, *Celtis mildbraedii* had the highest content and this was closely followed by *Cylicodiscus gabunensis*. The carbon content for the other species in decreasing order *Distemonanthus benthamianus> Ceiba pentandra >Albizzia ferruginea> Petersianthus macrocarpa> Antiaris africana.*

In the Moist Semi-deciduous zone, the carbon content in decreasing order were *Cylcodisus gabunensis> Albizzia ferruginea> Petersianthus macrocarpa> Ceiba pentandra> Celtis mildbraedii >Antiaris toxicaria> Distemonanthus benthamicumus.*

This same pattern was observed for the accumulation of nutrients. Comparing the two ecological zones, it could be observed that species in the moist semi-deciduous zone had higher accumulation than the species in the moist evergreen zone. The differences observed could be attributed to the soil pH and nutrients in the different zones (Schulte 1994). The moist semi-deciduous zone which has soils of slightly lower pH and higher cation capacity than the soils of moist evergreen zone had the higher accumulation of carbon due to the higher growth rate and hence higher biomass. However, the differences observed for the different species in the same ecological zone could be attributed to the inherent characteristics of the species which differ from one species to another (Whitmore 1975).

Conclusion

Lesser-Used species contribute significantly to the productivity of the forest ecosystems through storage of nutrients that are subsequently re-cycled through litter fall and decomposition. They also fix a lot of carbon dioxide into timber that is expected to prevent global warning. Since decreased productivity and global warning will have negative effects on many forest ecosystems, these ecological functions of the LUS are wise investments for sustainable forest management. However, the amount of carbon and nutrients stored differ between species on the same site and also differ for the same species under different site contributions.

Thus in allocation Lesser-Used species as yield for felling consideration should seriously be given to these ecological functions they perform.

Table 2: Amount of carbon and other nutrients (kg/ha) in whole tree of some Lesser-Used species (LUS) in Moist Evergreen Forest Zone

Species	Biomass	C*	N	P	K	Ca	Mg
Albizzia ferruginea	10.3	5173	236	5	51	206	26
Antiaris toxicaria	7.8	3939	181	4	39	157	19
Ceiba pentandra	11.6	5811	267	6	58	232	29
Celtis mildbraedii	21.8	10900	501	11	109	436	55
Cyclicodiscus gabunensis	20.1	10190	409	10	101	407	51
Distemonanthus benthamiamus	12.3	6168	283	6	61	246	31
Petersianthus macrocarpa	8.1	3939	186	4	41	163	20

**The C content was estimated from C = stem volume x 1.6 x Density x 0.5*

Table 3: Amount of carbon and other nutrients (kg/ha) in whole tree of some Lesser-Used species (LUS) in Moist Deciduous Forest Zone.

Species	Biomass	*C	N	P	K	Ca	Mg
Albizzia ferruginea	14.1	7060	324	7	71	282	35
Antiaris toxicaria	8.7	4354	200	4	43	174	22
Ceiba pentandra	11.7	5862	269	6	59	232	29
Celtis mildbraedii	11.5	5795	116	6	58	232	29
Cyclicodiscus gabunensis	23.1	11550	531	12	115	462	58
Distemonanthus benthamiamus	6.3	3168	145	3	32	126	16
Petersianthus macrocarpa	12.8	6400	294	6	64	256	32

The C content was estimated from C = stem volume x 1.6 x Density x 0.5

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Appendices

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Appendix III - Conference Programme

Day 1 - Tuesday, 17th February 1998

8.00 a.m.	Registration of participants	
Opening Ceremony		
	Chairperson: Ashanti Regional Minister	
9.30 a.m.	Introduction of Chairman	Director, FORIG
	Chairman's Response	
	Welcome Address	Director-General, CSIR
	Brief Statement	Minister of Environment, Science & Technology
	Brief Statement	Minister of Trade & Industry
	Brief Statement	ITTO representative
	Keynote Address	Minister of Lands & Forestry
	Chairman's Closing Remarks	
	Vote of Thanks	Director, WITC
	Opening of Exhibition	Minister, MEST
	Group Photograph	
	Tea/Coffee Break	

11.00 a.m. **Technical Session I: Project Overview**

Chairperson: Mr. E. Kofi Smith, Technical Director, ML & F

1st Keynote Paper: International trends in timber engineeringand utilisation of Lesser-Used timber species	Dr. R.H. Leicester
Overview of ITTO Project PD 179/91	Project Leader, Dr. A. Addae-Mensah

1.00 p.m. **Lunch**

2.00 p.m. **Technical Session II: Ecology, Hydrology and Resource Base**

Chairperson: Mr. E.O. Nsenkyire, Chief Conservator of Forests

Distribution and abundance of Lesser-Used timber species	Dr. D. Blay Jnr.
Logging disturbance and tree damage after logging	Dr. V.K. Agyemang & Dr. M.D. Swaine
Regeneration after logging in two different forest reserves	Mr. A.R. Adam & Dr. M.D. Swaine
Forest resources utilisation and its impact on the environment	Dr. V.K.Agyeman & Dr. D. Blay Jnr.
Wood volume recovery in selective logging	Mr. A.R. Adam
Break	
Forest degradation and its effect on sustained water supply	E.O. Bekoe (WRI)
Forestry and rural development in developing countries	Mr. Adam Abu

6.00 p.m. **Cocktail Party**

Day 2 – Wednesday, 18th February 1998

9.00 a.m. **Technical Session III: Processing and Product Development**

Chairperson: Dr. E.O. Bello, Director, FPDRI, Philippines

2nd Keynote Paper: Increased utilisation of Lesser-Used species: Social and economic impact	Mr. Ben Kuffour
Identification of Lesser-Used timber species of Ghana	Dr. A. Oteng-Amoako, *et al.*
Processing and product development of Lesser-Used timber species	Mr. K.G. Nilsson
Machining characteristics and allied properties of LUS	Mr. Eddie Prah
Recent advances in the machining of Lesser-Used wood species	Dr. Reynolds Okai
10.30 a.m.	**Tea/Coffee Break**
Status of the timber industry in Ghana	FPIB
Durability of solvent-based wood finishes	Dr. K. Frimpong-Mensah
The quality of mouldings, furniture and cabinets manufactured from lesser-utilised tropical hardwoods	Mr. C.K. Gyamfi
Wood residue densification technologies: their applications, prospects and problems in the developing countries	Dr. S.A. Dada
12.30 p.m.	**Lunch**
1.30 p.m.	**Excursion to wood processing companies**

Day 3 – Thursday, 19th February 1998-09-03

Chairperson: Mr. Johnny François, Forestry Consultant, Accra

9.00 a.m. **Technical Session IV: Marketing and socio-economic issues**

Marketing of LUS: Impact on the timber industry	Prof. Ivan Eastin & Mr. S.K. Appiah (TEDB)
The enhanced utilisation and marketing of Lesser-Used species: A policy perspective	Mr. J.G.K. Owusu
Administrative and institutional structures for ensuring sustainability of the forest ecosystem	Mr. E.O. Nsenkyire
10.00 a.m.	**Tea/Coffee Break**

10.30 a.m. **Technical Session V: Timber engineering and reconstituted wood**

Lesser-Used timber species in construction	Mr. D.L. Jayanetti
Design and experimental qualification of the mechanical properties of plywood	Prof. Daniel Guitard
Prospects of utilisation of Lesser-Used species	Mr. K.S. Nketiah
Re-cycling of wood wastes for the manufacture of structural laminated cement-bonded particle boards	Dr. S.O.O. Badejo
Effect of under-water storage on utilisation value of rubber wood	Dr.T.K. Dhanodaram & Dr. R. Gnanaharam
12.30 p.m.	**Lunch**

2.30 p.m. Statement by Mr. K. Wireko-Brobbey

Expert Committee recommendation and discussion on the utilisation of LUS

3.00 p.m. **Tea/Coffee Break**

3.30 p.m. **Closing Session**

Chairperson: Dr. J.R. Cobbinah, Ag. Director, FORIG

Highlights of the Conference	E. Siisi Wilson
The way forward	Chairperson
Vote of thanks	Mr. Bedu-Mensah
Closing	
7.00 p.m.	**Dinner**