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Domestication and commercialization of non-timber forest products in agroforestry systems

Food and Agriculture Organization of the United Nations

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Proceedings of an international conference held in Nairobi, Kenya
19-23 February 1996
edited by

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Foreword

The International Conference on Domestication and Commercialization of Non-Timber Forest Products in Agroforestry Systems, hosted by ICRAF, was held in Nairobi, Kenya, from 19 to 23 February 1996. This was the first world-level meeting to be held exclusively to draw attention to issues dealing with domestication and commercialization of non-timber forest products in agroforestry systems.

Coordinated by ICRAF, a number of international and national agencies, namely: FAO, IUFRO, Unesco, the Australian Centre for International Agricultural Research, the British Development Division in Eastern Africa, the Centre Technique de Coopération Agricole et Rurale, the International Foundation for Science, the Ministry of Foreign Affairs of the Netherlands, the Overseas Development Administration - Forestry Research Programme, the United States Agency for International Development, and the International Society of Tropical Foresters, collaborated in this undertaking by providing funds, background materials and papers, by sponsoring participants and/or by direct attendance.

The outcome of the Conference was substantial, with clear recommendations for action. We have pleasure in sharing it with all interested persons and institutions.

We wish to take this opportunity to acknowledge with thanks the contribution of all those who attended the Conference and their active participation in the discussions, which made this meeting a remarkable success. We also wish to thank all those who collaborated with, and supported the efforts of, ICRAF in organizing this Conference. Special thanks are also due to the Chairpersons of the five working groups (C. Kleinn, C.K. Mwamba, V. Shah, F. Sinclair and I. Kone) and the respective rapporteurs (R. Kindt, D. Kiambi, J. Were, I. Dawson and P. Rudebjer). We fully appreciate the contribution of R. Leakey, A. Temu, M. Melnyk and P. Vantomme in reviewing and editing the Conference report. Finally, we wish to thank M. Kimenye and H. Abdalla for their hard work retyping the manuscripts, D. Odanga for the design and layout, and H. van Houten and K. Kebaara for editorial support.

No doubt, the perspectives on domestication and commercialization of non-timber forest products in agroforestry systems, as they emerged from the discussions at the Conference, and the light they throw on how to address issues dealing with resource assessment, indigenous knowledge, product development, socio-economic benefits, environmental impact, and institutional and policy aspects, will help national and international agencies in designing and implementing their activities on non-timber forest products. ICRAF and FAO are committed to pursue the outcome of the Conference and to support the implementation of its recommendations, in collaboration with partner agencies and countries.

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International Centre for Research in Agroforestry

Countries participating in ICRAF's ecoregional programmes.

The International Centre for Research in Agroforestry (ICRAF), established in 1977, is an autonomous, non-profit making research body supported by the Consultative Group on International Agricultural Research (CGIAR). Its goal is to help mitigate tropical deforestation, land depletion and rural poverty through improved agroforestry systems.

ICRAF's objectives are to conduct strategic and applied research, in partnership with national institutions, aimed at developing appropriate agroforestry technologies for more sustainable and productive land use; to strengthen national capacities to conduct agroforestry research; to encourage inter-institutional collaboration; and to promote training, education, information and dissemination activities in agroforestry. ICRAF has research activities in 20 countries in Africa, Latin America and Southeast Asia, and dissemination activities in very many more countries.

ICRAF works in six ecoregions: the humid lowlands of West Africa, the humid tropics of Latin America, the humid tropics of Southeast Asia, the sub-humid plateau of southern Africa, the highlands of East Africa and the semi-arid lowlands of West Africa.

ICRAF's activities are conducted through four research and three dissemination programmes: Natural Resource Strategies and Policy, Domestication of Agroforestry Trees, Tree–Crop–Environment Interactions, Systems Improvement, Training, Education and Information.

The objectives of ICRAF's Domestication of Agroforestry Trees Programme are to improve the genetic quality of agroforestry trees by collecting, evaluating and selecting germplasm for compatible production of food, fodder, fuelwood, timber and other products with companion crops, and for providing environmental services such as soil conservation and the amelioration of soils.

ICRAF is governed by a Board of Trustees, which has equal representation from developed and developing countries. Financial support for ICRAF's research, training and information activities is provided by 32 donors

THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO)

International organizations have major roles to play in fostering the protection and wise management of the world's forests and related natural resources. The forestry mission of the Food and Agriculture Organization of the United Nations is *to enhance the contribution of trees and forests to global human well-being.*

This mission is carried out through three medium-term objectives, each of which are equally important and are simultaneously pursued, as follows: (i) the environmental objective is the maintenance of the biological diversity, health and other environmental services of forest ecosystems and wooded lands; (ii) the economic objective is the realization of the full economic potential of the multiple goods and services of forests and wooded lands, without impairing their productive or protective capacities; (iii) the social objective is the increase of public participation in decision-making and the sharing of costs and benefits of trees and forests while facilitating the resolution of conflicts and promoting collaboration among interest groups.

The FAO forestry programme constitutes among the largest bodies of international forestry and related natural resources expertise available in the world. It includes some 80 full-time professional staff with a diverse range of skills in forestry, wildlife resources, watershed management, agroforestry, non-wood forest products, genetics, economics, forest products utilization and engineering. This broad skills-base allows the Organization to address the full environmental-economic-social spectrum of sustainable forest management. Also, linkages of the forestry programme to the agriculture, economics, fisheries and sustainable development programmes in FAO give it a multi-disciplinary, cross-sectoral strength that facilitates consideration of forestry's role in food security, rural development and land use. At the operational level, the forestry programme is supported by up to 200 contracted project professionals responsible for providing on-site technical assistance to developing countries.

In common with other UN agencies, FAO provides: a neutral forum for policy and, technical dialogue; information and knowledge; and technical assistance. Since its founding in 1945, FAO has grown to include 174 member countries. This broad membership allows FAO to address issues facing all the world's forests - boreal, temperate, subtropical and tropical; forests in developed and developing countries; dry forests and humid ones; high altitude forests and mangroves; even trees on farms and in cities.

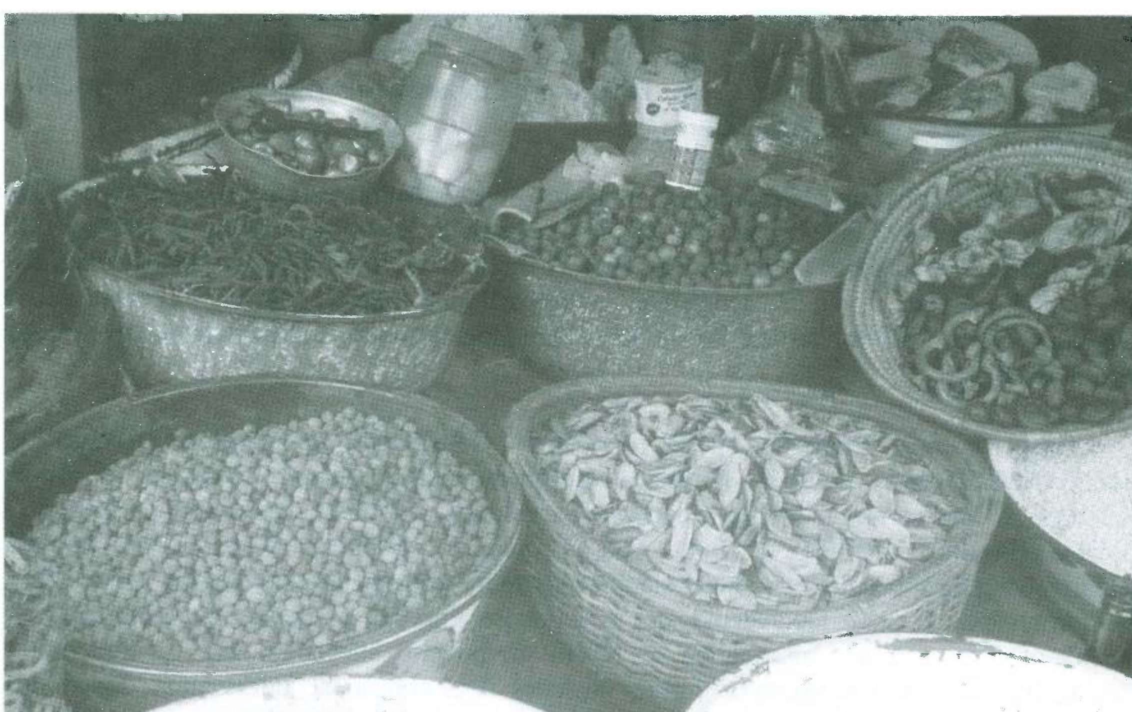
The programme "Promotion and Development of Non-Wood Forest Products (NWFP)" at the Forest Products Division of FAO's Forestry Department, aims to enhance the value of non-wood forest products and services through improved harvesting, utilization, trade and marketing. The sustainable utilization of NWFP, combined with an equitable distribution of the benefits obtained by closely involving local people, contributes significantly to the wise management of the world's forests, to the conservation of their biodiversity and to a precise appraisal of their socio-economic values. Income generation and the contribution of NWFP to poverty alleviation and food security are important elements. The programme further includes data collection, information dissemination, technology transfer, networking and strengthening of partnerships on NWFP development, training and policy advice.

Conference recommendation to FAO for the World Food Summit

During the Domestication and Commercialization of Non-timber Forest Products for Agroforestry Systems Conference, 19–23 February 1996, the delegates made the following recommendation:

- recognizing that non-timber forest products (NTFPs) have played a traditional role in the feeding of people throughout the tropics;
- recognizing that NTFPs play an important role in food security, especially in dry years;
- recognizing that NTFPs play a crucial role in the health and nutrition of people in tropical countries;
- recognizing that the sale of NTFPs allows people the freedom to purchase essential inputs in support of agriculture;
- recognizing that through domestication many NTFPs can be improved qualitatively and quantitatively to be more attractive to farmers, more marketable and so contribute to the alleviation of malnutrition and poverty,

This conference recommends that FAO includes edible non-timber forest products, and their domestication, on the agenda of the forthcoming World Food Summit.



Kernels of Irvingia gabonensis *and* Ricinodendron heudelottii *on a market stall in Kumba, Cameroon. Products of many tropical trees worthy of domestication are traded locally and regionally in this way. Domestication of such trees requires that these traditional markets be expanded. (Photo: R.R.B. Leakey)*

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Product domestication and adoption by farmers

Linkages between domestication and commercialization of non-timber forest products: implications for agroforestry

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Introduction

People throughout the tropics have depended on their indigenous plants for food security and a host of everyday products, from medicines to fibres. The study of these uses is the domain of ethnobotany, while their place in trade is that of economic botany. Trees, in particular, have been an important group of plants meeting the needs of hunter-gatherers, subsistence and small-scale farmers. Too often scientists have overlooked the needs of people for these products, and considered that 'access by farmers to modern inputs such as improved livestock, crop varieties and hybrids, fertilizers, and pest control measures, as well as credit, technical assistance, and improved farm management practices are essential components of a successful strategy to meet food production and development goals' (Pinstrup-Anderson 1993).

With the ravages of deforestation the overlooked indigenous plant resources have come under severe pressure, made worse by the growing numbers of people in tropical countries, many of whom depend upon these sources for fulfilling some of their basic needs. These pressures have led to the concept of domesticating many of these indigenous plants (Leakey & Newton 1994a, Leakey & Jaenicke 1995, and the papers of this volume) and incorporating them in agroforestry systems (Sanchez 1995, Sanchez & Leakey in press) primarily for the benefit of small-scale, resource-poor farmers. This represents a new paradigm for feeding the world. Instead of focusing on a limited number of highly domesticated crops, often grown in monocultures, this new paradigm is based on a much greater diversity of plants, including many partially domesticated tree crops providing an array of products for consumption and trade. Is this a viable option?

Domestication

In 1992, a conference pulled together the growing amount of biophysical information on the techniques to domesticate a wide range of these overlooked 'Cinderella' tree species (Leakey & Newton 1994 a, b) and indicated that this could be the start of a woody-plant revolution (Leakey & Newton 1994c), to match the importance of the very successful'Green Revolution'. Many people and organizations are increasingly publishing information about the use, domestication and marketing of non-timber forest products (NTFPs): see for example the references quoted in the papers of this proceedings. This groundswell of activity augurs well for the future; both for resource poor people in the rural and urban tropics and for the forests which currently bear the brunt of exploitation. However, despite this level of interest among biophysical scientists there is a need, as pointed out by Dewees and Scherr (1996), for policy scientists to 'stretch their conceptual framework . . . and to consider more carefully the links between markets, the environment, household production and household welfare'.

Commercialization

Many of the products from Cinderella trees are already sold on local and regional markets, and a few have broken through into the international marketplace. For example, while the pulp of the bush mango *(Irvingia gabonensis)* is eaten fresh, its extracted kernels and those of the related species *I. wombolu* are traded regionally throughout the year. From Cameroon, this trade extends to Nigeria, Equatorial Guinea and Gabon (Falconer 1990, Ndoye 1995). Similarly, the trade of kola nuts extends from humid zone countries of west Africa up into the dry zone, where there is a big demand by the Muslim community (Falconer 1990). Chewing sticks likewise are traded northwards in West Africa, with a street value put on the trade from Kumasi market in Ghana of about USD 9 million per year (Falconer 1992). Again in Cameroon, the bark of *Prunus africana* (pygeum) is exported to Europe where pharmaceutical products estimated to be worth USD 150 million per year are produced for worldwide trade and treatment of prostate gland disorders (Cunningham & Mbenkum 1993). In southern Africa, some indigenous fruits are marketed locally as wines and jams, with a liqueur from *Sclerocarya birrea* fruits ('marula') now on the international market. In Amazonia, products from the peach palm *(Bactris gasipaes)* are also being exported. The palm heart trade has been estimated at around USD 50 million per annum (Clement & Villachica 1994), with the fruits also having a similar value.

It is clear from these few examples that NTFPs have a place in the economies of tropical countries. Those being traded internationally usually involve some processing, either before or after exportation. Currently, most of these products are being collected in the wild, and of the above examples only peach palm is being grown purposefully for export markets. These examples indicate that one possible way of increasing the welfare of smallholder farmers would be to undertake research on two complementary topics, namely, the domestication of selected tree species by improving specific traits (e.g., quality, extension of period of production) and the marketing and processing of the NTFP from these selected species to expand the trade for their products and so provide farmers with greater economic opportunities.

Initiating domestication and commercialization

The problems that arise in devising a programme of domesticating or commercializing NTFPs are twofold: which species are the most appropriate for domestication and which of all the possible traits that could be improved by genetic selection are likely to provide the necessary incentive for market expansion. The first of these problems can probably be answered, at least from the producers' perspective, by consulting a range of actors, including farmers and researchers. Consequently ICRAF has developed guidelines to identify farmer priorities and to modify these according to the scientific knowledge of the species we have and existing market information (Franzel et al. 1996). The second problem is perhaps more difficult. Again, the farmers' perspective is useful, but the farmer and the entrepreneur are likely to have very different viewpoints. Consulting with farmers is relatively easy for agroforesters, and certainly farmers know that trees differ in their fruit size, flavour, yield and periodicity of production. This is important information, and even more important is the assistance of the farmer in the identification of individual trees with these different characteristics. Increasingly, farmers' rights and national sovereignty over germplasm are issues of great importance to domestication programmes, which have to be addressed.

In addition to the farmers' perspective, it is essential to obtain the industry's ideas on what is important. This is much more difficult. Agroforesters working in tropical countries seldom meet the people responsible for product development in, for example, the food industry. Furthermore, when they do meet, their motivations and objectives are so different that it is not easy for them to work together.

A 'chicken or egg' situation

Before embarking on the domestication of a tree, the agroforester needs to ascertain whether it is likely that there will be a market for its products, while the industry that develops the market wants to know that there is a minimum reliability of supply for a uniform product of a given quality before committing capital to developing that market. It was our perception of the need to discuss this 'chicken or egg' situation that was the inspiration for organizing this conference. Unfortunately, few industrial companies were able to attend the conference. Nevertheless, some progress was made in thinking about the impact on small-scale, resource-poor farmers of domesticating and commercializing NTFPs.

Perhaps the most important outcome of the working group sessions (see Reports in this volume) was the debate on the fate of small-scale farmers practising agroforestry, if domesticated trees became commercially attractive to international companies who see large-scale monocultural plantations as the most profitable production option.

Domestication and commercialization: a poverty trap?

There are many definitions of 'domestication' (see Leakey & Newton 1994a) and it is clear that the process has evolved as humans have become more intimately associated with plants and animals. The steps in this evolution can, in general, be identified as:

- extractivism for own use
- extractivism for barter with others
- extractivism for sale locally, regionally or internationally
- retention of desirable species in farm land
- planting around settlements
- creation of plantations and ranches
- genetic selection, cloning and breeding
- biotechnology

This pattern is not followed in every case, and to date relatively few tree species have progressed beyond the fourth or fifth step. However, associated with the latter steps we find the development of extensive commercial activity, the start of processing and the expansion of trade. Commercialization is both necessary and potentially harmful to farmers. It is necessary in that without it the market for products is small, and the opportunity does not exist for rural people to make the money they need to pay for the things that will increase their standard of living. A degree of product domestication is therefore desirable. On the other hand, commercialization is potentially harmful to rural people if it expands to the point that outsiders with capital to invest come in and develop large-scale monocultural plantations for export markets. Rural people may benefit from plantations as a result of greater available employment and hence off-farm income, and from the better infrastructure that is associated with plantation agriculture (that is, schooling, health clinics, and so forth). However, plantations, like monopolies, may also distort market forces to their advantage (for example, by imposing low wages, which will restrict the social and economic development of local people). The major beneficiaries of large-scale exports will probably be the country's elite and, perhaps, the national economy. While expansion of the national economy is of paramount importance, would it be possible to identify ways in which both small-scale farmers and the nation can benefit? Agroforestry appears to be an example where this may be possible. If market developments occur that target small-scale farmers for equity reasons, then numerous low-cost, small-scale processing and marketing units could be established within the rural community. These would enable villagers to capture for themselves the value added to the new products and would thus result in an improvement in community welfare. For a tropical country, another equally important advantage of this small-scale rural development through agroforestry could be the reduction of the deforestation and environmental degradation associated with more sustainable land uses. In the past, monocultural plantations have been responsible for massive deforestation and environmental degradation. Experience shows that agroforestry often results in a land-use mosaic. However, we do not yet know whether such mosaics are the most efficient and sustainable form of land use (van Noordwijk et al. in press).

In the broader picture, Sanchez and Leakey (in press) argue that through the combination of this commercially intensified, small-scale agroforestry with an enabling policy environment, and the alleviation of soil fertility depletion, a better balance between food security and natural resource conservation can be achieved, which could transform land use in Africa, where per capita food production continues to decline.

Can agroforestry spring the trap?

Interestingly, two papers in this conference provide examples of industrially important natural products that are produced in agroforestry systems by small-scale farmers (gum arabic—see Seif el Din & Zarroug; damar resin and jungle rubber—see Michon & de Foresta). This suggests that commercial interests and small-scale production, as in agroforestry, are not necessarily incompatible.

Agroforestry has been a collective term for land-use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land-management unit, in either a spatial mixture or a temporal sequence. The trees in agroforestry practices generally fulfil multiple purposes, involving the protection of the soil or improvement of its fertility, as well as the production of one or more products (Cooper et al. 1996). The domestication of these agroforestry trees should enhance their capacity to fulfil either or both of these service or production functions. Domestication should also aim at increasing the social and economic benefits of agroforestry, through improved profitability, reduced risks and diversified sources of income to buffer against crop failure (Sanchez 1995). This will act as an incentive for adoption by farmers.

The other potential benefit of agroforestry is that of the diversification of species grown on farm. Through this, and the domestication of an increasing number of tree species, it should be possible to make smallholder farming both more biologically diverse and more rewarding economically. Through the incorporation of a range of domesticated trees into different agroforestry practices within the same landscape, agroforestry can become, as recently defined (Leakey 1996), *a dynamic, ecologically based, natural-resource management system that, through the integration of trees in farmland and rangeland, diversifies and sustains smallholder production for increased social, economic and environmental benefits*. Perhaps the best examples of agroforests of this sort are the complex, multistrata damar, durian/cinnamon and jungle rubber agroforests of Sumatra, described during this conference as 'domesticated ecosystems' (Michon & de Foresta, this volume). These economically viable, biologically diverse systems suggest that agroforestry can produce NTFPs commercially and in a sustainable way. If we can understand the set of circumstances, including the policy environment, within which this has occurred in Sumatra, it may be possible to introduce domesticated trees into agroforestry systems to produce NTFPs for national and international markets without industrial pressures converting them to monocultures. In other words, the evolution of the domestication process can perhaps be stopped before the step into plantations.

Instead of big is beautiful, this new paradigm is in tune with the African proverb that says:

> If many little people, in many little
> places, do many little things, they can
> change the face of the earth.

What are the new conceptual frameworks for policy development required to ensure the economic viability of agroforestry for small-scale farmers? Alternatively, under what conditions is small-scale production competitive with large-scale production? These are questions for urgent consideration if natural forest resources are to be protected from destruction and used in a Woody Plant Revolution to alleviate poverty in tropical countries.

References

Clement C.R. & Villachica H. 1994. Amazonian fruits and nuts: potential for domestication in various agroecosystems. p 230–238. In: *Tropical trees: the potential for domestication and the rebuilding of forest resources*, ed. R.R.B. Leakey & A.C. Newton. HMSO, London.

Cooper P.J.M., Leakey R.R.B., Rao M.R. & Reynolds L. 1996. Agroforestry and the mitigation of land degradation in the humid and sub-humid tropics of Africa. *Experimental Agriculture* 32:235–290.

Cunningham A.B. & Mbenkum F.T. 1993. Medicinal bark and international trade: a case study of the afromontane tree *Prunus africana*. Report of the WWF/UNESCO/Kew 'People and Plants Programme. WWF, Surrey, England. 43 p.

Dewees P.A. & Scherr S.J. 1996. *Policies and markets for non-timber tree products*. EPTD Discussion Paper No. 16. IFPRI, Washington, DC. 78 p.

Falconer J. 1990. The major significance of 'minor' forest products: the local use and value of forests in the West African humid forest zone. *Forest, Trees and People*. FAO Community Forestry Note 6. FAO, Rome. 232 p.

Falconer J. 1992. Non-timber forest products in southern Ghana. ODA Forestry Series 2. UK Overseas Development Administration, London. 23 p.

Franzel S., Jaenicke H. & Janssen W. 1996. *Choosing the right trees: setting priorities for multipurpose tree improvement*. ISNAR Research Report 8. ISNAR, The Hague. 87 p.

Leakey R.R.B. 1996. Definition of agroforestry revisited. *Agroforestry Today* 8(1):5–7.

Leakey R.R.B. & Jaenicke H. 1995. The domestication of indigenous fruit trees: opportunities and challenges for agroforestry. p 15–26. In: *Proceedings of 4th International BIO-REFOR Workshop, Tampere, Finland*, ed. K. Suzuki, S. Sakurai, K. Ishii & M. Norisada. BIO-REFOR, Tokyo.

Leakey R.R.B. & Newton A.C., eds. 1994a. *Tropical trees: potential for domestication and the rebuilding of forest resources*. HMSO, London. 284 p.

Leakey R.R.B. & Newton A.C., eds. 1994b. *Domestication of timber and non-timber forest products*. MAB Digest 17. UNESCO, Paris. 94 p.

Leakey R.R.B. & Newton A.C. 1994c. Domestication of 'Cinderella' species as the start of a woody-plant revolution. p 3–5. In: *Tropical trees: potential for domestication and the rebuilding of forest resources*, ed. R.R.B. Leakey & A.C. Newton. HMSO, London.

Ndoye O. 1995. The markets for non-timber forest products in the humid forest zone of Cameroon and its borders: structure, conduct, performance and policy implications. Report to CIFOR. Bogor, Indonesia. 86 p.

Pinstrup-Andersen P. 1993. World food trends and how they may be modified. Report to CGIAR International Centres Week, Washington, DC, 25–29 October. IFPRI, Washington, DC. 44 p.

Sanchez P.A. 1995. Science in agroforestry. *Agroforestry Systems* 30:5–55.

Sanchez P.A. & Leakey R.R.B. In press. Land use transformation in Africa: three imperatives for balancing food security with natural resource conservation. In: *Proceedings of 4th Congress of European Society for Agronomy, Wageningen, 7–11 July 1996.*

van Noordwijk M., van Schaik C.P., de Foresta H. & Tomich T.P. In press. Segregate or integrate nature and agriculture for biodiversity conservation. In: *Proceedings of Biodiversity Forum, 4–5 November 1995.* Jakarta, Indonesia.

Plate 1. *Preparing young stems of* Bactris gasipaes *(peach palm) in Peru as 'heart of palm' for marketing as a delicacy. (photo: P.A. Sanchez)*

Plate 2. *In Brazil 'heart of palm' from* Bactris gasipaes *is bottled for domestic and international markets. (photo: P.A. Sanchez)*

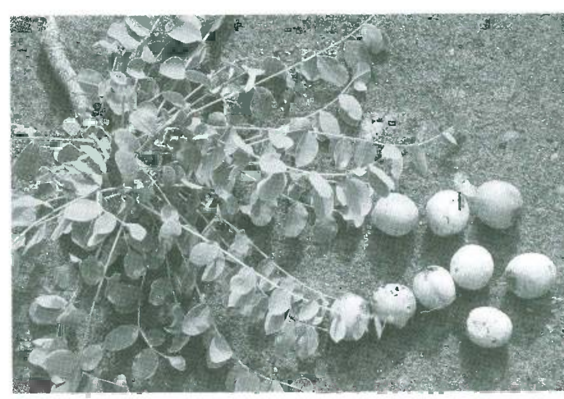

Plate 3. *Fruits of marula (*Sclerocarya birrea*), one of the priority indigenous fruits of the miombo woodlands of southern Africa. (photo: R.R.B. Leakey)*

Plate 4. *'Amarula', a liqueur prepared from the fruits of the marula tree (*Sclerocarya birrea*), is marketed internationally. (photo: R.R.B. Leakey)*

ICRAF's strategy for domestication of non-wood tree products

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Introduction

Tropical forests are full of tree species that people use every day of their lives for their own needs (food, fodder, medicines, building materials, resins, dyes, flavourings): the so-called non-wood tree products (NWTPs). These species, however, have generally been less studied than their industrial counterparts (*Eucalyptus*, *Pinus* spp.). Leakey and Newton (1994) referred collectively to these neglected taxa as the 'Cinderella' species since their potential is yet to be unveiled. Yet, if carefully promoted and marketed they raise hopes of alleviating rural poverty and increasing the sustainability of agroecosystems.

There is a growing recognition of the interdependence between forests and agriculture and the role of trees on farms in meeting the tree needs of rural communities and stabilizing land productivity. As such there is no discrete interface between agricultural fields and forests but rather a blurred edge at which poverty commonly abounds. Poverty, in simplest terms, restricts choice and options for development leading to short-term perspectives in the management of natural resources. NWTPs can greatly modify the balance between forests and agriculture but will improve natural resource management only if they result in reasonable rewards to the people who derive their livelihoods from the forest and surrounding areas (Bennett 1992).

Non-wood tree products

This paper uses the term NWTPs to refer to products arising from individual tree species and excludes the products of the wider forest that are not tree derived (e.g., bush meat, mushrooms). Non-wood is used in preference to non-timber since it excludes not only timber but also fuelwood and poles. In essence, the term NWTPs is restricted to products that are tree derived but for which it is not necessary to fell the tree.

Non-wood tree products have satisfied human needs since before the first tree was felled and long before the Greeks coined the word 'economy'. They are currently receiving focused attention from ethnobotanists, conservationists, policy-makers and breeders, as they embody the goals of conservation, development and production activities. With forested areas declining to accommodate agricultural expansion, and with human populations rising, the logical endpoint must be a choice between more people moving into the forest or moving more trees out of it. Many of the tree species that would move out of the forest onto farms would be those that provide NWTPs.

Multipurpose trees, or MPTs, have been variously described and mean different things to different people. One definition (ICRAF 1992) is 'Multipurpose trees and shrubs are those that can produce food, fodder, fuelwood, mulch, fruit, timber and other products'. This definition seems to fit well the progenitor species of modern agroforestry, *Leucaena leucocephala*. The problem is that it also fits many industrial tree species such as those in the genera *Pinus* and *Eucalyptus*. In fact, which tree is not multipurpose? Should we then rather talk about trees that primarily provide timber, fruit, gums, fodder or medicines, and collectively refer to them as *agroforestry trees*.

The needs for research on new food crops have been cited by Arkcoll and Clement (1989) to be danger of reliance on a small number of species, agricultural expansion into marginal lands unsuited to existing crops, avoidance of food imports, emergence of new nutritional recommendations, emergence of new agricultural systems, and the desire for novelty. Interestingly, NWTPs could fulfil all these criteria.

Agroforestry

Much research and development expenditure on agroforestry is founded, rightly or wrongly, upon the premise that growing trees on farms will simultaneously restore the environment, conserve tropical forests, generate income for resource-poor farmers and catalyse more sustainable land-use practices. To many, agroforestry is about stand-alone technologies such as alley cropping or improved fallows, although Leakey (1996) provides greater insight with a revised definition of agroforestry. This definition conveys the idea that the various agroforestry practices that have been devised play different roles in the ecological succession towards 'climax agroforests' at a landscape scale. The cultivation of trees that provide NWTPs is pivotal in many of these practices. Unlike their crop counterparts, however, they remain in a wild or semi-domesticated form and are certainly not optimally fit for their roles in the evolving agroforestry practices. Therefore, the selection and management (domestication) of these wild trees providing NWTPs is a key thrust of the International Centre for Research in Agroforestry (ICRAF).

Agroforestry is certainly not a new answer to the problems of the inadequate natural resource base for sustained development. Dubois (1995) in studying forest dwellers in Brazil found three historical levels of intervention in the forest, namely: (1) simple harvesting without intentional management, (2) enrichment of long duration tree-fallow, and (3) systematic manipulation of forest stands or enrichment planting in temporary agricultural fields, leading to agroforests. What is new is the concept of applying modern techniques of domestication to the trees of agroforestry systems.

Domestication

Domestication has recently been accepted as a phrase applicable to agroforestry as evidenced in a number of articles and conference proceedings (e.g., Leakey and Newton 1994). Indeed, as a corollary to the Green Revolution of crop plants, the *Woody Plant Revolution* is now being heralded (Newton et al. 1994). To domesticate is to naturalize to human conditions and involves human-induced change in the genetics of a plant (Harlan 1975, cited in Leakey and Newton 1994). Put simply, it means to bring into human use. It was a topic that so fascinated Charles Darwin that in his great work, *The Origin of Species*, he devoted the first chapter to 'Variation under domestication'.

In genetic terms, domestication is accelerated and human-induced evolution. The consequences are either loss or gain of genes, altered gene frequencies or modifications to the way genes are packaged (gene complexes). There is much historical evidence of the human role in shaping present-day vegetation patterns (Briggs & Walters 1984). Even the floral composition of the pristine rainforests of Amazonia has been shown to be affected by the activities of Amerindian cultures (Mabberley 1983). The domestication of trees, then, does not have to occur outside the forest. Other examples of humans changing the species-richness and abundance of desired trees in forests are reported in Asia (Whitmore 1992) and Africa (Shepherd 1992). Domestication of tree species must therefore be seen as a continuum—from unmolested state, to management of trees in forests, to cultivation of semi-domesticates, to monocultural plantation of advanced generation breeding lines. The level of domestication activity will be dictated by biological, policy, market and social factors.

Domestication of any plant species is concerned with selection and management by humans and is not only about breeding *per se*. Selection can be deliberate or inadvertent. Deliberate choices might be made for fruit characters, growth rate, form, etc., whereas inadvertent selection could be for insect resistance, tolerance of selfing, etc. Of course inadvertent selection could also be carried out for any trait that was genetically linked or correlated to a trait that was being deliberately selected. Traits that confer fitness may be either enhanced or depressed, whichever the form of selection practised. Management is also linked to the genetics of a plant in that the ability of a plant to be managed in a certain way is often expressed genetically. The direction and speed with which domesticated trees diverge from their wild progenitors will depend upon the size of the population, the heritability of traits under selection, the mating system, the intensity of selection and the inherent variability of the traits.

Potential gain from domestication

Trees are predominantly outcrossing. This results in progeny that segregate with respect to parental traits. This wide genetic variation not only provides buffering against differing environments and management practices but also affords the opportunity for selection. Most quantitative traits (height, biomass, etc.) are under low to moderate additive genetic control, which means that only 10–30% of the variation we see for a trait in a population can be captured in individuals following selection. Using a fairly high intensity of selection (say 1 in 50) we could expect the progeny to outyield the group of parents from which it was derived by approximately 15–25%.

Qualitative traits such as fruit shape, taste, tree form, date of first fruiting are usually much more tightly inherited, from selected individuals. The genetic gain we would expect in one cycle of selection for a qualitative trait would be much higher, such that 60% of the progeny might be similar to their parents.

Cloning is the ultimate means of capturing useful genetic variation in that there is no recombination or segregation of genes. There is a need, however, to screen large numbers of trees to identify clones with superior traits. Vegetative propagation, however, is not genetic improvement in itself, and regular testing and introduction of new material is advocated strongly (e.g., Leakey 1991).

Candidate trees for domestication

Notwithstanding further discoveries and taxonomic debates, we can reasonably assume there are 50 000 extant tree species. More than 2500 trees have been described for use in agroforestry systems (most of which provide NWTPs), which is both a fair proportion and a large absolute number of tree species. And yet, ethnobotanical studies continue to reveal a vast array of new tree products of importance to people (food, medicines, fibre, etc). The assertion that untapped potential exists is unequivocal, but the question remains of how best to allocate scarce research resources to such a plethora of species. It is an extremely expensive exercise to carry out the rangewide exploration and collection required for genecological studies, and only after a species has proven itself is this justified. The paradox is that a species may not be able to prove itself until its full intraspecific variation has been tested.

Which species to domesticate will depend on the objectives of domestication and will differ if it is for income generation, germplasm conservation, forest conservation or farm diversification. No studies are available that combine the economic, social and environmental benefits and costs to compare the merits of domesticating various species in the forest or on the farm. Until this lack of knowledge is addressed, species priority-setting will continue to be influenced most by the more readily available information relating to biological and social considerations.

Extractivism

It is clear that extractivists can earn a relatively good living from the forest as evidenced by the study of Allegretti (1994) in Amazonia, where annual family income exceeded USD 900 from the collection of about 750 kg of rubber and 4500 kg of Brazil nuts. This level of income, however, could not be earned by an infinite number of people in that the amount of Brazil nuts available is finite. Already 40% of the agricultural labour force in the state of Acre is involved in vegetal extractivism (Allegretti 1994) and overharvesting would affect income levels and stability. Overharvesting would also have a negative impact on natural regeneration and the fauna that depend on the Brazil nuts as food.

Clusener-Godt and Sachs (1994) question the extent that extractive reserves are consistent with the five dimensions of sustainable development (social, economic, ecological, geographic and cultural). They present a balanced view of the limitations and possibilities of extractivism without accepting it as the paradigm for agricultural development.

Recognition of the overreliance on extractive reserves led the National Council of Rubber Tappers of Brazil in 1991 to search for agroforestry systems that would diversify production (Allegretti 1994). They concluded that agroforestry systems should use native species and should be preferentially implemented in degraded areas. Not all share this view, with Homma (1994) articulating well the concerns of the agroforestry panacea. He cautions against unbridled enthusiasm for agroforestry, suggesting that it may lead to saturation of markets since a smaller land base is needed. Further, a class structure based on competency would develop since an intensive and well-managed production system is required, thus creating social inequities.

At low densities of human population, the impact of extractivism on the biodiversity of natural forests can be minimal. With increasing extractive pressure, however induced, not only is the diversity of the tree providing the NWTP under genetic erosion, but also the forest itself when we examine recommendations by authors such as Viana and Mello (1995), who call for liberation thinning of Brazil nut trees to enhance productivity.

Homma (1994) prophesies that the extractivist economy is doomed to gradual disappearance. He cites four phases of the evolution of the extraction of plant resources. Expansion is the first phase. The evolution then reaches a stabilization phase in which supply and demand are balanced, which is close to the maximum extractive capacity. This is followed by a decline phase, caused by the reduction of resources and increased costs of extraction. This in turn is followed by the cultivation phase, which had its beginnings in the stabilization phase when technologies and planting materials became available. The model of Homma (1994) is useful to examine where agroforestry can have a meaningful intervention. For instance, conflicts have arisen over the right to collect or market NWTPs, whether on state or communal land (e.g., between long-term residents and recent migrants), although with tree cultivation (and tree tenure) this can be actively minimized even in the absence of land tenure.

Marketing and policy studies

Both agroforestry and NWTPs are multisectoral in nature, and invoke different amounts of government intervention in particular countries. Dewees and Scherr (1996) provide a comprehensive review of the extent and deficiencies of policy and market studies of

NWTPs. To increase returns from NWTPs, some authors insist markets must pre-exist, whereas others acknowledge scope for evolving markets. Raintree and Francisco (1994) argue that new markets can easily be promoted through increased supply of existing NWTPs to meet increased demand or through developing demand for new species. The sustainability of NWTP markets (new or existing) preoccupies several studies in the available literature. Of greater importance, according to Dewees and Scherr (1996), is that market information systems are adequate to enable domestication efforts to respond quickly to change.

Another common preoccupation in the literature is the transitional nature of production from small-scale extractivism to monocultural large-scale plantations (Dewees & Scherr 1996, Leakey & Izac this volume). It is clear that the benefits for forest-dwellers and for the agrarian populace may not always be congruent. For example, harvesting of Brazil nuts *(Bertholletia excelsa)* from natural forest is reportedly threatened from establishment of plantations (Mori 1992). Cross-national perspectives are also evident as typified by the loss of revenue to Latin American countries with the establishment of rubber plantations in Southeast Asia (Browder 1992).

Global benefits (social and economic) of whether NWTPs should be produced on small or large scales are harder to discern when one considers a crop like bananas. Notwithstanding the inequity of three corporations controlling 67% of the world market, there are 300 000 workers in Ecuador who depend on the banana trade and 21% of the labour force in Panama are also dependent on it (ITM 1992). And yet, home consumption and village markets must dwarf the international markets. This illustrates the compatibility of concurrently having multinationally owned monocultures and small-holder agroforests.

Market conservatism will be as important for NWTPs as it is for timber products. It is perplexing that the Amazonian rain forest might contain up to 250 tree species per hectare with 50% having a commercial potential, but only 3–4 species are logged. There are timbers that look like, feel like and work like *Swietenia,* but because they are not labeled 'mahogany' they are very difficult to market. Similarly, many NWTPs may be promoted as substitutes for other products but may be underutilized because of market intransigence; Arkcoll and Clement (1989) note that many indigenous fruits are remarkably unpleasant or uninteresting to people not accustomed to them.

ICRAF's approach

ICRAF is working in six major tropical ecoregions to help to mitigate deforestation, land depletion and rural poverty through the development of improved agroforestry systems. To achieve these goals ICRAF's research agenda is engaged in a thrust on the domestication of agroforestry trees.

Almost without exception the tree germplasm that is used or envisaged for immediate use in agroforestry is wild and unimproved. To domesticate or not to domesticate? That is the question faced for each of the 2500 species that ICRAF could potentially work with. At a given time some species will warrant domestication while others will not. Consequently, the emphasis of ICRAF's approach to domestication is on developing objective decision-making frameworks that will first ascertain whether domestication should proceed, and then determine in which way and at what level.

In the domestication of agroforestry trees, ICRAF is dealing with an imperfect knowledge base. For instance, in deciding which species have a commercial future problems arise because of lack of data on yield, absence of selection criteria, inadequate botanic knowledge and lack of information on consumer acceptance. In addition, ICRAF and its partners will never be able to advance domestication of all agroforestry species.

Accordingly, ICRAF uses a number of species in the six ecoregions as case studies to build and optimize the decision-making framework. Many trees that provide NWTPs are represented in each of these ecoregions (e.g., *Adansonia digitata* in semi-arid lowlands of West Africa, *Irvingia* spp. in humid lowlands of West Africa, *Prunus africana* in eastern and central Africa, *Uapaca kirkiana* in southern Africa, *Bactris gasipaes* in Latin America). This, together with the strategies and techniques for capturing and using genetic variation (Leakey & Simons, in press) can be used to model approaches to domestication.

Objectives of domestication

The domesticates of tree species that provide NWTPs have the primary purpose of enhancing the productivity and sustainability of agroforestry systems. In turn, it is envisaged that the domesticates may contribute to the conservation of genetic resources of such species and also the preservation of natural habitats (e.g., rainforests, woodlands, savannah) in which their progenitors reside. It is further desired that the provision of improved germplasm will accelerate adoption and expansion of agroforestry technologies.

There are many assumptions surrounding this approach, not least that domestication is a beneficial exercise. FAO (1995) lists six advantages and four disadvantages of the domestication of NWTPs that usefully summarize the situation. Advantages include reliable production, relieving pressure on forests, income generation, ease of harvesting, improved growth rates, increased value of the crop. The disadvantages focus on increased susceptibility to pests, loss of ecological function, reliance on new sources of wild seed, added-value benefit to large corporate entities.

ICRAF has a very diverse client group. The resource-poor farmers of the tropics plant trees that provide NWTPs for a variety of reasons (food, income generation, risk aversion through diversification). Fitness of purpose of agroforestry trees is the prime objective of domestication, and this is best ensured through provision of a choice of priority species to farmers.

Priority species

Historically, research priorities among tree species were determined by researchers with varying degrees of research self-interest. Such subjectivity has led to suboptimal use of resources, although this does not mean that no successes have occurred. Rigorous priority setting, however, requires understanding of user needs and preferences, technological opportunities and systematic methods for ranking species. ICRAF, in collaboration with national agricultural research systems (NARS), has developed more objective procedures for priority setting of agroforestry tree species for genetic improvement research (Jaenicke et al. 1995).

The recently published ICRAF/ISNAR (International Service for National Agricultural Research) guidelines on species priority-setting represent a great advance in procedural methodology (Franzel et al. 1996). The process described involves seven stages at which the number of species under consideration is consecutively reduced. The steps involved are (1) team building and planning, (2) assessment of client needs, (3) assessment of species used by clients, (4) ranking of products, (5) identification of priority species, (6) valuation and ranking of priority species, and (7) final choice.

These methodologies have now been used in a number of ecoregions, including the humid lowlands of West Africa (HULWA), the semi-arid lowlands of West Africa (SALWA), the lowland forest of the Peruvian Amazon and the Yucatan Peninsula in Mexico. In these regions, and in the miombo ecozone of southern Africa, the lists of the top five species have all contained mostly food-producing trees that provide NWTPs either as the prime purpose or as a secondary purpose.

Genetic Resource Unit

Tree germplasm is unequivocally the primordial input to agroforestry. Great progress has been made in commercial forestry through assembly and testing of rangewide collections of germplasm of timber trees (Barnes & Simons 1994). In contrast, work on agroforestry trees for NWTPs has lagged noticeably behind. Nevertheless, even where comprehensive collections exist of some species there is general under-appreciation of intraspecific variation by agroforesters and farmers alike. For trees providing NWTPs and for agroforestry trees in general, what is planted is usually what is most readily available and does not necessarily relate to germplasm quality (physical or genetic). ICRAF recognizes its role in raising awareness of the importance of quality germplasm.

ICRAF received endorsement to establish its own Genetic Resource Unit from the wider germplasm community at an International Consultation held in 1992 (ICRAF 1993). At this meeting, a number of recommendations were taken up by ICRAF, which included the role of ICRAF in establishing field genebanks of material that is difficult to store (recalcitrant), in the need to assist in providing information on quality germplasm sources, and in encouraging *ex situ* and *in situ* conservation. ICRAF is respectful of the Convention of Biological Diversity and the need to share benefits and farmers' rights. All collections it carries out are with national partners and follow the voluntary FAO Code of Conduct for Germplasm Collecting, which is in line with ICRAF's policy on intellectual property rights.

In collecting germplasm of agroforestry tree species that provide NWTPs, ICRAF uses different approaches depending upon extant distribution, degree of human disturbance on natural genepools, threat of genetic erosion, reproductive biology (hermaphroditism, monoecy, dioecy) and floral synchrony (Ne/N). One aspect common to all species, however, is whether collections should be carried out using either (1) a random approach, (2) a targeted approach, or (3) a combination of the two methods—in essence, whether phenotypic selection is efficient or not.

Protagonists of the random-collection strategy argue that to sample as much of the variation as possible it is necessary not to narrow down the range of mother trees from which to collect on the basis of a few traits (e.g., fruit size, fruit quality). On the other hand, advocates of the targeted approach ask why seeds should be collected from trees with bitter fruit since these would never be given to farmers. Genetic theory is used to defend both approaches. Randomists argue that other genes with more latent expression (e.g., disease resistance) might be negatively or positively genetically correlated to fruit traits and therefore targeted collections may inadvertently omit to sample useful variation. Further, randomists question the ability to select accurately trees growing in different microsites, of different age and putatively different previous management (e.g., lopping of branches). Targetists reply that if phenotypic selection is not very efficient then it should not result in genetic variation carrying it out. Although their prime assumption is that since fruit traits are highly heritable then they should be able to capture the desirable phenotypes in progeny of their targeted selections.

ICRAF is using several tree species (e.g., *Inga edulis*, *Sclerocarya birrea*, *Uapaca kirkiana*) that provide NWTPs to provide hard evidence to determine which approach is more appropriate. Since most fruit tree species that ICRAF is working with have recalcitrant seeds, live-genebanks are being established which have a conservation as well as a utilization purpose. These are typically set up as progeny trials to allow determination of genetic parameters (heritabilities and genetic correlations). In this way, the reduction in additive genetic variance (in juvenile traits—e.g., height, form) from targeted selections can be calculated. In parallel with this study, molecular characterization (Dawson et al. 1995) is being carried out to identify the genetic bottleneck from targeted selections. As species come into fruit it is possible to compare parental fruit phenotypes with those of their progenies.

Quantifying and forecasting demand

To justify investment in large-scale seed or clonal production or in a formal breeding programme there needs to exist a strong demand for the species. Yet without improved material of new species little demand may develop. Most of the trees that provide NWTPs are found in natural forest or communal lands and are largely uncultivated. ICRAF distinguishes two groups of clients, namely, (1) the rarer group with a tradition of tree planting or nurturing natural regenerants and (2) the common group with no tree cultivation experience.

Those in the first group are easier to target with improved materials since the leap of faith required by them is only that the new germplasm is superior to their wild or semi-domesticated germplasm. But superior in what way? ICRAF recognizes that it is crucially important for farmers to be involved in the identification and selection of traits for improvement. A key question that remains is whether farmers would buy improved material when they have the option of collecting their own seed or cuttings from fields or the forest. Street et al. (1992) carried out an economic analysis of growing agroforestry trees in Haiti and concluded that when farmers had to pay for seedlings the net present values were negative, irrespective of the economic product.

To stimulate demand for improved replacements (free or otherwise) the new germplasm would have to be markedly and demonstrably superior. Assuming farmers were interested in, for instance, greater fruit production, how closely can they discern differences between germplasm and thus express demand for particular sources? There would likely need to be an actual difference in quantity of greater than 30% for farmers to appreciate the difference. The length of fruiting season, for example, would likely have to be two weeks longer or 25% of the fruiting period, whichever is the lower. It is important, therefore, to weigh up the biological threshold for improvement (genetic gain) versus the farmers' threshold for improvement. Using clones will usually push the biological threshold much higher than using sexual propagules, and this may mean the difference between farmer acceptance or not. It is important to clarify, however, that just because the biological threshold is above the farmer's threshold does not guarantee that there will be adoption.

The second, and larger group of clients are the farmers for whom the tree planting philosophy has not taken root. Yet, if farmers are to be convinced to adopt tree cultivation it will most generally be first with trees providing income or food security. In this regard, NWTP agroforestry trees are the ideal candidates. ICRAF considers that if better germplasm were available then adoption would proceed at a faster rate. This explains the great importance ICRAF attaches to assembling rangewide collections of germplasm (both targeted and random).

For either of these two groups of farmers, domestication can be (1) done for them, (2) done in conjunction with them, or (3) done by them alone. ICRAF conceives that the second method is generally the most appropriate for trees providing NWTPs. Participatory breeding by farmers is encouraged and in such cases ICRAF is careful to provide them and national research institutions with sufficient diversity from which to make selections.

Demand for germplasm of a particular species in agroforestry development projects has often been stimulated by the provision of incentives (cash, livestock, food, fertilizer, etc.). In these instances, it is difficult to dissociate the real demand from that created by the incentives. To fill a void in policy aspects of tree germplasm, ICRAF is to hold a workshop on this subject in November 1996.

Understanding that germplasm availability (improved or not) is often cited as a constraint to increased tree planting, ICRAF is using a number of case studies to examine how much germplasm will be needed, by whom, when, and for how long. It is crucial that this demand is real and not just perceived. For instance, demand might be overestimated if NGOs or other organizations ask for large quantities of planting materials in advance of well-meaning extension projects that subsequently under-achieve in relation to their planting targets.

Germplasm delivery pathways

If improved germplasm is to be provided to farmers, what are the delivery pathways currently available or in need of creation to ensure availability of improved germplasm? Very little information is available for agroforestry trees on the supply-side parameters. Indeed, even the seed regulatory frameworks (variety development, variety release, seed certification, distribution and sale) for many agricultural crops in developing countries are poorly formed and are considered unresponsive to the needs of resource-poor farmers (Tripp 1995). We would be in a far better position to have impact with domestication efforts if we better understood the pathways of germplasm delivery, namely:

- *distribution* (to NARS, NGOs, communities, private sector)
- *dissemination* (to farmers)
- *diffusion* (farmer-to-farmer exchange)

The link between the demand and the supply of germplasm of a species determines the efficiency with which improved material is used. The demand side of germplasm delivery is being assessed by ICRAF at three levels, namely that of (1) the farmer, (2) the disseminator (e.g., NGOs, community programmes), and (3) the distributor (NARS, international projects, etc.). Demand from farmers is being determined using farmer surveys. These examine aspects that are both qualitative in terms of the useful traits they desire and quantitative in terms of the amount of germplasm they require. The demand from disseminators is being assessed through questionnaires and direct contact with various groups. The distributors are similarly polled using both questionnaires and direct contact.

The supply side of germplasm is being examined by compiling a list of suppliers. This is being put into a database that links species information with individual suppliers. Easy-to-fill-out questionnaires have been sent out to several hundred suppliers. Surveys of large- and small-scale tree nurseries are also being carried out in several countries. Further, the possibilities of private sector involvement and contract multiplication and delivery are being investigated by ICRAF and its partners.

Tree improvement

Breeding of most commercial forest tree species has been in progress for less than 40 years (Barnes & Simons 1994). Using a strategy of recurrent selection for general combining ability and seed production from progeny tested clonal orchards, average gains of around 20% were attained in the first generation of selection (Barnes & Simons 1994). Is this a strategy that should be followed for agroforestry trees providing NWTPs. Irrespective of the strategy followed, a key question is 'whose strategy is it?'—that of governments, of research projects, of international organizations? The most important question for genetic improvement is whether farmers are setting the breeding objectives. It is fair to say that most literature on improvement of non-industrial trees equates superiority with greatest growth, yet it is recognized that farmers may want more stable production than enhanced but variable production (Simons 1992). In essence, is biggest (and probably most competitive in agroforestry systems) the best? Kanowski (1993) concluded that there has been a 'northern temperate bias' to tropical tree improvement and there exists a need to re-evaluate methods.

In the absence of comprehensive survey information of what farmers want from improved germplasm it seems prudent to pass on as much genetic variation to them as possible. In some situations, ICRAF is also promoting efforts to broaden the genetic base of genetically depauperate landraces (e.g., *Alnus, Grevillea*). Wei and Lundgren (1991) call for development of breeding methods that combine the goals of gain and diversity. Gain is associated with economic return while diversity is a more nebulous concept. The loss of diversity is dependent on the selection method used and the selection intensity (Wei & Lundgren 1991). To date, the improvement of agroforestry trees has largely followed the methodology used for commercial tree breeding, which in turn borrowed exactly the methods used for agricultural crops (Barnes & Simons 1994). Certainly, agroforestry trees and agricultural crops share many biological attributes, and classical genetic theory holds true across both groups. However, a number of attributes relevant to improvement strategies distinguish them. Most notable are their size and their perenniality.

There is a need to carry out many of the sequential steps of tree improvement in parallel to reduce the time to delivery of improved materials. Investigations into the basic biology (e.g., reproductive biology) of species are under way (see Ladipo et al. this volume, Leakey & Jaenicke 1995), which are especially important if it is the reproductive produce (fruit, seeds) that are the NWTPs. Germplasm multiplication is being carried out in advance of identification of the most superior material. This approach, therefore, means that while some multiplied materials may never be used, nucleus amounts of superior germplasm are sure to be available when demand is incipient.

Agroforestry trees are biologically a very heterogeneous group, as are their users, the resource-poor farmers of the developing tropics. A single strategy for improvement will not suffice for all agroforestry species, given these prerequisites and an awareness that improvement activities would differ for trees if they were (1) exotic or indigenous, (2) a new or an existing introduction, (3) of low value or high value, (4) for home use or for sale, (5) subject to recurrent improvement or not, (6) sexually or vegetatively propagated. What is clearly needed is a decision-making framework, first to determine whether improvement is worthwhile and second to identify a specific strategy for improvement. This will lead to strategies that are not only species specific but also ones that are location or market specific.

Decision-making framework

Agroforestry offers a flexible environment in which to domesticate trees providing NWTPs at an intensity and pace to suit the local populace. Decisions on improvement of agroforestry trees are being made throughout the tropics, although these may be flawed without consideration of the full spectrum of determinants. Various categories of such determinants are given in figure 1. The challenge ICRAF faces is to integrate these parameters and factors into a usable decision-making model. As an example, Maghembe et al. (1995) usefully describe the relevant research needed for fruit trees indigenous to the miombo woodlands of southern Africa. It is by using the case study species from the different ecoregions that progress will be made in the generation of a usable framework for domestication.

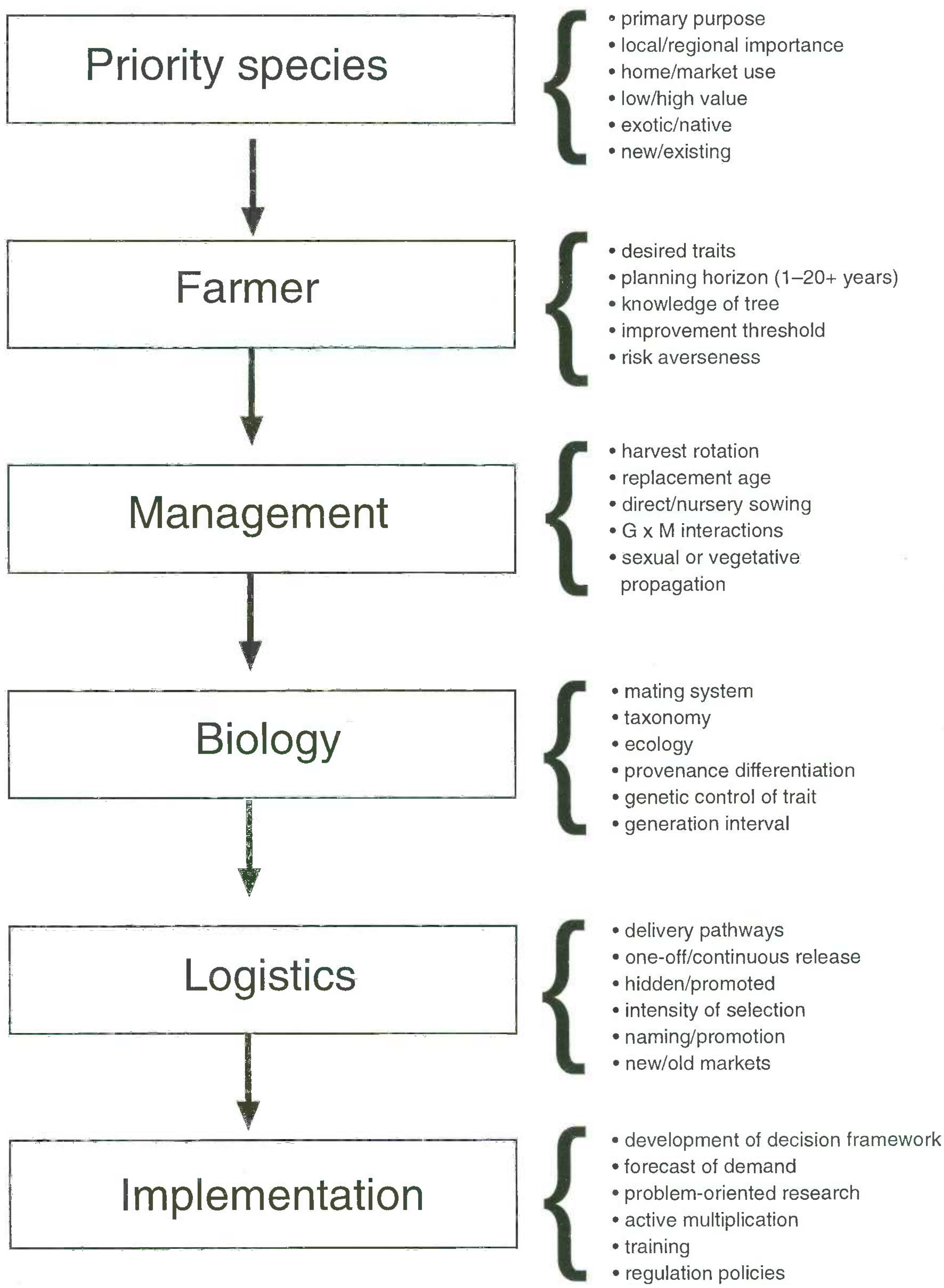

Figure 1. Determinants of strategies for genetic improvement of agroforestry trees.

Genetic conservation

Conservation of tropical trees and forests is a subject that has received considerable attention after the United Nations Conference on the Environment and Development (UNCED), yet the term often remains undefined. From a species-centric perspective, one can seek to (1) preserve the habitats where the species exists, (2) prevent the species from going extinct, (3) preserve all possible genes or genotypes of that species, or (4) preserve all genetic variation of a high utility value. It is axiomatic that these four aspects are considered simply as conservation, and confusion can arise as to specific objectives of conservation efforts.

Without doubt, tree species are best conserved *in situ* in pristine forests. Recognition of the difficulties of such an approach for species of important human use has led to calls for conservation through utilization. A laudable, yet subjective, concept. From experience with agricultural crops it can be seen that greater utilization of a species can lead to a reduction in the amount of genetic variation used and, hence, conserved. Indeed, the use of improved material is based on selections that alter gene frequencies for favourable traits.

The challenge of linking the conservation of high-value trees providing NWTPs to their use lies in expanding the cultivation of the species. This can be done most easily by having germplasm available that is perceived by farmers to be superior to alternative species or to material available in the wild or semi-wild state (i.e., of high utility value).

Farmers at the forest edge can reduce pressure on natural stocks and thus conserve genetic resources by cultivation of high-value trees. In this way, the raw germplasm can be protected in the natural ecosystem while the germplasm of greatest utility value can be conserved and promoted through the cultivation and domestication of trees on farms. This germplasm is the priority material for conservation by ICRAF. Dubbed *circa situ* conservation (near the site of origin), this approach runs the risk of contaminating the natural genepools with new genes or changing the frequencies of existing genes. However, this accelerated evolution is far preferable to gene loss or species extinction, especially if through agroforestry it is simultanously benefiting farmer welfare and providing other valuable environmental services.

Conclusions

The development of new tree crops on a sufficient scale in sustainable agroforestry systems is a challenge to link genetic improvement research with marketing to ensure income generation and food security. Domestication is both about product development and product creation. ICRAF is aware, however, that greatest focus should be on existing markets while keeping watch for emerging ones. Nevertheless, wherever focus is placed, research on input markets (e.g., planting material) is as important as research on output markets in understanding smallholder investment in and output of NWTPs.

The use of agroforestry may avoid many of the problems with monoculture plantations reducing the risk to farmers of crop loss and the need for agrochemical application. Agroforestry systems where NWTPs trees could play a role are numerous and include homegardens, scattered trees in fields, multistrata systems and boundary plantings. The undomesticated nature of agroforestry trees and the marked intraspecific diversity within them augurs well for genetic improvement through selection and breeding. The real challenge then is not just the mechanics of improvement but rather the reconciling of the potential for genetic advance with the practical realities of farmer needs, farmer perceptions and the imperfect framework for germplasm delivery.

Domestication is human-induced change, or more aptly farmer-induced change, in the genetics of a plant, and it will differ in magnitude and direction from farmer to farmer, species to species and location to location. The formulation of objective decision-making frameworks is essential to ensure optimal use of resources and provide opportunities for maximal adoption. In several cases it may be that we do not need enhanced domestication (i.e., semi-domesticates may suffice), while in many other situations accelerated domestication may offer distinct advantages. Farmers may plant trees but in many cases are reluctant to thin them or cull out poor performers, and in the absence of silvicultural improvement, genetic improvement becomes increasingly important. What is required is a cohort of barefoot tree breeders!

Conservation is an integral part of ICRAF's strategy although not solely for curatorial purposes. ICRAF seeks to promote conservation of genetic resources through use, and also through contributing to policy formation and regional and international collaboration and coordination. In essence, we are interested in genes for sustainable development. In this regard, we believe there is scope for coevolution of the cultivated and the 'wild' populations.

From surveys of both buyers and suppliers of agroforestry germplasm it is clear that we are dealing with an imperfect market. There is no premium paid for quality (physical or genetic) and there is little appreciation of intraspecific diversity. Germplasm, almost without exception, is marketed under the species name only. Greater awareness of differences among trees of a given species and attachment of names to such differences are needed.

The International Union of Forest Research Organizations (IUFRO), in their summing up of the recent quinquennial conference noted that 'IUFRO should look at further domestication of tree species. In addition, greater attention should be given to agroforestry systems'. ICRAF is taking up the challenge of domesticating trees that provide NWTPs in agroforestry systems, to ensure that much of the unwritten agenda of the 20th century is completed before we tackle UNCED's Agenda 21. It is envisioned that we may soon hear a modification to the old adage 'you can't see the wood for the trees' which would be 'you can't see the trees for the products'.

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References

Allegretti M.H. 1994. Policies for the use of renewable natural resources: the Amazonian region and extractive activities. p 14–33. In: *Extractivism in the Brazilian Amazon: perspectives on regional development*, ed. M. Clusener-Godt & I. Sachs. MAB Digest 18. UNESCO, Paris.

Arkcoll D.B. & Clement C.R. 1989. Potential new food crops from the Amazon. p 150–165. In: *New crops for food and industry*, ed. G.E. Wickens, N. Haq & P. Day. Chapman and Hall, London.

Barnes R.D. & Simons A.J. 1994. Selection and breeding to conserve and utilize tropical tree germplasm. p 84–90. In: *Tropical trees: the potential for domestication and the rebuilding of forest resources*, ed. R.R.B. Leakey & A.C. Newton. HMSO, London.

Bennett A.J. 1992. Dynamics of forestry and agriculture at the forest edge. p 139–148. In: *Wise management of tropical forests 1992*, ed. F.R. Miller & K.L. Adam, Proceedings of the Oxford Conference on Tropical Forests. OFI, Oxford.

Briggs D. & Walters S.M. 1984. *Plant variation and evolution*. 2nd ed. Cambridge University Press, Cambridge. 412 p.

Browder J.O. 1992. The limits of extractivism: tropical forest strategies beyond extractive reserves. *Bio Science* 42:174–182.

Clusener-Godt M. and Sachs I. 1994. *Extractivism in the Brazilian Amazon: perspectives on regional development*. MAB Digest 18. UNESCO, Paris. 88 p.

Cromwell E. & Wiggins S. 1993. *Sowing beyond the state*. ODI, London. 94 p.

Dawson I.K., Simons A.J., Waugh R. & Powell W. 1995. Diversity and genetic differentiation among subpopulations of *Gliricidia sepium* revealed by PCR-based assays. *Heredity* 74:10–18.

Dewees P.A. & Scherr S.J. 1996. *Policies and markets for non-timber tree products*. Environment and Production Technology Division Discussion Paper No. 16. IFPRI, Washington. 76 p.

Dubois J.C.L. 1995. Silvicultural and agrosilvicultural practices in Amazonian Native and Traditional Communities. p 67. In: *Invited Paper Abstracts, IUFRO XX World Congress,* Tampere, Finland. IUFRO, Vienna.

FAO. 1995. *Non-wood forest products for rural income and sustainable forestry*. FAO Technical Report No. 7. Non-wood Forest Products Division, FAO, Rome. 127 p.

Franzel S., Jaenicke H. & Janssen W. 1996. *Choosing the right trees: setting priorities for multipurpose tree improvement*. ISNAR Research Report No. 8. ISNAR, The Hague. 87 p.

Harlan J.R. 1975. *Crops and man*. American Society of Agronomy/Crop Science Society of America. Madison, Wisconsin.

Homma A. 1994. Plant extractivism in the Amazon: limitations and possibilities. p 34–57. In: *Extractivism in the Brazilian Amazon: perspectives on regional development*, ed. M. Clusener-Godt & I. Sachs. MAB Digest 18. UNESCO, Paris.

ICRAF. 1993. *Annual report* 1992. International Centre for Research in Agroforestry, Nairobi, Kenya.

ICRAF. 1993. *Proceedings of the International Consultation on the Development of the ICRAF MPT-Germplasm Resource Centre*. ICRAF, Nairobi, Kenya. 228 p.

ITM. 1992. *Third world guide*. Instituto del Tercer Mundo, Montevideo, Uruguay. 632 p.

Jaenicke H., Franzel S. & Boland D. 1995. Towards a method to set priorities amongst multipurpose trees for improvement activities: a case study from West Africa. *Journal of Tropical Forest Science* 7:490–506.

Kanoswki P.J. 1993. Mini-review: forest genetics and tree breeding. *Plant Breeding Abstracts* 63:717–726.

Leakey R.R.B. 1991. Towards a strategy for clonal forestry: some guidelines based on experience with tropical trees. p 27–42. In: *Tree improvement and breeding*, ed. J.E. Jackson. Royal Forestry Society of England, Wales and Northern Ireland, Tring, England.

Leakey R.R.B. 1996. Definition of agroforestry revisited. *Agroforestry Today* 8(1):5–7.

Leakey R.R.B. & Jaenicke H. 1995. The domestication of indigenous fruit trees: opportunities and challenges. p 15–26. In: *Proceedings 4th International BIO-REFOR Workshop, Tampere, Finland*, ed. K. Suzuki, S. Sakurai, K. Ishii & M. Norisada. BIO-REFOR, Tokyo.

Leakey R.R.B. & Newton A. 1994. *Domestication of tropical trees for timber and non-timber forest products*. MAB Digest No. 17. UNESCO, Paris. 94 p.

Leakey R.R.B. & Simons A.J. In press. When does vegetative propagation provide a viable alternative to propagation by seed in forestry and agroforestry in the tropics and subtropics? In: *Problem of forestry in tropical and sub-tropical countries: the procurement of forestry seed—the example of Kenya*.

Mabberley. 1983. *Tropical rain forest ecology*. Blackie and Son Ltd, London. 156 p.

Maghembe J.A., Ntupanyama Y. & Chirwa P.W., eds. 1995. *Improvement of indigenous fruit trees of the miombo woodlands of southern Africa*. ICRAF, Nairobi, 138 p.

Mori S.A. 1992. The Brazil nut industry—past, present and future. p 241–251. In: *Sustainable harvest and marketing of rain forest products*, ed. M. Plotkin & L. Famolare. Island Press, Washington.

Newton A., Moss R. & Leakey R.R.B. 1994. The hidden harvest of tropical forests: domestication of non-timber products. *Ecodecision* (July):48–52.

Raintree J.B. & Francisco H.A. 1994. Marketing of multipurpose tree products in Asia. In: *Proceedings of an International Workshop, Baguio City, Philippines, December 1993.* Winrock International, Bangkok.

Shepherd G. 1992. *Managing Africa's tropical dry forests.* Overseas Development Institute, London. 117 p.

Simons A.J. 1992. Genetic improvement of non-industrial trees. *Agroforestry Systems* 18:197–212.

Street D.R., Sullivan G.M., Huke S.M. & Fox J.M. 1992. *Haitian tree farm financial case studies.* Nitrogen Fixing Tree Association, Hawaii, USA. p 222–237.

Tripp R. 1995. *Seed regulatory frameworks and resource-poor farmers: a literature review.* Agricultural Administration. Network Paper 51. Overseas Development Institute, London. 53 p.

Viana V.M. & Mello R.A. 1995. Ecology and management of Brazil nut populations in extractive reserves in Xapuri, Acre, Brazil. Poster 61, p 37–38. *Poster Abstracts, IUFRO XX World Congress, August 1995, Tampere, Finland.* IUFRO, Vienna.

Wei R-P. & Lindgren D. 1991. Selection effects on diversity and genetic gain. *Silva Fennica* 25:229–234.

Whitmore T.C. 1992. *An introduction to tropical rainforests.* Oxford University Press, Oxford. 226 p.

Integrating the assessment of non-wood forest products into the forest inventory of a large area: experiences from Nepal

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Abstract

This paper describes an attempt to integrate the assessment of some non-wood forest products (NWFPs) in the framework of a standard forest inventory. The study is restricted mainly to medicinal and aromatic plants, i.e., herbal NWFPs, a group that has economic importance in the hill regions of Nepal. Several specific difficulties are discussed. They arise from the fact that a regular forest inventory is not specifically designed for a survey of herbaceous plants. A pilot inventory carried out in two districts in Nepal is described. The experiences are reported and discussed.

Introduction

Non-wood forest products (NWFPs) are attracting more and more attention from researchers worldwide. In many studies the importance of these products and their sustainable management is stressed. Their contribution to the subsistence of local populations and to the macroeconomic development differs very much from region to region. The promotion of NWFPs can and should complement the objectives of rural development and appropriate forest management (Hammet 1993), as they are sources of alternative employment and income generation (Sharma 1995). In short, the full economic valuation of endangered tropical forest ecosystems is not possible without consideration of the value of non-timber forest products (Hall & Bawa 1993). Sustainable reliance on NWFPs also creates the need to maintain and conserve biodiversity (Sharma 1995). Thus, management of NWFPs cannot be seen separately from general forest management, which, unlike forest plantation, affects vegetation and biodiversity in general.

It is frequently emphasized that detailed and systematic data about this natural resource is lacking (Malla et al. 1995). Sharma (1995) points out the lack of an ecological data base. Existing information is extremely scant regarding the status of the resource base, the probable impact of harvesting and collecting practices, etc., and area-specific sustainable harvesting. This, of course, is a situation that makes management of any resource difficult.

So it appears justified to think about the assessment of NWFPs in a general way. Forest inventories are evolving from a pure timber orientation towards multiresource (Lund & Wigton 1994). They should take into consideration other products and services and sometimes extend even to areas not falling under the definition of 'forest'. Inclusion of NWFPs in land-use inventories therefore seems a straightforward idea.

However, there is no comprehensive publication yet that systematically addresses the specific problems in the context of the assessment of NWFPs. This paper makes a contribution towards such a publication by presenting practical experiences from Nepal.

Classification of NWFPs for inventory

The term non-wood forest products (NWFPs) is used here in a more restrictive sense than that proposed by Chandrasekharan (1995), as for this study the service functions of forests are disregarded.

Many techniques have been developed to assess wood volume, its quality and its spatial distribution in traditional forest inventories. It is a minor issue to integrate the assessment of non-wood forest products, which show some relationship with known tree dimensions, into a forest inventory. Other products unrelated to the trees pose more severe problems, but they can be classified into three groups according to feasibility of estimating them in forest inventory (table 1).

Table 1. Summary of three groups of NWFPs according to feasibility criteria of forest inventory

NWFP Group	Group description	Examples	Comments
1	Non-wood tree parts	Tree fruits, leaves, twigs (fodder, ornamental)	Can be related to tree dimensions
2	Products from ´tree like´ plants	Bamboo, rattan	Relatively easy measurable dimensions
3	Herbs and other plants	Medicinal and aromatic herbs	Some specific properties to be taken into consideration when incorporating into standard forest inventories

Note that products like fuelwood, charcoal and small-dimension wood materials for carving are excluded in the definition of NWFPs. Yet they are included when the term non-timber forest products is used.

The first group of NWFPs comprises products that come from trees. In this group products like fruits and nuts, bark, leaves, twigs for fodder or ornamental purposes, leaf litter and dry foliage, natural gum and resin are included. The occurrence of these products is dependent on the trees. So to estimate their presence, quantity and possibly quality of the produce, it is necessary to establish the relationships between the products and characteristics of the trees.

To assess the potential of fruit or nut production, for example, one needs to know the tree species and the conditions for fruiting. This is species specific; the variables determining season and intensity of fruiting might include the weather, tree age, tree dimension (stem and crown), phytosociological position in the stand, and the level of competition. In addition, the size of the fruit crop can be greater than what is available for harvest. Normally only part of the fruit is accessible to the harvesters. A similar problem occurs in timber-oriented inventories. Only part of the growing stock of the forest is for harvest. Some areas are excluded, e.g., for conservation reasons or because of problems of accessibility. Because of size or species, only a portion of the timber is utilizable or merchantable. While these proportions can be determined relatively easily for timber, it is more difficult to do so for the NWFPs of group 1.

The second group comprises products like bamboo, rattan, palm trunks, palm leaves and palm syrups. These products are different from those in the first group as they do not originate from dicotyledonous trees. With respect to a field survey, however, they exhibit characteristics similar to those of trees and can be relatively easily assessed. Bamboo, rattan and palm species are easily detectable and have clearly measurable dimensions (length and diameter), although there are some practical problems in carrying out accurate measurements.

The third group comprises non-woody plants parts, usually of the forest undergrowth. It comprises medicinal and aromatic herbs, roots and rhizomes, and ornamental plants, mushrooms. Much less experience exists in forest inventory with respect to the systematic assessment of these herbal NWFPs. These plants exhibit some characteristics quite different from those of the first two groups. Field assessment is a much more difficult task for the following reasons:

- Seasonality: Many of the usable herbs can be identified only in a particular period of the year. For the rest of the year they are not detectable as they are only in the form of seed or underground organs. If it is assumed that an inventory goes for direct identification of the herbs, field assessment is restricted to the short period of the year when they are growing. Therefore, to cover a large area, many field teams have to be employed to finish the survey in the short time available. This contrasts with a regular forest inventory where a longer part of the year is available for field measurements.

  This issue of seasonality also means that permanent sample plots have to be remeasured at about the same time of the year on each occasion. This restriction poses some difficulties for organizing non-wood forest product assessments. The situation is complicated further by the fact that not all the NWFP species have the same seasonality and that the growing period is also a function of the climatic conditions of the year of the inventory.
- For some of the NWFPs in group 3 the harvest is destructive, with the entire plant or vital parts of it being removed (roots, tubers, rhizome). In this case, no traces of the former existence of these plants are left, and an inventory field team visiting such a site would classify it as one in which this species does not grow. Depending on the completeness of the harvest and the species occurrence in the vicinity, recolonization may take some time.

  In plant science, site conditions are generally assessed together with the occurrence. Each plant has a set of site demands, but whether plants grow on suitable sites depends on other factors (history or just pure chance). Thus, it is useful to assess not only the plants themselves but also the site. In this way, it is possible to draw conclusions from the site conditions about the potential occurrence of the plants. This, of course, requires detailed knowledge of the NWFP species or species groups. In the ideal case, from an inventory point of view, one would be able to correlate characteristics that can be discerned in aerial photos with habitats of the plants of interest. These are, for example, macro characteristics of site (like elevation, aspect, slope, geology) in a particular forest type that are easily detected. Others are species composition, density, age and stand structure.
- A great variety of herb species are usable. To be able to identify them, botanical knowledge and experience are necessary, which normally forest inventory field teams do not have. As in tropical forest inventories, where tree species are identified by local tree spotters, it is possible to employ local collectors for the field work. To guarantee consistency, it would be preferable to work with a permanent group of botanists. These, however, are highly specialized people, often too expensive to be employed throughout the entire fieldwork period.

Appropriate training for the field teams is required in any case. The species to be considered must be limited to the most important ones (Malla et al. 1995).

- Herbal plants are not as striking as trees. Trees can hardly be overlooked in a field plot. This does not hold for all herbal plants, and situations can occur in which some herbal plants are quite easily missed. To avoid negatively biased results, it is desirable to introduce 'detection probabilities', as used in wildlife surveys (e.g., Thompson 1992). Several factors affect the chance to locate a herb, and they are likely to differ between species. Other important factors are the density of the understorey, the weather conditions, and the knowledge and experience of the team.

  Detectability and ease of identification are problems that can reduce data quality. This is a major issue for the inventory of herbal NWFPs.
- Experience shows that control measurements are indispensable for achieving a satisfactory level of data quality. However, seasonality of herbal NWFP puts limits on the time available for control measurements, and the problem of detectability complicates the interpretation of differences between original and control measurements.
- The scale and the spatial distribution in the occurrence of herbal plant populations show a pattern completely different from that of trees. Field plots, as used for forest inventories, are not necessarily appropriate for the survey of herbal plants. Demarcation of the plot boundaries in the field by cords or tapes is very helpful to guarantee that a correct decision is made as to whether an individual is in or out of the plot area.
- Quantitative assessments of trees are relatively easy to make. With herbal plants this is not so. Even simple counting can be difficult if the plants occur in dense clusters. Biomass or weight of the entire plant or of parts of it cannot be measured directly. For some plants, the parts of interest are underground and not even visible (roots, tubers, rhizomes). Estimation then requires relations between simply measurable attributes and the target attribute. These relations have to be developed first. Again, because of the great variety of herbal NWFPs, a single generalized method of quantification may not be applicable to all species.
- Many of the NWFPs in group 3 do not occur only inside forests. They might also grow in shrubland or in woodlands that do not fall into the vegetation or land-use class of forest, or even of grasslands. This ecological amplitude must be known for the species under assessment, so that it is clear that a forest inventory is not capable of delivering the entire picture. Trees outside forest boundaries are also similarly ignored in inventories.

  The above problems of seasonality, the great variety of species, and the detectability problems are a hindrance but not an overwhelming constraint to carrying out inventories. They do, however, pose additional organizational and reliability problems.

The simple classification of NWFPs shows that the main problems of NWFP assessment are with group 3. Their assessment extends more into the field of general vegetation research and quantitative techniques to sample vegetation. Experiences from Nepal with herbal NWFPs are presented here as a detailed example of making NWFP inventory.

Some experiences from Nepal

General situation

Nepal is one of the principal countries of the world producing non-wood forest products (see Sah & Dutta, this volume). Non-wood forest products, especially medicinal and aromatic plants, are important, particularly in the hill and mountain region. About 650 plants are utilized and commercialized in one form or another. Currently about 100 of these have a high commercial value and are traded. Medicinal and aromatic plants, as well as the NWFP-based industries, form one of the six sector programmes in the Nepal Master Plan for the Forestry Sector (MPFS) 1989. The royalties and the levies paid when exporting NWFPs provide a considerable income for the government.

Harvesting NWFPs has grown from occasional collection by shepherds and mountain people to a large business involving full-time collectors, middlemen and dealers on several levels. These activities started to threaten the existence of some of the species, because some collectors leave no regenerative material on the site (Malla et al. 1995). Although nobody knows the actual situation in the field, the figures in the export statistics show that the trade with some of the products is decreasing dramatically. Assuming that the market demand has remained unchanged, this can be interpreted as a sign of the fact that these plants have been overexploited.

Management and monitoring of the harvest activities has to be based upon quantitative and spatial information about the resource. As a considerable portion of the NWFP comes from forests, it seems reasonable not to separate the NWFP issues from the other forest management issues. Their forest planning and management should be carried out within the framework of a general management plan. So it is natural that the assessment of NWFPs should be considered an important part of any forest inventory planning. But research is needed on methods for providing good quality data on NWFP.

Only a few studies could be found in which surveys of NWFPs had been considered. One had been carried out by the Department of Plant Research in the mountain area of Jumla. It was an evaluation of official statistics, and it is not clear how accurately the true situation is reflected. Malla (1991) gathered data on the type of NWFPs, their existence in different districts and the quantity said to have been collected. This study was based mainly on interviews with collectors and traders and on an evaluation of official statistics made to keep track of royalties and export levies.

However, it is generally accepted that an evaluation of official statistics and interviews with collectors and dealers cannot serve to obtain an objective picture of the NWFP situation, neither quantitatively nor with respect to their spatial distribution. Often the statistics are collated from information of the dealers, in regions other than their collection area (Edwards & Bowen 1993). This distorts the picture of their natural occurrence. At best it may help to get a general idea about the importance of the NWFP trade and about the relative market share of different products. Obviously, NWFPs are also subject to illegal collecting and smuggling, and such products would not appear in any official statistics.

Several studies stress the necessity to conduct objective surveys as the basis for management activities. In Edwards and Bowen (1993), it is stressed that inventories should seek to clarify the ecological requirements of species, the area of land meeting these requirements and the abundance of different species.

Case study

The Forest Resources Information System (FRIS) Project, funded by FINNIDA and carried out by the Finnish Forest and Park Service in cooperation with the Forestry Department in Kathmandu, has the objective of building up and establishing a comprehensive forest information system for Nepal. Within this project, a National Forest Inventory was designed and pilot studies were carried out in several districts, as it was felt that NWFPs form an important part of the forest resource in Nepal that requires inventorying. This was then put into practice in a pilot inventory in the two districts of Dhading and Nuwakot (Kleinn 1994, Laamanen et al. 1994).

A cluster layout is depicted in figure 1. To assess tree characteristics, two circular plots were used in one cluster (radius 18 m each, plot area 1017.9 m^2). They were 100 m or 200 m apart from each other, depending on terrain conditions. NWFPs were assessed in a strip connecting the two circular plots within a cluster; the area of the NWFP assessment strip was 1000 m^2, with side lengths 200 x 5 m or 100 x 10 m. Altogether 20 clusters (40 plots) were laid out during the pilot inventory exercise.

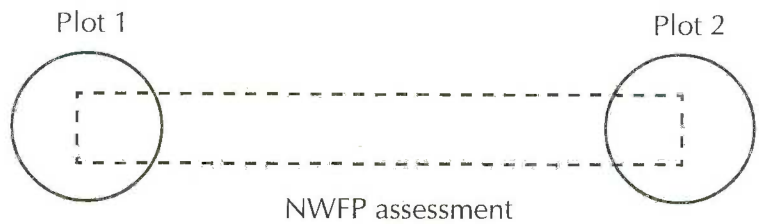

Figure 1. Field plot design of pilot inventory, combining classical forest inventory and NWFP assessment. NWFP assessment on a 1000-m^2 strip (200 x 5 m or 100 x 10 m) connecting the two circular forest inventory plots.

The strip, demarcated by rope in the field, was made narrow to facilitate plant counting. Transects are standard field sample plot shapes employed in quantitative vegetation research, but the area of 1000 m^2 is regarded too small in vegetation research to sample distribution or abundance. It was used here for reasons of feasibility of field work.

A team of NWFP specialists, consisting of a botanist, an assistant botanist, a field assistant and a local helper, accompanied every forest inventory field team. As soon as the centre point of the first circular plot was determined, the NWFP team started with the measurements on the strip while the forest inventory team worked on the circular plot. This procedure worked smoothly and without problems. To arrive at quantitative estimates of the products, the useful parts of a sample of five specimens of each species were weighed. The average weight was then used to estimate the total weight per unit area.

The pilot inventory had the objective of learning more about the sampling procedure and its feasibility rather than producing numbers about the occurrence of NWFPs; however, some general results (following Laamanen et al. 1994) can be presented:

- It was observed that the occurrence of some important NWFPs was well correlated with the surrounding forest type. For example, *Woodfordia fruticosa*, *Asparagus racemosus* and *Osyris wightiana* occurred in *Schima-Castanopsis* forests, in pure *Shorea robusta* (Sal) and in mixtures of them. This supports the idea that indirect measures could be developed for assessing NWFPs. If one could succeed in correlating their occurrence with geographic attributes (physiographic zone, altitude, geology, soil, etc.) or stand characteristics (forest type, species composition, crown cover, mean dimensions of the trees) the sampling procedure would be considerably facilitated. Aerial photographs could even be usefully used.
- A similar need has been stressed by Malla et al. (1995) regarding a quantitative assessment of *Rheum australe* and *Asparagus racemosus*. They indicate the need to find out which of the NWFPs have similar demands on their habitat so that they can be classified by habitat. It will probably not be possible to do this for all of the

100 most important NWFPs of Nepal. In addition, it is equally important to find indicators to characterize the preferred habitat for each of the main groups of NWFPs. These indicators should be easily measurable.

- Seasonality is an important consideration. During the survey, many of the *Asparagus* tubers were found to be rotten already. The best time to survey these species would probably be after the rainy season, or in early autumn.
- Variation in number of NWFPs between the field plots was very high, indicating clustering of the individuals, which can be due to minor changes of site conditions. The 1000-m^2 plot was therefore too small, particularly if a quantitative assessment is to be carried out. A sampling intensity of 5–10% of the target area is therefore proposed for a fair estimation. This is not, however, congruent with the basic idea of large-area inventories, which should normally have a much lower sampling intensity.
- In many plots NWFP assessment was hindered by the dense undergrowth of the understorey.
- Many of the medicinal plants have not been explored yet. A medicinal plant locally called 'teet pindalu' and used for a variety of medicinal purposes was identified as *Arundina graminifolia*.
- On average it took 3 hours to complete one strip.

The conclusion of this study was that combining the forest inventory with a non-timber forest product assessment was technically feasible (Laamanen et al. 1994). However, for application over a large area the budget required would become a major constraint.

Discussion and conclusions

There is a need to reflect upon the usefulness and justification of including NWFPs within the framework of large-area forest inventories. First it is important to be clear about the objectives and particularly to identify who will benefit from the information collected.

Large-area forest inventories are to provide information on the status and condition of the forests. Sampling intensity is usually small, while the units reported on are large. The results are generally used to support regional planning and policy formulation being evaluated and used by government departments. Often there is also an interest in such data from other organizations and projects dealing with forestry, land-use aspects, ecology, etc., on regional, national or international scales.

The benefits of improved information in regional planning or forest policy formulation cannot be easily quantified economically. Therefore, justifying the investment for an inventory of a large area is sometimes not easy, especially when NWFPs are included in the list of variables to be assessed. The questions to be answered must be clearly identified.

There are different schools of thought on the usefulness of NWFPs inventories. Godoy et al. (1993) recommend that the inventory (the stock quantity in the forest) and the flow (the quantity actually used by people) be distinguished. They further state that, for most purposes, the inventory is meaningless, being related neither to present nor to sustainable use. For both timber and non-wood forest products, only a part of the stock quantity is normally available for harvest and utilization. For economic evaluation, the proportion must clearly be known (explicitly for specific products and also for specific regions). However, there are many concepts of forest inventories and many ways to use the data collected. The authors of this paper therefore find the general argument of Godoy et al. (1993) not very useful.

A more specific criticism has been pointed out by Edwards and Bowen (1993): who indicate that macro-level inventories of NWFPs are of limited value unless specific case studies are conducted to support the data. Within the overall objective of contributing to conservation by employing sustainable management of NWFPs, one has to realize that a large-area inventory is only one part of the process. Gunatilleke et al. (1993) have emphasized that socioeconomic, biological and silvicultural information is required for a reasonable multiple-use management of rain forests. Large-area forest inventories do deliver some pieces of needed information in this mosaic.

From large-area forest inventories, data on occurrence (geographical distribution) and quantity (number of plants, size, weight of usable parts, etc.) of selected NWFPs can be obtained. Not all usable plants can be included. A selection of the most important NWFPs, or groups of NWFPs, must always be made. From the experience with our pilot study, it appears that at least 20 species can easily be managed without botanists, provided useful field manuals for identification of those plants are made available to well-trained field crews. Observations on additional species can of course be recorded as additional information. Further data collected refer to the surrounding vegetation type and to the topography that is possibly associated with the occurrence of the NWFP species.

Data analysis will give a picture of the spatial distribution of the NWFPs. Because of the nature of large-area inventories, this is an estimate referring to larger geographical units, and comparison with other regional statistics will be informative. The data will give sound baseline information for identification of endangered species, particularly when remeasurements are available so that changes in the population can be observed.

On the research side, the data can be used to build relationships between auxiliary data and the occurrence of species. This will be useful during further inventories, but also as a general contribution to the knowledge of their biology. Such data, if easily retrievable from a database, will be most valuable for many kinds of studies, such as the adjustment of royalties or other means of fund raising. However, the availability of this data could lead to further exploitation of the resource.

It is difficult, to draw general conclusions from all of these considerations. The authors' opinion from this experience in Nepal is that the data collected in the large-area inventory was very worthwhile and can contribute to the development of a strategy for managing NWFPs. One of the outputs may be the protection of species that have been found to be endangered. This protection must be enacted by government, but its enforcement for the sustainable management of NWFPs can succeed only through community awareness and action.

References

Chandrasekharan C. 1995. Terminology, definition and classification of forest products other than wood. p 345–380. In: *International Expert Consultation on Non-wood Forest Products*. FAO Non-wood Forest Products No. 3.

Edwards D.M. & Bowen M.R., eds. *Focus on Jaributi*. Proceedings of the Non-timber Forest Products Seminar, Kathmandu, 12 May 1993. FRSC Occasional Paper 2/93. 26 p.

Godoy R., Lubowski R. & Markandya A. 1993. A method for the economic valuation of non-timber tropical forest products. *Economic Botany* 47(3):220–233.

Gunatilleke I.A.U.N., Gunatilleke C.V.S. & Abeygunawardena P. 1993. Interdisciplinary research towards management of non-timber forest resources in lowland rain forests of Sri Lanka. *Economic Botany* 47(3):282–290.

Hall P. & Bawa K. 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant population. *Economic Botany* 47(3):234–247.

Hammet A.L. 1993. Non-timber forest products: profits or panacea? p 2–3. In: *Focus on Jaributi*, ed. D.M. Edwards & M.R. Bowen. Proceedings of the Non-timber Forest Products Seminar, Kathmandu, 12 May 1993. FRSC Occasional Paper 2/93.

Kleinn, C. 1994. Forest resources inventories in Nepal: status quo, needs, recommendations. FRIS Project Paper No. 1. Forestry Department, Kathmandu, Nepal. 80 p.

Laamanen R., Malla S.B., Battarai N.K. & Subedi M.N. 1994. Pilot forest inventory in Dhading and Nuwakot: assessment of minor forest products in Dhading. FRIS Project Paper No. 2. Forestry Department, Kathmandu, Nepal. 28 p + annexes.

Lund G. & Wigton W.G. 1994. A primer for designing multiple resource inventory (MRI) and monitoring programs. AIFM/IUFRO Conference on Multiple Resource Inventory and Monitoring of Tropical Rain Forests, 21–24 November 1994, Seremban, Malaysia.

Malla S.B. 1991. Medicinal plants: their utilisation and management and the biological diversity of the flora of Nepal. p 401–444. In: *Background papers to the National Conservation Strategy for Nepal*, vol. 2. World Congress Union, IUCN.

Malla S.B., Shakya P.R., Rajbhandari K.R., Battarai N.K. & Subedi M.N. 1995. Minor forests products of Nepal: general status and trade. FRIS Project Paper No. 4. Forestry Department, Kathmandu, Nepal. 27 p + annexes.

Sharma P. 1995. Non-wood forest products and integrated mountain development: observations from Nepal. p 157–166. In: *International Expert Consultation on Non-wood Forest Products*. FAO Non-wood Forest Products No. 3.

Thompson S.K. 1992. *Sampling*. John Wiley & Sons. 343 p.

Sow's ears and silk purses—non-timber forest product identification, assessment and monitoring

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Abstract

There are possibly an infinite number of potential products available from the life forms on our forested lands. The 'products', or functions of organisms, such as plants and animals, may provide useful goods or services for human needs. Methods to identify use include observation, inquiries, reading and research. Assessment and monitoring techniques depend on the life form being studied, its abundance, habitat, and whether it is domesticated or not. Where specific commodities have not been identified, using multiple resource inventories is recommended.

Introduction

The theme of this international conference is 'Domestication and Commercialization of Non-timber Forest Products in Agroforestry Systems'. It is appropriate that this conference starts with a paper on product identification, assessment and monitoring. But why are we looking for new products, uses and services from our wild lands? We do this because we want to—

- improve the economic status and well-being of the local populace—that is, to alleviate hunger, malnutrition, food insecurity, poverty and disease
- prevent further degradation of our limited land base
- maintain or increase forest (vegetation) cover

We need new products to feed and shelter our increasing population and to keep people healthy. With more inhabitants, there will be more pressures on the land. Simultaneously, there will be an increasing need to preserve our natural resources for environmental, ecological, social and economic needs. If we can find new uses for the resources on our 'wild' lands, we can probably preserve and sustainably use these resources. Simultaneously, we can probably maintain the much needed diversity.

Is it important that we sustain both biological and economic diversity? We need biological diversity to maintain viable populations of plant and animal species, to maintain gene pools, and to provide new product sources. Most nations have agreed to conduct biodiversity surveys and to sustain the existing diversity (anon 1992, 1993). We need economic diversity to minimize risk in the event that our primary income sources fail.

If we can find new products from our lands, we can bolster what may be a sagging or nonexistent economy. Development of non-timber forest products can provide a stimulus to conservation and sound resource management through incomes generated by local people, and through its contribution to national incomes and export earnings.

Products and product identification

A product is an outcome of work (including hunting, gathering or manufacturing) or the growth of living things. Labour, study and skill can increase the quantity and quality of products. The source of a product may be animal, vegetable, mineral, or a combination. Harvesting or conversion of plant or animal material into forms suitable for human use is an example of production.

Non-timber products are any from forest lands, other than those used for building or structural purposes. Non-timber products may include minerals, water, fauna and flora (including woody parts used for fuels) used for medicinal, cultural, ornamental, or religious purposes.

Every product on our planet is derived, one way or another, from natural resources. There are over 100 chemical elements and 1000 minerals. The potential number of products from the earth's living organisms is almost countless. This paper focuses on the living (renewable) resources. Failure to recognize the potential of the flora and fauna we have on hand is a serious weakness in our quest to develop new products.

We have an obvious lack of knowledge about the identity of the species there are on earth. There are an estimated 7–20 million species of life on earth—with the real figure probably falling between 13 and 14 million (Hawksworth & Kalin-Arroyo 1995). Of these, some 1.7 million organisms have been described (table 1).

Table 1. Approximate numbers of species in major life forms (in 1000s)

Group	Described species (no.)	Total species in group (estimated no.)
Viruses	4	400
Bacteria	4	1000
Fungi	72	1500
Protozoa	40	200
Algae	40	400
Plants	270	320
Nematodes	25	400
Crustaceans	40	150
Arachnids	75	750
Insects	950	8000
Molluscs	70	200
Vertebrates	45	50
Others	115	250
Totals	1750	13620

Source: Hawksworth & Kalin-Arroyo 1995

Approximately half of the 13 million species are believed to be insects. For vertebrates, there are about 45 000 described out of an estimated 50 000. There are 240 000 described vascular plants out of an estimated 320 000. Of the 240 000, 25% are believed to be edible. Up to 5000 plants have been used for food, although most of the world's people rely on less than 200 (Stelljes et al. 1995). These 200 plants provide about 90% of human food supplies.

Another information shortcoming we face is how we can use these organisms. There is a potential for any species to be beneficial to humans. To make the situation more complex, we may use the entire life form, just parts of it, or its by-products.

There is an old saying 'we use everything from the pig but the squeal'. From animals, we may use the exterior (skins, shells, hides, furs, antlers, horns, hooves), interior (meat, fats, bones, teeth), body liquids (venom, milk, blood, oils, musk), DNA, body parts and organs (eyes, ears, stomachs, livers, intestines), or animal products—such as nests, honey, wax, silk, and even excrement. From plants, we may use fruits, nuts, seeds, leaves, stems, bark, saps and resins, germplasm, roots or even the genes.

Besides products, many life forms can provide services that directly or indirectly benefit humans. For example, we use dogs to herd sheep, provide guard services, detect drugs, etc. We use insects such as the praying mantis *(Mantis religiosa)* or lady-bugs *(Hippodamia convergens)* to control other insects. Certain fish control algae. We use many plants for their beauty or for their environmental functions of soil stabilization, watershed protection and carbon sequestration.

How do we go about learning what organisms will be useful? There are several ways:

- Ask someone, especially people in the local area; this is the simplest method for finding out what is useful or not.
- Observe by visiting local markets, or go with hunter–gatherers in the woods.
- Check the literature.
- Consult historical records and archeological sites; these sources may reveal past and forgotten uses.
- Do research and development.

Indigenous knowledge and ethnobotany are discussed in another session in this conference. As we seek new plants and animals to meet our needs, we need to keep in mind that similar species may have similar uses. Thus, if we find that one species meets a need, a closely related one may also. A single species may have also several uses. Another possibility is that those species that are unrelated but thrive together in similar environments or ecological niches may also have similar uses or functions.

As we search for potential applications, we may find that although local people use most species for something, many plants or animals may have no obvious commercial value. This may not mean that the organism is not useful or a potential product source. (Techniques to actually develop a product will be covered in another session in this meeting.) It could mean that—

- we may not have the technology to use the species
- there may have been a use in the past that may have been lost between generations
- the animal or plant may be too rare for a use to have developed
- there are other species with similar uses that are more abundant and better
- the plant or animal may be so plentiful that its use may be overlooked
- culture or policies prohibit use

Besides products, forest lands can also provide functions or services that may yield economic returns to the local community.

A service is a useful result that is not a tangible commodity. Water storage and water-shed protection are examples of two types of services. One benefit that is on the increase is recreation—especially ecotourism. For this use, we need to assess why people would want to come to the location —it may be to see unusual or abundant plant or animal life, scenic beauty, historical or cultural interest, etc. Visitors need to be assured of adequate access, living conditions and security. As we search for new uses of our forest resources, we should not overlook opportunities to recycle what we have already developed. Except for a handful of space probes, every product created on earth and every life form that ever existed is still here in some form or another. The recycling potential is unlimited.

Commercialization and domestication

Commercialization

Commercialization is the development of a product or service that is suitable or fit for a wide public market. It is one's intent to profit by commercialization. This may or may not be true for domestication. For plants or animals, the resources may be maintained in natural settings such as a forest or in domesticated environments such as a farmer's garden, chicken coop, or a pine plantation. Commercialization should be carried out on a sustained basis, but often it is not.

Non-timber forest products can be extracted on a sustainable basis only under certain circumstances. These situations usually involve climate, soils and numbers of the organisms. To ensure that the product can be sustained, it is necessary to develop a checklist of attributes and requirements for successful and sustainable development for extraction. Methods are also needed to apply this checklist in land-use planning. The Tropenbos Foundation (Lawickse Allee 11, Wageningen, The Netherlands) is developing such a checklist. It will enable the identification of areas where commercial extraction of non-timber forest products is promising as a conservation strategy (anon. 1995).

Domestication

Domestication is the act or process of converting animals or plants to household use (see Leakey & Newton 1994 for other definitions). That often means moving an organism from its natural habitat, introducing it to a modified habitat, and providing the means for it to maintain itself in its new location. This may involve genetic modification and breeding. An example may be removing a fruit-producing plant from the wild, planting it near one's house, harvesting the crop, and planting the seeds for a future crop. The domesticated plant or animal may be used for one's own enjoyment or consumption, or it may be domesticated for commercial purposes. Techniques for product domestication are discussed in another session in this conference.

We domesticate because it is amicable to have that particular life form around, because it is easier to deal with at home, or because through cultivation it can be improved. Frequently it is also because it is more economical to produce the product than to continually collect it from the wild. If we do not domesticate, the reasons are probably that there is no need—the organism is plentiful in the wild—or else the habitat requirements are too difficult to duplicate on a farm or in a garden.

Commercialization can change an area's ecology by favouring or exploiting one species instead of another. This is not necessarily bad, as many creatures modify their environment to suit their needs. We just have to be aware that we are shaping the future by our management activities and plan accordingly.

Together, domestication and commercialization may lead to monocultures. While monocultures may not be desirable from a diversity perspective, they may be economically, and perhaps environmentally, acceptable. Agroforestry systems may be more diverse and environmentally acceptable, but they are not necessarily as productive and profitable as plantations. However, if the environment and the external benefits are costed, agroforestry systems may be the most beneficial in the long run.

Marketing

Market development involves the estimation of demand, analysis of supplies, and assessment of problems and economics of transportation. One must be able economically and effectively to move goods from the producer to the market. Besides economic considerations, one must also consider the ability to deliver in a timely manner. There are three general approaches to market development:

- find out what is out there and then try to find a use for what is abundant
- identify a need and then find a product that will meet that need
- identify what is used locally then determine if the demand can be expanded

The second and third options are desirable, but the first is more common. Successful commercialization depends on market demand. There is an old saying that 'you cannot make a silk purse out of a sow's ear' (note that both pigs and silkworms are natives from the forest). In other words, you cannot make something valuable out of something that is worthless. However, what is worthless to one person may be valuable to another. This value may exist or be created through good marketing strategies.

To commercialize, it is necessary to have or create a demand. One should show that the product—

- is better or more economical than available alternatives
- is good for the user
- makes the user feel good
- makes the user look better
- is rare or unique or different
- makes the user one of the crowd

An opportunistic approach can be used when the product is truly needed. In product development, it is often necessary to look at what is currently used on a small-time basis, then explore needs and opportunities to expand the market.

In our quest to develop new products, we need to keep in mind that unforeseen problems may occur. Commercialization, for example, can lead to a depletion of the resource. Any time we favour one species we do it at the expense of another. Domestication, on the other hand, may lead to the creation of monocultures. While monocultures may be acceptable economically, socially and perhaps even environmentally, they may not be wanted from an ecological perspective. In any case, we must weigh our losses with our gains. Policy and institutional aspects of commercialization and domestication will be discussed in another section of this workshop.

Assessments and monitoring

An assessment is the act of determining the amount or value of a resource. We need to assess both the supply of the resource and its demand. This paper examines only the supply end of the process. We make inventories to determine the extent of the supply of the plants or animals available to us. An inventory can help decide if a plant or animal requires domestication by revealing its apparent abundance and habitat.

As we make our enquiries, we need to decide what organisms are used, how we use them, and if and how they need to be processed. To learn how to domesticate the plant or animal, we need to know what are the habitats or environments in which it is found, when it is usually found (season, time of day, time of year), what is its reproductive requirement, and under what environmental variations can it successfully survive. Such information will be useful in developing the inventory and monitoring systems.

When we have a clear picture of the products we intend to produce and the biotic source of those products, making an inventory is straightforward. Since nearly all life forms depend on vegetation, it makes sense that flora is the focal point of many of our inventories. Inventory techniques are different depending on whether the potential product is domesticated or occurs in the wild.

If we have domesticated the plant or animal, the task is very simple. In all probability 'domesticated' plants are found in fields or plantations. Domesticated animals are usually confined to pens or pastures. In other words, we know where the organisms are. For vegetation or animals confined to a small area, we can merely do an enumeration. Where large areas are involved, some type of sampling may be necessary. This again may not be a major problem, especially with vegetation. Most domesticated vegetation is grown in even-aged monocultures or relatively simple mixtures. The expected variation among plants is small. Therefore we can get by with fewer samples than we would need with the same plant in the wild. Finally, fields, plantations and pastures are usually close to some transportation network (roads, trails). With easy access, we can inventory and monitor the resource more frequently and economically.

If the resource occurs in the wild, an inventory becomes more complex. Variation will be greater; we will need more rigorously selected samples. In addition, access may be more difficult, thus costs will be greater. Remote sensing may be required, especially for large areas. If we know the habitat requirements, we can save some money by mapping and stratifying the forest and concentrate our data collection efforts on where the organism is likely to occur. If we do not know the habitat requirements, then we may have to use a systematic sample.

In areas where potential uses and products are anticipated but not well defined, consider using a multiple resource inventory (MRI). In an MRI, one collects sample information on major vegetation types, soils and terrain features. A minimum set of vegetation information to collect is life form (tree, shrub, herb, grass), its numbers, average height, and percentage of ground cover of each. Optimally, one should try to detect and record the genus and species of each plant present and the average dimension of each. From this we can compute biomass, which can then be equated to nearly any product anticipated, by use of a harvest index.

An MRI may also be appropriate where there are known multiple uses of the land. For example, a piece of land may be used for grazing, timber, fuelwood, etc. Rather than collecting data on these uses in separate efforts, a combined inventory may be more economical. A common glossary of terms is a first step in developing an MRI (Resource Inventory Coordination Task Group 1989). Guidance on how to design a multiple resource inventory may be found in Lund (1986), Lund (1995) and Lund and Wigton (1994).

Monitoring is the process of observing changes according to a set of standards or protocols. As with assessments, we need to monitor both the supply and the demand end of the resource. Changes in demand will affect the need to supply. At the supply end, we monitor—

- to note changes in the resource base
- to determine if we can meet future demands
- to see if our management activities are going according to plans

For such monitoring, it would help to know the history of any trends in the availability of the resource. This would help decide monitoring methods and frequency. Again, asking village elders, consulting historical records, etc., may help. Monitoring requires making the same observations at the same location, but at different times.

For naturally occurring vegetation, we often use permanent plots. Guidance on how to establish permanent plots for monitoring forest conditions is found in Päivinen et al. (1994). For animal populations it is essential to monitor habitat as well as the animal numbers. Monitoring should include collecting data on changes in numbers, condition, success of reproduction, and habitat. This information is essential for sustainable forest management. If the organism is not domesticated, it is essential to leave enough individuals and habitat for successful reproduction. To monitor demand, one must not only keep track of changes in number of consumers but also changes in competition, transportation methods, etc.

Conclusions

I have introduced the subjects of product and product identification, commercialization and domestication, and assessment and monitoring. The possibilities of creating new products and uses from our wildland resources are nearly limitless and indeed exciting. It has been conservatively reported that one species becomes extinct every three hours (Center for Plant Conservation 1995). What could have gone for good is gone for good. Yet, we do not know how many species there are on earth and how they can be used. Given these facts, I believe we can reach these conclusions:

- A high priority is to complete biodiversity surveys going on throughout the world to learn and record what species exist on earth.
- We desperately need to find new uses and sources of income in many parts of the world. More ethnobiological surveys are required to learn how indigenous people use local flora and fauna.
- Domestication and commercialization of potential non-timber products offer opportunities to improve the well-being of the world's peoples. However, we need to recognize that domestication and commercialization will result in changes in the 'natural' environment, and work to mitigate the effect of these changes.
- To develop and commercialize new products, assessments or inventories of the resource's abundance, condition, distribution and habitat are needed. Multiple resource inventories may provide a good solution for gathering resource information when specific uses are not known.
- As commercialization develops, we need to monitor changes in supply, demand and transportation.
- As we seek new uses, we need a general policy and strategy to carry out resource inventories, research and management activities that will maintain or increase—
- local people's well-being and the land's environmental functions
- vegetation cover
- soil productivity
- biodiversity
- ecosystem functions . . .

  . . .in that order; local support is essential for success in meeting these needs. Finally, benefits have to be realized immediately and then sustained in the long run.

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References

Anonymous. 1992. *Earth Summit Agenda 21: the United Nations Programme of Action from Rio*. United Nations, New York. 294 p.

Anonymous. 1993. Documents of the Earth Summit. Rectors of the Costa Rican Public Universities.

Anonymous. 1995. Commercial extraction as a strategy to save tropical rain forests. Press release. The Tropenbos Foundation, Wageningen, Netherlands.

Center for Plant Conservation. 1995. The risk of extinction—diversity is a vital feature of all living systems. Center for Plant Conservation. Brochure.

Hawksworth D.L. & Kalin-Arroyo M.T., eds. 1995. Magnitude and distribution of biodiversity. p 107–191. In: *Global biodiversity assessment*, ed. V.H. Heywood & R.T. Watson. United Nations Environment Programme & Cambridge University Press, Cambridge, UK.

Leakey R.B.B & Newton A.C., eds. 1994. Tropical trees: potential for domestication and the rebuilding of forest resources. HMSO, London. 284 p.

Lund H.G. 1986. *A primer on integrating resource inventories.* Gen. Tech. Dept. W0–49. Forest Service, U.S. Department of Agriculture, Washington, DC. 64 p.

Lund H.G. 1995. The far side of integrating resource inventories—people and politics. p 11–26. In: *Simplicity versus efficiency and assessment of non-timber resources: the Monte Verità Conference on Forest Survey Designs.* Monte Verità, Ascona, Switzerland, 2–7 May 1994, ed. M. Köhl, P. Bachmann, P. Brassel & G. Preto. Swiss Federal Institute for Forest, Snow, and Landscape Research, Birmensdorf, Switzerland.

Lund H.G. & Wigton W.H. 1994. A primer for designing multiple resource inventory and monitoring programs in the tropics. *Proceedings of AIFM International Conference on Multiple Resource Inventory and Monitoring of Tropical Forests, 21–24 November 1994, Seremban, Malaysia.*

Päivinen R., Lund H.G., Poso S. & Zawila N.T., eds. 1994. *IUFRO international guidelines for forest monitoring.* IUFRO World Series Report 5. International Union of Forestry Research Organizations, Vienna, Austria. 102 p.

Resource Inventory Coordination Task Group. 1989. *Interim resource inventory glossary.* Forest Service, U.S. Department of Agriculture, Washington, DC. 96 p.

Stelljes K.B., Wood M., Hardin B. & Senft D. 1995. Genebanks—treasure houses of uncommon food. *Agricultural Research* 43(10):4–5.

Uncultivated plants for human nutrition in Côte d'Ivoire

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Abstract

The importance of uncultivated plants for human nutrition was studied in the V-Baoulé, central Côte d'Ivoire. The inhabitants of this region live at the border between the forest and the savanna. They know and use both ecosystems. The ethnobotanical, biochemical and nutritional features of 48 uncultivated plants were evaluated. Their relative importance with respect to the diet was assessed. Social and cultural factors interacting with their utilization were recorded.

Although nutrition is based on agricultural crops, uncultivated plants are an important source of vitamins and minerals, some being part of the daily diet. Leaves are prepared as vegetables mostly in times when fresh vegetables from the field are scarce. Uncultivated fruits are gathered throughout the year. They add variety and complement the children's diet particularly. Palm wines are consumed by all groups of the population. They are a valuable source of energy, vitamin C, niacin and potassium.

This paper discusses the most important plant species and the prospects of sustainable use. It also highlights the possibilities and constraints of their potential domestication. Special attention is given to the wine- and fruit-producing palm tree *Borassus aethiopum*, to the fruit-producing shrub *Annona senegalensis*, and to the annual, semi-domesticated *Corchorus olitorius*.

Up to now, the gathering of products from the wild has been possible without major effort. Farmers will grow these products only if there is a market demand or if, because of environmental pressures, these products become scarce. When selecting species for domestication, their possible negative image must be taken into account ('attracts snakes', 'famine food').

Introduction

Most of the traditional knowledge in Africa is transmitted orally. The knowledge on wild plants is in danger of getting lost as habits, value systems and the natural environment change. To preserve this knowledge, which potentially is highly valuable for future generations, it needs to be recorded systematically. We undertook this in the V-Baoulé, in central Côte d'Ivoire, in the village of Zougoussi (200 inhabitants), which lies at the border between the Guineo-Congolian rain forest and the forest-savanna transition zone. The villagers know both natural environments and practise shifting cultivation in the savanna as well as in the forest, where there is also some cash crop production (coffee, cocoa).

In addition to this ethnobotanical study, the contribution of uncultivated plants to the human diet was assessed. The nutritional importance of gathering products has repeatedly been pointed out for different regions throughout Africa. However, because of methodological problems, no quantitative assessment had previously been made.

After a brief description of the methods used, the general features of vegetables, fruits and beverages from uncultivated plants in the diet are discussed. Three selected species are then presented and conclusions are drawn for the sustainability of their use and their potential for cultivation.

Methods

Precise descriptions of the methods applied are given elsewhere (Gautier-Béguin 1992, Herzog 1992). Ethnobotanic interviews were followed by botanical and ecological descriptions of the uncultivated food plants. Their consumption was assessed by interviews recording the food intake during the 24 hours preceeding the questioning (24 hour recall), repeated monthly over one year (September 1988 to August 1989). Biochemical analyses of the foods were carried out where necessary (general composition, vitamins, minerals) and related to the recommended dietary allowance (RDA) as specified for the location (Herzog 1992).

Uncultivated plants in the diet

A total of 48 undomesticated plant species are known to yield edible products; 10 of them are herbaceous plants, 12 are shrubs, 6 are lianas and 20 are trees; 16 species have parts (leaves, fruits, seeds, flowers, sprouts) that are prepared as vegetables, 31 have edible fruits and 5 are used to prepare beverages.

Vegetables

Nutrition is based on tubers (yams, manioc, etc.), which are prepared and consumed together with a soup or stew made from vegetables and containing, if available, some fish or meat. The food frequency for sauces or stews is represented in figure 1. There is a kind of basic recipe for sauces, which consists of tomatoes, onions, peppers, oil, salt, etc. This soup can be consumed alone (item D in fig. 1) or with other vegetables added.

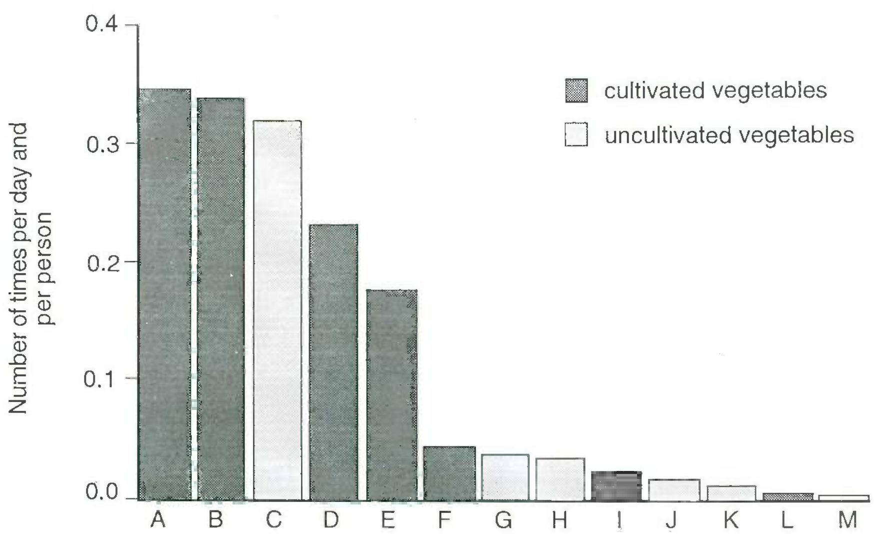

Figure 1. Frequency of the consumption of different soups or stews in Zougoussi, V-Baoulé, Côte d'Ivoire in 1988–1989

A *Abelmoschus esculentus* (fresh) *heudelotii*
B *Abelmoschus esculentus* (dried)
C *Elaeis guineensis* dura type
D 'sauce claire': tomato, onion, pepper
E *Solanum melongena*
F *Arachis hypogea*
G *Corchorus olitorius*
H *Ricinodendron heudelotii* ssp.
I *Cucumeropsis edulis*
J *Solanum indicum* ssp. *distichum*
K *Solanum americanum*
L *Solanum torvum*
M *Hibiscus congestiflorus*

Fresh or dried *Abelmoschus esculentus* (L.) Moench (gombo, okra) is the vegetable most frequently used. Next is the red palm oil, which is prepared from fruits of the uncultivated 'dura type' of *Elaeis guineensis* Jacq. Its oil is preferred by the local populations over the oil from cultivated types of oil palms because of its quality (see also Böni 1993, Böni et al. 1994). Palm oil is an important source of fat, often lacking in the diet in rural West Africa. In addition, palm oil provides carotenes, which contribute to the vitamin A supply. A daily intake of 5 g of red palm oil is sufficient to cover the RDA of an adult.

Eggplant (*Solanum melongena* L.) is also frequently consumed. The other vegetables listed are prepared less often; most are from uncultivated plants (fig. 1). Basically, vegetables from uncultivated plants can be grouped into two categories:

- Highly appreciated specialities such as *Elaeis guineensis* dura type, *Corchorus olitorius* L., *Ricinodendron heudelotii* (Baill.) Heckel subsp. *heudelotii*, *Solanum indicum* L. subsp. *distichum* (Thonn.) bitter.
- Vegetables that are eaten mainly when fresh vegetables form the fields are scarce. *Solanum americanum* Miller and *Hibiscus congestiflorus* Hochr. were recorded; nine others are known to have edible parts but were prepared so seldom that they were not recorded in the interviews. These vegetables contribute to food security, the importance of which needs not be stressed.

Fruits

Half the fruits consumed are from uncultivated species (fig. 2). The consumption of individual fruits depends on several factors:

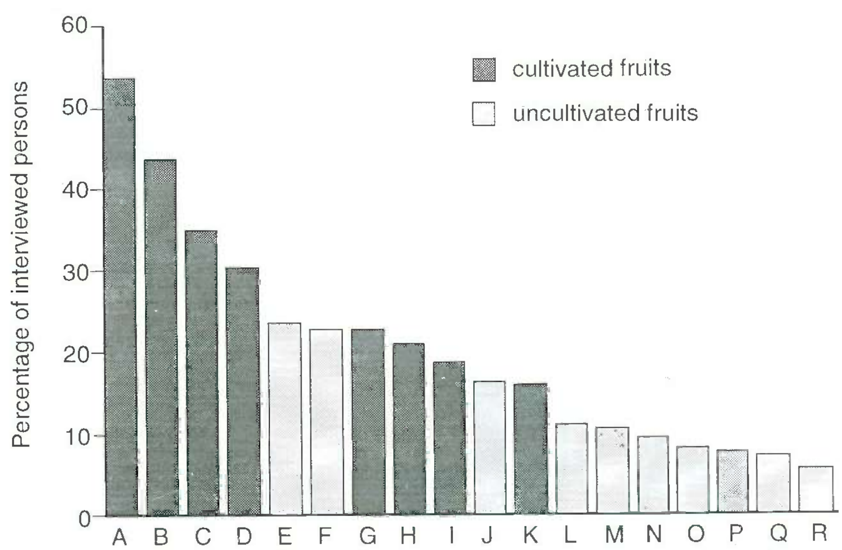

Figure 2. Fruit consumption in Zougoussi, V-Baoulé, Côte d'Ivoire, in 1988-1989; percentage of interviewed persons eating each fruit during the 24 hours preceding the interview (Herzog et al. 1994).

A *Cocos nucifera*
B *Carica papaya*
C *Saccharum officinarum*
D *Ananas comosus*
E *Aframomum alboviolaceum*
F *Spondias mombin*
G *Musa sapientum*
H *Citrus sinensis*
I *Psidium guajava*
J *Annona senegalensis*
K *Mangifera indica*
L *Borassus aethiopum*
M *Lantana camara*
N *Napoleonaea vogelii*
O *Landolphia hirsuta*
P *Sarcocephalus latifolius*
Q *Persea americana*
R *Vitex doniana*

- the availability of ripe fruits throughout the year; the most frequently consumed fruits are available during several months (coconut, papaya), whereas others are ripe only during a short period
- the productivity of the plants
- the preferences of the population

The consumption also varies with the age groups. *Lantana camara* L., for example, is a small, relatively unattractive fruit from shrubs growing near the villages. It is eaten only by children. *Landolphia hirsuta* Beauvois on the other hand is highly appreciated by the whole population but the fruits, growing on a liana, are rather difficult to obtain. Therefore, the adults get the biggest share. *Aframomum alboviolaceum* (Ridley) K. Schum. is preferred by the elderly people.

The children, however, are the most important consumer group of wild fruits. For them in particular, the fruits are a good source of vitamins because they are eaten raw, whereas in prepared meals, a number of vitamins are affected by the preparation process. In the region, the uncultivated fruits are particularly rich in carotenes, vitamin C and vitamin B1. They also contain significant amounts of potassium and iron (table 1).

Table 1. Coverage of the recommended dietary allowances (RDA) with vitamins and minerals for a child (7–9 years) per 100 g edible portion of some uncultivated fruits

		Vit.A (µg)	Vit.B1 (mg)	Vit B2 (mg)	Niaci n (mg)	Vit. C (mg)	K (mg)	Mg (mg)	Fe (mg)	Ca (mg)
RDA 7–9 years		400	0.8	1.2	13.4	20	200	220	8	500
Species	100 g = x fruits	Percentage of recommended dietary allowance								
Aframomum alboviolaceum	5.9	–	19	5	7	11	52	11	10	1
Spondias mombin	17.9	59	5	2	11	80	–	–	13	6
Annona senegalensis	5.9	156	12	4	7	27	22	18	24	8
Pseudospondias microcarpa	71.4	5	23	2	9	38	26	10	14	7
Borassus aethiopum	0.2	–	5	2	2	26	–	–	13	5
Lantana camara	45.5	23	11	7	14	21	26	14	23	10
Napoleonaea vogelii	4.1	–	39	5	11	96	16	18	9	4
Landolphia hirsuta	3.1	65	7	12	7	12	10	6	6	1
Sarcocephalus latifolius	1.5	42	14	5	9	191	22	21	7	15
Vitex doniana	19.6	–	18	2	4	0	34	6	9	4

Sources: – no values (adapted from Herzog 1992 and Herzog et al. 1994)

Beverages

The most important beverage, next to water, is the tea prepared from the leaves of *Lippia multiflora* Moldenke, a shrub growing in the savanna (fig. 3). It is usually prepared for breakfast. Palm wines are obtained from the sap of the palm trees *Elaeis guineensis* dura type and *Borassus aethiopum* Mart. The other beverages are of only marginal importance.

The seasonal consumption of palm wine varies between about 0.5 and 1 litre per person and per day throughout the year. With an alcohol content of the wine ranging

Figure 3. Consumption of beverages in Zougoussi, V-Baoulé, Côte d'Ivoire, in 1988-1989; percentage of interviewed persons claiming to have consumed a particular beverage during the 24 hours preceding the interview.

A 'Thé de savane' (*Lippia multiflora*)
B Palm wine (*Elaeis guineensis*)
C Palm wine (*Borassus aethiopum*)
D Other alcoholic drinks (spirits, beer, wine)
E Soft drinks
F Beverages based on milk

between 2 and 6%, the alcohol consumption from palm wines is similar to that from wine and beer in European countries. The two palm wines complement each other. During the rainy season, the quality of the sap from the oil palm is insufficient and then *Borassus* is tapped instead and vice versa (Herzog et al. 1995).

Depending on the season, palm wine consumption accounts for 7 to 17% of the coverage of energy requirements of the population. In addition, they contain sufficient vitamins and minerals to meet significant parts of the RDA, namely for vitamin C, niacin, potassium and iron (table 2). For vitamin C, the intake even exceeds the recommended amount, and this is more marked for elderly people and for men—the groups of the population that consume the most.

Selected examples of important food species

***Borassus aethiopum* Mart.**, Hist. Nat. Palm. ed. 3, 1: 221. 1938
Family: ARECACEAE
Vernacular name: [kue]
Common names: African fan palm / Palmyrah palm / Ron palm / Rônier

Description: The *Borassus* palm is characterized by a crown up to 8 m wide, forming 15–30 fan-shaped leaves up to 3.5 m long. The young palms are covered with dry leaf stalks, showing gradually fading leaf scars. The old trees (over 25 years) have a swelling of the trunk at 12–15 m above ground (at 2/3 of the height). Flowers are dioecious, yellowish. Male flowers are clustered in a branched spadix up to 1.5 m long. Female

Table 2. Energy and nutrients obtained from the palm wines of Elaeis guineensis *and* Borassus aethiopum *in Zougoussi, V-Baoulé, Côte d'Ivoire, in 1988-1989. Percentage of RDA (mean values for the different groups of the population during the examination period).*

	Energy	Vit. B1	Vit. B2	Niacin	Vit. C	K	Mg	Fe	Ca
	(% of recommended dietary allowance)								
Children	7	3	3	7	90	18	5	3	1
Adults	10	6	6	12	148	28	8	9	2
Elderly	21	13	12	26	238	44	14	19	2
Women	10	5	5	12	122	22	6	6	1
Men	14	8	7	17	204	40	11	13	2
Mean	12	7	7	14	162	31	9	10	2

Source: Herzog et tal. 1995

flowers have an unbranched and shorter spadix. The fruit (a drupe) is large (diameter about 15 cm), ovoid, orange to brown when ripe. The fibrous pulp contains 3 woody kernels with an albumen becoming hard when ripe.

Distribution: Guineo-Congolian and Sudanian savannas, centres of endemism; Guineo-Congolia/Sudania transition zones (Senegal, Mali, Côte d'Ivoire, Burkina Faso, Ghana, Nigeria).

Ecology: Borassus is abundant and characteristic in all types of savanna of the region. Up to 120 trees ha^{-1} occur, of which 40 can be tapped for palm wine and 20 are fruit producing. The fruits have a large edible part (around 500 g each) and are available from December to July.

Utilization: Of all plants in the region, *Borassus* probably is the one most intensively used by the local population. From roots to leaves, each part of the tree is useful for a certain purpose. *Borassus* is particularly appreciated because of its sap, which ferments to palm wine [kue za], the traditional Baoulé beverage. For palm wine tapping, the terminal bud of the tree is cut and the dripping sap of the phloem is collected in a receptacle. The cut is renewed twice every day for 3 to 4 weeks until the tree is exhausted and dies. During this period, a *Borassus* palm can yield about 200–250 litres of sap. Palm wine can be distilled to form 'koutoukou'. This spirit often contains undesirable esters and free acids (Varlet 1956).

The fruits [kue ma] have a fibrous pulp that smells strongly from therbenthine. They are consumed raw or prepared, preferably with rice. The kernels (usually 3 per fruit) contain an albumen [kpoko], which before ripening is sweet and refreshing. The fruits are sometimes assembled on cleared, sandy locations at the village border. The germ [kule], which appears after a few weeks, is roasted and appreciated because of its bitter taste. While the fruits were not for sale on the local market, they are frequently sold along roads, as are the sprouted embryos.

In traditional medicine, palm wine is a component of several aphrodisiac preparations, as described also in Nigeria, in the Niger and in Senegal (Dalziel 1937, Kerharo 1968). The flower helps against aphonies, and young leaves are used to stop haemorrhages.

The strong trunks [kue bo] are very resistant against decay; they are therefore frequently used as posts and for the construction of bridges. The boards cut from the trunks [kue bui] are used for the construction of shower cabins. Adult leaves [sagro] are used for roofing, whereas the young leaves, before unfolding, can be split into stripes [sagro nia ko] and woven into mats, baskets and other household objects. From the nerves of the leaves [sagro die] strings are prepared. The leafstalks [tiedre] are used as stakes. Their ending [koglo] can also be soaked in water to provide fibres [kue saka], which are used as sponges or filters.

Cultivation: Because palm wine tapping destroys the trees, the 200 inhabitants of the village of Zougoussi need 130 *Borassus* palms every year for local palm wine consumption. The natural regeneration of *Borassus* appears to be sufficient around Zougoussi, but in areas closer to roads the *Borassus* populations are reduced, due to increased palm wine tapping for urban markets. To compensate for this increased exploitation, the cultivation of *Borassus* would be easily possible—at least technically. There is a tradition of artificial germination as mentioned above and the planting of *Borassus* would require only a change of attitude, the germs being planted instead of consumed. A major drawback, however, is the slow growth of *Borassus:* it takes 6 to 8 years until the trunk appears and another 25 years until the tree has reached its final size.

Instead of planting, the introduction of less harmful techniques for tapping would seem to be more promising. In other regions of West Africa the tapping process is interrupted after about 2 weeks. The tree is then left to recover and can be tapped again after about one year (Maydell & Götz 1971). In Indonesia with *Borassus flabellifer* L., the inflorescence (instead of the terminal bud) is cut to collect the sap. This procedure is less harmful for the tree, which can be exploited that way over a long period (Chrystopher & Theivendirarajah 1988a,b).

Annona senegalensis **Pers. subsp.** ***oulotricha*** **Le Thomas,** Flore du Gabon:102.1969.
Family: ANNONACEAE
Vernacular name: [amlu]
Common names: Wild custard apple / Annone africaine

Description: Generally a shrub growing from numerous root-shoots up to 2 m high (occasionally up to 6 m if protected from fire). The young stems are ferruginous, velvety to greyish tomentose, glabrous when old. The alternate leaves are simple, entire, up to 10 cm long and 7 cm wide, elliptic, ovate or ovate-elliptic, very fragrant when crushed; the upper side is pubescent, the lower side is distinctly brighter and with prominent venation. The yellow-greenish, waxy flowers hang down from peduncles about 1–2 cm long, solitary or 2–4 together, fasciculated, bell-shaped, about 1.5 cm long. The fruit (a syncarp) is up to 3 cm long, ovoid, yellow-orange when ripe and characterized by numerous smooth elevations on the surface. Numerous seeds are embedded in the yellow, farinose fruit pulp.

Distribution: Guineo-Congolian and Sudanian savannas, centres of endemism; Guineo-Congolia/Sudania transition zones (Senegal, Sierra Leone, Mali, Côte d'Ivoire, Cameroon).

Ecology: Annona occurs mainly in tree savannas where up to 1500 fruit-producing shrubs per hectare were counted. Edible fruits are available in April and May only. The individual production is relatively low (20–30 fruits per shrub), each fruit weighing around 25 g, of which 16 g are edible.

Utilization: The fruits are highly appreciated by the regional population; almost everybody knows and consumes them. However, fruits fallen to the ground are not collected as they are reputed to attract snakes. It was reported very early that the fruits are edible (Sébire 1899) and their consumption is common all over West Africa.

In traditional medicine, wood and leaves are used to heal sprains. The roots, when mixed with the fruits of *Xylopia aethiopica* (Dunal) A. Rich. or the flowers of *Hibiscus sabdarifa* L., help against nervous excitement. The leaves are used to heal asthenia and to cure guinea worm. For the latter purpose also roots and sometimes a mixture of the bark and the leaves of *Parkia biglobosa* (Jacq.) G. Don are added. In Senegal, *Annona* is used similarly to treat guinea worm (Sébire 1899), whereas in Nigeria, the consumption of many fruits is said to have the same effect (Dalziel 1937).

Domestication: The domestication of *Annona* has been repeatedly proposed, starting with the botanist Chevalier (1948). It appears to be promising, the fruits being appreciated by the population. Annonaceae of American origin have been domesticated successfully. However, a significant effort of selection and breeding would be necessary to improve the relation between the seeds and the pulp (now only 66% of the fruit is edible) and the productivity of the shrubs. A major drawback comes from *Annona*'s reputation of attracting snakes. This must be taken into account when cultivation is proposed.

***Corchorus olitorius* L.**, Sp. Pl.:529. 1753
Family: TILIACEAE
Vernacular name: [korala]
Common name: Jute

Description: Annual herb up to 2.5 m high, often suffrutescent. The stems are woody at the base, fibrous, sparsely pilose to glabrescent. Leafs alternate; they are entire and subglabrous. The leaf-blades are 4–15 cm long and 1–5 cm wide, elliptic or ovate, chartaceous. Inflorescence in 1–2 (or –3) flowered fascicles. Pentamerous flowers bracteolate. The stamens are numerous. The fruit (a capsule) is cylindrical, woody, 2.5–6.0 cm long, 0.3–0.7 cm wide, splitting into 5 (–6) valves tapering to a short beak. Seeds are numerous, blackish, 0.1–0.2 cm long, pyramid-shaped.

Distribution: pantropical.

Ecology: Corchorus is often associated with human presence; it mainly occurs on agricultural fields, where it is protected by the farmers. The leaves, available throughout the year, are collected regularly by women.

Utilization: The leaves are used to prepare stew or soup [korala] throughout West Africa. The species probably originates from India, where it has traditionally been cultivated. It is probably one of the first vegetables to have been introduced in sub-Saharan Africa. It is cultivated in numerous gardens and used to prepare soups and side dishes comparable to European spinaches. The sauce [korala] is highly appreciated and is the most frequently prepared leaf in the village of Zougoussi.

In traditional medicine, the seeds are used against vertigo. Textile uses of the fibres are unknown in the region.

Domestication: Whereas *Corchorus* is a common agricultural crop in northern Africa, Nigeria and Cameroon (e.g., Fawusi 1983, Stevels 1990), it is semi-domesticated in Côte d'Ivoire. On the villagers' fields, it grows spontaneously, then is protected by the farmers and not removed as are other weeds. Around the urban centres, *Corchorus* is planted and produced in horticultural areas. Siemonsma (cited by Terrible 1983) estimates that over 20% of the leaves sold on Ivorian markets are from *Corchorus*.

Conclusions

The data indicate that the contribution of uncultivated plants to the human nutrition is significant. This is further confirmed by ongoing investigations in a second village (Bringakro) of the region (Müller, in preparation). This indicates that in nutritional surveys, where gathered products are not usually taken into account, the intake of energy and nutrients is underestimated. This survey is therefore of considerable importance to our knowledge of nutrition in the humid region of West Africa.

The extension of agricultural land use has detrimental effects on gathering activities. The forest and the savanna, where the products can be found, are driven back. Furthermore, the orally transmitted knowledge about wild plants tends to get lost as lifestyles change and children go to school and learn other non-traditional ways of life.

Some of the traditional food products can be replaced by substitutes, but the domestication of the more important plants would also be possible. There are, however, some major constraints. There is normally a reason why certain species have not been domesticated up to now. It is clear that the farmers will not be ready to make the extra effort of planting and domesticating these plants if—

- the product is still available in sufficient quantity and quality from wild plants
- the product has a low preference
- attractive substitutes exist
- there are major technical difficulties
- the plant has a bad image, such as *Annona senegalensis*, which is said to attract snakes and a number of uncultivated vegetables thought of as 'famine food' or 'food for the poor'

There are two situations in which the farmers in the V-Baoulé will consider the effort of domestication as justified:

- if there are market opportunities; although in the V-Baoulé, food security is not much of a problem, the production of marketable goods would be a major incentive
- if a product that is indispensable for household consumption is no longer available and there is no substitute for it

In both cases, the farmers can be expected to make the first steps towards domestication. Technical support, however, with propagation methods and improved genetic material, may help them to progress more rapidly and to achieve better results.

References

Böni B. 1993. Femmes et transfert de technologie: introduction d'une presse à huile de palme dans un village Toura (Côte d'Ivoire). Dissertation ETH-Zurich Nr. 10051. 140 p.

Böni B., Gautier-Béguin D. & Herzog F. 1994. *Le palmier à huile.* Sempervira 3. Swiss Academy of Sciences and Centre Suisse de Recherches Scientifiques. 50 p.

Chevalier A. 1948. Les espèces du genre *Annona* comme plantes à fruits et les *Annona* américains introduits en Afrique. *Revue internationale de botanique appiquée et d'agriculture tropicale* 28(303–304):73–79.

Chrystopher R.K. & Theivendirarajah K. 1988a. Palmyrah palm wine; part 1: microbial and biochemical changes. *Journal of the National Science Council of Sri Lanka* 16(1):131–141.

Chrystopher R.K. & Theivendirarajah K. 1988b. Palmyrah palm wine; part 2: improvements in alcohol production. *Journal of the National Science Council of Sri Lanka* 16(2):147–157.

Dalziel J.M. 1937. *The useful plants of west tropical Africa.* Crown Agents for the Colonies, London. 612 p.

Fawusi M.O.A. 1983. Quality and compositional changes in *Corchorus olitorius* as influenced by N-fertilisation and post harvest handling. *Sciencia Horticulturae* 21(1):1–7.

Gautier-Béguin D. 1992. Plantes de cueillette alimentaires dans le Sud du V-Baoulé en Côte d'Ivoire: description, écologie, consommation et production. *Boissiera* 46:1–341.

Herzog F. 1992. Etude biochimique et nutritionnelle des plantes alimentaires sauvages dans le sud du V-Baoulé, Côte d'Ivoire. Dissertation ETH-Zurich Nr. 9789. 122 p.

Herzog F., Farah Z. & Amadò R. 1994. Composition and consumption of gathered wild fruits in the V-Baoulé, Côte d'Ivoire. *Ecology of Food and Nutrition* 32:181–196.

Herzog F., Farah Z. & Amadò R. 1995. Chemical composition and nutritional significance of wines from the palms *Elaeis guineensis* and *Borassus aethiopum* in the V-Baoulé, Côte d'Ivoire. *Tropical Scence* 35:30–39.

Kerharo J. 1968. Revue des plantes médicinales et toxiques du Sénégal. *Plantes Médicinales et Phytothérapie* 2:108–146.

Maydell von H.-J. & Götz E. 1971. Palmen in agroforstlichen Landnutzungssystemen der Sahel- und Sudanzone. *Beiträge zur Weltforstwirtschaft–World Forestry Miscellanea* 5:41–143.

Müller K. In preparation. Ernährung–Teil eines vernetzten Systems: Analyse von Ernährungssystemen und Ernährungsstrategien als Voraussetzung für eine verbesserte Ernährungssituation. Das Beispiel der Baoulé und der Djoula in der Côte d'Ivoire. Dissertation, Universität Zürich, Philisophische Fakultät 1, Seminar für Ethnologie.

Sébire R.P.A. 1899. *Plantes utiles du Sénégal, plantes indigènes–plantes toxiques.* Baillière & fils, Paris. 341 p.

Stevels J.M.C. 1990. *Légumes traditionnels du Cameroun, une étude agro-botanique.* Wageningen Agriculture University Papers 90-1. 262 p.

Terrible J.N. 1983. Plantes alimentaires et légumes locaux en Côte d'Ivoire (synthèse bibliographique). SODEFEL, Projet PNUD/FAU/IVC/79/009.

Varlet F. 1956. Fabrication et composition de l'alcool de bangui. *Notes Africaines* 71:74–75.

Plate 5. *In central Côte d'Ivoire, palm wine is tapped from* Borassus aethiopum *by cutting the terminal bud, which eventually leads to exhaustion and death of the tree. The introduction of less harmful techniques might lead to a more sustainable use of this valuable resource.* (photo: F. Herzog)

Use and commercialization of non-timber forest products in western Burkina Faso

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Abstract

The farming system in Burkina Faso is featured by the omnipresence of trees owing to their non-timber products. These products are very important for the nutritional quality of rural populations and their contribution to income (particularly that of women). However, they remain undervalued. A better knowledge of the potential utilization of these products, and the constraints attached to their transformation and commercialization, would favour their promotion.

The aim of this survey is to study the traditional utilization of the various products in the households and their commercialization in village markets. About 100 households have been monitored to determine the frequency of use of these products in the meals of rural families. The trading and use of about 30 products has been followed in 10 village markets, over a whole year. These products were derived from 17 woody species. Five of these products, originating from *Vitellaria paradoxa*, *Parkia biglobosa*, *Bombax costatum* and *Adansonia digitata*, cost more than 200 CFA francs per kilogram. Compared with other products, non-timber forest products, especially foods, were the most frequently used. The raw forms of these products supply vitamins for the nutritional health of the rural population. Considering the importance of this role, one might expect to see these species cultivated in plantations, but the way of regenerating these species remains the traditional fallowing practice of the present farming system. The reasons for this can be found in some mythical beliefs about the reproduction of the local species, beliefs that are supported by local evidence. For example, the local species are thought to be slow growing. The growth patterns of the useful local species constitute a challenge to domestication that should be addressed by forestry research.

Introduction

The parkland system is the most widespread system of agricultural production in Burkina Faso (Ouedraogo 1995, Boffa et al. this volume). Trees are present everywhere on farmers' fields. Trees of useful species are selected in fallow land for retention, before bringing the land into cultivation. Thus tree regeneration is the result of the practice of fallowing. The main reason for maintaining woody species in the fields is the demand for food and traditional medicines, for both humans and animals. These products, which are currently undervalued, contribute to the enhancement of the nutrition of rural populations, a better family income (particularly for women) and the economy of the country. For the products to become commercially important, they must be utilized beyond the national borders. This requires better governmental policies in food technology and processing. The first step is the development of better knowledge of the potential utilization of the various products, and of the constraints associated with processing and commercialization. The aim of this survey is to contribute to better knowledge of these parameters in Burkina Faso.

Very little work has been done on this subject at a national scale. Pasco (1990) inventoried some 24 ways of utilizing the products of 21 woody species in the central part of the country. In 7 months of market observations he found 17 products in small-scale trade in the village markets. Hasberg and Coulibaly (1989) observed some 40 products in one of the larger markets in the southwest of the country. They found 15 products valued at over 200 CFA francs kg^{-1} (in 1989, 200 CFA francs = USD 1). Pasco had identified six of these. Their uses ranged from snacks to family meals.

This survey has identified the traditional forms of consumption of non-timber forest products (NTFPs) and estimated the frequency of their use in rural households; it has explored the products that are for sale in local markets. In addition, this survey has examined the hypotheses that—

- the dependence of rural populations on these products and their commercialization is growing, because of the loss of forest resources, relative to population growth and deteriorating climatic conditions
- in commerce, parameters such as the time of production, product quality, the ecological zone and the marketing system, determine the prices charged for the products

Survey of rural households

The survey covers NTFPs that are consumed daily by rural populations, either raw or cooked, and that are more and more involved in small-scale trade in local markets.

Study zone

The study zone of western Burkina Faso lies between latitude 10° and 13° N and longitude 3°–6° W. The climate is Sudanian, with mean annual rainfall between 800 mm in the north and 1000 mm in the south. The vegetation is forest savanna. The agricultural landscape features the Sahelian parkland system, predominated by woody species that bear edible fruit, such as *Vitellaria paradoxa* Gaertn., *Parkia biglobosa* Benth., *Tamarindus indica* L. and *Borassus aethiopum* Mart.

Choice of villages and households

The villages of the survey were the four (Dimolo, Kayao, Kawara, Yasso) where the Institute of Agricultural Research carries out studies on farming systems. They were chosen on the basis of a number of criteria to represent zones having a similar production system. In each village, we sampled 10% of the households (groups of people) sharing the same meal. Each family was chosen at random and followed for 6 days by women interviewers, to note the utilization of NTFPs and potential substitutes for them in the cooking of meals. In total about one hundred households were involved. The survey took place from January to April 1995: a dry period when the populations were not involved in farming activities and lived on the cereals that had just been harvested.

Choice of markets

Two markets clusters were used, one in the northern part and the other in the southern part of the study zone. The market survey was organized in such a way that the five or six closest villages in turn provided the market to be studied. In other words, every fifth or sixth day the market was in the same village. One of the markets of each cluster of five or six village markets represented a district market. Like urban markets, the district markets could be better supplied with products and have relatively higher unit prices.

Procedures

The use of NTFPs in the meals was closely observed—the ingredients of each meal, their monetary value and their means of acquisition noted. Analysis has stressed use of the forest products themselves and the substitution of alternative products. The investigation on the markets covered a whole year. The objective was to examine the various products that appeared and to see the price fluctuations during the year.

The same market was sampled every third market day. One objective was to list all the NTFPs that were traded. For this, it was decided to interview systematically anyone appearing on the market as a vendor. The choice of this approach was justified by the size of the village markets, and it favours a complete inventory of all the products. During the investigation, parameters like the nature of the products, their uses, their sources of supply, the quantities handled every market day were noted. We also purchased samples to determine the weights and unit prices. A descriptive analysis was used to explain the utilization and commercialization of the products. The factors that determined the prices were studied through variance analysis.

Household uses of forest products

Non-timber forest products used in preparation of meals

Observation of the households identified that some 30 NTFPs were used, raw or cooked, and that they came from 17 tree species of the savanna or traditional agroforestry parklands. Two levels of consumption were identified—transformed or raw. The first level concerned the NTFPs that are transformed and generally used as ingredients for meals. The second was snacks or a 'fast-food' form—crude or fresh products that are generally eaten outside normal meal times and often when in the bush.

Sixteen types of meals were observed. In general, forest products were used more frequently than purchased substitutes. The nutrition of the population of this zone is based on maize or millet dough *(tô)*, accompanied with a sauce. Four types of meals were the most frequent in the average household: sauce 6 times a week, tô 5 times, porridge with cereal 3 times, and couscous with cereal once. The principle ingredients of meals from forest products were young leaves and the fruits. These ingredients can be divided into fats, spices, vegetables and acidic products.

Fats

Szolnoki (1985) reported that as a general rule, the taste and digestibility of some dishes are enhanced by fat, especially karité (shea nut) butter from *Vitellaria paradoxa* fruits. It is the only tree product used as a cooking fat in the households of the zone and is used more frequently than other oils (table 1).

Shea nut butter and oil are used for tô—to prevent its surface from drying up, to improve the taste and to make it more appetizing. Another use of shea nut butter that should be mentioned is the frying of fritters and griddle cakes for sale in the markets.

Table 1. Frequency use of karité butter and other oils (cotton oil, groundnut oil or sesame oil) for cooking in Burkina Faso

	Karité butter (%)	Other oils (%)
Couscous	80	20
Dough sauce (sauce de tô)	89	11
Porridge	100	0
Cereal dough (tô)	66	34

The occurrence of this activity in the marketplace was the reason that it was not observed in the household survey.

High-quality shea butter is white, odourless and made from fresh nuts. Stale material results in a dark butter with an unpleasant bitter taste, which has to be disguised by adding garlic or lemon juice. Local research (IRBET & ISN/IDR 1988) has identified ways of handling shea nuts that result in good quality butter. Further research by food technology laboratories could examine other means of ensuring quality and, hence, value.

The spices

Spices are by definition substances used to season the dishes and give them a better taste. The NTFP used as a spice in the meals is *soumbala*, made from the fermented seeds of *Parkia biglobosa*, or néré. Purchased 'Maggi' sauce and the fermented grains of *Hibiscus sabdarifa* (sorrel) are sometimes used to replace soumbala. Néré soumbola is used in tô 50% of the time and in couscous 71%; Maggi 34% in tô and 29% in couscous; and sorrel soumbala 16% in tô and not at all in couscous.

Given the low density of *Parkia biglobosa* trees, the fruits are plundered before they are completely ripe. The soumbala obtained from unripe fruit is generally of poor quality. Hasberg and Coulibaly (1989) report that the traditional authorities in Diongolo, a village in their study zone, have set a date for the start of harvest because otherwise the population pillages the *Parkia biglobosa* pods at night. Because of the resulting low quality, housewives tend to use Maggi spices when their purchasing power allows them to do so. Just a small quantity of Maggi is sufficient to improve the flavour. Pasco (1990) reports that women with big families associate Maggi with soumbala to get a better taste for the least cost. The consumption of Maggi spice is not without risk. Stocks are often past their 'sell-by' date and old stock can be the cause of blood pressure diseases, according to local doctors.

Soup vegetables

Soup is the most commonly cooked meal in the houses of the region. Several elements enter into its preparation. However, vegetables are the base that one combines with other products. The leaves of *Adansonia digitata* (baobab) were used in soups 41% of the time and the flower parts of *Bombax costatum* 12%; vegetable products consumed in soups included okra (26%), sorrel leaves (8%), *Ceratoteka sesamoides* leaves (5%), sesame (4%), beans and eggplant (2% each).

In addition, the leaves of *Corchorus* spp., *Securidaca longipedunculata* and *Vitex doniana* are important soup vegetables for the dry season. However, the consumption of these species was not observed during our investigation.

Acid or alkaline products

The cooking of meals such as tô and porridge is based on water and cereal flour. To give these meals a sour or potassic taste, women add some acidic or alkaline products. The former seems to improve the keeping quality of the tô. The results showed that 71% of porridges and 53% of the tô cooking are treated with acidic or alkaline products and that a number of different products were used (table 2).

Leaf and fruit products of tamarind *(Tamarindus indica)* are the most commonly used tree products for the souring of meals. Compared with the substitution products, which are cereal or beer residues, juice and lemon, the tamarind products are the ones most used in the houses. The sourness of juice from beer residues is obtained by keeping it for two or three days. Potash is a filtrate of ashes obtained by calcinating vegetable matter. The composition varies from region to the region.

Table 2. Use frequency of acidic or alkaline products in cooking in Burkina Faso (in percentage)

	Porridge	Dough
Tamarind	47	38
Lemon	30	0
Fermented juices from cereal flour	18	16
Fermented juices from local beer residues	3	6
Potash	1	40

Household consumption

The average size of a household in the study area was 11 people. Estimates of the quantities and values of tree products used for each meal were obtained during the household and market survey (table 3). The values obtained are clearly higher than Pasco's (1990). This can be justified by the poor forestry resources of the study zone and the existence of very competitive substitution products.

Table 3. The quantity (g) and value (CFA francs) of an average household (11 people) intake of non-timber forest products in Burkina Faso, according to the type of meal*

	Sauce		Dough		Porridge		Couscous		Rice	
	CFA	g	CFA	g	CFA	g	CFA	g	CFA	g
Karité butter	21	61	14	42	21	62	29	87	86	257
Oil	50	–	61	–	–	–	67	–	–	–
Soumbala of *P. biglobosa*	21	46	–	–	–	–	17	37	21	46
Soumbala of *H. sabdarifa*	16	–	–	–	–	–	–	–	–	–
Maggi spice	23	–	–	–	–	–	29	–	33	–
A. digitata leaves	19	188	–	–	–	–	–	–	–	–
Flower parts of *B. costatum*	20	72	–	–	–	–	–	–	–	–
H. esculentus fruit	32	–	–	–	–	–	–	–	–	–
Leaves and fruit of *T. indica*	–	–	16	–	17	–	–	–	–	–
Total	202		91		38		142		140	

* 200 CFA francs = USD 1 in 1989

To make a sauce of baobab leaves or from the flower parts of *Bombax costatum*, the housewife should invest 40 CFA francs on average to obtain the main ingredients. This is a high price for women who generally have no profit-making activities, nor any financial support from their husbands for condiments.

Acquisition of the products used for meals

Women most frequently buy karité butter and néré soumbala, rather than obtain the tree products free (table 4). Not all women master their processing. Women, even if they

Table 4. Proportion of meal ingredients bought and obtained free

	Bought	Free
Maggi	98	2
Soumbala of néré	90	10
Oil	88	12
Leaves of baobab	85	15
Butter	77	23
Okra fruits	69	31
Soumbala of *Hibiscus esculentus*	65	35
Tamarind	57	43
Bombax	48	52
Potash	18	82
Leaves of *Corchorus* sp.	5	95
Lemon	0	100

manage to collect the fruits, prefer to sell them fresh and to buy the finished product from processing specialists when they need it. This is because the technologies themselves take a lot of time. The flowers of *Bombax costatum* are less frequently bought, however, because they need no processing. Baobab leaves are bought because they are scarce.

Snacks

The products eaten as snacks by individuals are difficult to quantify and were not recorded in this survey. The main species are, however, known from market surveys and the literature (von Maydell 1983, Pasco 1990) (table 5). The frequency of use and quantities eaten by families have not been estimated.

Consuming fruits direct from trees is important for the nutrition of rural populations, as it maximizes vitamin intake (Szolnoki 1985). Various products are available at different times of the year and complement the basic foods such as jóreal dough, which is relatively low in vitamins and minerals. These snacks are therefore important for the health of the people.

These fruits become available at the time that farmers are starting their annual farming cycle and when food stocks are low. This makes them especially important during the cultivation period. Eating these snacks provides the energy for work.

Furthermore, the ground pulp of *P. biglobosa* forms a flour that is often taken to the field as the only meal for the day. Mixed with water into a dough, or bulked up with millet flour, its consumption supplies the farmer with energy, because of its high glucid content in (table 6).

Nutritional importance of non-timber forest products

The chemical composition of some NTFPs has been investigated by several authors: Szolnoki (1985), Bergeret and Ribot (1990) and Pasco (1990), as summarized in table 6.

Commercialization of non-timber forest products in Burkina Faso

Two categories of tree products from the parkland and forest savanna, were identified in this study:

- products available for only a very short period (1 to 3 months), which were mostly consumed as snack foods

Table 5. Tree species contributing to nutrition as snacks in Burkina Faso

Tree species	Product	State and mode of consumption	Production period
Adansonia digitata (baobab)	white pulp that covers the seeds of dry fruit	sucked as snack; ground into flour, and used in juice, added to millet couscous	January–March
Vitellaria paradoxa (karité or shea nut)	pulp of fresh mature fruit	grated directly	June–August
Balanites aegyptiaca	pulp of mature fruit skin is removed	sucked as snack after November–December	
Blighia sapida (akee apple)	fresh aril of the seed	detached from the seed and consumed raw	March–July
Detarium microcarpum	fruit pulp	sucked as snack, fresh or boiled after skin in removed	February–May
Parkia biglobosa (néré)	powdery pulp	eaten directly as snack or boiled into an edible paste or porridge	March–August
Saba senegalensis	pulp of fruit	sucked as snack	May–June
Sclerocarya birrea	nut	eaten like groundnut	June–August
Ziziphus mauritiana	pulp of the fruit	eaten directly or ground into flour, formed into fritters	January–February
Trees for honey	nectar taken and turned by the bees into honey	consumed directly or as sweetener in other dishes	March–June

- products available for at least 4 months on the markets; these products can be dried or processed for storage and are often the main ingredient of meals

Factors determining product prices

In general, product price is governed by its availability and condition of acquisition, place of origin and the kind of market. Traditionally the ownership of the trees in forest savanna and parkland was communal. Nowadays the ownership of trees in young fallows and parkland is private (Lamien & Bayala 1994). Only people exploiting these lands and their relations are permitted to gather products from these trees.

This study identified three means of product acquisition:

- gathering from the trees in farm land and from newer family fallow lands

Table 6. Food value of some non-wood forest products

Non-timber forestry products	Proteins*	Lipids*	Glucids*	Calcium (mg)	Equival Vit A (mcg	Thiamin Vit. B1**	Ribo-flavin Vit.B_2**	Niacin (ppm)	Vit. C **	Phosphorus **	Iron **	Kcal per 100 g
Adansonia digitata												
– fresh leaves	4.0	0.3	14.4	395	–	–	–	–	42	67	25-50	69
– dry leaves	12.5-13.1	2.9	53.5	2266	4856	0.13	0.82	4.3-4.4	tr.	261-266	25	279-282
– flour of baobab	2.3	0.1-0.3	75.6	293	20	0.38	0.06	2.16	169-270	96-118	7	280
Vitellaria paradoxa												
– fresh pulp of the fruit	1.9	1.2	21.7	–	–	–	–	–	–	–	4.7	94
– nut	6.8	49	35.6	100	–	0.52	–	–	–	–	3	579
Detarium microcarpum												
– fruit pulp	4.9	0.4	81.8	82	–	0.03	–	–	32	84	1.8	310
Parkia biglobosa												
– dry pulp of the fruit	3.4	0.3-0.5	80.7	125	1200	1.1	0.7	1-3.03	255	164	3.6	310
– raw grain	43.6	21.8	32	233	–	0.54	–	–	6	503	11	432
– fermented grain (soumbala)	35	29	16.4	264	520	0.03	2.1	–	0	477	–	431
Saba senegalensis												
– pulp of fresh grains	–	–	18.5	–	–	tr.	tr.	tr.	48	–	–	71
Sclerocarya birrea												
– almond	30.6	–	0.5	0.17	–	–	–	–	–	102	–	–
Tamarindus indica												
– fruit	1.9-2.0	0.1-0.9	8.6-16.6	21-60	–	0.18	0.09	0.6	9	97-190	2.2	270
– leave	14.1	3.5	56.2	230-506	–	–	–	–	–	22	–	73
Ziziphus mauritiana												
– pulp of fresh fruit	1.9	tr.	25.2	51	–	tr.	tr.	tr.	66	20-86	–	93
– pulp of dry fruit	4.3	0.2	75.4	210	0	0.03	0.02	2.1	24	56	3	286

Data from Bergeret A. and Ribot J.C. (1990), Pasco L. (1990)
* = grams per 100 g of matter ** = milligrams per 100 g of matter

- gathering from the trees of old communal fallow lands or by theft from other families' farms
- purchasing from suppliers

The means of acquisition had a significant effect on the price (table 7), the products purchased from a supplier being the most expensive.

Product price was also determined by the ecological zone. Markets in the north were more expensive than those in the south (table 8). This is related to the northern area being drier (700 mm vs 1000 mm) and having a greater population density (60 vs 9 inhabitants km^{-2}). These two factors continue to make tree products more scarce in the northern area. Prices therefore reflect the laws of supply and demand.

Table 7. Average product price per kilogram of various non-timber forest products in Burkina Faso, according to the means of acquisition, 1994/95

Products	Personal trees		Communal trees		Supplier	
	CFA francs kg^{-1}	no samples	CFA francs kg^{-1}	no. samples	CFA francs kg^{-1}	no. samples
Néré grains	83.1	68	141.5	16	161.1	8
Soumbala	369.3	8	351.3	47	437.6	95
Néré flour	31.1	17	99.0	2	185.1	9
Butter	170.9	9	248.4	32	255.5	89
Soap	–	–	367.5	2	233.1	95
Karité nut	31.9	64	–	–	41.0	1
Honey	249.0	8	–	–	–	–
Baobab leaves	98.0	10	103.1	10	–	–
Tamarind fruit	139.8	8	201.1	32	243.8	9
Bombax flower parts	268.3	7	377.7	29	–	–
Others	113.1	94	165.3	20	157.9	16

In 1994/95, 500 CFA francs = USD 1

Table 8. Average product price per kilogram of non-tmber forest products in Burkina Faso, according to the ecological zone, 1994/95

Products	Northern zone		Southern zone	
	CFA francs kg^{-1}	no samples	CFA francs kg^{-1}	no samples
Néré grains	151.1	23	83.0	69
Soumbala	602.8	42	330.9	111
Néré flour	174.4	11	31.1	17
Butter	383.6	33	199.8	98
Soap	287.4	28	214.7	70
Karité nut	–	–	32.1	65
Honey	373.0	1	187.0	8
Baobab leaves	105.9	16	60.0	4
Tamarind fruit	208.8	48	34.0	1
Bombax flower parts	389.2	29	194.7	7
Others	153.3	54	106.4	76

In 1994/95, 500 CFA francs = USD 1

Contrary to expectation, and with the exception of shea nut and shea butter, the village markets were not significantly cheaper than the district markets (table 9). Market prices were also strongly affected by the time of year and availability of the products.

Table 9. Price per kilogram of non-tmber forest products in Burkina Faso, according to the type of market, 1994/95

Products	District markets		Village markets	
	CFA francs kg^{-1}	no samples	CFA francs kg^{-1}	no samples
Néré grains	100.7	50	103.8	42
Soumbala	386.9	48	414.1	105
Néré flour	44.3	15	127.2	13
Butter	260.8	42	240.6	89
Soap	259.0	24	227.8	74
Karité nut	38.7	19	29.3	46
Honey	280.0	5	187.0	4
Baobab leaves	80.4	9	117.2	11
Tamarind fruit	195.1	22	212.6	27
Bombax flower parts	309.5	13	383.2	23
Others	140.9	53	120.8	77

In 1994/95, 500 CFA francs = USD 1

Vitellaria paradoxa

For example, the nuts of *Vitellaria paradoxa* averaged 34 CFA francs, while the butter and soap made from them averaged 306 and 257 CFA francs respectively. These figures compare with those of Hasberg and Coulibaly (1989) of 69, 345 and 289 CFA francs for the nuts and for yellow and grey butter respectively. The price of the nuts was lowest from May to July, the period of nut harvest (fig. 1). Trading started in August and September, and the price rose with the increased demand as traders intervened. But the demand from the traders did not last because the possibilities of distribution on the regional and international scale were limited and often uncertain. IRBET & ISN/IDR (1988) report that the products of karité from Burkina were detrimentally affected by mishandling, which lowered the quality and price. The period of August to September corresponded to the period when the great majority of the women devoted themselves to roasting and process-

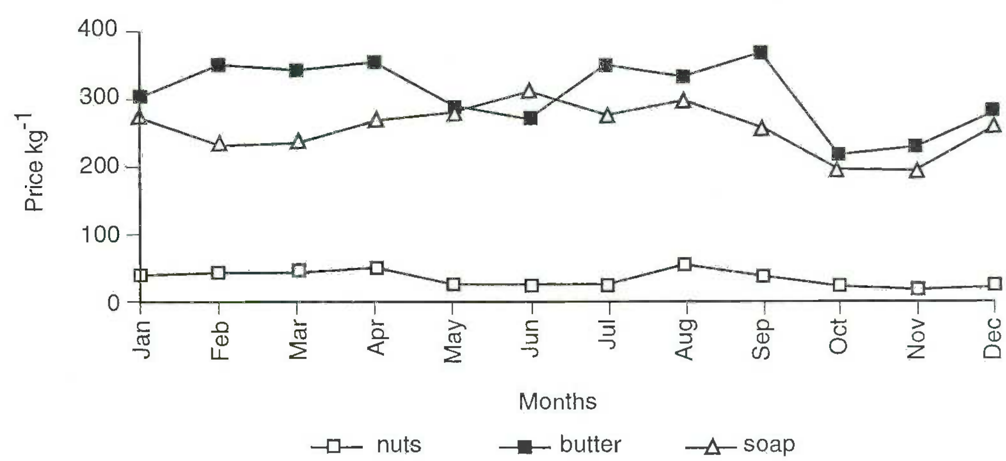

Figure 1. Price changes (CFA francs) during the year for Vitellaria paradoxa *products, 1994/95 (500 CFA francs = USD 1).*

ing their nuts into butter or into soap. This caused a decline of the price of these processed products. Prices then rose again as women became more involved in the cropping activities

Parkia biglobosa

The products of *P. biglobosa* are seeds and their by-products: the soumbala and the pulp of the pod, which forms a yellow flour. The average price per kilogram is 128 CFA francs for the grains, 477 CFA francs for the soumbala and 43 CFA francs for the flour. These prices fluctuate during the year. The harvest is in April–May, when prices are low (fig. 2). After this period, the seed prices increase regularly until they reach a value of about 200 CFA francs in December. The price of soumbala rises from 410 CFA francs at harvest to between 450 and 500 CFA francs for the rest of the year. Seed storage occurs while traders wait for this price rise. It logically causes a rise of prices, which then declines as stocks are used to make soumbala. The flour is marketed for only 8 months because of storage problems. Its price is highest shortly after the harvest period.

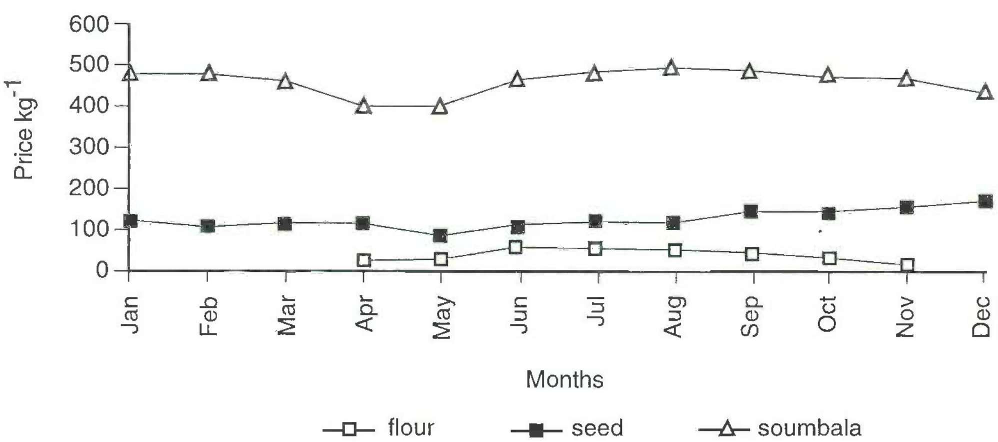

Figure 2. Price changes (CFA francs) during the year for Parkia biglobosa *products, 1994/95 (500 CFA francs = USD 1)*

Adansonia digitata

Young leaves of baobab are available from May to July (fig. 3). The women dry them immediately for storage and use them in January–April, when it becomes more difficult to find soup vegetables. This is associated with a rise of the price of dry and powdered

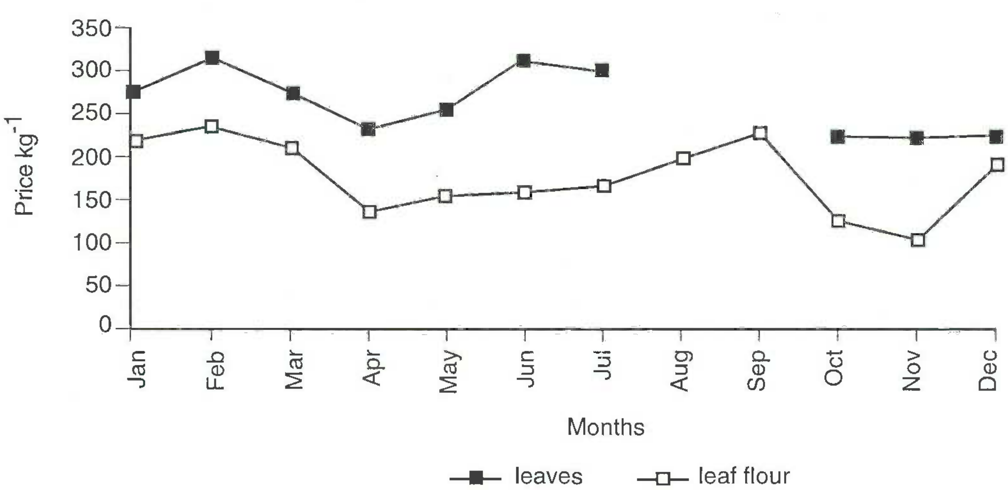

Figure 3. Price changes (CFA francs) during the year for Adansonia digitata *products, 1994/95 (500 CFA francs = USD 1).*

leaves following a growing demand from the traders. The low price in October–November is said to be because the baobab leaves cause lips to crack in the cool season.

Tamarindus indica

Fruit and leaves are available in October and May respectively (fig. 4). They both play the same role, that of souring meals, and they can be processed and preserved for a time. The average price per kilogram of fruit is 116 CFA francs, whereas the price of leaves is 102 CFA francs. These values are lower than Hasberg and Coulibaly's (1989), owing to the fact that latter were obtained on urban markets. The fruit prices rise to their highest value from February to April. The period corresponds to the preparation for Muslim fasting. *T. indica* products are in particular demand to sour or even to sweeten the fasting porridge.

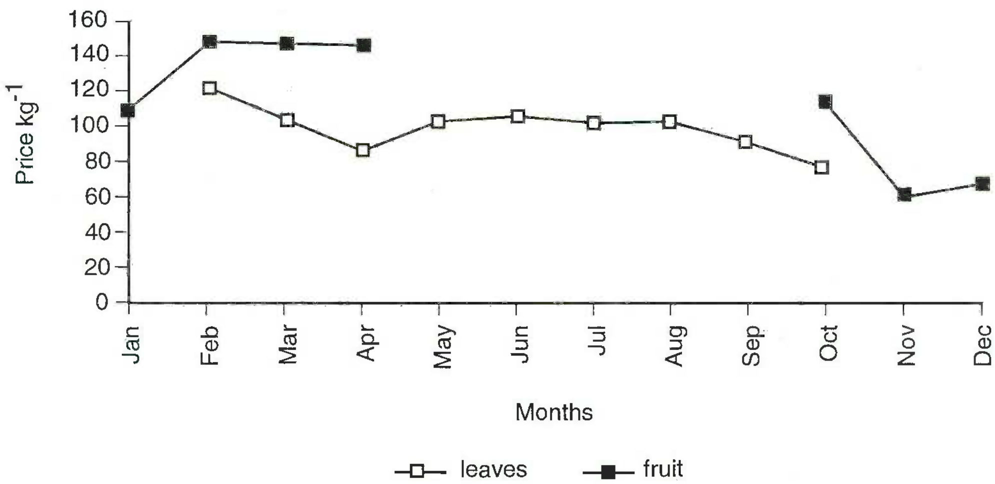

Figure 4. Price changes (CFA francs) during the year for Tamarindus indica *products 1994/95 (500 CFA francs = USD 1).*

Bombax costatum

Bombax flowers are used as vegetables for soups. Flowering occurs between November and January when the price is 260 CFA francs, this rising to 580 CFA francs when the product becomes rare (fig. 5). These prices are higher than previously recorded (Hasberg & Coulibaly 1989, Pasco 1990) but this is probably because of differences in availability between years and sites. In this case the higher price seems to be found in sites where the tree is common—so apparently increasing the demand.

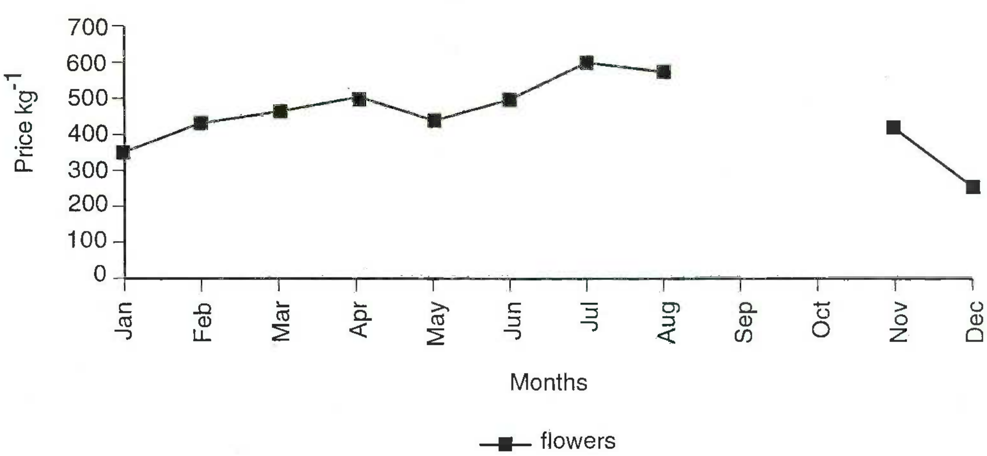

Figure 5. Price changes (CFA francs) during the year for Bombax costatum *products 1994/95 (500 CFA francs = USD 1).*

In general, we can conclude that the evolution of prices of NTFPs during the year conforms to the theory of demand and supply. However, we observe a certain irregularity in the evolution of the prices that can be explained by two phenomena. On the one hand, most of the sales people are not specialists in marketing. A woman will never sell all her stock, even at the moment when the price received by the supplier is at its highest level. On the other hand, as for cereals, groundnuts, farm animals, the stocks of NTFPs constitute a kind of saving. The farmer therefore sells only to solve a problem. *P. biglobosa* seeds, for example, are often exchanged for cereals to bridge a period of poor availability.

Conclusion

We have shown the omnipresence of NTFPs in the daily nutrition of the rural population of Burkina Faso. Products from various tree species of the parklands agroecosystem are used as major ingredients of the diet throughout the year and also contribute important snacks during the period when other foods are scarce. Thus, it is clear that these products are extremely important to the welfare and health of the rural population. Despite this importance, the tree products continue to be produced by the traditional practice of fallowing and preserving the useful trees in the subsequently created fields. Tree planting is not a tradition because it is believed that the trees are slow growing and that 'you will not see the fruit of the tree you have planted yourself'. To motivate people to domesticate local tree species, genetic selection is needed to promote faster growth, earlier fruiting and improved yield and quality. It must be mentioned, however, that the corollary of domestication is an increased value for their products. This could occur through expanded trade and better postharvest technology.

Acknowledgements

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References

L'Arbre nourricier en pays sahélien. Edition de la Maison des Sciences de l'Homme, Paris. 233 p.

Hasberg S. & Coulibaly E. 1989. Etude de marché des produits forestiers. Document de travail N° 8. FAO/MET, Banfora, Burkina Faso. 15 p.

IRBET & INS/IDR. 1988. *Séminaire national sur la valorisation du karité pour le développement national: Bilan et perspectives*. ICRAF, Ouagadougou, Burkina Faso. 185 p.

Lamien N. & Bayala J. 1994: Espèces ligneuses des parcs agroforestiers du terroir de Yasso: fonctions dans le système de production agricole et stratégies de leur gestion rapport de recherche. INERA, Bobo-Dioulasso, Burkina Faso. 32 p.

Maydell von H.-J. 1983. *Arbres et arbustes du Sahel: leurs caractéristiques et leurs utilisations*. Eschborn GTZ, Germany. 531 p.

Ouedraogo J. S. 1995. Parcs Agroforestiers au Burkina Doc. N° 79 Rapport de consultation sur le réseau SALWA–IRBET, Ouagadougou, Burkina Faso. 96 p.

Pasco L.J. 1990. Utilisation et commercialisation des produits ligneux et non ligneux des essences forestières locales dans le département de Zitenga (province d'Oubritenga). Mémoire IDR Université de Ouagadougou, Burkina Faso. 80 p.

Szolnoki T.W. 1985. *Food and fruit trees of the Gambia*. Stiftung Walderhaltung und Bundesforschungsanstalt für Forst- und Holzwirtschaft, Hamburg. 132 p.

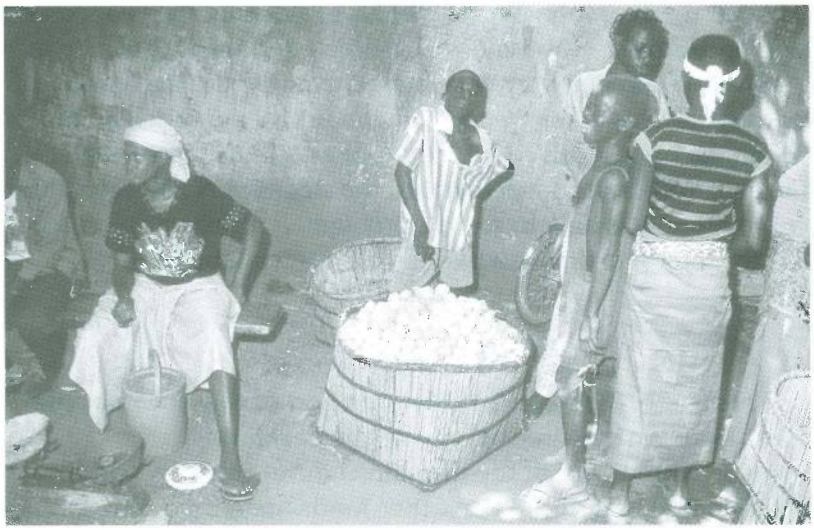

Plate 6. *A trader purchasing shea nut butter at a village market in Burkina Faso.* *(photo: N. Lamien)*

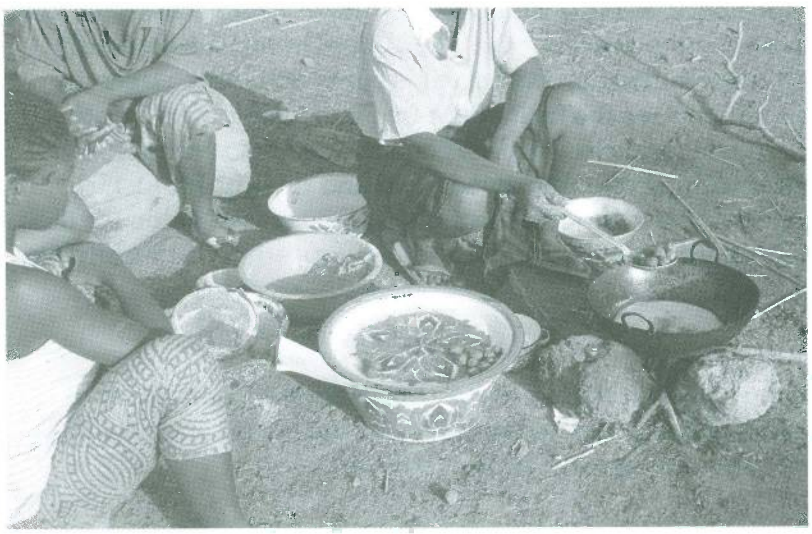

Plate 7. *A lady frying* Parkia biglobosa *flour cake with shea nut butter.* *(photo: N. Lamien)*

Plate 8. *Commercialization of soumbala (fermented grains of* Parkia biglobosa*) at a market in western Burkina Faso.* *(photo: N. Lamien)*

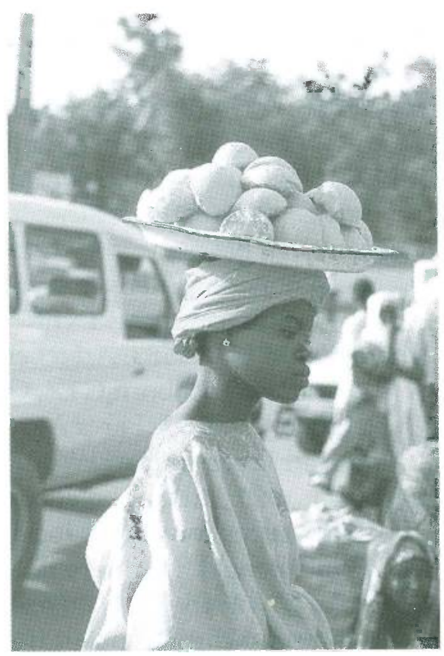

Plate 9. *A girl selling soumbala in the street.* *(photo: J. Baxter)*

Utilization of non-timber tree products in dryland areas: examples from southern and eastern Africa

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The livelihood of the majority of rural people in African drylands depends on the forests and woodlands as sources of agricultural land, firewood and charcoal, as well as non-timber tree products such as food, fibre and medicines. As the ecological balance in arid and semi-arid environments is delicate, sustainable land-use practices are required if people's basic needs for the future are to be fulfilled. Sustainable utilization of tree and shrub resources, as in agroforestry, is an integral part of this.

The main objectives of this paper are to emphasize the variety of non-timber tree and shrub products found in drylands, to describe their utilization and to indicate local people's knowledge.

Field research and observations took place in Kenya and Mozambique, where migration and changes in settlement have occurred in recent history. Such migration has brought together varied experiences, and it has also caused changes in traditional woodland utilization.

Field experience has been checked with other information from the drylands of southern and eastern Africa, so as to give a broader view of current woodland product resources and their potential in the region.

Introduction

As examples of the utilization of non-timber tree products (NTTP) in dryland Africa, we present two case studies from different ecological zones: northern Mozambique, where higher rainfall induces subhumid conditions and miombo woodland vegetation, and northern Kenya, with arid conditions and sparse natural vegetation. Both examples are from regions where migration and settlement changes have taken place in recent history and have influenced land-use practices. The approach to developing agroforestry systems and integrating NTTP species differs between the two regions. In both sites indigenous plants are preferred. The question of testing suitable species for introduction is more relevant in the case of Kenya, while in Mozambique, an inventory of locally existing plants and products has first priority.

The Mozambican experience

Field work was undertaken between 1989 and 1995 in the province of Cabo Delgado, located in the northeast of Mozambique, in collaboration with the 'Projecto Piloto de Reflorestamento de Cabo Delgado' (PPR, Cabo Delgado Pilot Afforestation Project), a project of the Mozambican Ministry of Agriculture, supported by the African groups of the Swedish Recruitment Organization (ARO).

The area represents littoral plains, a plateau up to 850 m in the north, and varied landscape with elevations of about 500 m in the central and southern zones. The soil types range from poor coastal dunes and lithic soils in the littoral to mostly ferralitic soils in the interior. The climate falls in the transition between tropical subhumid to semi-arid, with a mean annual precipitation between 800 mm at the coast and 1300 mm in the interior. The dry season from April–May to October–November lasts about seven months. The natural vegetation for the greater part is miombo woodland, characterized by *Julbernardia–Brachystegia* species. In the north, semi-deciduous forests occur, which include timber species such as *Pterocarpus angolensis* DC., *Millettia stuhlmannii* Taub., *Afzelia quanzensis* Welw. and *Dalbergia melanoxylon* Guill. & Perr. In the littoral savannas, *Adansonia digitata* L. predominates; while along the coast mangroves are important (Ministério da Educacão 1986, Millington & Townsend 1989, Chonmtica et al. 1990).

Subsistence agriculture dominates the social economy, although some fisheries and a few extractive industries also occur. These activities have been adversely affected by civil war, land-use change and economic breakdown. After independence, the dispersed rural population was settled in communal villages, and cultivation changed from itinerant or semi-itinerant to more permanent practices. Migration and further population concentration during the civil war led to exhaustion of soils around villages. There has been some reversal of these trends since the end of the war.

In the smallholder farming systems, the main subsistence components of dry-farming crop production are cassava, maize, sorghum and groundnut with little or no cash crop production. Farmers cannot afford external inputs, and crop yields are low (SPPF 1990).

There is great potential for agroforestry systems and the production of NTTP in this area:

- There is a need for sustainable low-input production systems, as an alternative to current non-sustainable land-use practices.
- Agroforestry could provide opportunities for the rural population to improve their production of subsistence crops and to initiate cash-generating opportunities.

Study objectives and methods

The 'Projecto Piloto de Reflorestamento' (PPR) started in 1985 as an afforestation project with a research component, beginning with species trials (mostly exotic plantation species). Later its activities shifted to forest extension and should in the future include management of indigenous forests and woodlands, and especially woodland utilization by local people. As a consequence of this interest, a survey about the utilization of tree products (timber and non-timber) was conducted in nine districts of the province, in 1992/93. This was primarily intended to give indications for planning extension activities, rather than achieving scientific standards. A later study, in 1995, focused on one village in Pemba-Metuge District (50 km from the provincial capital), with special reference to village-level utilization and management of woodland resources.

The survey methods started with interviews based on questionnaires developed by technical staff, conducted by the extension workers stationed in the districts. The questions covered the utilization of tree products (timber and non-timber), preferred species for certain different uses, and the experience of local people with tree planting and cultivation. The information collected was not subjected to quantitative analysis because of variability in the types and numbers of people interviewed in each district.

In the field study, semi-structured and open interviews were made in the village, targeting individuals and groups. Visits were made to forest areas and farmers' fields for interviews with key informants from the rural extension service and forest service. In this instance, selection of interview partners focused on differentiation and contrast by gender, ethnic origin and settlement. Cross-checking and triangulation were applied whenever possible. Assistance from local extension staff was used for translation from Makua to Portuguese.

The identification of local tree species was done partly by collection and cross-referencing with botanical specimens and partly by matching vernacular tree names with unpublished botanical information from earlier studies (Silviconsult 1984). This approach does not represent a thorough ethnobotanic survey of the region.

Results

About 150 local trees and shrubs for all utilization categories, timber and non-timber (including carpentry, firewood and charcoal), were recorded from the survey and the field study. This included some exotic, introduced species. About half of the species were identified by botanical names, while the remainder were identified only by their vernacular names, some of which could well have been synonyms for the same species or the name of a product of a given species.

Variety of NTTP utilization

Non-timber tree products recorded in the study included foods, medicines, fibres and dyes. Among the most frequently named species:

Foods. *Sclerocarya birrea* (A. Rich.) Hochst., *Ziziphus mucronata* Willd., *Adansonia digitata* L., *Tamarindus indica* L., *Annona senegalensis* Pers. (fruit or fruit pulp), *Ricinidendron rautannenii* Schinz (kernels) and *Moringa oleifera* Lam. (leaves). Other fruit species named include *Ximenia* sp. (*X. caffra* Sonder and *X. americana* L.), *Flacourtia indica* (N.L. Burm.) Merr., *Pachystela brevipes* (Baker) Engl., *Vitex* sp. (*V. doniana* Sweet and *V. payos* (Lour.) Merr.), *Cordyla africana* Lour., some of them being consumed mainly during times of food shortage. The total of about 20 species mentioned seems rather low and might be because of the low representation of women in the interview surveys.

Medicine. *Sclerocarya birrea* (A. Rich.) Hochst., *Crossopterix febrifuga* (Afzel. ex G. Don) Benth. (bark), *Annona senegalensis* Pers., *Terminalia sericea* Burch. ex DC., *Dichrostachys cinarea* (DC.) Wight & Arn., *Afzelia quanzensis* Welw. (root), *Tamarindus indica* L. (fruit), *Moringa oleifera* Lam., *Adansonia digitata* L. and *Eucalyptus camaldulensis* Dehnh. (leaves). The total number of species mentioned was about 40, all of them known to villagers, as no special information was obtained from traditional healers.

Bark fibres. *Brachystegia boehmii* Taub. and *Sterculia africana* (Lour.) Fiori (mainly in house construction), together with several unidentified species.

Dyes. *Pterocarpus angolensis* DC. (bark resin) and several unidentified species.

Utilization of most of these species has been described in literature for other regions of southern Africa (Carvalho 1968, Palmer & Pitman 1972, Jansen & Mendes 1984, FAO 1986, Booth & Wickens 1988, Palgrave 1992, Abbot 1993), including the use in folk medicine, although the application may differ from the one recorded in Cabo Delgado. Medicinally active substances are known to occur in different parts of *Sclerocarya*, *Adansonia* and *Moringa* (FAO 1986, Booth & Wickens 1988).

Most of the species mentioned are indigenous, with the exception of *Moringa oleifera*, an introduced species that has become very popular as a living fence for village and township homegardens, and *Eucalyptus camaldulensis*, which has been distributed by the PPR in recent years.

NTTP utilization, domestication and commercialization

The present stages of NTTP species management observed in Cabo Delgado, summarized in table 1, show patterns similar to those described in other case studies from the southern African region (see Campbell et al. 1991, Packham 1993).

Different tenure regimes regulate access to products. In natural woodlands almost anybody has open access to trees and their products. However, planted trees in a

Table 1: Management of NTTP species in Cabo Delgado

Location	Management	Species
Woodlands	opportunistic utilization	natural-growth indigenous species
Fields	selective conservation	indigenous multipurpose species *(Tamarindus indica, Sclerocarya birrea, Adansonia digitata, Ziziphus mucronata)* and planted domesticated fruit trees (mango, cashew)
Homegardens	planting	few indigenous fruit species *(Sclerocarya birrea, Ziziphyus micronata),* introduced species *(Moringa oleifera, Eucalyptus camaldulensis)* and domesticated fruit trees (mango, guava, coconut, citrus)

homegarden are private property, and the owner executes full control over the products. The situation regarding natural trees left standing in fields is less certain. Although the cultivator may be considered the owner of the tree, access to some of its products, like fruit, can still be open.

Selective retention of trees seems to be motivated by a combination of expected benefits from a tree, including non-timber and timber products, as well as shade. *Tamarindus indica* and *Sclerocarya birrea* are much valued, both for their fruits and for their timber, which is used to make utensils like mortars. *Ziziphus mucronata* poles are used for construction in the coastal area, and *Adansonia digitata* is not usually cut because of its spiritual significance.

Most products are processed and consumed within the household. The above-mentioned tree fruits are either consumed fresh or used in food preparation. The utilization of medicinal products is mostly the domain of traditional healers, whom people still actively frequent for treatment .

Commercialization of NTTP in Cabo Delgado is at present limited to the occasional sale of tree fruits (e.g., *Adansonia digitata, Ziziphus mucronata, Tamarindus indica*) in local markets or from street stalls. Bark and other fibres, along with poles and bamboo, are used in house construction in the vicinity of the provincial capital. Traditional house construction requires forest material and continues in villages as well as around Pemba township. Of all tree products, construction material and fuel (firewood and charcoal) have become the most important sources of cash income for rural households in this area.

Potential of NTTP

Theoretically, several of the local NTTP species recorded in Cabo Delgado represent material suitable for domestication and commercialization. Some of them have far greater potential than their present level of exploitation in the province, compared with experience from other countries (FAO 1983, Booth & Wickens 1988). *Moringa oleifera*, for example, is a multipurpose species that has a variety of possible uses, in addition to using the leaves for food and medicine.

Packham (1993) states that 'planting a species would appear to be a "step on" from preserving a species, and would coincide with high population pressure and a highly preferred tree'. This situation is still rarely found in Cabo Delgado, and thus the planting of indigenous species has been limited to highly valued species like *Sclerocarya birrea*. Without any information of future marketing prospects for non-timber products like indigenous fruits, people cannot safely be recommended to intensify their domestication efforts.

For many products, it can be expected that gathering from the wild will remain an adequate form of management, as long as the products can still be found in abundance. In many areas of Cabo Delgado this is still the case, but woodlands are under increasing pressure, mainly because of the search for fertile land for cultivation and the exploitation of trees for timber and fuel products. Sustainable woodland management, with active participation of the local communities, therefore, is needed to sustain the resource base for all forest products.

The Kenya experience: 'Durte Farm', North Horr/Chalbi Desert

A silvicultural consultation was done in March–April 1993 in the Chalbi Desert in the northwestern part of Kenya, east of Lake Turkana. This area of Chalbi is characterized by special biophysical and social conditions, which make it an interesting case study for NTTP utilization.

Ecologically, the study area was situated in the northern part of the Chalbi Desert, which has erratic annual rainfall, averaging about 110 mm. The soils are calcareous, salty and alkaline (pH ~ 9.0), which cause a poor physical structure. The groundwater level is at 4 m only, and the water is brackish. Water samples analysed by the National Agriculture Laboratories, Nairobi, were very high in salinity. A steady wind dries up the soil and the plants very rapidly, so that vast areas are devoid of vegetation.

Apart from famine relief, the availability of resources that support life, such as water and forage for livestock, is highly variable in time and space. So mobility and social cooperation are essential for survival in the Chalbi Desert. A common strategy among the Turkana people living in these drylands of northern Kenya is the redistribution of surpluses of food and wealth (Morgan 1981).

In the Chalbi Desert, however, the social conditions and relationships are different. Originally it was an area of the Samburu and Rendille tribes (Becker 1984), but there is now a neighbourhood of sedentary and nomadic people in and around North Horr town. They come mainly from Borana and Gabbra areas, bordering Ethiopia. Many of them are refugees, who also come from Somalia and Sudan. Additionally, there are external influences from an Islamic and a Catholic centre, and also the mission hospital, all of which have brought in new values.

Some own goats, sheep and camels, but for long periods many of the people have to rely on famine relief. The concentration of people in the feeding camp has taken them out of their pastoral lifestyle. Even a low population of stock in this environment results in serious localized depletion of the vegetation. The restricted range of movement by these now-sedentary herds strains the vegetation resource further (see also Broch-Due & Storas 1981, Barrow 1988). Consequently, environmental degradation is serious and related to the social, policy and tenure issues of the area.

A tree planting project, 'Durte Farm', was initiated at the end of the 1980s by Mr. R. Haller from Baobab Farm Ltd., Mombasa and assisted by Mrs. M. Dunkel, an agriculturist, on the grounds of the Catholic mission in North Horr and at some other spots and water points in the Chalbi area. The aim of the project was to sensitize people from the feeding camps to the value of vegetation and to motivate them to plant and take care of trees. More than 40 tree species from different origins were planted by Mrs. Dunkel and her assistants. The preferred species were those providing non-timber tree products. Seedlings and cuttings were produced under shade in the project nursery at the mission in various mixtures of fertilized soils and sand with different irrigation schemes. Survival will depend upon the root system finding the groundwater table. Although the revegetation approach seems artificial, the intention is to foster soil improvement and a better microclimate, so that natural regeneration will subsequently take place.

Barrow (1991) emphasized that in many drylands 'it makes good sense to lay emphasis on sustained conservation and utilization of the natural resources, as opposed to tree planting exercises, through conservation and management of existing trees; natural regeneration of trees; and building on existing viable and valuable natural resources management strategies'. Barrow (1988) also recommended that the 'tree species to plant should be based on what people want to plant, after all it is they who will be using and managing the trees. New species can be introduced but this should be done initially on a demonstration basis.' So in Barrow's sense, Durte Farm has to be regarded as a demonstration of new species that may be introduced, and of the methods to re-establish those species that have already disappeared from the Chalbi Desert.

Methods and objectives of the study

Without the idea of commercializing NTTPs, an inventory was carried out in 1993 of the species that showed drought tolerance, deep rooting and tolerance to high salt concentrations and alkalinity. Those species with useful NTTP were emphasized. These products act as an incentive for people to plant them.

In addition to Haller's proven method of trying out seeds from many different species from comparable climates, we also searched the literature for well-adapted species (Dale & Greenway 1961, Palmer & Pitman 1972, Palgrave 1977, Becker 1984, Rocheleau et al. 1988, Friis 1992, Weiss 1993). Names and information about the trees were also cross-checked with this literature.

During the inventory, community members of different origins, social and ethnic backgrounds and age groups were interviewed in an unstructured manner and observed concerning their use of trees and shrubs. Collecting information about the medical use of plants was not an objective, because of the proximity of the mission hospital and the low expectation of making close contact with traditional healers within the short period of the survey.

We had to carry out interviews very carefully because of the extremely difficult social situation in North Horr. Those interviewed during the survey included men and women, older people and children. The interviews were focused on the people in the feeding camp, who were influenced by the nomads, and some of whom had a nomadic background. Nomads outside the camp were not interviewed. The questions were related mainly to the area close to North Horr (i.e., within a distance of a one-day walk) and the existing tree vegetation and not on the trees people knew from other areas. In cooperation with the 'gardeners' of Durte Farm, we also collected local information about specific trees in people's homesteads. Although many of these plants were still too young to bear fruits, information was collected in this way about the natural vegetation.

Lack of time, money and infrastructure prevented full rapid rural appraisal (RRA) (McCracken et al. 1988), farming systems research (FSR) or ICRAF's 'diagnosis & design' techniques, but we did use elements of them. Our group was too small to be called an interdisciplinary team, and we did not have enough time for 'triangulation' in every case. This survey was limited by the short time available for the study and the dependence of the expatriate researcher on assistance from mission personnel in arranging visits and interviews, and for translation from local languages to Kiswahili and English. For this reason the survey can be regarded only as a preliminary study requiring further in-depth investigation in the future.

Inventory results from North Horr

The utilization of NTTPs in North Horr is far below the level of subsistence farmers, because of the change of lifestyle, the overpopulation and, especially the young age of the plants. Although there are frequent reports about the rapid decline in the vegetation caused by the increase in human population and new values brought in by migrants and refugees (Campbell 1986, Brokensha & Riley 1986), a wide theoretical knowledge about the potential utilization possibilities of trees and their NTTPs was found. This is encouraging even if answers have been influenced by the interrogations of the observer. But, compared with our experience in Mozambique, there are very few hints for active use or passive knowledge about NTTPs.

As foreseen, more indigenous than introduced species were named. We found children using NTTPs as 'snacks' (mainly fruits but sometimes leaves); for example, newly planted *Prosopis juliflora* (Swartz) DC. pods and *Moringa oleifera* Lam. leaves were collected. Similarly, leaves of fruits of *Balanites aegyptiaca* (L.) Del., *Boscia coriacae* PAX. *Cordia ovalis* R. Br. ex A.DC., *Hyphaene coriacae* Gaertn., *Salvadora persica* L. and *Ziziphus mauritiana* Lam. (fruits and leaves) were eaten from natural vegetation. Interestingly, another snack children from all origins liked very much was the sweetened and coloured seeds and pulp from *Adansonia digitata*, packed in plastic tubes and imported from Mombasa. These were available in the North Horr shops.

Balanites aegyptiaca fruits were eaten raw, as in Ferlo, Senegal, despite the information that in Turkana fruits have to be boiled before consumed (Becker 1984). This was the case in our experience with the fruits of *Dobera glabra* (Forsk) R. Br. Furthermore, a few women cook milk with the pulp of *Hyphaene* fruits. So this fruit is also one of very few plant parts gathered in large quantities (see also Little et al. 1984). A systematic gathering of food plants for storage or further preparation was the exception, but it did occur. We found the use of ashes leaves and twigs of *Atriplex canescens* L., *Salsola dendroides* Pallas and *Sueda monoica* Forsk. Ex. J.F. Gmel. used as salt. Various plant parts from *Salvadora persica* L. were also used as a toothbrush.

The above-mentioned plants include the five that are the most important (*Hyphaene, Cordia, Salvadora, Boscia, Dobera*) in the diet of the Turkana (Becker 1984). Except *Hyphaene* and *Cordia sinensis*, three of the five most important plants in the Samburu diet, *Grewia tenax, G. villosa* and *Cyphostemma maranguensis*, were not mentioned in the North Horr interviews. These plants are either absent or not yet old enough, following replanting in the Chalbi Desert. Very many plants were used as browse and collected for firewood. For browsing, donkeys seemed to prefer pods from *Prosopis juliflora, Acacia tortilis* Hayne and *Acacia alba* Del. Construction and fencing material was taken mainly from *Hyphaena coriacea* (see also Barrow 1988), *Acacia reficiens* Wawra Peyr. ssp. and *Acacia brevispica* Harms. (branches), but there was very little choice from other large-sized trees. *Hyphaene* branches and leaves were used for basketry and mat making. Medical uses were not as often reported as expected from literature (e.g. Kokwaro 1976, Ostberg 1988).

Food, except the Life Aid supplies, is in chronic shortage in this region. NTTPs could supply food during famines and food shortages, as reported by Falconer (1990). There are some indications that refugees in the North Horr camps know about trees and their NTTP values, but they do not make much use of them. Tree planting is not perceived as important work, as people are not permanently resident there. Consequently, the planting and irrigating of trees has to be initiated by 'Food for Work' projects.

Conclusions and recommendations

We agree with Barrow (1988), who emphasizes the importance of any arid-lands tree-planting project to make the connection between what the community knows (i.e., value of the trees) and what it does not know (i.e., the importance of tree planting).

The description of environmental and socioeconomic factors of both study regions indicates the need for development of balanced land-use systems in which tree species with useful non-timber products can contribute to food security and economic development of rural people. The two presented studies were conceived in a practical rather than a scientific context and were constrained by limited resources; they have been preliminary assessments of existing local knowledge and the state of exploitation of these resources. As such, they show the variety of NTTP utilization according to the resource base available (the relative richness of species of the miombo woodlands compared with that of the Chalbi Desert), and to social conditions, including the provision of food and medical aid.

The following recommendations for a development strategy to improve local livelihoods at both sites can be made:

- ***for Cabo Delgado.*** Build on the existing resources of indigenous and already introduced species by (1) the management of indigenous woodlands to sustain the resource base and (2) the further domestication of the most valued species already existing in farmers' fields and homegardens.
- ***for North Horr.*** The need is to improve the living conditions in and around the feeding camps by introducing NTTP species that could enrich the limited potential of natural vegetation. These would involve tree planting of new, introduced species or the reintroduction of indigenous species. Demonstration plots will be required to familiarize people with these species and their products. Conservation of the still-existing vegetation should also be promoted.

The research priorities for these regions are—

- completion of ethnobotanic inventories
- quantitative research on product use and availability
- a participatory assessment of the real needs of the rural people, with regard to subsistence and cash income opportunities
- an appraisal of land and tree tenure, because the availability of the product and its potential for contributing to improvement of people's living conditions depends on access to the resource base (common or open-access woodlands, individual fields, homegardens)
- an assessment of the possible influence (ecological and socioeconomic) of introducing new and indigenous tree species

References

Abbot P.G. 1993. Research and development of simple silvicultural systems for community management of miombo in Malawi. p 98–105. In: *The ecology and management of indigenous forests in southern Africa: proceedings from an international symposium in Victoria Falls, Zimbabwe,* ed. G.D. Piearce & D.J. Gumbo. Forestry Commission, Harare, Zimbabwe.

Barrow E. 1988. Trees and pastoralists: the case of the Pokot and Turkana. Overseas Development Institute, Social Forestry Network Paper 6b. 24 p.

Barrow E. 1991. The challenge for social forestry extension work in pastoral Africa. Overseas Development Institute, Social Forestry Network Paper 12e. 36 p.

Becker B. 1984. Wildpflanzen in der Ernaehrung der Bevoelkerung afrikanischer Trockengebiete: Drei Fallstudien aus Kenya und Senegal. PhD dissertation, Goettinger Beitraege zur Land- und Forstwirtschaft in den Tropen und Subtropen. 341 p.

Booth F.E.M. & Wickens G.E. 1988. *Non-timber uses of selected arid zone trees and shrubs in Africa*. FAO Conservation Guide 19. FAO, Rome. 176 p.

Broch-Due V. & Storas F. 1981. The relationship between nomadic adaption and alternative economic forms with specific references to the organisation of work and productive relations. Turkana Project Progress Report No. 5. Department of Social Anthropology, University of Bergen, Norway.

Brokensha D. & Riley B.W. 1986. Changes in uses of plants in Mbeere, Kenya. *Journal of Arid Environments* 11:75–80.

Campbell A. 1986. The use of wild food plants, and drought in Botswana. *Journal of Arid Environments* 11:81–91.

Campbell B.M., Clarke J.M. & Gumbo D.J. 1991. Traditional agroforestry practices in Zimbabwe. *Agroforestry Systems* 14:99–111.

Carvalho M.F. 1968. *Plantas silvestres de Mocambique com interesse alimantar*. Gazeta do Agricultor, Laurenco Marques. 93 p.

Chonguica E.M.W., Ferraz B.P., Leite B., Marques M.R., Massinga A.V.R., Pedro A.M.A. and Pereira I. 1990. *Situacão actual do meio ambiente*. Grupo de Trabalho Ambiental (GTA), Maputo, Mozambique. 128 p.

Dale J.R. & Greenway P.J. 1961. *Kenya trees and shrubs*. Buchanan's Kenya Estates Ltd. and Hatchards, London. 654 p.

Falconer J. 1990. 'Hungry season' food from the forests. *Unasylva* 41(1):14–19.

FAO. 1983. *Food and fruit bearing forest species. 1. Examples from eastern Africa*. FAO Forestry Paper 44/1. FAO, Rome. 172 p.

FAO. 1986. *Some medicinal plants of Africa and Latin America*. FAO Forestry Paper 67. FAO, Rome. 252 p.

Friis I. 1992. *Forest and forest trees of northeast tropical Africa*. HMSO Kew Bulletin, Additional Series 15. 396 p.

Jansen P.C.M. &. Mendes O. 1984. *Plantas medicinais: seu uso tradicional em Mocambique*. Instituto Nacional de Livro e do Disco, Maputo, Mozambique. 259 p.

Kokwaro J.O. 1976. *Medical plants of East Africa*. East African Literature Bureau, Nairobi, Kenya. 348 p.

Little M.A., Galvin K. & Leslie P.W. 1984. Health and energy requirements of nomadic Turkana pastoralists. p 290–317. In: *Coping with incertainty in food supply*, ed. I. De Garine & G.A. Harrison. Oxford Clarendon Press, Oxford.

McCracken J.A., Pretty J.N. & Conway G.R. 1988. *An introduction to rapid appraisal for agricultural development*. IIED, London.

Millington A. & Townsend J., eds. 1989. Mozambique. p 106–121. In: *Biomass assessment: woody biomass in the SADCC region*. Earthscan, London.

Ministério da Educacão. 1986. *Atlas geográfico*. vol. 1. Maputo, Mozambique. 49 p.

Morgan W.T.W. 1981. Ethnobotany of the Turkana: use of plants by pastoral people and their lifestock in Kenya. *Economic Botany* 35(1):96–130.

Ostberg W. 1988: We eat trees: tree planting and land rehabilitation in West Pokot District, Kenya. A baseline study. Working Paper No. 82. International Rural Development Centre, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Packham J. 1993. The value of indigenous fruit-bearing trees in miombo woodland areas of south-central Africa. Overseas Development Institute, Social Forestry Network Paper 15c. London. p 13–20.

Palgrave K.C. 1992. *Trees of southern Africa*. Struik Publishers, Cape Town. 959 p.

Palmer E. & Pitman N. 1972 *Trees of southern Africa*. vol. 1,2,3. A.A. Balkema, Cape Town. 2235 p.
Rocheleau D, Weber F. & Field-Juma A. 1988. *Agroforestry in dryland Africa.* ICRAF Science and Practice of Agroforestry 3. ICRAF, Nairobi. 311 p.
Servico Provincial de Planeamento Fisico (SPPF). 1990. Relatório provincial sobre meio ambiente. Pemba. 16 p.
Silviconsult Ltd. 1984. *Inventory of the forest resources in southern Cabo Delgado, Mozambique*. Bjärred, Sweden.
Weiss E. 1993. *Range management handbook III-1*, Guide to plants tolerant of arid and semiarid conditions. Kenya Ministry of Livestock and German Agriculture Team. 543 p.

A holistic approach to the domestication and commercialization of non-timber forest products

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Abstract

In the southern African context, this paper looks at the formal and informal sectoral approaches to the commercialization of non-timber forest products (NTFPs). Various trends are identified, such as urban market resistance to traditional wild foods, occurrence of pie-in-the-sky planning and government apathy towards 'minor' forest products. In addition, and importantly, there is a general lack of knowledge and awareness on the part of NGOs and development agencies of the wide range of potential NTFPs that can be produced in any ecosystem. Special emphasis is given here to the risks and dangers of commercializing NTFPs which, without management controls, can impose severe pressure on the resource base, or even threaten extinction.

The commercialization of any NTFPs must be implemented using a holistic approach. There is a critical need to ensure that the gatherers and producers obtain maximum benefits and are directly involved in the sustainable management of their resources. Such an approach requires full participation of the target groups, in all stages of planning from conception to implementation. The roles of NGOs, government and donor agencies are examined and suggestions made for various approaches, which emphasize the call for sensitivity to cultural needs and biases. Research needs are examined with particular regard to identifying market demands and knowledge gaps. Special emphasis is put on product design and development; processing and quality control; domestication and genetic improvement of indigenous plants of high economic potential; the development of innovative agroforestry techniques, particularly for semi-arid areas; and the cataloguing of the value of NTFPs that contribute to each country's gross national product. The latter information has caused at least one African government to change its forest policy in favour of NTFPs.

Proposals are made for regional cooperation and collaboration in the form of networking, personnel exchange and sabbaticals, and the development of one or more centres of excellence, which can become regional resource and training centres.

Finally, an overview is given of the research work undertaken by Veld Products Research (VPR), an NGO in Botswana. Since 1989, VPR has been involved in the domestication of indigenous fruit trees of socioeconomic importance. VPR recently started research in agroforestry, using water-harvesting microcatchment systems for traditional crops, so as to improve the possibility of a harvest in poor rainfall years.

Introduction

Veld Products Research (VPR) is an NGO established in Botswana in 1981, to promote the country's natural resources and tackle the problems associated with them. Many of these resources and problems are common to other countries of eastern and southern Africa.

For the past decade, there has been a growing awareness of the importance of non-timber forest products (NTFPs), not only for the role they play in the subsistence economy, but also for their potential and real importance to the economies of many developing countries.

There is considerable ignorance in many quarters concerning the optimal utilization of this resource base to uplift the rural poor, while at the same time protecting biodiversity and ensuring sustainability. What often happens in practice is that any NTFP that is in high demand is exploited unsustainably, until the resource base is exhausted. Invariably, the middlemen gain the profits at the expense of the economically poor gatherers.

In addition to the known NTFPs in any country, there are often many more with good commercial potential known only to local people. Potentially these NTFPs are often industrial products, such as gums, resins and essential oils, while others could include florist materials, ornamental plants, etc. This paper does not claim to have all the answers, but it hopes to point out some possible avenues of exploration, as well as to open discussion on important issues that have to be taken into account in the domestication and commercialization of NTFPs.

Commercialization of NTFPs

Government policies

Very few governments in Africa are aware of the extent of use, or the value, of NTFPs in the informal sector. Nor are they aware of the magnitude of dependence of the rural poor on these resources. This ignorance has caused some governments and international agencies to refer to these products as 'minor forest products'. The result has often been forest policies that are detrimental to both the resources and the people who depend on them.

Frequently, government interests conflict with those of the people living on the edges of forest reserves and game parks. However, if governments can be made aware of the real value of NTFPs to the people, as well as to the national economy, it may be possible to work out practical solutions, in collaboration with the people. At the same time, solutions can be found for protecting the resource base.

The Botswana government recently realized that the value of timber exports (USD 15.5 million) was exceeded by the value of NTFPs (estimated to be in excess of USD 26 million). This resulted in the Division of Forestry holding consultative workshops in the districts that have communal forest areas, as well as designated forest reserves. The chiefs, headmen, councillors, members of local conservation committees, etc., were invited to contribute to discussion on how they would like the forest policy to be modified to meet their needs for sustainable utilization and management.

Without such enlightened government policy, the NTFP resource base of Botswana, and of many other countries, will continue to be eroded. To achieve an adequate solution, both governments and the people need a change of mindset. Governments need to be made aware of the real value of NTFP resources to their national economies, and also to be sensitized to the needs of the population who are dependent on them. On the other hand, people, particularly those in countries where there have been serious conflicts with the government, need to change their attitude. There is a tendency to think that government is always the 'enemy' and that its regulations are there only to be broken.

To assist governments to realize the importance of NTFPs, it is essential that inventories, valuations, and consumption and marketing studies be undertaken in their countries (see Kleinn, this volume). There are some differences of opinion on how to place values on NTFPs, especially those that are gathered for domestic consumption. It is essential that researchers and resource managers in the region agree to use a uniform method to calculate value, to arrive at statistics that are realistic and comparable from one country to another.

Informal markets

Informal markets generally share similar characteristics throughout the eastern and southern African region, with the possible exception of those in Botswana, where informal market places did not exist until after independence.

Marketing channels for informal markets can vary according to the product and from district to district, but in general they will still have some commonalities throughout the region. In most cases, the poor and marginalized groups do most of the harvesting of NTFPs. They either peddle their wares within the local community or else sell them to middlemen, who take the products to distant markets where better prices are available. Either way, the harvesters–gatherers invariably receive a pittance while the middlemen make profits.

In cases of substantial supplies of certain NTFPs, tens of thousands of people are gainfully employed each season in harvesting the resources and selling to middlemen. These resources include *Uapaca kirkiana* Muell. Arg., a wild fruit, and *Gonimbrosia belina*, otherwise known as the mopane worm.

The informal market for traditional medicines is substantial, with the majority of people in some countries being dependent on them, preferring them to western medicine. Unfortunately, harvesting pressure has invariably caused severe reductions in medicinal plant populations, and their extinction in some areas. The active ingredients are usually contained in the roots and bark of plants, the harvesting of which can kill the plants. Traditional harvesting methods, which usually protected the plants to some extent, are now being ignored, as the pressure to generate income exceeds concern for the resource base.

This problem has become particularly apparent in the Kwa-Zulu Natal Province of South Africa, where the Zulu sangomas and herbalists are renowned for their herbal treatments (see Manders, this volume). To counteract this overexploitation, the Durban Parks Board started a programme of domestication of the most important medicinal plants. After the programme had extensive publicity, many herbalists now are growing their own high-value herbs and benefiting financially.

Formal markets

The range of NTFPs formally marketed is considerably below that of informal markets. The formal markets carry products such as crafts, honey, gums, resins, and also a few wild foods and medicines. The formalization of the marketing of the other NTFPs is constrained by infrastructure, and it suffers from quality that is variable and products that are availabile only in small quantities.

Prejudices and problems

There are a number of constraints to the marketing of NTFPs. Urban populations have regarded it as a backward step to eat wild foods. In rural areas, people will eat wild foods only in times of hardship or drought, or consider them as children's food. Fortunately, there are indications that these prejudices are changing. For example, in Botswana 20 years ago there was a strong resistance to selling wild foods in Gaborone, the capital. Today, many people are more open to buying wild foods on the street and do not feel embarrassed about it.

The situation is quite different in the townships of South Africa, where people have lived for several generations with little contact with the countryside. A market survey (Taylor 1983) revealed that in these townships there is a very substantial demand for traditional wild foods. Several people commented that the white man's food makes them 'weak' and they wanted their traditional foods instead. A marketing consultancy firm that specializes in the needs of these townships has strongly recommended up-market packaging and presentation of indigenous foods, as the market is becoming very discerning.

It is generally considered that most indigenous fruits in southern Africa will have virtually no market outside Africa unless they first are processed into jams, juices or dried fruit products. This is because they generally have very little flesh, and the flesh there is may be difficult to get off the kernel (e.g., *Sclerocarya birrea* (A. Rich.) Hochst.) or difficult to chew (e.g., *Azanza garckeana* (F. Hoffm.) Exell & Hillcoat). These attitudes are also changing as the power of domestication is realized.

Domestication of NTFPs

The domestication of natural resources involves a move from gathering in the wild on communally owned land to the deliberate cultivation of NTFPs on tenured farmland. The domestication of a chosen species then involves genetic selection and the management of varieties or cultivars. Through selection, yield and quality are improved so that the price paid for the product increases. Profits from these improved cultivars growing under personal control are the incentive to plant and manage the resource sustainability.

There are however several constraints to domestication and the formal development of markets for NTFPs; these include:

- a lack of infrastructure in the rural areas, making access to markets difficult
- low volume of products
- poor or variable quality of products
- no continuity of supply
- poor handling and storage qualities
- limited knowledge of the product among consumers

One group of NTFPs with commercial potential is the essential oils. Here again, the potential for the exploration of essential oils from wild plants is severely restricted, as there are several problems that make the essential oil industry wary of getting involved. For example, the quality of some oils can vary from region to region. When Israel tried to break into the geranium oil industry, it obtained its germplasm from France, which is a top producer. However, the Israeli oils were found not to be acceptable to the market until a special niche was created for them.

As with other NTFPs, essential oils also suffer from supply problems. One success story, however, comes from South Africa, where it was found that *Tagetes minuta* oil had characteristics that the market needed, although continuity of supply was difficult to guarantee. The answer was to cultivate it. Now, many ex-maize farmers in marginal areas of South Africa and Zimbabwe prefer to grow *Tagetes* rather than more ordinary crops, as they are more likely to get a harvest.

Risks and dangers

There are many potential risks and dangers in the commercial exploitation of NTFPs. The first is that of overexploitation. This is a result of everyone getting on the bandwagon to harvest as much as they can, as quickly as they can, before anyone else. Generally any traditional (or government) management controls are ignored in this rush to exploit the resource. Within a relatively short time, the resource is either wiped out or placed under severe pressure. For example, the very successful basket industry in Ngamiland, Botswana, has threatened the palm *Hyhpaene benguellensis* var. *ventricosa* (Kirk) Furtado, and the woodcarving industry in eastern Africa has all but wiped out the black hardwoods.

The second is that the gatherers put themselves at risk, by exploiting the resource on which they are dependent. This non-sustainable exploitation arises because of the harvesters' desire for cash. Both of these situations arise from the lack of ownership of the resource by the exploiting community. Access to cash is one of the major constraints in the lives of most people, so when an opportunity to get cash arises, they exploit it to the full. The commercialization of NTFPs therefore has the potential to destroy natural resources and leave the most needy people worse off than ever before, unless it is carefully controlled. However, if means can be found to give people the ownership of the resources, then they are more likely to protect them, and exploit them sustainably. There are, however, many examples of projects that have tried to do this, and failed.

'Pie in the sky' planning seems to be a universal problem, particularly when NTFPs are involved. The main cause has been ignorance by development agencies: ignorance of the resource base, its size and its characteristics; ignorance of the rural people, their needs and aspirations and their traditional natural resource management practices; and, finally, ignorance of the market forces. But above all of these causes of failure, there is the crucial need for people to have ownership of the resource. Land, or at least tree, tenure is essential if tree crops are to be managed sustainably. Even then, much can go wrong and a holistic approach is needed to develop the right conditions to promote the domestication and commercialization of NTFPs. Part of the development of this holistic approach involves the creation of incentives for people to establish the trees and other plants. One of these incentives is cash —not handouts, but the opportunity for farmers to profit from growing the products themselves.

Managing the natural resources

Surveys need to be undertaken of all the renewable natural resources to which the people have access. These need to quantify both the resource base and its potential utilization. The surplus available for marketing can be calculated once the needs of local people, livestock and wildlife have been quantified. People within the community need to be trained in these procedures, as well as in the methodology to monitor the impact of utilizing the resources.

Part of this process involves the development of a policy for year-round use of a range of available resources of different species, so that income can be generated throughout the year. The NTFPs could include foods, medicines, gums, resins, essential oils, insects, dried florist materials, rawhide, leather, horn products. In addition, markets have to be researched, particularly for new products. This involves determining market demands, price fluctuations, and supply requirements and opportunities.

Developing a holistic approach

A holistic approach to the domestication and commercialization of NTFPs should involve the local community at grassroots level from the very beginning. Using participatory rural appraisal techniques, communities can develop their own strategies to utilize and manage their renewable natural resources sustainably. The monitoring agency, be it an NGO or a government office, should be a facilitator and be as transparent as possible while providing the technical advice, training and other facilities.

Two approaches to the commercialization of NTFPs can be developed: (1) the sustainable management of the natural resource and (2) its domestication and cultivation. These are not mutually exclusive.

For the domestication and commercialization of NTFPs to be successful in the long run, it is essential that a holistic approach be taken. This is a long-term, slow process. There are no quick-fix solutions. It requires a multidisciplinary team, preferably by collaborating agencies, each having its own specialist inputs.

To maximize returns at the grassroots level, it is advisable to research the development of NTFPs so that they meet market needs and trends. The trap that many people fall into is that they think that when they develop a product, the market will be found for it. Sometimes that works, but very often it does not. Emphasis should, therefore, be on simple technologies such as the production of dried fruit rolls, which have a relatively long shelf life and do not spoil with handling, as does fresh fruit.

Product development is of particular importance to crafts that are based on NTFPs. To gain access to and maintain a foothold in the international craft market, it is essential to maintain product development and innovation. The craft market thrives on such stimulation—and so do crafts people, when they recognize the rewards.

Domestication of indigenous fruits at Veld Products Research: a case study

Veld Products Research started its research in the domestication of indigenous fruit trees in 1989.

Identifying superior phenotypes

The identification of superior fruit trees in the wild is the starting point for the development of improved cultivars. The approach taken by Veld Products has been to initiate nationwide school competitions. School children know the best trees in their areas, the ones that produce the biggest and sweetest fruits. Attractive prizes have been offered to the individual children, and their schools, identifying the best individual trees. From this approach, 10 superior phenotypes of *Sclerocarya birrea* have so far been identified. In addition, some superior provenances have been identified with fruit weighing 2.5–3.3 times the average for *S. birrea* (30 g) in Botswana. Similarly, six superior phenotypes of *Strychnos cocculoides* have been identified with average fruit numbers of between 300 and 700 per plant. The competition for *Vangueria infausta* is still under way, but another five to six superior phenotypes are being added to the single superior provenance identified so far.

Propagation and growth

Research into propagation of indigenous fruit trees through seeds and vegetative material has been investigated for the past 5 years. Experiments with the following species have produced encouraging results, while there have been great difficulties in germinating and growing other species in the nursery.

Sclerocarya birrea (marula)

First fruiting:	grafted 4 to 5 years, ungrafted 8–10 years	
Yield in the wild:	average of 35 000 fruits	
Fruit weight:	average: 25 g each	
	superior phenotypes:	70–98 g each
Street value:	2 US cents each fresh = USD 700 per tree (theoretically)	
	4 US cents per kg from processing industry = USD 70 per tree	

In Botswana and South Africa (University of Pretoria) the best results have been obtained with seed germination and grafting of scions carried out in spring (September–October). Removal of the operculum has resulted in very high levels of germination of 200% or more, as the seeds have multiple embryos. Research has shown that removal of the operculum is not essential for successful germination, but it is very important to keep seeds dry during cold months and to germinate them when mean maximum temperatures are at least 21°C. Keeping seeds in a dry condition in the cold season after fruit ripening is important to release them from dormancy. Moisture in winter causes seeds to develop deeper dormancy.

Mature scions grafted onto spring-sown seedling rootstocks have developed into plants that yielded first fruits in the 4th or 5th year after grafting. Plants from seedlings not grafted have been observed to take 8 to 10 years before first signs of flowering (Taylor et al. 1995).

In the field, growth rates of grafted trees improved greatly with increased moisture availability. Macro- and micro-catchments, constructed to harvest rainwater, improved tree growth by over 50%, compared with trees without catchments.

Attempts at propagation by cuttings have not succeeded either in the open or under 50% shade netting. However, a propagation box for cuttings (Leakey et al. 1990) has now been built and will be used to propagate this and other species. Propagation by truncheons has been successful, but as this method has no commercial application it has not been followed up.

Studies of the effects of pot size on seedling development have revealed that bigger pots give greater growth of both roots and shoots. Seedlings raised under 25% shade showed such good growth that within 12 months the seedlings were big enough for grafting. In the 1995 grafting session, 100% take was recorded on the seedlings that were raised under 25% shade. Seedlings raised under 50% and 100% shade were too thin or too short respectively.

VPR is carrying out field trials in three areas of Botswana to establish which provenances of *Sclerocarya birrea* will grow best in each area. Initial indications show that trees in Gabane (southern Botswana) are growing much better than those in Serowe (central Botswana). Reasons for differences in growth rates between the two sites were the differences in soil type and temperatures during winter months. Young trees are not frost resistant and they will die back to ground level and regrow in spring. Mature trees are frost resistant. The trees in Serowe are growing in 'cotton soils', which are dry but can easily be waterlogged in rainy seasons. The third trial, near Maun in northern Botswana, is newly established and therefore no results are available.

Strychnos cocculoides	
First fruit:	4 to 5 years (ungrafted)
Yield in the wild:	300 to 400 fruits
Fruit size:	average 100 mm diameter
	superior phenotypes: 150 mm diameter
Street value:	40 US cents each = USD 140 per tree

Propagation by seed has been successful; 80% germination has been recorded on seeds sown in summer in the propagation box. Seeds sown in winter took more than 9 weeks to germinate, while those sown in summer germinated within 3 weeks. Cuttings under 50% shade sprouted within 3 weeks, but no root development was observed.

Research into growth rates has shown difficulties. This species seems to be affected by mycorrhizal factors as well as shade. The symbiotic relationship between plant roots and certain species of mycorrhizae can enhance the plant's uptake of important nutrients, as well as make the plant more drought and disease tolerant (see Munyanziza, this volume). Collaborative research into mycorrhizae is being undertaken with the University of Pretoria.

In the field at Gabane, growth of this species has more than doubled in 13 months. In Zambia reports indicate that trees raised from seeds yielded fruits within 3 years of transplanting (C. Mwamba pers. comm. 1995). However, some of the trees at the Gabane have remained below average in height in the past 3 years and have not flowered. This varied response requires further investigation.

Strychnos cocculoides responds positively to inorganic fertilizers. In net-house experiments, seedlings treated with super phosphate and Nitrosol fertilizers doubled (760 cm) their heights within 3 months, while those untreated remained below 20 cm for 3 years.

Azanza garckeana (morojwa)	
First fruits:	18 months (ungrafted)
Yields:	2000 fruits; fruit size: 30–40 mm diameter
Street value:	4 US cents each = USD 80 per tree

In Botswana, this is the only indigenous species that is semi-domesticated by local people, who grow the tree in their own yards. The species is drought tolerant and fast growing, reaching more than 2 m in one season. The species responds favourably to propagation by cuttings. This species has shown good germination throughout the year, good transplantation responses, and bears its first fruits in the second year. Five potential varieties have been identified.

Azanza garckeana cuttings responded favourably in the propagation box, where vegetative growth was observed within 3 weeks. However, no roots were observed after 3 months in the box. So far, rooting hormones (Seradix No. 2) do not seem to effectively induce rooting.

The tree sprouts quite easily. At the research site, trees over 3 m were cut back to 1 m and 0.5 m in November 1995, and they coppiced within 3 weeks. The new growth started to bear fruits within 3 months of sprouting on some varieties. Clearly, this species can be kept short to ease harvesting, as the tree can grow up to 10 metres tall, making fruit difficult to harvest. Fruiting takes place only on each season's new growth, so a pruning management regime should improve fruit yield. This has yet to be proven. In field trials, this species is one of the fastest growers. At Gabane, growth of over 2 m has been recorded within 10 months. Some varieties fruited within 12 months.

Vangueria infausta	
First fruit:	8 months (ungrafted)
Yields:	1500 fruits ; fruit size: 25 to 150 mm diameter
Street value:	4 US cents each = USD 60 per tree

The domestication potential for this species is very good. Plants at the research site have been separated into four varieties on the basis of stem colour, leaf size, leaf hairiness and leaf shininess.

Germination is reportedly sporadic until the seeds are scarified or treated with hydrogen peroxide (H_2O_2) (Msenga and Maghembe 1989). At VPR, no difficulties in germination have been observed with seeds sown in the summer months; 70% germination has been recorded within 21 days of sowing in sandy beds.

Domestication of *V. infausta* faces two potential problems. First, drought or erratic rainfall causes fruit to abort, but supplementary irrigation can overcome this problem. The second problem is a mite that causes galls on the leaves. The mite spreads easily and quickly if the trees are grown at high density, and severe infection will probably affect production adversely.

Field performance in the trials has been very encouraging. Some trees bear as many as 400 fruits per tree on 2-year-old trees of about 1.3 m. In Malawi, spectacular growth and production were obtained within the same period (Maghembe 1995).

Multilocational trials

Three multilocational trials have been established between 1994 and 1996, each involving over 500 trees in total of *Sclerocarya birrea, Strychnos cocculoides, Azanza garckeana* and *Vangueria infausta.* A further 23 similar trials are planned at sites around the country in 1996/97.

Agroforestry

In Botswana the official statistic for arable agriculture is that crops fail one year in three, because of poor or erratic rainfall. However, in Gabane, at the VPR site, the last good harvest was about 15 years ago. In areas like this, it has been realized that agroforestry could be the answer to food security. The trees would provide fruit in drought years, and perhaps also allow a crop of traditional cereals and pulses, even in poor rainfall years, when such crops usually fail in traditional agriculture.

In 1995, an agroforestry trial was established in a 6-year-old orchard of *Sclerocarya birrea* trees, which are in rows 15 m apart along the contour. The trees are 12 m apart. Interplanted in the 12 m between the *S. birrea* are three 1-year-old trees planted at 3-m intervals. The centre trees are *Strychnos cocculoides,* while the two adjacent to the *Sclerocarya birrea* are *Vangueria infausta.* The latter species is a shrub often found growing in the wild under the canopies of *S. birrea,* which can be 30 m diameter when mature. Each of the trees have half-moon micro-catchments of 1 m radius around the tree. They all have stone mulches. The slope is about 1:20, facing east. Contour bunds are placed at 6-m and 4-m spacings between the rows of fruit trees. The bunds are 50 cm wide, 20 cm high at the top of the crest, and about 60 m long. Short 50-cm bunds have been placed at 1-m intervals on the uphill side of the bunds to create catchments to hold the runoff. The area between the rows was cleared of weeds and smoothed to enhance water runoff.

Seeds of sorghum and cowpeas were hand planted at set spacings and in pure stands both on the bunds and in the 1 m x 50 cm water-holding area.

One contour bund was treated with water-absorbing, polymer crystals at the rate of 100 g per square metre and to a depth of 20 cm. These crystals can absorb water up to 500 times their weight. The objective of this experiment was to see what beneficial effects these may have on the harvest in a drought year.

Traditional watermelons were planted at 8-m intervals in the centre of the catchment areas. A control plot was ploughed and planted in the traditional manner. The 1995/96 rainy season has been the best in 20 years, resulting in good crop growth for all farmers. The harvest will start in about May 1996. It will require about 10 years of data before definite results can be obtained concerning the advantages of this dryland form of agroforestry.

Recommendation

Recognizing that most NTFP resources are common to all countries in eastern and southern Africa, it is recommended that ICRAF establish a network for NTFP and agroforestry research in the region to achieve the following:

- to coordinate research so as to prevent unnecessary duplication

- to encourage collaboration between research institutions within the region as well as with first world countries
- to disseminate research findings to all interested bodies within the region as well as internationally
- to establish standardized systems for (1) valuation of NTFPs to determine their contribution to national economies, thereby influencing government policies affecting NTFPs and (2) inventory techniques for NTFP resource bases
- to identify centres of excellence within the region, which may be used as resource and training centres
- to facilitate the sharing of genetic material between research institutions in the region
- to publish a regular newsletter

Conclusion

Experience has shown that the commercial exploitation of NTFPs in the region invariably has led to the decline or extinction of the resource base. The answer in some situations would seem to be that a multidisciplinary approach is needed, coupled with full participatory planning by the communities involved, to help them to develop their own strategies to utilize and manage their NTFP resource base sustainably.

The domestication of indigenous fruit trees seems to hold great promise in arid and semi-arid areas. A collaborative research network in this whole field, coordinated by an agency like ICRAF, could make a significant contribution to ensuring greater success in achieving objectives.

References

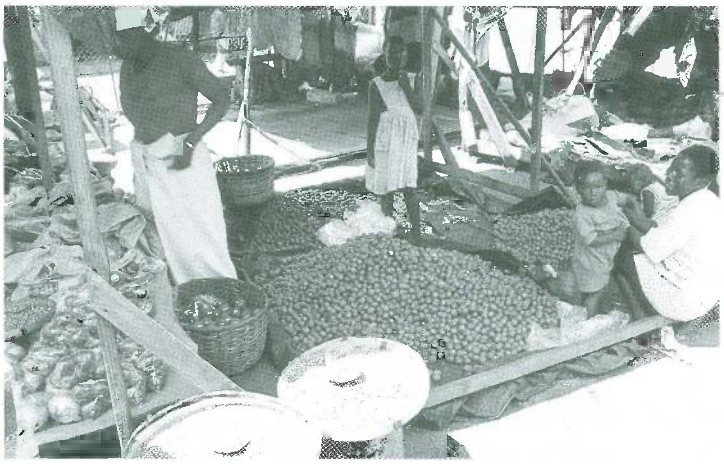
Leakey R.R.B., Mesen J.F., Tchoundjeu Z., Longman K.A., Dick J.M.P., Newton A.C., Matin A., Grace J., Munro R.C. & Muthoka P. 1990. Low technology techniques for vegetative propagation of tropical trees. *Commonwealth Forestry Review* 69:247–257.

Maghembe J.A. 1995. Achievements in the establishment of indigenous fruit trees of the miombo woodlands of South Africa. SADC-ICRAF Agroforestry Project, Malawi.

Msanga H.P. & Maghembe J.A. 1989. Physical scarification and hydrogen peroxide treatments improve germination of *Vangueria infausta* seed. *Forest Ecology and Management Journal* 28:301–308.

Taylor F.W. 1983. *The potential for commercial utilization of veld products in Botswana*. vol. 1.

Taylor F.W., Butterworth K.J. & Matoke S.M. 1995. The importance of indigenous fruit trees in semi-arid areas of southern and eastern Africa. *African Academy of Sciences Second Roundtable Discussion on Non-Wood/Timber Products*. Pretoria, South Africa.



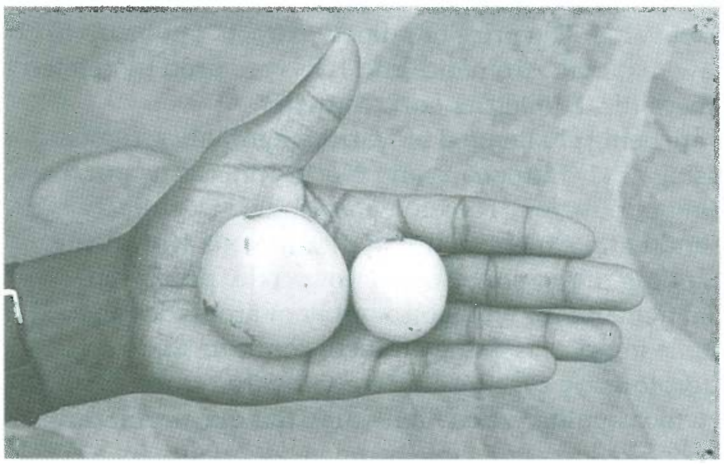
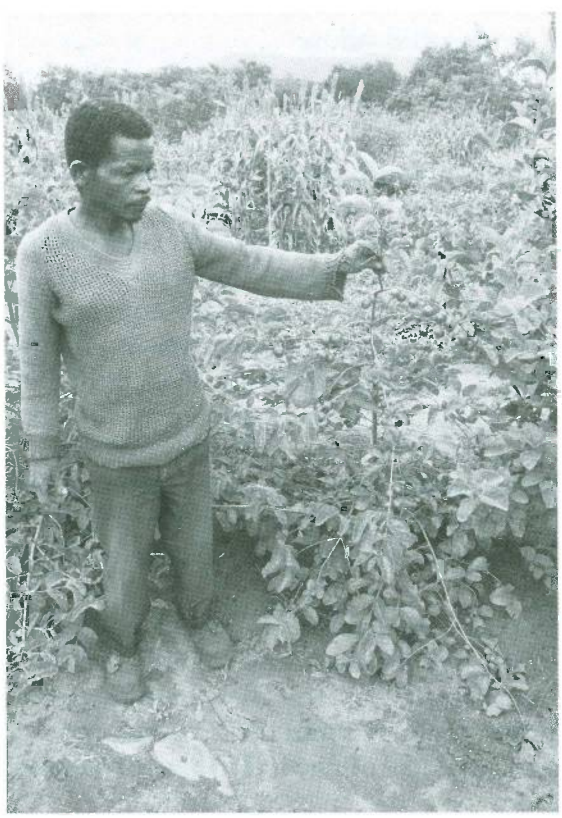


Plate 10. *Fruits of* Uapaca kirkiana *in a Mutare market, Botswana.* *(photo: F. Taylor)*

Plate 11. *Genetic variation in size of fruit from trees in the wild. The small one is an average-sized* Sclerocarya caffra *sub. spp.* birrea *fruit, while the larger one is from a tree in Mochudi, southeast Botswana (25gm:96gm).* *(photo: F. Taylor)*

Plate 12. Vangueria infausta *producing 120 fruits at 20 months. This tree is part of an agroforestry experiment. Veld Products Research research site, Gabane, Botswana.* *(photo: F. Taylor)*

Plate 13. *An experimental orchard with* Vangueria infausta *and* Sclerocarya caffra *sub. spp. birrea. Note the micro catchments after a rainstorm. Veld Products Research research site, Gabane, Botswana.* *(photo: F. Taylor)*



Flavours, spices and edible gums: opportunities for integrated agroforestry systems

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Abstract

Natural flavours, spices, other aromatics and polysaccharide gums (PSGs) share several common features. They are extracted from tree bark, sap, roots, fruits, flowers and seeds of a diversity of plant species, then processed, preserved and enhanced to preserve them and to raise their market value. The price of refined extracts can be up to 20 times the price of the harvested raw material. Aromatics and PSGs are used by related industrial companies: food, pharmaceutical, toiletries and cosmetics.

While these natural biologicals are being challenged by various synthetics, demand for flavours, spices and PSGs is rising as (1) Europeans and North Americans purchase more highly spiced foods, (2) ageing populations consume more pharmaceuticals and cosmetics, and (3) Asian, African and Latin American urban populations with rising incomes diversify their diets, expending more money on commercially processed foods. As a consequence, industrial demand for a reliable supply of aromatics and PSGs, consistent in quality and stable in price, is rising and will continue to do so.

Herein lies an opportunity for agroforestry systems that combine tree crops, bushes, vines and ground plants, each of which synthesizes a high-value flavour, aromatic or PSG. Such extractives should be processed to acceptable commercial quality by a rural industry established close to the area of production. Particular opportunities exist for semi-arid regions and for ecologies threatened by desertification.

Introduction

Natural flavours, spices, other aromatics and polysaccharide gums (PSGs) share many attributes and common features. They are mainly secondary metabolites of various woody and non-woody plants and originate in bark, sap, stems, leaves, roots, flowers and seeds. Aromatics and PSGs may be isolated or concentrated by simple physical processes, such as cleaning, grinding and screening and by extraction with aqueous, polar or non-polar solvents. These compounds find their predominant markets among the same industries: in foods, pharmaceuticals, cosmetics and toiletries. Most aromatics and many natural PSGs are harvested in tropical and subtropical ecosystems. Almost all are exported as dried tissue or crude extracts, to be refined by industries in more affluent countries. Prices realized for the refined products are many times greater than the prices paid to producers and gatherers of the raw material. The producing countries thus at present derive little of the added-value benefit or the related employment opportunities.

Aromatics and PSGs derived from wild species are less consistent in yield, composition and essential properties than those from cultivated plants. Many suitable species are adaptable to dryland ecologies; therefore, agroforestry systems that combine compatible woody and non-woody plants that produce aromatics and PSGs, integrated with contiguous extraction and refining facilities, could be of particular benefit to poor communities in the arid and semi-arid tropics.

Flavours and spices

The brief observations that follow seek to be indicative and illustrative of opportunities for flavours and spices, not a definitive, exhaustive account of all technical and economic possibilities. Natural flavours from woody and non-woody plants include sugars that occur in nectars and sweet saps, such as the African sugar bush, *Protea mellifera* Thunb., and essential components of virtually all edible fruits and aromatic herbs that stimulate taste buds and olfactory organs. As illustrated by the extensive industrial use of flavours extracted from citrus fruits, opportunities to utilize other tree fruit extracts appear almost limitless and will expand as food processing industries increase and diversify in Asia, Africa and Latin America. As an example, the processing of citrus fruits yields cold-pressed essential oils from the peel; molasses and dried pulp for animal feed from the residue; and monocyclic terpene and limonene, which may inhibit the onset of some epidermal tumours and oral cancers.

Spices and aromatic herbs

'Spice' derives from the Latin *species aromatica*. Earliest classifications were related to their use: in perfumes, for incense and embalming. Today, any distinction between spices and other aromatic plants is arbitrary. The US Food and Drug Administration describes a spice as 'an aromatic vegetable substance, in whole, broken or ground form . . . whose function is for seasoning rather than nutritional'. Others have defined spices as aromatic herbs from tropical ecologies, all others being 'culinary herbs'. Spices and aromatic herbs may also be classified as:

- ***Pungent spices*** including the fruits of *Capsicum* spp—cayenne, chillies, tabasco—and *Piper nigrum* L.
- ***Aromatic fruits and seeds*** such as nutmeg and mace, respectively the seed and the aril of *Myristica fragrans* Houtt.; allspice, the dried berries of *Pimenta dioica* (L.) Merr.; mustard seed *Sinapis alba* L.; and clove the dried flower bud of *Syzigium aromaticum* (L.) Merr. & Perry
- ***Aromatic bark*** including cinnamon and cassia from, respectively, *Cinnamonum verum* J. Presl. and *Cinnamonum aromanticum* Nees.
- ***Aromatic leaves,*** which include bay (*Laurus nobilis* L.), West Indian bay (*Pimenta racemosa* (Miller) J. Moore) and Californian bay (*Umbellularia california)* (Hook & Arn.) Nutt.

Trade in spices and aromatic herbs

For many centuries whole, unground spices have been shipped to European and other importers to be recleaned, ground and sold as ground spices, singly or in mixtures. More than 50% are consumed by secondary processors, a proportion that will increase with rising demand for processed foods. Prices paid by North American and European consumers for packaged ground spices are often 15 to 20 times the price paid to developing country producers. The constraints to grinding before shipping are several, including assurance of quality standards required by food regulatory agencies, food industries and consumers in importing countries and the prevention of loss of essential aromatics by oxidation and volatilization during shipment. These constraints are illustrated by export statistics: the US imports about 15 000 tonnes per year of unground cinnamon and cassia but less than 300 tonnes of the ground products; India exports about 40 000 tonnes of whole pepper and less than 100 tonnes of the ground spice; 99% of cloves are shipped whole and virtually none as ground spice. Similar patterns are evident among most other aromatics exported from less developed countries.

Processing and quality

Spices and aromatic herbs are marketed in three forms:

- large tissue fragments (whole seeds, flower buds or leaves)
- ground particles of the above
- extracted essential oils and oleoresins

Essential aromatics remain relatively intact in whole spices if protected from excessive moisture, high temperatures, infection, infestation and other contamination. Aromatic herbs and spices suffer rapid oxidation when ground in the air, a process accelerated by above-normal temperatures. Tropical environments and frictional heat from grinding, which accelerate oxidation and flavour degradation, can be offset by grinding in the presence of inert refrigerants such as liquid nitrogen, liquid or solid carbon dioxide.

Modern food and cosmetic industries are more disposed to using extracted essential oils or oleoresins rather than whole or ground spices. Production of essential oils and oleoresins begins with clean whole seeds or other whole plant tissues. Essential oils are constituents of all aromatic plants. They may be extracted by steam or dry distillation and 'rectified' by subsequent fractional distillation. Efficiently processed, packaged and stored, essential oils are uniform and stable in quality and free from microbial and other contaminants.They are oxidized if exposed to air and unfavourably high temperatures. Oleoresins are extracted by organic solvents. They consist of essential oils, various resins and non-volatile oils, and fatty acids. Their composition is dependent upon genotype, conditions of cultivation, the solvent and conditions of extraction. Efficiently processed, packed and stored, oleoresins are uniform, with close resemblance to the original flavour, free from contaminants, have a long storage life, and, being highly concentrated, are less expensive to ship and transport than whole spices. Those in food industries, such as bakers, meat processors, canners and frozen food and dry-mix producers, buy essential oils or oleoresins, mixed or compounded with other materials, from intermediate processors to facilitate weighing and ease of mixing and blending.

Since extracted essential oils and oleoresins converted to free-flowing particles are stable, highly concentrated and less cumbersome and expensive to transport than whole spices, there would seem to be as yet unrealized opportunities for some producing countries to add value by processing and exporting stabilized extractives. During such processing, certain standards would need to be fulfilled. Standards for extractives are based upon the weight of oleoresin that is equivalent in odour and flavour to 100 kg of freshly ground whole spice. For example, from allspice, so named because the flavour suggests a blend of cinnamon, cloves, nutmeg and pepper, 2.4 kg of essential oil or 5.0 kg of oleoresin are equivalent to 100 kg fresh ground spice (see table 1).

The above numerical estimates are indicative and relate to good quality and efficiently processed materials. All vary according to species and genotypic source (wild or culti-

Table 1. Standards for extractives

Aromatic plant	Essential oil (%)	Weight (kg) oleoresin = 100 kg of raw material
Bayleaf	30%	5 of leaf
Cinnamon	1–3%	2 of bark
Cloves	17% (mainly eugenol)	6 of ground flower bud
Mace	10–15% (88% monoterpene)	7 of ground aril
Nutmeg	16% (mainly erimysisticin)	6 of ground kernel

vated) and their environment. In addition to the woody species, there are many other plants that synthesize extractable aromatic secondary metabolites. These are also used by food industries and are plants that could be cultivated in agroforestry systems. *Piper nigrum* is a perennial climbing vine that could be cultivated among other woody species. *Capsicum annuum* L. and *Capiscum frutescens* L., which respectively give paprika and chillies, are in worldwide and growing demand. Their genotypes adapt to many environments. In common with the polysaccharide gums, discussed below, spice and other aromatic herb plants provide the raw materials used in many highly profitable and expanding food and cosmetic industries. It is later suggested how, through agroforestry integrated with efficient extractives processing facilities, tropical countries with suitable ecologies and technological capabilities could benefit both economically and socially.

Polysaccharide gums

Origin, nature and uses

Polysaccharide gums are present in virtually all plants; however, the difficulties of extraction can be industrially uneconomic. Commercially economic sources include—

- exudates and extracts from the bark, sap, leaves, fruits, seeds, roots, rhizomes of various woody and non-woody plants
- metabolites of microbial fermentations
- metabolites of aquatic macro-algae
- organic derivatives of starch and cellulose

PSGs display a wide variety of desirable functional properties, determined by species, origin and genotype, all of which influence their molecular composition and structure. Though several are extracted from wild species, in general yields are higher and the desirable properties are more consistent from systematically cultivated species.

In some connotations, 'industrial gum' includes a wide range, from hydrophobic hydrocarbons with high molecular weight, such as rubber and the latex 'chicle' from *Manilkara zapota* (L.) P. Royen used in chewing gum, to resinous saps from evergreens. However, the most common commercial usage of 'gum' relates to an assortment of plant and microbial polysaccharides and their derivatives that are miscible with hot or cold water to form viscous solutions or gelatinous dispersions at relatively low concentrations. Criteria that determine industrial choice and selection include the specific properties required, cost, reliability of supply and consistency of quality.

Total annual global industrial use of PSGs, including modified starches and celluloses, is valued at about USD 2 thousand million, with roughly half being consumed by US industries. Total US industrial consumption is estimated at 1.13 million tonnes with US food and feed industries using roughly 280 thousand tonnes valued at USD 375 million. Consumption of PSGs is increasing throughout European industries and can be expected to rise among the rapidly industrializing nations of Asia, Africa and Latin America. A particular attraction of most PSGs is that they can truly be described as 'natural products' from renewable biological sources. Because of their wide availability from natural and synthetic sources, PSGs used in the food industry are generally regarded as safe by the US and other food and drug regulatory authorities.

Health benefits

Of all the natural polysaccharides, only starches are fully hydrolysed in the digestive tract. Enzymes in the upper gastrointestinal tract hydrolyse starch and carbohydrates derived from hydrolysed starch. PSGs and cellulose and its derivatives pass relatively unchanged into the large intestine, since neither upper gastrointestinal enzymes nor stomach acids exert any appreciable effect on cellullose or PSGs. Of recent interest is the ability of some PSGs to mimic solid saturated fats in textural and mouth-feel properties. As a result they are increasingly used to provide desirable eating qualities in low-fat and low-calorie foods. Also PSGs with high solubility increase faecal bulk and function as soluble fibre to reduce blood plasma cholesterol. Attributes such as these will expand their utility and and raise consumption by food-processing industries.

Commercial gums

Exudates

PSGs from exudates were the earliest used, being the most readily accessible from trees and shrubs by tapping or incising the bark. Exudates come mostly from wild species, which display considerable variability in functional properties within and among species. Trees cultivated in plantations from selected genotypes give higher yields of PSGs with more consistent properties.

Most plant families include species that exude gums, although only a few are economically useful. The most widely used PSG exudates include arabic (*Acacia senegal* (L.) Willd.), ghatti (*Anogeissus latifolia* (DC) Wallich ex Guillemin & Perrottet), karaya (*Sterculia urens* Roxb.), and tragacanth (*Astralagus gummifer* (Lab)).

Gum arabic. An exudate of *Acacia senegal* and other *Acacia* species, gum arabic is the most extensively used of the natural exudates (see also Seif el Din & Zarroug, this volume). Its first reported uses, about 3000 BC, were as an adhesive in hieroglyphic paints and in the embalming of Egyptian mummies. The main producing countries are Sudan, Nigeria, Senegal and Mauritania; however none refine the gum to food commercial quality. The market price of high-quality refined gum arabic, USD 15–25 per kg, is 8 to 10 times the price paid for the crude exudate. From wild species, gum yield per tree varies from 20 to 2000 g per year. Yield, consistency and profitability are significantly improved by integrated systematic selection, cultivation, tapping and processing. Acacia trees can be cultivated in plantations and the gum can be processed and refined locally.

Coincident spray-drying encapsulates flavour, spice oils and oleoresins to produce dry particles suitable as ingredients of dry soup, sauce, dessert and cake mixes. Its gels form the bases of many varieties of pastilles, gum drops, jelly candies, cough lozenges and other confections high in sucrose. It acts as a stabilizer in marshmallows, caramels and nougats; and as a protective coating for nuts and a glaze for baked bread and cakes; in toppings and icings for cakes; foam on beer. It is extensively used as an emulsion stabilizer and binder in a wide assortment of lotions, emollient creams, lotions and other cosmetics.

Gum karaya. Second in commercial importance to gum arabic is this exudate of a bushy tree, *Sterculia urens*, which grows on dry, rocky soils in India. Total annual production of the gum is about 4500 tonnes, the average yield per tree about 4.5 kg $year^{-1}$ with a market price for high-grade gum of roughly USD 5 per kg. Its industrial applications are similar to those of gum arabic, being used in many food, pharmaceutical and toiletry products. It stabilizes salad dressings, cheese spreads and ground meat; prevents ice crystal growth in frozen foods; and improves the stability of whipped egg albumen and other protein foams.

Gum ghatti. *Anogeissus latifolia*, which produces this exudate, grows in deciduous forests in India and the Indian subcontinent, often in the same areas as *Sterculia urens*. World production is roughly 1000 tonnes; market price of graded quality is about USD 3 per kg. Its commercial applications are similar to those of gum arabic; that is, it is used as a stabilizer for syrup emulsions and as a carrier for oil-soluble vitamins.

Gum tragacanth. This gum from *Astralagus gummifer* was in trade at the time of Theophrastus (300 BC). The quality varies among different *Astralagus* species, which grow mainly in the semi-arid, mountainous regions of Iran, Syria and Turkey. After incision, the gum exudes as flakes or ribbons. Although gum tragacanth has attractive properties, international trade has declined as the price has increased, largely influenced by rising labour costs in the countries of origin. Harvesting, handling and grading of exudates from wild species is highly labour intensive. Silvicultural experiments in Arizona indicate that yields and quality can be improved and labour costs reduced in plantations with 25 000 trees per hectare, spaced 60 cm apart, and by incising the bark with a battery-operated hand drill. The USA, the largest importer (700 t $year^{-1}$), recognizes five grades, which range in price from USD 30 to 90 per kg. In foods it is an effective emulsion stabilizer at low pH, a useful property in French, Italian and Roquefort salad dressings. It is also a stabilizer of frozen foods that contain acid fruits, of acid fruit centres in chocolates and of vitamin C in beverages. It provides body and 'mouth-feel' to low-calorie mayonnaise, salad dressings and sauces. Its capacity to form thick, viscous gels provides an important pharmaceutical application in spermicidal jellies. It facilitates absorption of steroids and oil-soluble vitamins and acts as an emulsifier for cod liver oil. In toiletries it is a useful humectant in toothpaste, skin and hair creams.

Extracts —gums from seeds and leaves

The most important sources of PSGs, other than starch and cellulose, are the seeds of the locust bean, guar, tara, tamarind, quince and psyllium. After seed extracts, the most extensively used PSGs are pectin and pectic acid derivatives extracted mainly from fruit pulp as well as agar, alginates and carrageenans extracted from various seaweeds.

Extracted gums from genetically modified microorganisms and chemically modified cellulose, starches and seaweed extracts are gradually superseding exudates because of the variability among exudate PSGs from wild species. Standards of quality for all food grade exudates and other PSGs are specified by the Joint FAO/WHO Expert Committees on Food Additives and in the Food Chemicals Codex of the US National Academy of Sciences.

Guar gum. The gum is produced by grinding the endosperm of the decorticated seeds of a leguminous plant, *Cyanopsis tetragonolobus* (L.) Taubert, an annual that grows in arid and semi-arid areas in India. Breeding and agronomic studies in Oklahoma have raised yields. US food processors use about 7000 tonnes per year as a stabilizer and thickener and as a humectant in baked cereals. Guar gum complements the viscoelastic properties of hydrated wheat flour gluten, a property of value to developing countries who seek to reduce importation of wheats by producing fermented bread from composite flours containing significant proportions of non-gluten-forming cereals. Its high viscosity favours its use in cosmetics and toiletries, particularly in hair conditioners and shampoos, and in latex paints.

Locust bean (carob) gum. First known as an adhesive in Egyptian mummy bindings and, biblically, as the desert food of John the Baptist, locust bean gum is obtained from the ground endosperm of the seeds of the legume *Ceretonia siliqua* (L.), which grows naturally around the Mediterranean. A large tree can produce over 1 tonne of pods, each weighing 15–40 g. World production is about 500 000 tonnes of pods.

Annual use by US food industries approximates 1500 tonnes. It is used as a stabilizer, binder and thickener in processed cheese, in toppings and syrups for ice cream, frozen desserts; in processed meats and heat-processed canned foods; and to improve sheeting in pastry doughs for tortillas and pizzas. It has special applications in sizing, printing, dyeing and fabric finishing in textile industries.

Psyllium seed gum. This is obtained from the seeds of *Plantago*, which grows around the Mediterranean and is cultivated in France, Spain and Italy. High PSG content has been found in Indian cultivars. It is a mucilaginous gum used for many centuries as a remedy for intestinal disorders, as a mild laxative, and to alleviate irritation of mucous membranes.

Quince seed gum. The gum is extracted from the seeds of a deciduous bushy tree, *Cydonia oblonga* Miller; the fruit pulp is converted into preserves and marmalades. The gum properties are particularly suited as an ingredient in hair lotions used to set artificial waves and curls.

Tamarind gums. The gums come from the seeds of the leguminous *Tamarindus indicus* (L.), cultivated in India. The pulp of the mature pods is used in curries and chutneys and is a good source of vitamin C. Seed coats are removed by parching. The dehulled seeds are then dry-milled to produce the PSG. The powdered gum disperses in hot and cold water; its maximum viscosity is reached when it is boiled. Viscosity of the hot paste is over five times that of maize starch at 5% concentration. PSG produced from the seeds can in part replace pectin in jams and jellies and acts as a stabilizer or thickener in various foods. It acts as a binder in pharmaceutical tablets, as a humectant and emulsifier in cosmetics, and as a sizing agent for jute and cotton fibres.

Tara (huarango)—Peruvian carob gum. The gum is produced from milled seeds of a shrub species of *Caesalpina*, which is extensively grown and processed in Peru. Its properties and uses are similar to those of locust bean.

Fenugreek gum. The gum comes from the seeds of an annual, *Trigonella foenum-graecum* L., which, when cultivated, yields 900 kg ha^{-1} an^{-1}. It is used in curries and as an essential ingredient of imitation maple syrup. The oil also contains the pharmaceutically useful steroid diosgenin.

Aloe gum. This gum is extracted from the leaves of *Aloe* species, for example, *A. vera* L. Burm., grown as a plantation crop in Texas at about 20 000 plant ha^{-1}, and in Central America and the Caribbean. Aloe gum yields approximate to 70 kg $plant^{-1}$ an^{-1}. It is used in cosmetics as a skin lotion and emollient, and in pharmaceuticals as a therapeutic for skin lesions.

Chia gum. This gum from the seeds of *Salvia hispanica* L. displays exceptional mucilaginous properties at low aqueous concentration. The seed also contains 35% of good quality oil and 25% protein. The roasted seed was historically a popular food among Mexican Amerindians.

Okra gum. The gum can be extracted from the pods of *Abelmoschus esculentus* (L.) Moench, which when cultivated is mostly harvested when immature and cooked as vegetable 'gombo'. The PSG displays uniquely mucilaginous properties with the ability to be whipped to stable foams. Mixed with egg white, okra gum produces commercially superior confectionery products.

Yellow mustard gum. A product of recent commercial origin, this gum is produced from yellow mustard seeds (*Sinapis alba* L.). It has wide application as a binder for ground meats and in bread coatings for fried chicken and fish. It also provides antioxidants, which being of natural origin are not classed as 'additives'.

Pectins

Pectins exist in all higher plants, particularly as structural materials of soft fruits and fleshy roots. Most common commercial sources are citrus peel and apple pomace, both by-products of fruit juice manufacture. From citrus peel (about 30%) pectin is isolated by acid aqueous extraction, followed by filtration, concentration and precipitation with ethanol, methanol or isopropanol.

Although most widely used in jams and jellies, pectins also stabilize fermented and acidified milks, fruit yogurts and related foods. They act as protective colloids in cosmetic emulsions and surgical dressings.

Pectic substances are extractable from many tropical plants. An interesting source is the jujuba tree (*Ziziphus mauritiana* Lam. /*Z. jujuba* Miller), indigenous to Africa, which is highly resistant to drought and salinity. The fruit, like a small plum, has a long post-harvest shelf life, can be eaten fresh, dried or candied and is high in vitamin C (about 75 mg per 100 g); when underripe it is ideal for jams, jellies and chutneys. The leaves contain functionally useful vegetable tannins. The jujuba is only one of many arboreal species that deserve systematic study as components of agroforestry systems that can produce extractable PSGs and other commercial products.

Starch

Starch and many derivatives may be considered as PSGs in that they are polysaccharide polymers that produce viscous solutions or gels. Principal sources are maize, other cereal grains, cassava, roots, tubers, rhizomes and stems from species of the Palmae family. Starch is composed of two principal components: amylose, a straight chain, and amylopectin, a branched chain of glucopyranosyl units. Each starch source can be identified by the shape and size of its granules, by its amylose-to-amylopectin ratio, and by its pattern of swelling and gelatinization when it is hydrated and heated.

Starch granules are released from cleaned vegetative tissue, roots or seeds by maceration or grinding, then are extracted with clean water. The suspended starch granules gradually settle by sedimentation, a process accelerated by centrifuging. The wet starch is dewatered, dried, milled and screened to predetermined particle size. From whatever source, starch can be extracted and processed by either labour-intensive or highly mechanized processes. Cleaning, grinding, macerating, dewatering, screening and packing can be by hand or by machine. Drying can be by insolation or by heating with fuel under vacuum or moving hot air. Labour-intensive processes are least expensive but are also less efficiently productive. For example, cassava roots processed by manual labour, using gravity sedimentation and sun drying, will yield about 12–15% starch, while a modern mechanized process will yield 25% starch proportionate to the root source. Furthermore, starch derived from selected cultivated plants harvested close to the processing factory is more consistent in yield and quality than that from wild or unselected crop types. A study of alternative production systems for sago starch from the palm *Metroxylon sagu* Rottb/*M. rumphi* C. Martius has indicated that intensive cultivation will yield 25 t starch ha^{-1} an^{-1}. More primitive systems produce barely 5 t ha^{-1} an^{-1}. Starchy rhizomes suitable for agroforestry systems in appropriate ecologies include the various 'arrowroots' from species of *Tacca*, *Canna*, *Curcuma* and *Maranta*, several of which can be cultivated to yield over 30 t ha^{-1} an^{-1} with starch contents between 20 and 30%.

Starch can be chemically converted to an immense diversity of derivatives, with properties to suit various industrial requirements. Thin boiling starches are used by laundries, for warp sizing in textiles, and in paper and paper board manufacture. Starches oxidized by hypochlorite have many applications in paper and textile processing. Dextrins from thermal treatment are widely used as adhesives.

Cellulose and lignocellulose

Lignocellulose is the most abundant yet most profligately wasted natural polymer. Woody tissue of crystalline cellulose is surrounded by a matrix of xylan and lignin. The thermoplastic lignin can be converted to a wide range of useful phenolic substances, such as ethyl vanilla, important in food flavours as the synthetic substitute for vanilla. Xylan is a PSG used as a binder and emulsifier in various food, cosmetic and pharmaceutical products.

Cellulose derivatives

Though indigestible by non-ruminants, pure cellulose and several derivatives are technologically important in food products. PSGs of industrial importance are the cellulose alkyl ethers: methyl, hydroxyethylmethyl-, hydroxypropylmethyl-, and carboxymethyl-cellulose. Annual global production of methylcellulose derivatives, by over 40 chemical companies, is in excess of 100 000 tonnes (table 2).

Table 2. Consumption and value of cellulose derivatives in the USA

	Tonnes ('000)	USD million
CMC	42	125
Hydroxyethylmethyl	22	96
Methyl	12	55
Microcrystalline	6	27
Other	2	10
Total	84	313

The first industrial cellulose PSG was sodium carboxymethylcellulose, made in Germany in World War I as a substitute for gelatin. The earliest extensive use of CMC was in the 1930s in synthetic detergents.

Though not digestible, those used in food are non-toxic and generally regarded as safe by the US Food and Drug Administration. PSGs derived from methylcellulose are used in low calorie and dietary foods to replace lipids and carbohydrates, as well as in salad dressings, syrups, preserves and jellies. They effectively supplement hydrated wheat flour gluten in fermented breads. In other baked and frozen foods they retain moisture, stabilize doughs, batters, decorative icings and fillings. They stabilize emulsions in non-dairy whipped toppings; act as binders in extruded foods; and reduce fat absorption in fried meats, fish and vegetables. They can be converted to clear, flexible films, which provide effective barriers to lipids and are useful as packages for fatty foods. Agricultural applications include coatings for eggs; binders for animal feeds, fertilizers and water dispersible pesticides; and adhesives to bind pesticides to seeds.

Recommendations

The harvesting of raw materials from which aromatics and PSGs are commercially extracted and refined provides employment and income for rural people in tropical and subtropical countries. As most refining takes place in North America, Europe and other affluent regions, producers and gatherers of the raw materials receive the added value from processing, which in most instances is substantial.

Growth in demand is apparent among industries and their consumers in North America and Europe, where increased consumption of processed foods in general and of exotic highly flavoured foods in particular is clearly evident. A progressive growth in demand can be predicted among the economically advancing nations of Asia and Latin America where expanding urban populations with rising disposable incomes will purchase more industrially processed foods, as well as more cosmetics and toiletries. Ageing populations on all continents may be expected to consume more pharmaceutical products. Present yields of PSGs from plant cell and tissue culture are generally too low to be economic; therefore, cultivation is the better alternative. Tissue culture of explants from *Acacia senegal* produce gums that are different in their properties from gums extracted from the original tree.

Industries that process foods, pharmaceuticals, cosmetics and toiletries are the dominant users of refined aromatics and PSGs. These industries require refined materials that are reliable in supply and consistent in quality and essential properties, all of which are most efficiently provided from selected, cultivated species and from chemical and biosynthetics.

Tropical and subtropical sources, particularly of PSGs from wild species, are increasingly challenged by products of chemical and biosynthesis whose essential properties are more controlled and consistent.

Aromatics and PSGs from agroforestry

Now that it has been noted that chemical and biosynthetics can offer consistent quality, a trend in consumer preference for 'natural' over 'synthetic' is evident in Europe and North America. The expanding future demand for aromatics and PSGs, particularly by Asian and Latin American industries that serve local consumers, could and should be satisfied from production and processing facilities established within the regions. To continue to export dried and crude extracts from Asia, Africa and Latin America, then to reimport refined extracts from Europe or North America, constitutes economic colonialism. There are several countries of Asia, Africa and Latin America where desirable species could be selected, genetically improved and cultivated in agroforestry systems, and where there exists the scientific and technological capability to maintain and control processing facilities to produce refined extracts of essential and consistent quality.

Herein lies an as yet unrealized opportunity for agroforestry systems. Each system, designed for a prevalent environment, would combine compatible woody and non-woody perennials and annuals, each genotype being a selected productive source of a commercially valuable aromatic or PSG metabolite. The natural flavours, aromatics and PSGs of commerce are derived from tall trees and bushy trees, from climbing vines, from perennial and annual plants of various heights and phenotypic conformations. It should be possible, therefore, to design systems that are highly productive and make the most efficient use of land, water and other essential resources. It is suggested that attention be given first to dryland areas, because an impressive number of species producing aromatics or PSGs are indigenous or adaptable to semi-arid ecological niches. The desert reclamation programme in Egypt has demonstrated the advantages offered by agroforestry systems in arid environments.

A factory equipped to extract and refine essential flavours, aromatics and PSGs could be established adjacent to and integrated with each agroforestry production area. The processing and refining of flavours, aromatics and PSGs employ extractive technologies based upon similar basic principles. As described above, there are common industrial markets for refined aromatics and PSGs. Two or more PSGs are often used in combination to provide a broader spectrum of utility than is possible from a single substance. PSGs are widely employed as protective colloids and as carriers for aromatics. There is therefore logical reason to cultivate suitable species and to extract and refine aromatics and PSGs in neighbouring locations.

The feasibility of what is proposed, particularly for poor dryland areas, may be questioned on several counts, in particular the need for adequate clean water to extract PSGs, and for chemical solvents to extract aromatic oleoresins. Water used for PSG extraction can be microbially purified.

There is a modern alternative, called supercritical gas extraction, which has many advantages over organic solvents for the extraction of essential oils and oleoresins from aromatics. Though the ability of supercritical gases to act as solvents was known early in this century, only as recently as the 1970s was supercritical carbon dioxide first used industrially to extract the essential oils of hops and for the decaffeination of coffee. Extraction with supercritical carbon dioxide does not entail economic difficulties with solvent recovery nor potential toxicological hazards of solvent residues in the aromatic extracts. High-pressure components suitable for relatively small-scale processing units are now available from several industrial engineering companies.

Conclusions

As demands for industrially processed foods, pharmaceuticals, cosmetics and toiletries increase on every continent, so will the consumption of flavours, aromatics and PSGs. PSGs and, in the near term to a lesser extent, aromatics of natural origin, will be in competition with chemical and biosynthetics. Countries that continue to rely on exports of crude extracts and dried tissues of wild species will be at an increasing disadvantage. A growing number of nations, until recently classified as 'developing', are capable of cultivating species from which aromatics and PSGs can be extracted and possess the latent scientific and technological resources to establish agroforestry production systems integrated with modern technologies for extraction, refinement and quality control of commercially acceptable aromatics and PSGs. It is believed that particular opportunities exist in regions susceptible to recurrent drought and future desertification.

Indigenous enterprise for the domestication of trees and the commercialization of their fruits

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Abstract

Forests offer a great variety of products of potential market value. The indigenous peoples of Amazonas State, Venezuela, already recognize this value and have been selling their own native wild fruits in the state's capital, Puerto Ayacucho. They are able to sell there because they have access to public and private transport to the market. There is a distinct seasonality to the appearance of wild fruits, as seen through their increased sale during the wet season. One constraint to sale, however, is that as the population of Puerto Ayacucho and nearby villages increases, the availability of trees decreases as a result of pressures from home-building and agriculture. There have been examples where wild seedlings have been collected for village nurseries to be planted in gardens. These same species can potentially be incorporated into agroforests.

As a researcher develops programmes and projects for the domestication of indigenous trees and the commercialization of their products, it is important to select those trees preferred by local people and to ensure that local people will benefit. Furthermore, when selecting these species, the researcher should consider their seasonality, availability and management, as well as perishability, transport and pricing.

Introduction

Ethnobotanical inventories of indigenous knowledge of plants and their environment have great value in identifying species for domestication and commercialization. Indigenous people themselves are enterprising and have been selling and starting to domesticate these inventoried products without any intervention from outside commercial interests or from governmental or non-governmental organizations (Asibey 1974, 1977; Padoch 1987, 1988; Padoch et al. 1987). These accomplishments already achieved by indigenous peoples and other small-scale farmers should be further supported. To promote and improve markets to benefit local gatherers and vendors, it is important to consider resource tenure, distance to markets, access to transport, seasonal variations in supply of products and tree management (Scoones in press). Tree management could include their integration into agroforestry systems.

The study area

Non-timber forest products are actively marketed in Puerto Ayacucho in Amazonas State, Venezuela. In 1990, the Amazonas State population of about 100 000 included over 43 000 indigenous inhabitants (OCEI 1992a,b). All indigenous peoples within Amazonas State have the right to hunt, fish and collect wild products, including timber, for their personal consumption; thus they have the right to continue their traditional lifestyles. Edible wild plant products are collected mainly for household consumption and for sale in the local market. Wild fruits and fish may be sold legally, but the sale of game animals, birds, ornamental fish, wild orchids and timber is strictly prohibited by law. Although the fruits are described here as 'wild', this does not imply that they do not belong to anyone. On the contrary, they are the common property resources of the members of a particular village. 'Wild' is used only to distinguish forest from cultivated products. Very few indigenous villages within Amazonas State have full legal title to their lands; however, some villages have been given a collective title for the right to use and enjoy the land, according to traditional customs. Those villages without such rights are often found within national parks and protected areas that occupy approximately half the area of Amazonas State (García 1993). Those villagers without title do farm, fish and hunt. However, uncertainty exists about the future.

Most of the state's population is concentrated within urban areas, particularly Puerto Ayacucho, the major centre, with a 1990 population of over 36 000 (OCEI 1992a). There is a road running north–south through Puerto Ayacucho, which allows for the transport of agricultural and forest products from surrounding villages and other states to the central market. Vendors with permanent stalls sell agricultural produce both from within the state and from production sites elsewhere in Venezuela. These permanent vendors reside in Puerto Ayacucho and are *criollos*, the mixed-race population of southern Venezuela. The markets are open all days of the week except Sunday.

Although Saturday is the traditional market day in Puerto Ayacucho, indigenous vendors arrive from their villages in large trucks every weekday. The trucks are supplied either by the local government or by private owners. This transport is well organized and arrives in the villages in the early morning to pick up the vendors and their produce. It leaves Puerto Ayacucho again at midday to return to the villages. The indigenous vendors do not have stalls but sell instead along the pavement.

All the vendors in the main market were surveyed on average every 4 to 5 weeks over a period of 13 consecutive months. The origin of each vendor was noted and each was listed as indigenous, criollo with a permanent market stall, or criollo with no permanent stall. The prices and the origin of the products were also recorded.

The fruit gatherers came mostly from villages located approximately 60 km to the north or south of Puerto Ayacucho along the main road. Some vendors also came from farther south on the Orinoco River or from the neighbouring Bolívar State to the north. These people would normally come to Puerto Ayacucho for other reasons, such as to pick up a government cheque or take a family member to the hospital. They would then take advantage of the trip to Puerto Ayacucho to sell their agricultural and wild products, including agricultural produce, condiments, wild plant products, fish and termites (*Syntermes* sp.). Only the sale of wild fruits will be discussed here.

Vendors

The ethnic groups harvesting and selling edible wild fruits were the Huottuja (also known as Piaroa), Hiwi (also known as Guajibo), and Curripaco. Also, within the market some criollo vendors sold fruits originally bought from an indigenous gatherer. Of all the vendors selling wild fruits throughout the 13 months surveyed, 2% were criollos with permanent market stalls, 6% were criollos who arrived for that particular day (that is, non-permanent), and the remaining 92% were indigenous.

Fruit harvesting and seasonality

The appearance of wild edible fruits in the market generally reflects their availability relating to their fruiting seasons, rather than to any conscious decision by vendors to sell one product over another during a particular time (Melnyk 1995). The wild fruits sold within Puerto Ayacucho's markets were *Humiria balsamifera* (Aubl.) St. Hill.

(Humiriaceae) and the palm fruits *Euterpe precatoria* Mart., *Jessenia bataua* (Mart.) Burret, *Mauritia flexuosa* L.f. and *Oenocarpus bacaba* Mart. (Arecaceae).

H. balsamifera has a short fruiting period in February during the dry season. The height of fruiting for the palms was during the wet season from May to October. Pickers climbed to collect the fruit panicles of *E. precatoria*, *J. bataua*, and *O. bacaba*. Such non-destructive methods may be considered sustainable, but increased extraction of wild fruits might result in reduced regeneration of the species (Nepstad et al. 1992), although this seems unlikely (Peters 1990). Sometimes a man's wife may help him collect or carry the fruits back to the house. It is usually the man who sells the fruit in the market; however, he may be accompanied to market by his wife. The fruits of *M. flexuosa* and *H. balsamifera* are collected from the forest floor by women who then sell them.

Euterpe precatoria, *J. bataua*, *O. bacaba*, and *H. balsamifera* are sold as whole fruits. *Humiria balsamifera* is eaten fresh as a berry, whereas fruits of *E. precatoria*, *J. bataua* and *O. bacaba* are warmed in water to soften them. They are then ground in water to make a beverage from the mesocarp. After the seeds and the exocarp are removed, the beverage is ready to drink. *Mauritia flexuosa* is prepared for sale by removing the mesocarp from individual fruits to aggregate a kilogramme and then wrapping the kilogramme in a leaf. The buyer then mixes the mass in water to prepare a beverage or eats the pulp raw.

Profits and losses

When the value of time invested and the transport costs were taken into account, earnings from the sale of wild palm fruits were greater for an indigenous vendor than were the wages of a labourer in the area. The market day of 12 September 1992 provides an example, even though on that day the fruits commanded their lowest prices of the year. On most occasions, the vendor would harvest and sell one 40-kg sack of fruits; for example, *E. precatoria* or *J. bataua*. The price of both fruits was VEB 20 kg^{-1} (equal to USD 0.29; exchange rate Venezuelan bolivars (VEB) 68.82 = USD 1.00). Each vendor thus made VEB 800 gross. After paying VEB 120 for transportation, the net earning was VEB 680 for 14 hours of labour (9 hours for collection and transport plus 5 hours for selling). By comparison, a labourer with a minimum wage of VEB 300 for eight hours of work would earn only VEB 525 for the same 14 hours (Melnyk 1994).

With the money earned, indigenous vendors buy items such as pans, clothes, shotgun cartridges, kerosene and food such as tinned foods, white bread and soft drinks. The question, however, remains whether or not the purchased goods compensated nutritionally for the fruits sold. A comparison was made of the calorie, carbohydrate, fat and protein contents of one kilogramme of *J. bataua* fruits with examples of the nutritional content of purchased foods bought from the sale of 1 kg of *J. bataua* (table 1). Purchased foods in

Table 1. A comparison of the nutritional contents of 1 kg of Jessenia palm fruits with the nutritional content of other foods purchased for the same price; on 12 September 1992 the fruits sold for VEB 20 per kilogram (= USD 0.29)

	Calories	Carbohydrates (g)	Fats (g)	Proteins (g)
Jessenia bataua	470	40	30	10
Areya corn flour	2412	533	7	56
Rice	2066	454	2	41
Sardines, tinned	260	0	14	31
Corn oil	2528	0	286	0
Fish	606	0	16	107

Sources: Balick & Gershoff 1981, Instituto Nacional de Nutrición 1983 general provided a greater amount of calories, carbohydrates and proteins than the single kilogram of *J. bataua*. However, *J. bataua* is a better source of fats, with the exception of corn oil, the price of which is subsidized by the national government. Purchased foods can therefore compensate for nutritional values forgone from the sale of wild fruits; however, it is highly dependent on what is bought. Often items of low nutritional value such as soft drinks were bought. Alternatively, other household necessities such as soap or fish hooks were purchased. The nutritional status of a vendor's household will ultimately depend upon the vendor's choice as to how the money earned is spent.

Availability

The indigenous villages surrounding Puerto Ayacucho are among the largest in Amazonas State. With increasing population growth along the road, there has been an expansion of agriculture with the consequent loss of forest cover. As a result, the wild palms are farther and farther from the villages and the vendors must spend more and more time to collect the fruits. Some vendors reported that they walked as many as 8 hours to get their harvest. Harvesting sites beginning at a distance of 8 km from a village were observed directly during the field research; however, the reports were that 20 years previously harvesting was in the immediate vicinity of the village.

Indigenous peoples have responded in various ways to the decline in the availability of wild fruits. For example, sometimes village youths have gone on expeditions to collect wild seedlings for a village nursery, while on other occasions villagers collect seeds germinating in the forest to plant in homegardens. The Venezuelan Forest Service has also become involved and aided in reforestation projects using *J. bataua*, *O. bacaba* and *E. precatoria*.

Recommendations for expansion of NTFP use

Research and projects for the domestication of wild trees and the commercialization of their products should be based upon the products already sold in the market and build from them. For Amazonas State, the two species with great potential would be *J. bataua* and *E. precatoria*. The fruit of *J. bataua* provides a high-quality protein and oil (Balick & Gershoff 1981). Indigenous peoples have largely stopped processing the oil because it requires a lot of labour and subsidized vegetable oil is available. The oil can be used for cooking, but it is also believed to cure respiratory problems such as coughs and congestion. As a result, it is of high value, commanding VEB 1000 in 1995 (USD 3.70) for one litre. The production of palm oils such as that of *J. bataua* could contribute to the economic growth of Amazonas State and to Venezuela as a whole, because Venezuela imports close to 90% of the total vegetable oils consumed (anon. 1993).

Like *J. bataua*, *E. precatoria* can provide several products. In addition to the fruit, palm hearts are a possibility. The extraction and sale of this product have not yet been explored for Amazonas State and its peoples. The extraction would have to be sustainably managed, for example, through the incorporation of the palm into an agroforestry system. Furthermore, in Venezuelan cities such as Caracas and Valencia the leaves of *E. precatoria* are becoming a popular material for thatching the roofs of restaurants, etc., using the knowledge, labour and materials of the indigenous peoples of Amazonas State. Those involved have profited financially from this enterprise.

Puerto Ayacucho is the main market for wild NTFPs such as fruits. It could be expanded by developing other products, such as oils, palm hearts and thatch as described above. At the same time, it is important to support villagers to develop their own microenterprises for cultivating, selling and processing of wild products. Training in business management practices would help to ensure that gains in the commercialization of indigenous products and profits from them would remain with indigenous gatherers and vendors. The participation of local peoples is essential, but so is the involvement of local and national governments, to establish policies that promote the domestication of indigenous trees and the commercialization of their products. For example, the government should grant tree or land tenure and should assist in maintaining roads and providing transport, as well as invest in research. Public awareness campaigns and advertising could also promote the products.

If the market were expanded, production would consequently need to be increased, without overexploitation. Therefore, an opportunity to increase availability of these fruits would be to plant wild species in fields to enrich fallows and in homegardens. The palms readily germinate in homegardens when their seeds are discarded. Not only would this make trees more available for harvesting, but also a fallow containing a greater biomass than currently exists could decrease the length of time a particular field lies in fallow. If the rotation cycles of fields are decreased, then a possible result could be a decrease on the pressure to cut mature forests. Such a reduction in fallow periods to four years has been reported in Brazil, because of the inclusion of the babassu palm, *Orbignya phalerata* Mart. (Hecht et al. 1988), and might work with other species in Venezuela. Managed swidden fallows in Peru have been found to have more understorey growth than unmanaged fallows (Unruh 1988). This could possibly result in improved recovery of nutrients. Birds and bats were attracted to the fruit trees of the managed fallows and they deposited seeds while feeding, which could further enrich the fallow area (Unruh 1988). The planting of these species would also reduce harvesting pressure on the trees in the forest.

If one is to consider a steady income from the sale of products throughout the year, then seasonality of products must be assessed. The survey showed that wild palm fruits appeared mainly during the wet season. There is thus a production gap during the dry season. However, it is the dry season when cultivated products such as the peach palm (*Bactris gasipaes* H.B.K.) are available. By utilizing these seasonalities, a production system could be designed involving both wild and cultivated palms to maintain product availability and hence income throughout the year. Again an agroforestry system could be designed that incorporates the traditional, wild palms with the cultivated palm, to facilitate production and harvesting. Such a system would have added utility by reforesting previously cleared areas.

Overall, the promotion and planting of the above species should have a positive effect on the livelihoods of the indigenous peoples living near Puerto Ayacucho. They practise swidden agriculture, and they have a great opportunity to enrich their fallow fields with these species. Such an enrichment would bring the trees closer to the homestead, decreasing the labour and time invested in collecting the fruit from the wild. Moreover, as game and fish are becoming more scarce in the area, the good-quality protein provided by *J. bataua* could partially substitute for the decline in animal protein consumption, thereby contributing to household food security. As indigenous peoples become more involved in a cash economy, a system combining the traditional, wild fruits with cultivated fruits could allow them to maintain a steady income throughout the year.

Conclusions

The indigenous peoples in Amazonas State are able to sell wild fruits because of their right to harvest, their access to transport, and the demand for the fruit from urban inhabitants; however, the availability of wild fruit trees has been declining. This resource of wild fruits exists within the traditional territories of indigenous peoples, and this study documents how they and urban merchants already profit from the sale of fruit. It is the local market that directly benefits these people. The same benefit may not be true in international markets, where there are many intermediate transactions. Local markets, local preferences and product diversity should be considered in the design of the commercialization and even domestication of indigenous trees. As livelihood systems are diverse, utilizing both wild and agricultural products, so too should be production systems. Incorporating several species into production systems will guard against risks associated with market or environmental fluctuations. The advantages, therefore, of these products are that their sale can improve livelihoods, as they provide both food and income; their management can aid reforestation and forest conservation; and the cultural traditions of indigenous peoples would not be as greatly altered as they might be if they were to become engaged in wage labour, or if their land were converted to other uses.

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References

Anonymous. 1993. Aceites vegetales: nos ahogan las importaciones. *El Nacional*, Thursday, 13 May 1993, Caracas, Venezuela. p. D12.

Asibey E.O.A. 1974. Wildlife as a source of protein in Africa south of the Sahara. *Biological Conservation* 6(1):32–39.

Asibey E.O.A. 1977. Expected effects of land-use patterns on future supplies of bushmeat in Africa south of the Sahara. *Environmental Conservation* 4(1):43–49.

Balick M.J. and Gershoff S.N. 1981. Nutritional evaluation of the *Jessenia bataua* palm: source of high quality protein and oil from tropical America. *Economic Botany* 35(3):261–271.

García M.P. 1993. El servicio autónomo para el desarrollo ambiental del Amazonas (SADA-Amazonas): la política ambiental y desarrollo sustentable en el Estado Amazonas. *Ambiente* 15(47):19–22.

Hecht S.F., Anderson A.B. & May P. 1988. The subsidy from nature: shifting cultivation, successional palm forests and rural development. *Human Organization* 47(1):25–35.

Instituto Nacional de Nutrición. 1983. *Tabla de composición de alimentos para uso práctico.* Publicación no. 42, Serie Cuadernos Azules. Dirección Técnica División de Investigaciones en Alimentos, Ministerio de Sanidad y Asistencia Social, Instituto Nacional de Nutrición, Caracas, Venezuela. 71 p.

Melnyk M. 1994. Biodiversity's contribution to rural livelihoods: a component of environmental impact assessment. p 347–351. In: *Widening perspectives on* *biodiversity*, ed. A.F. Krattiger, J.A. McNeely, W.H. Lesser, K.R. Miller, Y. St. Hill & R. Senanayake. IUCN, International Academy of the Environment, Geneva.

Melnyk M. 1995. The contributions of forest foods to the livelihoods of the Huottuja (Piaroa) people of southern Venezuela. PhD thesis. Centre for Environmental Technology, Imperial College of Science, Technology and Medicine, University of London, London. 331 p.

Nepstad D., Brown I.F., Luz L., Alechandre A. and Viana V. 1992. Biotic impoverishment of Amazonian forests by rubber tappers, loggers, and cattle ranchers. *Non-timber products from tropical forests: evaluation of a conservation and development strategy*, ed. D. Nepstad and S. Schwartzman. *Advances in Economic Botany* 9:1–14.

OCEI. 1992a. *El censo 90–el terrritorio federal Amazonas*. Oficina Central de Estadística e Informática, Caracas, Venezuela. 152 p.

OCEI. 1992b. Tiempo de resultados. Año 2 no 2, Noviembre de 1992. Oficina Central de Estadística e Informática, Caracas, Venezuela. 4 p.

Padoch C. 1987. The economic importance and marketing of forest and fallow products in the Iquitos region. *Swidden-fallow agroforestry in the Peruvian Amazon*, ed. W.M. Denevan & C. Padoch. *Advances in Economic Botany* 5:74–89.

Padoch C. 1988. Aguaje (*Mauritia flexuosa* L.f.) in the economy of Iquitos, Peru. *Advances in Economic Botany* 6:214–224.

Padoch C., Inuma J.C., De Jong W. & Unruh J. 1987. Market-oriented agroforestry at Tamshiyacu. *Swidden-fallow agroforestry in the Peruvian Amazon*, ed. W.M. Denevan & C. Padoch *Advances in Economic Botany* 5:90–96.

Peters C. 1990. Population ecology and management of forest fruit trees in Peruvian Amazonia. p 86–98. In: *Alternatives to deforestation: steps toward sustainable use of the Amazon rain forest*, ed. A. Anderson. Columbia University Press, New York.

Scoones I. In press. Understanding non-timber tree product markets: the application of rapid rural appraisal techniques. Paper prepared for the IFPRI/ICRAF/CIFOR/NRI Non-Timber Tree Product Market Research Workshop, 12–14 December 1994, Annapolis, Maryland, USA.

Unruh J.D. 1988. Ecological aspects of site recovery under swidden-fallow management in the Peruvian Amazon. *Agroforestry Systems* 7(2):161–184.

Promoting the cultivation of indigenous plants for markets: experiences from KwaZulu-Natal, South Africa

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Abstract

A large and active trade in traditionally used indigenous plants exists within South Africa, particularly in KwaZulu-Natal. Rapidly increasing demand for these plants for medicinal and other purposes has resulted in overexploitation of wild populations, a reduction in supply and an increase in cost. The need for sustainable use of wild populations and for enhanced supply through cultivation is acknowledged.

Although the production of traditionally used plants has been suggested for over a decade, there has been little response. The lack of understanding with respect to the cultivation and economics of producing useful indigenous plants can be considered one of the most limiting factors in commercialization. Producers do not engage in commercialization as there is no indication of the potential costs and returns of producing plants for traditional markets. To promote greater understanding, the Institute of Natural Resources is currently testing the cultivation of indigenous plants in small-scale agricultural systems, and studying the economics of cultivating selected species in various agricultural systems. These projects, their approaches and preliminary findings, are discussed.

Medicinal plant trade

In KwaZulu-Natal, commercialization of indigenous plants is well developed in the informal sector, with a large and active trade. An extensive network exists, which harvests large volumes of plants from wild populations throughout the subregion and distributes them to the consumers, who may be both rural and urban. The trade network has an number of key components; it includes collectors, transporters, hawkers, wholesalers, retailers, mail-order companies, traditional healers and exporters. In the medicinal plant trade, several large urban street markets exist within the Durban metropolitan area and numerous stores or informal street sellers are found in almost every town and village in the region. Some 60–70% of urban Africans are believed to make use of traditional medicine. The size of the national market for medicinal plants is believed to considerable, with an estimated trade value of at least USD 128 million per annum in 1995. In addition, the trade is substantial in other plant products used for craftwork, housing, beverage, food and fuelwood. For example, in 1990 over 116 tonnes of dried *Juncus kraussii* (Hochst) was traded (Heinsohn 1991).

Unsustainable use

The demand for traditional medicines and other plant products continues to grow in South Africa. The growing human population, the slow employment growth rate, the influx of foreigners seeking work, and the limited resources of the government to service primary health care and other welfare requirements results in a rapidly increasing use of indigenous plant products. In addition, the strong cultural attachment by many communities to traditional practices, even within modernized urban settings, sustains the demand for traditional plant products. For example, the use of traditional medicine by South Africans is believed to have assisted them in winning the 1996 Africa's Cup of Nations [Africa's premier football event].

The increased demand for plant products results in greater harvesting intensity being placed on the remaining plant resources. In addition to unsustainable harvesting, development reduces the area of natural vegetation. This situation is illustrated by the localized extinction of popular medicinal and craftwork plants in KwaZulu-Natal. Numerous species are no longer found on private and communal lands. Harvesting pressure is so intense that one species, *Warburgia salutaris* (Bertol. f.) Chior., has become extinct in Hluhluwe Game Reserve. As a result of the above, demand exceeds supply and prices have increased. For example, small *Siphonochilus* tubers can fetch over USD 2.60, and large *Boweia* bulbs can cost over USD 5 per bulb. These prices fuel further exploitation, and more plant populations further afield are coming under harvesting pressure. In the Durban markets one now finds that *Warburgia* is being imported from Mozambique.

The need for a sustained supply

Indigenous plants are extensively utilized by both rural and urban populations, with a significant economic value to society in KwaZulu-Natal. Plant products provide society with a wide range of essential consumer goods, including fruit, housing material, fuelwood, craftwork and traditional medicines. In addition to consumer goods, the plants provide important trade goods, with numerous enterprises dependent on trading plant products.

The value of indigenous plant products and the need for sustained supply is illustrated by the use of medicinal plants. Traditional medicines are frequently used by low-income groups in urban and particularly in rural areas in primary health care. This is prevalent in the KwaZulu-Natal region, which has one of the highest incidences of poverty in South Africa. The medicinal plants are valuable for a number of factors. For example, the medicines are usually considerably cheaper than are the western medicines, and access to treatment is cheaper, as little travelling is required to visit a local traditional healer. The value of traditional healers is increasingly being recognized by health authorities, who see traditional medicine as an important element of primary health care. The cost to government of supplying sufficient western medicine to the entire low-income group is prohibitive and has high cost implications for the users, considering travel costs and time wasted.

In addition to the health value, the benefits to the economy are considerable. The USD 128 million per annum expenditure on medicinal plants in 1995 promoted additional economic activity and made an important contribution to job creation, with several hundred thousand people directly employed in the industry.

There is also a growing interest from large pharmaceutical companies, both local and European, for access to large volumes of plant material. For example in Namibia, several hundred tonnes of *Harpagophytum* are exported annually. Trade and adding value to plant products through local processing can present valuable economic opportunities in developing regions. These regions need a sustainable supply of useful indigenous plants, as these plants not only address essential needs in the short term but also have the potential to be important economic opportunities. In KwaZulu-Natal, the current and future welfare of the population is and will be dependent on the sustainable supply of useful indigenous plants.

Production advocated

The need to cultivate large numbers of popular indigenous plants was identified some 50 years ago by Gerstner (1946). Work done by Cunningham and Heinsohn in the 1980s and 1990s indicated the need for cultivating both medicinal and craftwork plants, citing the important role that these plants played in society (cited by Heinsohn 1991). A large volume of research has been and is currently being undertaken within South Africa, focusing on the mass production of useful indigenous plants.

A large body of information now exists regarding tissue culture for many of the popular medicinal plants, like *Boweia volubilis* (Harv.), *Eucomis autumnalis* (Mill.), and *Siphonochilus aethiopicus* (Shweinf.).

There have been frequent international calls for 'conservation through cultivation', but with little response from either the private or the public sector. In South Africa, one of the large timber companies took up the challenge to mass produce popular medicinal trees; however, it produces trees for distribution to interested groups and has not yet considered commercial production. More successfully, Durban City Parks Department has established a medicinal plant nursery to promote the cultivation of local plants. This nursery has been successful in pioneering cultivation techniques and makes plants available at nominal prices. There has been wide publicity associated with the nursery, but as yet commercial production has been minimal. Some success has, however, been achieved in developing the skills of traditional healers in plant production, and there is a growing interest in production at the homestead level.

The question arises why, with all this information and market signals, is there no real commercial cultivation of traditionally used plants?

Lack of understanding

In the private sector, there appears to be little understanding of indigenous plant cultivation in agricultural systems, particularly concerning the performance of plants and the economics of production and marketing processes. As a result, neither the state, private companies, nor individuals are able to recognize the value of commercializing the production of indigenous plants. As there is no clear indication of the costs and benefits of commercial cultivation, no serious consideration is given to production. Private companies and individuals do not understand the cost implication of production, and they do not understand what financial benefits they could gain from cultivation.

Small-scale farmers in communal areas, who are aware of the market in useful plants, have no tradition in cultivating indigenous plants and rely on the natural environment to produce them. There is also little awareness of the potential for cultivating indigenous plants and consequently cultivating them is not considered. Small-scale farmers are particularly averse to risk and so are unlikely to make an investment in a new venture unless benefits are guaranteed.

Large-scale farmers and agricultural companies have not understood the use of indigenous plants. The past racial divisions in South Africa have contributed to considerable ignorance as to the scale of trade in plant products, and there is suspicion with regard to traditional plant use. The large market and the potential market opportunities have largely gone unnoticed.

There has also been little understanding of the potential for domesticating indigenous plants for small- or large-scale farming systems. While there has been a lot of pioneering work, in the form of mass production, there has been little or no adoption by farmers.

An additional problem is that within the government, state departments do not understand the value of these plants to society and therefore do not consider production an option for addressing societal needs. Consequently, no effort is directed at promoting commercial cultivation, except by some nature conservation departments. As long as there is a lack of understanding in the social value of these useful indigenous plants, the better-funded government departments, like health and agriculture, will make little effort to promote their cultivation.

There is a need to know more about the cost implications of production and about supply and demand. For example, what price would the consumers pay for these plants and what is the volume of trade? There will be little investment in the commercialization of traditionally used plants until there are sufficient data on these important aspects.

Approaches being used to promote understanding

In an endeavour to develop greater understanding, the Institute of Natural Resources has initiated two projects focusing on cultivation in small-scale farming systems and the economics of cultivation. These projects are discussed here, giving an indication of the approaches being taken.

Testing the cultivation of indigenous plants in small-scale farming systems

The cultivation of indigenous plants could be a means of maintaining and increasing the supply of useful plants to the market. It is now opportune to undertake such a project within user communities throughout KwaZulu-Natal. Recent experience has shown that it is possible to cultivate numerous indigenous plant species in sophisticated agricultural systems; however, the feasibility of cultivating these plants in small-scale, low-input farming systems is unknown.

The project's approach has been to establish a number of trial sites in various rural locations by providing expertise, training, minor capital inputs (such as fencing and fertilizer) and plant material, while the user community or the individual farmer supplies the labour and local expertise. Various plant species and production systems have been tested and monitored. The trial sites are also used as demonstration farms. The duration of the project is 3 years, and thereafter the trial sites will be owned and managed by the interested group or individuals.

The approach adopted in the trials has been to integrate indigenous plants with conventional crop production since the slow returns from medicinal plants need to be supplemented by faster growing conventional food crops. In addition, the combination of indigenous plants and vegetable crops ensures that the plants are regularly watered and tended. In the medicinal plant cultivation trials, shade has been provided by adding the fast-growing pigeonpea (*Cajanus cajan*). Shade is essential for certain species of medicinal plants, and pigeonpea also promotes soil fertility and supplies valuable food.

Preliminary results

Initial observations in the two medicinal plant trials indicate that the addition of limited agricultural inputs such as lime, manure, mulching and minimal watering has made significant improvements to the production potential of the indigenous plants. Several bulb species, which normally die back, have continued to grow throughout the winter, have produced numerous bulbules, and have grown considerably within a year. Some tree species have also shown fast growth rates, but more data over several years will be required before any conclusions can be made. The key to success appears to be locating the plant in a site that is similar to its natural habitat. It has been observed, however, that farmers do not apply the same effort to growing medicinal plants as they do to their more traditional crops.

Progress has been exciting in the *Juncus kraussii* cultivation trial. During the last autumn over 5000 cuttings were planted. These plants grew well during the winter, with a large number of new culms being produced within a few months. In addition, numerous plants produced seed heads within 6 months after planting, and we expect that plant numbers will increase rapidly, from both germination and vegetative reproduction. In the *J. kraussii* trial, the only agricultural inputs were to plough the soil and to weed occasionally.

These trials have drawn considerable interest from the traditional healers and other community members in the associated areas. The growing difficulty of obtaining medicinal and craftwork plants appears to be making cultivation an increasingly acceptable option to traditional users. Large numbers of farmers, traditional healers and weavers are now indicating an interest in growing indigenous plants.

The economics of cultivating indigenous plants

Before any farmer will invest in a new crop, the following questions and many more need to be answered. Will the returns on plant sales outweigh the costs and give a profit? What agricultural inputs are required and how much will they cost? What will the selling price be in 3 years time? Will the cultivation of indigenous plants be the most economically efficient use of my land?

The aim of the project is to promote the sustainable use of indigenous plant species by evaluating the economics of production and informing people of the implications for commercial cultivation. The project focuses on 6 to 10 species, representing the popular plant forms that are traded in the market. The intention is to investigate the economics of cultivating the most popular and most highly valued species, as these would probably be the most commercially feasible options. If commercial cultivation is not feasible with these species, then it will probably not be feasible for the lower-valued species.

The approach involves three main components: (1) developing a greater understanding of the market, (2) determining or predicting indigenous plant performance in different production systems, and (3) establishing the production budgets for cultivation within various agricultural systems. The information gained from this work could then provide an understanding of what range of prices could be expected on the market, and what range of costs and yields could be associated with the different agricultural systems. The project will develop a model that will be able to assess a large number of combinations of variables such as price, market demand, yield characteristics, agricultural inputs and input costs. A flexible model is required because of the variability in plant performance, the diversity of agricultural systems, the fluctuations in price depending on location, season and substitute products, and the costs and availability of agricultural inputs.

The key project actions are as follows:

- undertake market surveys
- use existing information and expertise to predict potential yields in various production systems
- use existing information and expertise to estimate production budgets
- model the variables, including product prices, future product prices, yield characteristics and production budgets, to create a number of production scenarios
- evaluate the model and and use it to determine the economic feasibility of specific plants in various markets
- make recommendations as to what the various interest groups should be doing

Preliminary results

The acceptability of cultivating indigenous plants by traditional users and the concomitant willingness to supply accurate information to the market surveys have been positive except among some groups of traditional healers. Part of the market indicates that they will use cultivated plants, and the question arises what will the more reluctant groups use once wild stocks have been eliminated or are no longer available. It is likely that they may follow the trends already exhibited by numerous traditional healers and make use of cultivated plants. Consumers have also indicated an interest in using traditional medicines from commercial companies, and mail order companies have been successful in marketing traditional medicines.

Interest in the project and its products has been growing and a network is developing. Such a network will play an important role in distributing the research findings. In addition, the participatory nature of the study is also drawing people into it, increasing the numbers of those involved in the project. In the year ahead, the project will be investigating the market, potential yields and production budgets. By the end of the year, it is hoped that modelling on various production and market scenarios will begin.

Conclusions

An analysis of the situation in KwaZulu-Natal indicates that the trade in indigenous plants plays an important role in society's welfare and that this role is being threatened by unsustainable harvesting. The potential welfare losses have been recognized in the past, and cultivation is suggested as a solution. However, little or no commercial cultivation has taken place, mainly because of the lack of understanding with respect to marketing and cultivation economics. Farmers and other potential growers have not considered cultivating indigenous plants for traditional markets because of their limited understanding of the market and of the production of indigenous plants.

A synthesis of botanical, social and economic information, like that now in progress, will provide opportunities to identify the most economically efficient cultivation strategies. Such strategies could then be assessed by various producers in terms of their own limitations and opportunities.

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References

Gerstner J. 1946. Some factors affecting the perpetuation of our indigenous silva. *Journal of the South African Forestry Association* 13:4–11.

Heinsohn R.D. 1991. *The potential for cultivation of* Juncus kraussii *and other wetland species used for craftwork in Natal/KwaZulu*. Institute of Natural Resources, Pietermaritzburg, South Africa. 175 p.

Shea nut *(Vitellaria paradoxa)* production and collection in agroforestry parklands of Burkina Faso

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Abstract

Better knowledge of nut productivity of shea *(Vitellaria paradoxa)* stands is critical for the improvement of management of West African shea parklands. Nut production of 54 randomly selected shea trees, ranging from 10 to 44 cm in diameter at breast height, located on a Paleustalf soil mapping unit in bush fields was monitored from 1993 to 1995 in southern Burkina Faso. Nut production, highly variable between years, averaged 757 nuts per tree, or 2.4 kg of dry kernels per tree and 48 to 65 kg ha^{-1}. Also, there was a fivefold difference in the number of nuts produced between an average tree and the best producer. Half of the tree population contributed 15% of the total yield, while production of the upper 26% of trees was consistently high and represented 59% of production. Potential productivity of trees was influenced by genetic variability and by external factors still to be identified. Tree size had a positive effect on the number of nuts produced and on fruit weight. However, estimated crown volume and degree of *Tapinanthus* parasitism did not. This study demonstrates the potential value of genetic selection for increasing parkland nut production. Estimated maximum value of shea butter production per family per year was USD 35. Processing and marketing activities related to shea products are mostly women's responsibility. Questionnaire data show that nuts are primarily collected for home butter consumption. The fact that amounts collected are lower than amounts produced indicates that current prices do not encourage farmers to fully utilize this resource. Several areas needing further research for shea improvement and development are identified. This resource may become commercially more valuable with the development of more extensive applications of shea butter in the cosmetic and pharmaceutical industry.

Introduction

Farmers extract a variety of non-timber products from forests to consume or to generate income. These products include foods, fodder, medicines, spices, resins, dyes, construction materials, fuelwood and utensils. Non-timber forest products are important for food security, health, and social and economic welfare of rural communities (FAO 1989). They provide a significant nutritional contribution, especially crucial during times of drought and famine, and create more varied, palatable and balanced diets. Rural people also depend on forests for income and employment. Farmed parklands fulfil similar functions (Gakou et al. 1994, Guinko and Pasgo 1992, Poulsen 1982). Farmed parklands are landscapes with scattered trees in cultivated or recently fallowed fields. The parklands are regenerated during fallowing. The parklands will decline if fallowing continues to become less common.

The shea tree, or karité in French, is in the Sapotaceae family under the accepted name *Vitellaria paradoxa* C.F. Gaertn., formerly called *Butyrospermum paradoxum*

Gaertn. f. (Henry et al. 1983). It is a tree widely encountered in dry savannas, forests and parklands of the Sudan zone, but it does not extend into coastal areas. It occurs on an estimated 1 million km^2 between western Senegal and northwestern Uganda, where annual rainfall ranges from 500 to 1200 mm (Sallé et al. 1991). The species is found on various soil types but avoids alluvial hollows or land subject to flooding.

A decline in parkland tree densities over the last few decades has been documented in several agricultural areas of the Sahel (Gijsbers et al. 1994, Lericollais 1989). The combination of drought, population pressure (and the resulting shortened fallows), and technical change have increased tree mortality and removal and decreased tree regeneration. Shea populations are also threatened by the African mistletoe, a plant parasite of the genus *Tapinanthus*. This parasite, which causes discontinued growth, withering of tree parts and eventual tree death, affects a large portion of the regional shea population, including 95% of the trees in Burkina Faso (Boussim et al. 1993). Consequently, there is a risk of this resource declining even further in coming years.

The seed of *Vitellaria paradoxa*, with a fat content of about 50%, is used locally by many as a culinary fat or oil, for soap manufacture, as an ointment, cosmetic and illuminant, as well as for waterproofing house walls. The sweet pulp of its pericarp also represents a valuable source of energy during the early part of the rainy season. The wood is used for tool making, and its roots and bark have medicinal applications. Traditionally, shea butter was the only source of fat for purely agricultural ethnic groups such as the Mossi (the largest ethnic group in Burkina Faso). Currently, shea butter is probably the primary cooking fat for a large part of rural populations where the species occurs (see Lamien et al., this volume). Additionally, seeds are exported (mostly to European and Japanese food industries). Its fat is used in pastry for its high dough pliability and in confectionery as a cocoa butter substitute. Because of these characteristics, shea butter is used as a base for cosmetic and pharmaceutical preparations for the treatment of dry hair and skin, burns, and multiple skin ailments.

Because shea tree populations are wild, nut production fluctuates from year to year. Given the estimated number of shea trees of fruiting age (500 million) over its area of distribution, it is believed that potential nut production of the region far exceeds the amount utilized and entering trade. In 1980, the world trade shared by six West African countries was 150 000 tonnes. In Burkina Faso alone, shea nut exports peaked in 1985 at 60 000 tonnes (INSD undated) and represented its third largest export product in 1985 (World Bank 1989).

In spite of its local and national economic importance, there are few data available on shea fruit production, other than the primarily descriptive research undertaken by the Institut de Recherches sur les Huiles et les Oléagineux from 1945 to 1958 (Delolme 1947, Ruyssen 1957, Desmarest 1958). Several reviews on the shea tree have also been undertaken (Picasso 1984, Bonkoungou 1987, Sallé et al. 1991, Louppe 1994); a seminar on local Sahelian forest species and a seminar on the shea tree species were organized in Ouagadougou in 1987 and 1988, respectively (MESRS 1987, IRBET/Université de Ouagadougou 1988). Better knowledge of shea tree stand productivity is essential for improved management. Current fruit production and development potential at the national and regional scales need to be estimated based on stand productivity. Data are needed for cost–benefit evaluations of trees in agroforestry parkland systems. In addition, farmers play a central role in parkland tree management and are the primary participants in this important economic sector. Knowledge is thus needed on the economic value of the resource and the social organization of shea nut collection and appropriation.

The objectives that guided this study were to assess—

- the productivity of parkland shea trees, their variability over a 3-year period, and the relation between productivity and tree size, as well as fruit, nut, and kernel weight

- the economic value of nut production at the farm level
- the local collection and appropriation practices of this resource

Work to achieve these objectives was undertaken within a broader study assessing the biological and economic impact of trees on farm production and the farmer management of agroforestry shea parklands in southern Burkina Faso (Boffa 1995). This paper also reviews knowledge gaps regarding the shea tree's biology, physiology, and silviculture as well as the sociological, technological, and economic research needs for the species' improvement and development. These were primarily gathered from existing reviews (Picasso 1984, Bonkoungou 1987, Sallé et al. 1991, Louppe 1994).

Materials and methods

The study was carried out on farms in the *terroir* of Thiougou, a village of the Zoundwéogo Province, in southern Burkina Faso. Fifty-four trees were selected at random from 730 individual trees identified in seven bush fields located on a single soil mapping unit. One tree was cut down before the 1995 harvest. The soil unit was made up of leached tropical ferruginous soils (Paleustalfs according to the USDA classification system, Soil Survey Staff 1994), and was identified during a soil and landscape survey of the village. It was selected for this study because of its local dominance and representativeness of cultivated lands in Thiougou village. These deep soils are located on flat terrain, have a sandy-loam surface texture, and their profile is not interrupted by a plinthite pan.

Each tree in the sample was marked with a permanent metallic plate bearing an identification number and was mapped for later reference. The distribution of diameter at breast height (dbh), tree height (measured with a telescopic meter), and crown diameter of sampled trees was recorded. The average diameter of the 54 trees was 25.5 cm (SD = 8.0), average height 6.5 m (SD = 1.3), average crown diameter 5.5 m (SD = 1.6). Other measurements included east–west and north–south projections of crown diameters, proportion of crown height versus total tree height, and number of parasitic branches of *Tapinanthus* spp.

All nuts produced by sample trees were harvested manually. In 1993, because of to that year's low production, nuts were harvested between mid-June and mid-July, after complete nut formation but before the maturation of all the nuts. Nuts from each tree were counted and kept in individual bags. After removing the sweet outer pulp, ripe nuts were dried in the sun, shelled, boiled for a few minutes and dried again. They were then weighed individually. In contrast, nuts were harvested from mid-July to early August in 1994 and 1995, after complete nut maturation. Nuts of individual trees were counted and the nut harvest per tree was weighed with and without the outer pulp. Average nut production per tree was projected at the field level on the basis of average tree densities, tree productivity and field size obtained in the sample of fields in Thiougou (Boffa 1995).

The Yoruba dish is the local standard volume measure. To determine size and weight parameters of mature nuts, about 10 000 shea nuts contained in 11 yorubas originating from several merchants were counted and weighed at the local market. The yoruba capacity ranged from 646 to 1113 nuts and averaged 889 nuts. A yoruba dish of nuts weighed about 2.8 kg. The average nut weight measured at the market was 3.2 g. The yield of butter in dry kernels used in this study was 20%. The market price of a yoruba of nuts varied from 75 CFA francs in July (harvest time) to 150 CFA francs during the dry season in 1993 in Thiougou. An average of 110 CFA francs was used in this study (500 CFA francs are approximately equivalent to USD 1). The price of shea butter was established from a market sample of 10 balls. Balls with an average weight of 73 g were sold for 25 CFA francs each. Thus, processing nuts into shea butter increases the economic value of nuts 1.5 times.

In structured interviews concerning parkland management issues, 65 farmers (51 male and 14 female household heads) reported the volume of nuts they collected on the farm in 1992 and 1993. Fields managed by male household heads averaged 3.6 ha in size and contained 20 shea trees ha^{-1}. The size of fields managed by women was 1.1 ha on average and their shea density was 27 trees ha^{-1} (Boffa 1995).

Results and discussion

Nut production

Nut production over the 3-year average was 757 nuts $tree^{-1}$ (0.86 yoruba $tree^{-1}$ or 2.4 kg $tree^{-1}$), ranging from 0 to 3806 nuts $tree^{-1}$. Low-yielding trees prevailed in the Thiougou sample population (fig. 1). Average nut production in the sample was almost 5 times in 1994 and 1995 what it had been in 1993 (1004, 1047 and 219 nuts respectively). Fifty per cent of the sample tree population contributed 85% of the 3-year nut production.

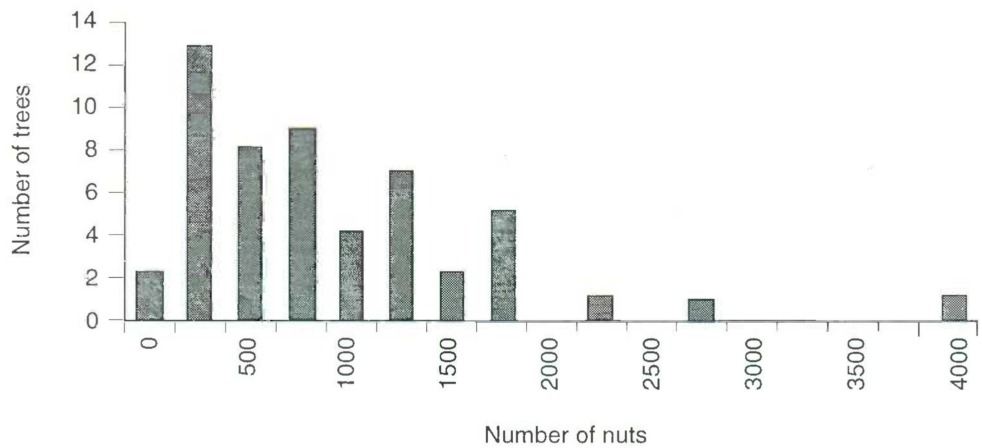

Figure 1. Average nut production of 53 shea trees from 1993 to 1995.

The interannual variation of nut yields shows that, based on cumulative production, 30% (16/53) of trees were virtually worthless, while 26.4% (14/53) were high and consistent producers (table 2). This latter group of high-yielding trees contributed 59% of the total production during the study period. Only a few trees (7/53) whose production was high over the period had alternating high and low yields. These results are similar to those

Table 2. Interannual variation of shea nut yields from Vitellaria paradoxa *trees in Burkina Faso during 1993–1995*

3-year production (no. of nuts)	Years in which nut production is higher than yearly average (no. trees)				
	0/3 years	1/3 years	2/3 years	3/3 years	Total
0–999	16	–	–	–	16
1000–2289*	6	10	–	–	16
2290–4999	–	7	7	3	17
5000 or more	–	–	2	2	4
Total	22	17	9	5	53

* 2289 nuts is the mean 3-year production in the sample.

of Desmarest (1958), who monitored shea nut yields over 4 years in Niangoloko, south-western Burkina Faso. Biennial bearing, which characterizes temperate fruit tree crops, may not therefore be the major factor responsible for the annual variability in fruit production in shea parklands. Rather, the variable potential productivity of individual trees may be under the influence of external factors, which need to be identified.

Parkland trees are not planted but simply saved during the clearing of natural forest or fallows. Farmers carry out shea tree selection at clearing time as well as in later years. Indeed 27% of surveyed farmers distinguish unproductive shea trees, using tree condition (trunk with burn patches or base openings, diffuse or partially dead foliage), nut, leaf and bark characteristics, as well as the amount of nuts found under trees. For example, narrow leaves may be a distinguishing sign of a *tam daaga*, which produces small and nutless fruits. Also, the nuts of individual shea trees called *zoonpela* fall before maturity.

The other 63% of the farmers claimed that they evaluate production potential of trees over a period of 2 to 6 years. While farmer selection activities have been documented, reports of planting seeds of superior value are uncommon (Louppe 1994). The need for shea population improvement was reported several decades ago (Chevalier 1943) but is yet to be undertaken. The fivefold difference between the average and the best nut-producing tree in Thiougou clearly demonstrates the potential of improving nut productivity.

Yield determinants

The number of nuts and the total fruit and nut yield per tree were substantially lower in Thiougou than in previous studies located in zones of higher rainfall and different soils, conducted in the 1950s (Delolme 1947, Ruyssen 1957, Desmarest 1958) (table 3). Furthermore, with the exception of Desmarest's study, for which the sample was large, sampling methods were not specified. Therefore, these earlier studies may have overestimated nut production per tree.

Table 3. Nut production per tree of Vitellaria paradoxa *in Burkina Faso, as recorded in literature*

					Per tree				
Authors	Location	No of trees	Year	Tree diameter (cm)	Nuts (no.)	Fresh fruits (kg)	Fresh nuts (kg)	Dry nuts (kg)	Kernels (kg)
Delolme (1947)	Ferkessedougou	49	1944–45	125 to 250	3268	*57.8*	28.9	*19.7*	13.8
Ruyssen (1957)	Saria	9	1935–44	–	3149	–	–	–	–
	Ferkessedougou	13	1944-48	–	3753	*72.6*	36.3[a]	22.4[a]	*15.7*
	Katibougou	20	1911–15	65 – 300 at 1 m	–	*17.6*	*8.8*	5.3	*3.7*
	Ina	25	1949–50		2498	57.3	*28.6*	*17.2*	12.2
Desmarest (1958)	Niangoloko	217	1954–57	67% ≥ 160 at 1 m	–	*20.6*	10.3	*6.2*	*4.3*
Boffa et al. (1995)	Thiougou	54	1993–95	10 – 44 at 1.3 m	757	18.8[b]	7.0[b]	*4.2*	2.4

Italicized numbers were calculated from weight ratios (fresh nut = 0.5 fresh fruit; dry nut = 0.6 fresh nut; dry kernel = 0.7 dry nut) provided by Ruyssen (1957). There may be slight discrepancies when more than one nut production variable was measured in the study.

[a] Calculated from average weight of nut

[b] Measured in 1994 and 1995, two years of relatively high production.

Data of the present study suggest that tree size partially determines the average number of nuts produced annually per tree. A positive and significant relationship was found between tree dbh and number of nuts produced ($P = 0.03$) in the present study and in the 5-year Katibougou data presented by Ruyssen (1957). Although large trees tend to be the main producers, trees that did not produce were found throughout the sample diameter range. The smallest diameter associated with above-average yield was 13.1 cm. Ruyssen (1957) estimated that shea trees start flowering around age 15 and nut production becomes significant after 20–30 years. If one assumes a yearly tree diameter increment of 4 mm (Picasso 1984), all trees in this sample should have entered their productive phase. According to Delolme (1947) and Ruyssen (1957), nut yields of shea trees rise rapidly around age 40 to 50, increase more slowly until age 100, are constant until age 200, and decline only after 200 or 300 years.

Desmarest (1958) identified the four most common crown shapes in *V. paradoxa* (spherical, columnar, umbrella and broom) and showed that broom-shaped trees were associated with low nut yields. In our study, estimated crown volume was not correlated with nut yields, perhaps because of the approximation method used, which did not account for crown shape. Desmarest (1958) also indicated that high foliage density was associated with high yields, while rainfall during the year preceding flowering did not seem to have any effect. Early flower initiation and higher minimum temperatures during flowering also contributed to higher nut production and may represent a potential factor for predicting yields of the following season. Bush fires during flowering and harmattan can have a negative influence on production.

Parasitism by *Tapinanthus* spp. occurred in 75% of the shea trees in Thiougou, with an average number of eight parasitized branches (maximum = 30). However, it did not significantly affect the number of nuts produced as the incidence of the parasite did not cause defoliation, desiccation and death, as described by Boussim et al. (1993). Because all trees in the sample were located on a similar soil mapping unit, soil type probably does not account for tree-to-tree productivity differences in Thiougou. While fertile soils may contribute to an increased average nut production, soil type is unlikely to sharply modify the proportion of low-producing individuals (Desmarest 1958). A great deal still needs to be learned about environmental determinants of shea yield. Such knowledge would allow better prediction of yield over the species' range and suggest management options.

Fruit characteristics

Tree dbh and average fresh nut weight were not correlated. In contrast, tree diameter was positively correlated with average fresh fruit weight ($P = 0.04$), while the ratio of nut to fruit weight decreased very slightly with increasing tree diameter ($P = 0.03$). However, the regression coefficients for both functions were low ($R^2 \leq 0.10$). This suggests that the proportion of pulp may increase with tree diameter. The statistical difference among trees with respect to these fruit characteristics could not be tested. Fruit and nut weights and pulp-to-nut ratio were not related to the number of nuts produced per tree. Also, the level of parasitism did not influence fruit weight within the observed range.

Tree dbh (range 10 to 44 cm) did not explain variability of kernel weight. A one-way analysis of variance revealed that the difference in average dry kernel weight among trees measured in 1993 was highly significant ($P < 0.01$). This was confirmed by farmers who reported that nut size and shape of particular trees were distinctive.

As with the fruits and nuts yields per tree, the mean sizes measured in our study tend to be lower than those of Ruyssen's (1957) (table 4). The lower kernel weight found in our study and confirmed in the market survey could be caused by a lower moisture content than the 7% reported by Ruyssen, or by climate and soil differences. Also, Ruyssen's larger nut weights may be due to the larger trees in his study, despite the lack of relationship between tree diameter and kernel weight found in this study, where the range of tree diameters was limited.

Assuming that the difference in nut size was insignificant from one year to the next, the average percentage of dry kernel (1993) to fresh nut (1994) was 47%. A similar proportion of 42% was reported by Ruyssen. Fresh nut weight was 37% of fresh fruit.

Research needs for the improvement of shea nut production

Table 4. Weights of fruit, nuts, and kernels of Vitellaria paradoxa *trees in Burkina Faso*

Authors	Fruit (g)		Fresh nut (g)		Dry nut (g)		Kernel (g)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Ruyssen	21	10–45	9.7	5.8–15.1	6.0	4–8	5.0	2.6–6.6
Boffa et al.	20	9–44	7.5	2.6–19.0	–	–	2.8	1.5–4.5

Many aspects of the biology, physiology and silviculture of the species are still poorly understood. First, to better evaluate the development potential of this resource, the current geographical range, condition and density of shea parkland populations in producing countries have to be assessed through more precise cartographic and field sampling exercises.

Furthermore, the three varieties (*mangifolium*, *poissoni* and *niloticum*) of the species described by Chevalier (1943) on a few phenotypic criteria should also be inventoried and the genetic basis of these phenotypic variations established. Superior individuals based on nut (number, size and butter quality) or pulp (weight and sugar content) characteristics (such as those identified in this study) should be identified with farmers and vegetatively propagated as cultivars and used for development purposes. The heritability of production characters of superior trees raised through seeds also deserves study. Individuals with early, lengthy or biannual flowering may be of special value for improved production or extended harvesting. At the farm level, the density of low-performance individuals could be reduced over time, while fallows could be seeded with high-performance material. Alternatively, other means of regenerating parklands should be sought. Additional research on the influence of climatic and edaphic factors on productivity is needed for enhanced capacity of yield prediction.

As indicated above, vegetative propagation could be used to improve the potential of shea through accelerated multiplication and greater consistency of production. Studies on rooting ability of shea cuttings have not produced successful results (Picasso 1984), although there is some hope for the feasibility of this technique (Bonkoungou 1987). Grafting methods have been developed and showed 25% success, provided that the grafts are not water stressed and that latex does not block the graft stock union (Grolleau 1989). Layering has also been successful, yet it is difficult (Picasso 1984). These techniques need to be improved through further research, to permit the multiplication of superior trees. Tissue culture should also be attempted.

Fresh seeds germinate easily yet they seem to lose this ability in a short time (Sallé et al. 1991). There are established procedures for multiplication through seeds and transplants. However, the contribution of improved seedling management and the use of mineral and organic fertilizers for faster growth and fruiting needs further research. Shea corymbs carry several tens of flowers, out of which only 2 to 4 are fertile (Chevalier 1948). A study of pollination and reproductive biology is also needed.

The shea tree has few fungal but many insect pests. The very high level of parasitism of shea by four species of *Tapinanthus* is a major concern for species sustainability. Suggested control methods include the control of bird populations responsible for *Tapinanthus* seed pollination and dissemination, increased seed predation by bird species, chemical control of the parasite, development of parasite-resistant varieties, and the removal of the parasite or affected plant parts from infected trees (Boussim et al. 1993). Efficiency of these methods should thus be tested and improved and techniques eventually transferred to farmers.

Nut collection

Nut harvest over two years amounted to less than half of nut production, suggesting that farmers do not fully utilize this resource (table 5). The variability of annual production is a disincentive to collection, as indicated by the fact that there was no collection in 5 and 27 fields in 1992 and 1993, respectively. The higher collection volume observed in family fields than in women's fields was due to the larger field size. The size of the active labour force had a positive influence on volume of nuts collected ($P < 0.1$).

On average, the economic value of shea nuts collected on all fields of an average family in Thiougou was USD 6.64 or USD 11.5 per year as unprocessed nuts or shea butter respectively (table 5). However, in any one year, shea nut production may be worth up to three times these amounts.

Table 5. Number and economic value of V. paradoxa *nuts collected and produced in Thiougou, Burkina Faso*

Field type[a]	Item	Shea nut collection				Shea nut production				
		1992	1993	Average		1993	1994	1995	Average	
		(kg)	(kg)	(kg)	USD	(kg)	(kg)	(kg)	(kg)	USD
Family field	Nuts	79	25	52	4.2	50	228	237	172	14.0
	Butter	16	5	10	7.4	10	46	47	34	24.3
Women's field	Nuts	50	8	29	2.4	21	95	99	72	5.8
	Butter	10	2	6	4.1	4	19	20	14	10.0
Total	Nuts	129	33	81	6.6	71	323	336	244	19.8
	Butter	26	7	16	11.5	14	65	67	48	34.3

[a] Sample size of family and women's fields was 50 and 11, and 54 and 14 for nut collection and nut production data, respectively.

The ratio of home consumption to marketing of shea nuts was 0.6 and 0.9 in 1992 and 1993, relatively good and poor production years, respectively. Additionally, the percentage of farmers who marketed none of their nut harvest was twice as high in 1993 as in 1992. Therefore, home consumption is the primary motive for nut collection. Home consumption was positively correlated to family size ($R^2 = 0.2$). In our study, the maximum economic value of shea nuts was equivalent to 7% of white sorghum production in bush fields, in which production, mostly of white sorghum grown for home consumption, is known to account for around 80% of total farm production in Thiougou. Also, the value of marketed products in relation to total farm production is typically low in sub-Saharan subsistence farms. Therefore shea nuts may represent a significant percentage of actual farm income. Ruyssen (1957) indicated that shea nuts represented 20% of total family market income.

Land and tree tenure

Rights to gather tree products in West Africa vary according to land tenure arrangements. In Burkina Faso, land is generally acquired through first occupancy, inheritance or as a gift (Boutillier 1964, Boffa 1991). A fourth kind of land occupancy is associated with positions of clan elders or village chiefs (McMillan 1986). Land can also be borrowed. In Thiougou, a recently settled village, farmers obtained already cultivated land from relatives (40%), uncultivated areas from the village chief (15%), or through spontaneous clearing (45%). Total tree densities were significantly higher in fields acquired through kinship (30 trees ha^{-1}), than in fields of spontaneous cultivators (23 trees ha^{-1}), reflecting different land-use strategies. Probably because of the relatively low human population density, no short-term land loans were recorded in the village.

Rules of access to tree products vary according to ethnic groups, the degree of land pressure, and the economic value of tree products (reviewed in Boffa 1991, McLain 1990). In Mossi country and in Mali, shea nuts usually belong to cultivators on lineage land (McLain 1990, Saul 1988, Ruyssen 1957), while they are claimed by village communities in Bobo and Gourmanche regions (Swanson 1979, Ruyssen 1957). Ownership claims to tree products by political or religious village chiefs more often apply to *Parkia biglobosa* pods than to shea nuts (Boutillier 1964, Ouédraogo 1990). On borrowed land, gathering shea nuts is often the exclusive right of the permanent landholder (Boutillier 1964, Hammond 1966, Saul 1988). However, there are variations according to ethnic groups and social bonds between groups involved.

In Thiougou, nuts generally belong to the family that cultivates the field. But any passerby may consume the fruit's pulp and leave the remaining nuts at the foot of the tree. Also, many farmers let other villagers collect nuts from trees in their fields. None of the farmers who obtained their land from relatives or from the village chief reported any restriction concerning the use of shea trees on their fields. A single farmer reported that pods of the *Parkia biglobosa* trees in his field belonged to his uncle, who had granted permission to cultivate this piece of land, while he himself had control over the shea nuts. The absence of a more structured tenure system may result from the dominance of the current political chief over the traditional religious chief in Thiougou. The latter would normally attend to land tenure issues and religious rites related to land. This lack of structure may also be due to the lower human population density and relatively more recent settlement in Thiougou than in other locations of the Central Plateau.

In this study, nut collection took place in farmers' fields in the large majority of cases (85%), with the remainder in fallows and natural forest areas. As in the villages surveyed by Gakou et al. (1994), nuts were almost exclusively collected by women. Income from the marketing of nuts was the exclusive right of women in 66% of the sample, that of the family head in 7% and was shared between them in 27% of the cases. In the Sahel, tenure regimes are undergoing a process of allocation to individuals. This process usually favours the property rights of male heads of households and may be detrimental to women's control of tree product resources (Freudenberger 1993). The rights to shea nut income by the majority of women in Thiougou may be due to the generally high level of resources enjoyed by farmers in this village, compared with drier and more densely populated areas of the Central Plateau.

More knowledge is needed on the distribution of tree rights among household members and village community groups. Interventions such as the introduction of new processing technologies or new market opportunities may lead to an increased economic value of this species and may cause tree rights to evolve. Research should be conducted to anticipate the positive and mitigate the negative consequences of such changes on the various rural groups, particularly traditional users, such as women and low-resource farmers.

Processing and marketing

Nuts are collected during the 1–2 months of fruit production. The preparation of nuts for marketing or butter processing includes pulp removal after fermentation or boiling, oven- or sun-drying, and shelling. Butter production requires nuts to be crushed, toasted and finely ground. The brown mixture obtained is then churned and strained until a white butter paste is produced. This lengthy and tiresome operation is primarily handled by women. Mechanization in West Africa mainly involves the crushing and grinding of nuts in mills, but there have also been attempts to use solar dryers, grinders, presses and centrifuges for shea nut processing.

The study of Louppe (1994) in Côte d'Ivoire shows that women's salary per hour for producing butter at home was 15 to 20 CFA francs. Salary from semi-mechanized butter production was also low except in years of low nut availability when nuts and butter sell for high prices. Butter was not only sold locally for home consumption but was also traded regionally for cosmetic use from Mali, Burkina Faso and northern Côte d'Ivoire to larger southern coastal cities. Shea prices are subject to supply and demand and are not regulated by the state. Because of their low purchasing price, the quality of nuts sold to local or European industries was poor, compared with nuts processed for local consumption and sale. The price disincentive to farmers reported in Louppe's study corroborates the observation in Thiougou that farmers do not take full advantage of nut production.

Butter composition and quality

Whereas the composition of shea and cocoa butter are fairly similar, the unsaponifiable matter content is much higher in shea butter (8% on average). Currently, shea is mostly treated as a substitute for cocoa and priced like other vegetable oils. Future development of shea nut oil depends on uses for its unsaponifiable matter, which displays several interesting physical and biomedical properties that could have pharmacological and cosmetic applications. These include prevention of skin drying, the soothing of sore skin, protection and lubrication, fast release and long retention of active ingredients, and high UV absorption (Louppe 1994). Further research is therefore needed on the properties and applications of the unsaponifiable matter. Recognition of shea butter's unique properties and applications could result in a price increase for the product. Higher profits would then encourage the improvement of oil quality and capital investment in its production.

Shea butter quality is high when its free fatty acid content is low. Free fatty acid content is naturally low in fresh nuts, but it increases rapidly through hydrolysis under poor storage conditions. Hydrolysis occurs through the lipolytic activity of the fruit lipase and microorganisms; it is halted by heating and by reducing the moisture content to lower than 8%. Louppe (1994) therefore recommended that nuts be boiled for an hour shortly after collection and then dried in the sun. Solar dryers would reduce the need to handle nuts daily. Techniques are also needed to eliminate possibilities of fungal infection when the nuts are stored in their shells.

Conclusions

Several features make the shea tree a valuable resource for semi-arid West Africa. It occurs on a large land surface area, regenerates well, is traditionally protected during clearing and is favoured by farmers. Ecologically, it combines well with cereal crops (Boffa 1995). It is an important economic commodity, both locally, where it is used as a cooking fat, ointment, cosmetic, and for soap manufacture, and internationally, where it is exported to food, cosmetic and pharmaceutical industries. However, shea is mostly a subsistence product resulting from gathering activities. Tree populations are wild and annual nut yields are variable. Also, shea tree populations have been subject to increased pressure from agriculture, drought and parasitism in recent years and may decline further in coming years. Relatively little research has been undertaken on this species since the 1940s and 1950s.

A demand-driven approach is needed to revitalize the shea nut market. Research is needed on aspects of tree and land tenure, regeneration of parklands and domestication of the species to take advantage of the considerable genetic variability in the productivity of individual trees. This process needs to be linked to developments in nut processing and expansion of the export market to supply the food, cosmetic and pharmaceutical industries.

References

Boffa J-M. 1991. Land and tree management and tenure policies in Burkina Faso's agroforestry system. M.S. thesis, Purdue University, West Lafayette, Indiana. 167 p.

Boffa J-M. 1995. Productivity and management of agroforestry parklands in the Sudan zone of Burkina Faso, West Africa. Ph.D. thesis, Purdue University, West Lafayette, Indiana. 101 p.

Bonkoungou, E.G. 1987. *Monographie du karité* Butyrospermum paradoxum *(Gaertn. f.) Hepper, espèce agroforestière à usages multiples*. Institut de Recherche en Biologie et Ecologie Tropicale, Ouagadougou, Burkina Faso. 67 p.

Boussim I.J., Sallé G. & Guinko S. 1993. *Tapinanthus* parasite du karité au Burkina Faso. 1ère partie: Identifcation et distribution; 2éme partie: Phénologie, biologie et dégâts. *Bois et Forêts des Tropiques* 238:45–65.

Boutillier J.L. 1964. Les structures foncières en Haute-Volta. *Etudes Voltaïques* 5:5–181. Centre IFAN-ORSTOM, Ouagadougou.

Chevalier A. 1943. Les Sapotacées à graines oléagineuses et leur avenir en culture. *Revue de Botanique Appliquée* 23(257, 258, 259):97–159.

Chevalier A. 1948. Nouvelles recherches sur l'arbre à beurre du Soudan, *Butyrospermum paradoxum*. *Revue de Botanique Appliquée* 28(303, 304):241–256.

Delolme A. 1947. Etude du karité à la station agricole de Ferkéssédougou. *Oléagineux* 4:186–200.

Desmarest J. 1958. Observations sur la population de karités de Niangoloko 1953 à 1957. *Oléagineux* 5:449–455.

FAO. 1989. *Forestry and food security*. FAO Forestry Paper 90. FAO, Rome. 128 p.

Freudenberger M. 1993. Tenure and farmed parklands: agroforestry systems in the Sahel: constraints and opportunities. Paper presented at the International Symposium of Agroforestry Parklands in the Semi-Arid Lands of West Africa, Ouagadougou, Burkina Faso, 25–27 October.

Gakou M., Force J.E. & McLaughlin W.J. 1994. Non-timber forest products in rural Mali: a study of villager use. *Agroforestry Systems* 28:213–226.

Gijsbers H.J.M., Kessler J.J. & Knevel M.K. 1994. Dynamics and natural regeneration of woody species in farmed parklands in the Sahel region (Province of Passoré, Burkina Faso). *Forest Ecology and Management* 64:1–12.

Grolleau A. 1989. Contribution à l'étude de la multiplication végétative par greffage du karité (*Vitellaria paradoxa* Gaertn.f. *Butyropsermum paradoxum* Hepper). *Bois et Forêts des Tropiques* 222:38–40.

Guinko S. & Pasgo L.J. 1992. Harvesting and marketing of edible products from local woody species in Zitenga, Burkina Faso. *Unasylva* 43(168):16–19.

Hammond P.B. 1966. *Yatenga: technology in the culture of a West African kingdom*. Free Press, New York. 231 p.

Henry A.N., Chithra V. & Nair N.C. 1983. *Vitellaria* vs. *Butyrospermum* (Sapotaceae). *Taxon* 32:286.

INSD. Undated. Institut National des Statistiques et de la Démographie, Burkina Faso.

IRBET/Université de Ouagadougou. 1988. *Séminaire national sur la valorisation du karité pour le développement national. Bilan et perspectives*, 15–18 novembre. 188 p.

Lericollais A. 1989. La mort des arbres à Sob, en pays Sereer (Sénégal). p 187–197. In: *Tropiques, lieux et liens*. Editions ORSTOM, Paris.

Louppe D. 1994. Le karité en Côte d'Ivoire. Projet de Promotion et de Developpement des Exportations Agricoles (PPDEA), composante recherche-développement. CIRAD-Forêt. 29 p.

McLain R. 1990. *Le régime foncier et l'agroforesterie au Mali Central: etude du terroir villageois aux unités familiales*. Land Tenure Center, Madison, Wisconsin. 74 p.

McMillan D.E. 1986. Distribution of resources and products in Mossi households. p 260–273. In: *Food in sub-Saharan Africa*, ed. A. Hansen & D.E. McMillan. Lynne Rienner Publishers, Boulder, Colorado, USA.

Ministère de l'Enseignement Supérieur et de la Recherche Scientifique. 1987. Recueil des communications présentées au séminaire national sur les essences forestiéres locales, Ouagadougou, 6–10 July 1987.

Ouédraogo J.S. 1990. Situation et dynamique des parcs agroforestiers de Watinooma en 1990, Province du Bam, Burkina Faso. DEA de Biologie Végétale Tropicale, Université Paris VI. 57 p.

Picasso G. 1984. Synthèse des résultats acquis en matière de recherche sur la karité au Burkina Faso de 1950 à 1958. Rapport IRHO. 45 p.

Poulsen G. 1982. The non-wood products of African forests. *Unasylva* 34(137):15–21.

Ruyssen B. 1957. Le karité au Soudan. *Agronomie tropicale* 12(2):143–172 and (3):279–307.

Sallé G., Boussim J., Raynal-Roques A. & Brunck F. 1991. Le karité, une richesse potentielle. Perspectives de recherche pour améliorer sa production. *Bois et Forêts des Tropiques* 228:11–23.

Saul M. 1988. Money and land tenure as factors in farm size differentiation in Burkina Faso. p 243–279. In: *Land and society in contemporary Africa*, ed. R.E. Downs & S.P. Reyna. University Press of New England, Hanover and London.

Soil Survey Staff. 1994. *Keys to soil taxonomy*. 6th ed. US Government Printing Office, Washington, DC.

Swanson R.A. 1979. Gourmantché agriculture, part 1. Land Tenure and Field Cultivation, BAEP Document No. 7. Fada N'Gourma, Integrated Rural Development Project Eastern ORD.

World Bank. 1989. Burkina Faso. p 45–50. In: *Trends in developing economies*. Washington, DC.

Plate 14. *Fruits of* Vitellaria paradoxa *(shea nut or karité), one of the priority indigenous trees selected for domestication by farmers of the Sahel.* (photo: R.R.B. Leakey)

Plate 15. *The kernel of the shea nut (*Vitellaria paradoxa*) is used for extraction of cooking oil or for soaps and cosmetics. The tree is commonly grown in the traditional parklands agroforestry system (see plate 17).* (photo: R.R.B. Leakey)

Inventory and future management strategies of multipurpose tree and herb species for non-timber forest products in Nepal

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Abstract

Little research has been done so far in Nepal on multipurpose trees that provide non-timber forest products (NTFPs). Nepal has about 700 medicinal plant species. The high-value medicinal plants are found in the higher altitudes, mostly in the form of herbs. The lower-value medicinal plants, mostly trees, are found in the lower altitudes. This paper reviews the status of NTFP-based income generation in local communities and discusses the role of community forestry. Income generation through community forestry has been found to have both positive and negative impacts on the local community through its influence on policy-makers and forest management. The importance of indigenous knowledge in sustainable NTFPs extraction and use is also described. It is concluded that community forestry products may greatly contribute to the major sources of income generation for rural people locally.

Introduction

It has never been more urgent to realize the full potential of forestry for sustainable development, both to meet the immediate and future needs of increasing populations and to provide the continuity of the natural resource base. Achievement of this goal requires a comprehensive approach in which the totality of the contributions of forest resources to society is fully appreciated. In modern times, forests have been mainly seen as a source of one product: timber. However, forests also provide a multiplicity of non-timber forest products (NTFPs), for commercial, industrial or subsistence use, such as foods, medicines, materials for handicrafts, spices, resins, gums, latexes, as well as a habitat for wildlife. These can be extracted sustainably from a forest ecosystem, in quantities and ways that do not downgrade the plant community's basic reproductive functions. From a resource manager's point of view, NTFPs offer scope for innovative variations on forestry, agriculture and forest industry practices. NTFPs also offer an opportunity to make integrated approaches to land use, such as agroforestry, still more versatile, while sustainable forestry practices can be promoted by enhancing their secondary benefits. In this way, local pressures to overharvest timber can be alleviated.

In both developed and developing countries, the utilization of NTFPs can extend the range of benefits from the forest and provide justification for their conservation. In the developing countries, enterprises based on NTFPs diversify opportunities for gainful employment and income generation, especially by disadvantaged groups of women, and therefore hold potential for rural poverty alleviation (FAO 1993). With responsible use and proper husbandry, NTFPs can support remunerative enterprises to supplement subsistence activities. It is therefore important to develop sound and sustainable means to bring NTFPs into the mainstream of modern economics, while retaining their accessibility to local communities.

In Nepal, many tree species have potential for multiple use. These can be grown to provide more than one product or service in the land-use systems they occupy (MacDicken & Lantican 1990). In homegardens in Nepal, multipurpose tree species provide many products for different purposes. However, little research has been done on their utilization for non-timber tree parts, such as bark, leaves, flowers, fruits and seeds, in making products such as food, animal feed, fertilizers and chemical products. Research on the utilization of these tree parts will help to identify new uses and improve the production of already known products. Such research could pave the way for new or improved small- and large-scale enterprises that use raw materials, which would favour tree growers and help to expand markets for tree products. Research is needed that promotes the welfare of small-scale farmers and encourages large-scale industrial processing of forest products. No significant research of this type has been done so far in Nepal, even on a small scale. This paper reviews the present status of NTFPs and their future management strategies in Nepal.

Potentially important NTFPs in Nepal

Both from mountains and hills and from the lowland regions of Nepal, 44 trees used for timber produce potentially important non-timber forest products (table 1). *Dalbergia sissoo* Roxb. ex DC has been considered the most important. It provides not only good-quality timber but also fuelwood and fodder with multiple management options. Other important species for the wood industries are *Eucalyptus* sp. (fibre) and *Shorea robusta* Gaertner f. (furniture wood), while *Acacia catechu* (L. f.) Willd., *Cinnamomum tamala* (Buch.-Ham.) Nees & Eberm, *Sapindus mukorossi* Gaertner, *Azadirachta indica* A. Juss. *and Daphne bholua* Buch. Ham. ex D. Don provide important non-timber forest products, as do also *Shorea robusta* Gaetner f. and various eucalypts. Over the last few decades, the marketing of NTFPs has gained increasing international recognition. Experience from many countries demonstrates that the collection and sale of NTFPs can provide important cash income for households. Income derived from harvesting NTFPs can be very substantial and can equal, or be in excess of, that derived from agriculture and timber. Quantification and valuation of these benefits is, however, often inadequate (Brown et al. 1993).

Role of community forestry in promotion of NTFPs

In many Asian countries, community-based NTFPs can contribute significantly to the national economy and constitute major sources of income and employment. For example, in Vietnam, NTFPs are a significant component of the forestry sectors income and the Ministry of Forestry has set itself a target of exporting USD 150 million worth of NTFPs in the 5 years from 1986.

In Nepal, the experience from the Nepal-Australia Community Forestry Project (NACFP) suggests that Community Forestry can play an important role in providing local employment, NTFP promotion and local markets (Malla 1993, Jackson & Ingles 1994). At present in the NACFP area, over 19 000 ha of plantation have been established, and these plantations are capable of yielding a range of NTFPs in excess of immediate local demand.

From the Koshi Hills Project, another Community Forestry Project in eastern Nepal (Maharjan 1994), it is estimated that a net income of 62 450 Nepalese rupees (USD 1200) per annum can be generated by 1 ha of chiraita cultivation *(Swertia chirata).* It is strongly believed by the forest user groups that such substantial income can support their forest management programme, as well as other community welfare activities.

Most of the southern parts of Koshi Hills are covered by substantial stands of chirpine (*Pinus roxburghii*), which produces resins for tapping. In Dumare Sanne, one of the

Table 1. Important multipurpose tree species of the plains and hills of Nepal

Tree species	Altitude	Uses
*Acacia catechu**	plain–900 m	F, Fo, extractives
Acacia nilotica	plain–500 m	Fo, F, T, tanning
Acer oblongum	1200–2400 m	T, Fo
Adina cordifolia	plain–1800 m	T, Fo
Aesandra butyracea	plain–1800 m	F, Fo, extractives
Ailanthus excelsa	plain	Fo, matches
Albizia chinensis	plain–1500 m	T, veneer, F
Albizia lebbek	plain–1000 m	T, F, Fo
*Alnus nepalensis**	900–2700 m	F, Fo, T
Anogeissus latifolius	plain–1700 m	F, T, Fo
Anthocephalus chinensis	plain–1000 m	veneer, pulp, Fo
Artocarpus heterophyllus	plain	fruit, T
Artocarpus lakoocha	plain–1300 m	Fo, fruit
Azadirachta indica	plain–900 m	F, Fo, T, extractives
Bauhinia purpurea	plain–1600 m	Fo, food, F
*Betula alnoides**	1200–1300 m	F, Fo, T, veneer
Betula utilis	2700–4300 m	T, Fo, M
Cassia fistula	plain–1400 m	F, T, ornament
Castanopsis tribuloides	450–2300 m	T, Fo, nuts
Cinnamomum camphora	1000–1200 m	T, extractives
Cinnamomum tamala	1000–1200 m	T, extractives
*Dalbergia sissoo**	plain–1400 m	T, F, Fo
Daphne bholua	1800–3600 m	paper
Eucalyptus sp.*	plain–1800 m	F, paper, M
Ficus sp.	plain–2000 m	Fo, fruits
Gmelina arborea	plain–1200 m	T, pulp, Fo, F
Grewia sp.	plain–1700 m	Fo, T, F, fruits
Lagerstroemia parviflora	plain–1200 m	T, F, Fo
Litsea sp.	plain–2700 m	F, Fo, fruits
*Mangifera indica***	plain	fruits, F
Myrica esculenta	1000–2300 m	fruits, M
Phyllanthus emblica	plain–1500 m	fruit, M, T, Fo
Pinus roxburghii	900–2000 m	T, F, resin
Pinus wallichiana	1800–3600 m	T, F
*Prunus cerasoides**	500–2400 m	F, fruit
Pyrus pashia	1300–2500 m	F, fruit
Quercus sp.	450–3800	T, Fo, F
Sapindus mukorossi	600–2200 m	fruit
Schima wallichii	450–2000 m	F, T
Sesbania sp.	plain	Fo, F
Shorea robusta	plain–1500 m	T, F, Fo, oil
Syzygium cumini	plain–1600 m	F, T, Fo
Terminalia sp.	plain–1500 m	T, F, Fo
Zizyphus sp.	plain–1600 m	T, F, Fo, fruit

F = fuelwood, Fo = fodder, M = medicines, T = timber
* fast-growing MPTS used for the farmlands in Nepal
** mainly for fruits in homegarden or marginal lands

community forestry projects managed by the Herbal Processing and Production Company (HPPCo) is annually managing resin tapping. From this enterprise each labourer makes an income every season of NPR 5000–6000 (approx. USD 100) from resin tapping, which is a good income for these forest users with little access to cash.

Present status of medicinal products trade

The diversity of physiography caused by altitudinal and climatic variations in different areas of Nepal has greatly contributed towards a rich diversity of vegetation in different areas, representing flora of tropical, subtropical, temperate and alpine zones. The list of medicinal plants so far enumerated by the Department of Medicinal Plants of Nepal comprises well over 700 different medicinal plants, out of an estimated 7000 higher plant species.

The reputation earned by Himalayan medicinal herbs is not restricted only to the Himalayan region. On average, Nepal exports each year a wide range of crude herbs and drugs worth well over NPR 20 million (USD 400 000) per annum. The quantity per species ranges from 10 to 400 tonnes per annum (tables 2 and 3).

The main products traded from high altitudes are herbal plants of high value, for example, chiraita (*Swertia chirata*), cardamom (*Amomum subulatum*), jatamansi

Table 2. The trade in high-value NTFPs from high altitudes in eastern Nepal markets, 1991/92

Plant species	Weight (t year^{-1})	Price (NPR kg^{-1})	Value (NPR year^{-1})
Swertia chirata (chiraita)	140	100	14 000 000
Picrorrhiza kurroa (kutki)	24	65	1 560 000
Nardostachys jatamansi (jatamansi)	30	50	1 500 000
Aconitum spicatum (bikh)	10	55	550 000
Swertia chirata (1 year old)	14	25	350 000
Others	6	–	220 000
Total			18 180 000

Source: Edwards 1994
1 USD = approx. NPR 55

Table 3. The trade in low-value NTFPs from low altitudes in eastern Nepal (terai) markets, 1991/92

Plant species	Weight (t year^{-1})	Price (NPR kg^{-1})	Value (NPR year^{-1})
Cinnamomum tamala (dalchinii)	100	28	2 800 000
C. tamala (tejpaat)	400	6	2 400 000
Asparagus recemosus (satawari)	45	40	1 800 000
Sapindus mukorossi (rittha)	100	8	800 000
Acacia consinna (sikakai)	50	10	500 000
Total	695		8 300 000

Source: Edwards 1994
1 USD = approx. NPR 55

(Nardostachys jatamansi), kutki *(Picrorhiza kurroa)*, bikh *(Aconitum spicatum)*. The total value of medicinal products traded through Hille and Basantpur in the 1991/92 trading season was estimated to be NPR 18 180 000 (USD 350 000).

At lower altitudes, low-value medicinal products (mostly from tree species) are marketed through the Lahan market (eastern terai). Over 60% of the value of this is in the bark (dalchinii) and leaf (tejpaat) of *Cinnamomum tamala*. The total trade amounts to about NPR 8 300 000 (USD 150 000). Unlike for the high-altitude trade, it is probable that the majority of this produce is cultivated on private land.

It is difficult to encourage quality control or primary processing at the local level where the present markets so rarely differentiate between grades of medicinal plants extracts or raw materials.

Importance of indigenous knowledge of NTFP extraction and marketing

Community forestry development has existed in Nepal for about two decades—about the time it takes some trees to mature and become available for harvesting and marketing. This long time-horizon makes careful planning especially important for community-managed forest resources, if they are to benefit the community and achieve their sustainable productivity. Indigenous knowledge of local forest use patterns and practices are therefore key information on which to base decisions. Unfortunately, indigenous knowledge is not always sufficient, nor always the best for enhancing NTFP productivity, but it can provide a critical point of departure, on which scientific forest management systems can be based. Development policy-makers and forest managers therefore need to recognize the nature of indigenous knowledge about NTFPs and balance this with scientific knowledge when developing their management plans of community systems. Unfortunately, support for studies on indigenous knowledge is still lacking in Nepal.

At the same time, it is apparent that villagers and middlemen do not know enough about resource growth and marketing to make the best use of existing opportunities for NTFP development. Evidence from many countries of the existence of indigenous management systems (Clark 1995, Fisher 1989) has revealed that local community management can indeed 'work' sustainably. So, well-trained community forestry developers are needed to extend useful knowledge to local communities about NTFP planning and management.

The knowledge base about modified NTFPs, their cultivation, processing and marketing whether from indigenous, technical, scientific or economic sources, is lacking in Nepal. Of the medicinal plants harvested in Nepal, only a small proportion is consumed in the domestic market; most of the plants are exported to India and neighbouring countries. Ayurvedic medicines processed in India, partly based on Nepalese NTFP resources, are then imported again. Processing could just as well be done in Nepal, saving valuable foreign exchange and encouraging better local resource management.

Potential effects of income generation through commercialization of NTFPs

Potential effects on central policy of commercializing NTFPs locally may be either positive or negative with regard to forest management and biodiversity, through its effects on policy-makers, politicians and local communities (including forest user groups and individual collectors).

Effects on policy

Belief that community forestry is oriented toward meeting subsistence needs may explain why central policy-makers have transferred forest management responsibilities from government field staff to user groups. If this is true, it can be hoped that these policy-makers will make a further paradigm shift and help user groups exercise a much broader range of forest management options, especially those involving risks and surrounded by uncertainty. Policy-makers, however, lack resource information and effective monitoring systems within the forestry agencies of developing countries. Thus there is the danger that schemes that increase income generation may provoke policy-makers to restrain the development of community forestry through overregulation of user groups, and control over them. Such overregulation could threaten the viability of commercial community forestry activities. Examples of overregulation include the need to obtain approval to sell or transfer the products outside local markets. Such examples are common in Nepal.

Effects on rural community

When forest user groups generate cash, rather than just providing forest products for their own consumption, several problems may arise. For example, there are several options as to how to distribute the cash, and these user groups are faced with politically complex decision-making. The user groups must agree upon a socially acceptable disbursement of cash and then implement the disbursement in such a way that the cohesion of the user group is maintained. Such decisions will be difficult where there are likely to be differences of opinion in the community as to how the disbursement should be done.

Effects on forest management systems

Income-generation objectives can result in decisions to select tree-based production systems that reduce the viability of systems important to a subgroup of users. In Nepal, for example, women wanting to grow fodder were disadvantaged when the men of the community decided to maximize income generation by producing timber. Within the community, therefore, all special-interest groups should be consulted, to reduce the potential for conflict or inequitable decision-making about common resources.

Effects on biodiversity

In many areas of Nepal where community forestry has been to some extent successful, there has been a decrease in the rate of forest degradation and an increase in the quality of natural forests. Jackson and Ingles (1994) have reported that the majority of plantations in the community forestry sites can, in the long-term, be converted into natural forests, if the user groups promote the return of naturally regenerating species through appropriate silvicultural practices. Under these circumstances, well-managed community forestry can contribute both to the economy and to the enhancement of biodiversity values of these forests.

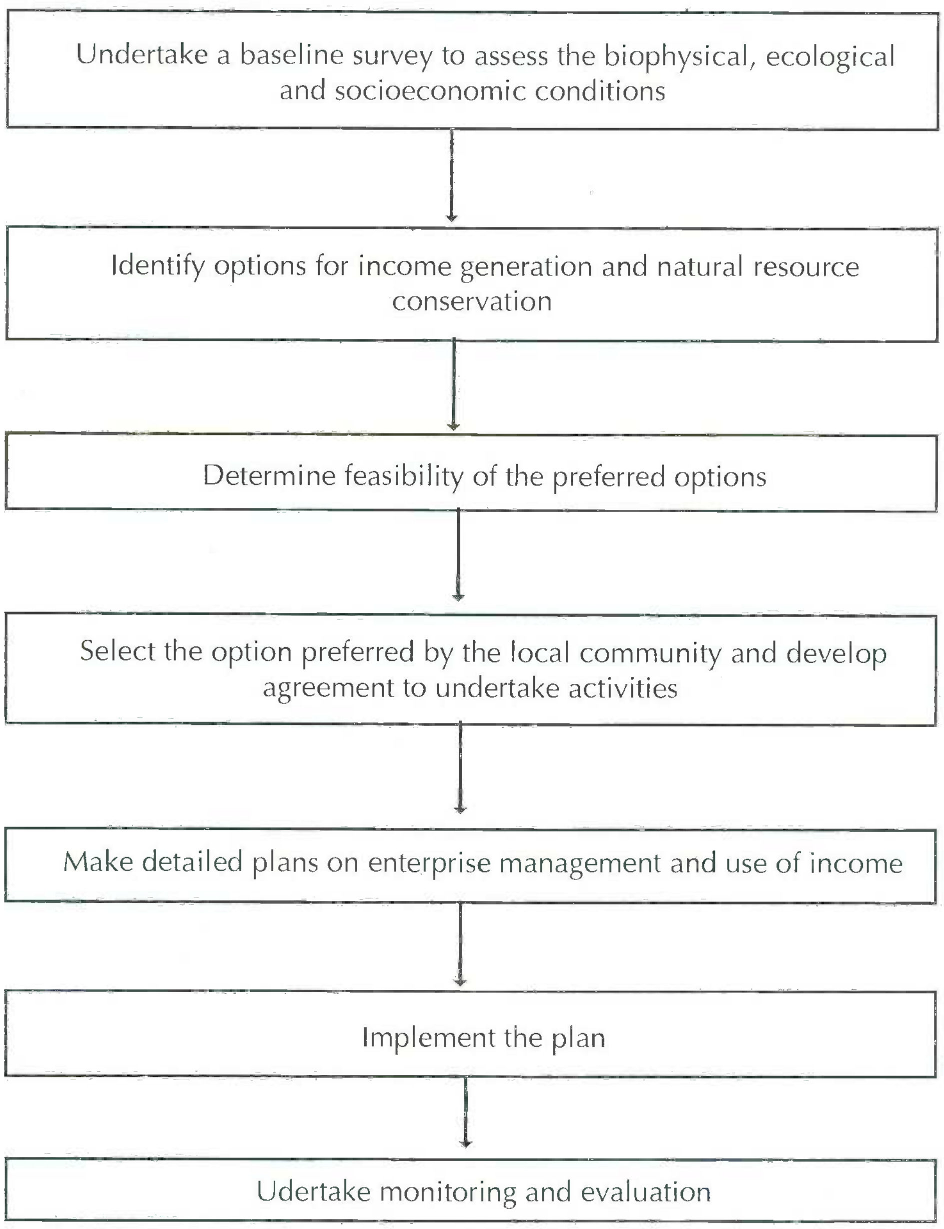
Management strategies for income generation through NTFPs

The multipurpose trees most preferred by farmers in Asia (including Nepal) are those that produce food as well as other products. However, local communities should also be informed about the full range of non-timber values of trees, so that they can be encouraged to plant them in agroforestry systems.

The following management strategies should be followed for multipurpose tree improvement:

- enhance ecological and silvicultural knowledge (such as site requirements, growth rates, and management practices) of suitable trees through research
- initiate regionally coordinated research on the utilization of NTFPs and identify new uses and improved production methods for already known products.
- develop cost-effective processing technologies for non-timber forest products
- assess the economic potential of utilizing non-wood parts of various multipurpose trees
- identify and develop effective enterprises for utilizing NTFPs
- motivate extension services for promotion of NTFPs
- develop policy reforms to promote the wise use of NTFPs

The following sequence of events should be followed when developing natural resources for the income generation in community development programmes:



Conclusions

It is clear that trees are important for many products in addition to timber, fuelwood and fodder, and that some of these products may be more valuable than the timber or alternative agricultural land uses.

It is clear that community forestry has the capacity to generate substantial economic benefits for local communities. However, sustaining both the income and the forest depends on the addressing a range of socioeconomic, political and institutional issues. The lack of a conceptual framework for addressing these issues is frequently a constraint when designing appropriate forms of intervention so that both government policy objectives and local community development objectives are met.

To establish markets that will enhance the development of small-scale production systems for NTFPs, foresters and planners have to understand relationships between local and outside markets.

Future research for income generation from NTFPs from multipurpose trees must consider the following:

- local indigenous knowledge in NTFP utilization and management
- the ecological impacts of NTFP extraction
- silvicultural techniques of multipurpose trees
- the collection of quantitative data throughout the year to assess seasonality of production
- the analysis and evaluation of the role of marketing cooperatives
- the development of appropriate small-scale processing technologies and enterprises
- monitoring equity by gender and subgroup in decision-making and sharing of benefits, rights and responsibility

References

Brown K., Pierce D., Perrings C. & Swanson T. 1993. Economics and the conservation of global diversity. Working Paper No. 2, Global Environmental Facility. World Bank, Washington, DC.

Clark J. 1995. *Building on indigenous natural resources management: forestry practices in Zimbabwe's communal lands.* Forest Research Centre Report, Zimbabwe.

Edwards D.M. 1994. Research into the collection and trade of jaributi from Middle Hills of Nepal: the Koshi Hills. p 4–18. In: *Focus on jaributi.*, ed. D.M. Edwards. Kathmandu, Nepal.

FAO. 1993. *More than wood.* Forestry Topics Report No. 4. FAO, Rome. 52 p.

Fisher R.J. 1989. Indigenous systems of common property forest management in Nepal. Working Paper No. 18. Environment and Policy Institute, East–West Centre, Honolulu, USA.

Jackson W.J. & Ingles A.W. 1994. Developing rural community and conserving the biodiversity of Nepal through community forestry. Paper presented at RECOFTC Regional Seminar, Income Generation through Community Forestry, 18–20 October 1995, Bangkok, Thailand.

MacDicken K.G. & Lantican C.B. 1990. MPTS research supported by F/FRED (1987–1990). Special Report No. 11. Bangkok, Winrock International, Thailand.

Maharjan M.R. 1995. Income generation through NTFPs in community forestry: case studies from the Koshi Hills. Paper presented at RECOFTC Regional Seminar, Income Generation through Community Forestry, 18–20 October 1995, Bangkok, Thailand. 10 p.

Malla Y.B. 1993. Changing role of the forest resource market: an ignored dimension of community forestry. *Ban Ko Jankari* 4(1):28–31.

Economic factors in farmer adoption of forest product activities

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Abstract

The adoption of commercial non-timber forest products NTFPs within an agroforestry system is influenced by a number of different economic factors. Income from NTFP activities helps a substantial proportion of rural households meet seasonal and other needs. The relevance of particular activities in different situations is often changing rapidly, and care needs to be taken to focus attention on those with continuing development potential. Rising raw material costs are being accompanied by a shift towards supplies available on or adjacent to farms, but this is largely an adaptation to raw materials available in fallow and farm bush. Commercial activities based on planted stocks are often a by-product of trees established primarily to meet subsistence or other needs, or a response to changing availability of the factors of production (land, labour and capital). Growing exposure to markets may increase commercial opportunities for tree crops and may also improve access to inputs that could substitute for goods and services presently provided by trees.

Introduction

Very large numbers of third world rural households generate some of their income from selling non-timber forest products (NTFPs). As pressures on the agricultural land base increase, leading to progressive fragmentation of farm holdings and overuse of arable land, the ability of farm households to achieve food self-sufficiency from their land has been declining widely. Rural populations are becoming increasingly reliant on farm and non-farm income in order to meet their food and other needs. Forest product activities have repeatedly been found to provide one of the main sources of non-farm income to rural households (Fisseha 1987, Liedholm & Mead 1993). Products of farm trees can also be important sources of farm income (Arnold & Dewees 1995).

There is a great deal of descriptive information about local uses of NTFPs, but this is generally concentrated in situation-specific ethnobotanical, anthropological or geographical studies. There are few analytical studies that have attempted to synthesize the information available in economic terms (Falconer & Arnold 1989, Beer & McDermott 1989, Falconer 1990). However, more studies with an economic focus have been carried out recently, and a number of household and activity surveys have begun to shed light on broader economic patterns of NTFP production and use.

This paper draws primarily upon two areas of recent economic research related to farmer involvement in tree-product activities. One is concerned with economic factors that enter into farm household participation in harvesting, processing and selling forest products (Townson 1995a). The other relates to economic considerations that influence farmer decisions about management of trees and tree crops (Arnold & Dewees 1995).

Because some of the products that people produce and sell from trees and forests are wood products, it can be difficult to separate out information about those that relate only to non-timber products from all the information generated by studies designed to look at relationships between people and the forest and tree resources they depend upon. Where necessary, therefore, some of the analysis in this paper takes account of all products that are important in understanding these relationships and not just those defined as non-timber forest products.

A related boundary problem arises because many marketed tree products are also used within the household. For many producers there are no clear distinctions between activities to meet their subsistence needs and those involved in producing for the market. They sell what is surplus to their needs or in response to the opportunity to generate needed cash income. Analysis of commercial decisions and actions at this level, therefore, need to take account of such subsistence (and cultural and spiritual) factors that determine the values that households place on different forest products.

Another definitional problem that arises in considering the process of domestication is that there is not a clear boundary between natural and domesticated tree stocks. Rather there exists a continuum from gathering from wild resources, through increasing intensities of management of naturally occurring stocks and the encouragement and protection of natural regeneration, to planted trees and other woody plants. Many NTFPs are also coproducts or byproducts of other forestry or agricultural products.

Within this framework of limited information and multiple uses and joint supply, the present review focuses on the factors influencing farm household commercial activities involving NTFP activities. The focus throughout is on products that serve local and other domestic markets, rather than on those destined for industrial processing overseas, as the former account for the bulk of what is traded.

The first part of the paper examines the main features of production and trade in such products, focusing on their magnitude and importance as sources of rural household income, and on the structure and dynamics of such activities. The second part looks in more detail at the sources of the main types of product and at shifts in the supply base that suggest which components are more likely to become domesticated. The third part reviews the main factors that determine the extent to which farmers are likely to adopt trees in different situations. The concluding section highlights a number of issues that may help in targeting interventions in support of domestication of products that can contribute to farm household incomes.

Patterns of NTFP activity

Magnitude of involvement

Density of involvement in NTFP selling varies widely. Recent countrywide surveys by the GEMINI Programme (Liedholm & Mead 1993) in six countries in eastern and southern Africa (Botswana, Kenya, Lesotho, Malawi, Swaziland and Zimbabwe), disclosed that on average 2.3% of rural populations and 0.8% of urban populations were selling more than half the wood products and the grass, cane and bamboo products that they were gathering or producing. A similar survey, but covering a wider range of products and users, in the forest zone of southern Ghana found 10% of rural people and 38% of households selling forest products (Townson 1995b). Studies in forest-rich areas adjacent to large urban markets show even higher levels of involvement—e.g., 68% of households surveyed in villages around the large market centre of Kumasi in Ghana (Falconer 1994) and all households in surveyed villages supplying the Amazon city of Iquitos (Padoch 1988).

A large component of forest product activities in the rural sector reflects the presence of raw materials, the size of rural markets for forest products, and the dispersion of these markets across large areas with a relatively poor transport infrastructure, so that they are more effectively supplied locally. They provide many of the products that farm households require at lower cost than can be achieved with supplies from the modern sector (FAO 1987).

As they are tied to the rate of change in agricultural activity and incomes, rural markets for most forest products, though very large, in aggregate tend to grow only slowly. More rapid growth in market demand is usually associated with expansion of urban use of wood fuels, certain foods, medicinal products, building materials and furniture, leaf and fibre packaging, and other forest products, which people continue to consume as they move to the towns. Most of such forest products are characterized as goods used primarily by low-income consumers. However, expenditure data from the 1991–1992 Ghana living standards survey indicates that in that country forest products are in fact bought by the bulk of the population, with about three-quarters of households in both rural and urban areas purchasing some of their forest product needs. Total household expenditure on just nine forest products, in the country as a whole in that year, was estimated to amount to the equivalent of more than USD 200 million. Although average household expenditures were low, rural markets accounted for the largest share of money spent on purchasing *akpeteshie* (spirit distilled from palm wine), bushmeat and furniture. Urban markets dominated expenditure on palm wine, bushmeat, snails, honey, firewood and charcoal (Townson 1995b).

NTFP income and household livelihoods

Many studies have indicated that, where people have had relatively unrestricted access to forests, the income from forest foods and forest products is often particularly important for poorer groups within the community. Thus dependence on income from NTFPs has been shown to be inversely related to size of landholdings in Orissa, India (Fernandes & Menon 1987), and in Brazil (Hecht et al. 1988), to family incomes in dryland India (Jodha 1990) and Sri Lanka (Gunatilake et al. 1993), and to levels of household rice self-sufficiency in the Philippines (Siebert & Belsky 1985).

Income from forest products seldom appears to account for a large share of a household's total income, but it is often important in filling seasonal or other cash flow gaps, and in helping to cope with particular expenses or to respond to unusual opportunities. Among persons generating some income from forest products activities in households surveyed in southern Ghana, 72% identified this income as being important either in absolute terms, or in meeting particular needs, or because of its timing (Townson 1995b). But only 10% of these respondents identified this as their sole source of income, and for only a minority was it the main source. For 66% of these households, half or more of their income came from agriculture. This is consistent with evidence from case studies from a variety of other situations (e.g., May et al. 1985, Falconer 1990 and 1994, Madge 1990, Davies & Richards 1991, Hopkins et al. 1994, Leach & Fairhead 1994).

Income-earning activities based on marketable forest products may be seasonal or year-round, or they may be occasional when supplementary cash income is needed. There are several dimensions to the seasonality of forest-based income-generating activities. Some are governed by seasonally induced cash needs, such as the need for income to buy food during the 'hunger period' between harvests, or to purchase farm inputs. Other activities are seasonal, largely because the crop or material can be gathered only at certain times of year. The fluctuation in timing of other forest product activities is dictated by the seasonality of other activities, such as demand for baskets needed at harvest time and the surge in demand for many items as agricultural incomes peak. Some activities are also linked to fluctuations in availability of labour and to decline in agricultural and planting seasons, or they are phased to take advantage of slack periods.

Often these pressures work in conjunction one with another. A study in Sierra Leone found that fuelwood sales provided the first cash income from land cleared for rice production. Subsequently fuelwood collection for the market was concentrated during the off-peak agriculture period, providing cash income in a period when food supplies are generally at their lowest (Kamara 1986). A study in the forest-savanna zone of Guinea showed that farmers link their wild plant collection and trading incomes to seasonally timed needs—e.g., to purchase seeds, hire labour for cultivation, and buy food at harvest to be processed and sold during the dry season. Many women traders generated their working capital from cropping, gathering and processing within sequences in which one activity's output becomes another's input (Leach & Fairhead 1994).

The role of forest-based activities as a source of income that people can fall back on in times of crop failure or shortfall, or to cope with some other form of emergency, has also been shown to be very important. Numerous case studies document how the numbers involved in the selling of forest products rise in such times. In addition, some forest-product activities may be opportunistic, taking advantage of unexpected or periodic surges in availability of a product to generate additional income or savings (Beer & McDermott 1989, Falconer 1990).

The high incidence of women's involvement in NTFP activities in most situations (e.g., 40–50% in Ghana and the six countries of eastern and southern Africa) appears to reflect easy access to the resource and low thresholds of skill and capital. As forest-product processing may often be performed at or near home, women are often able to combine these income-earning activities with other household chores (e.g., child care). In addition, as women traditionally use forest products to meet some of their household's basic needs (e.g., fuelwood, medicines and foods), gathering of forest products for the market can often be accomplished in conjunction with other collecting activities (Falconer 1990). Income from forest products can be more important to women than to men. In western Niger, for example, income from products of the commons was found to represent 27% of women's local non-farm income, as compared with 10% for men (Hopkins et al. 1994).

Patterns of change

Even a cursory examination of the information available demonstrates that the pattern and frequently the magnitude of NTFP activity are changing substantially (some activities expanding and some declining) and often rapidly. In some situations users are becoming more dependent on tree-product activities, in others they are moving away from dependence on them. If interventions to foster development of sustainable forest-product activities are to be effective, it is evidently important to be able to understand which categories are likely to continue to prove viable and important in the future and which are destined to decline and disappear.

At least three sources of the marked differences observed in the performances of different types of forest product activity can be identified:

- Product and market characteristics: the level of output in some activities is changing because of characteristics such as rapidly growing demand, absence of competitive alternatives, sustainable raw material, or a technology with no diseconomies of scale that encourage growth.
- Production or distribution process characteristics: these can enable the component enterprises to increase in size, or to add extra value by diversifying into additional stages of the process, or to organize the process more efficiently (or to exploit more than one of these avenues)—or prevent these events

- Features of individual enterprise: entrepreneurial and managerial talent, location, constraints and opportunities in the local agricultural economy, etc., can also be reasons for growth or decline of NTFP performance.

Performance is therefore likely to reflect a combination of factors related to the product, the way it can be produced and marketed, and the circumstances within which a particular enterprise is operating. In economically stagnant regions, much growth in non-farm activity comes about as people who cannot find employment in agriculture (or urban activities) try to move into the non-farm economy, being absorbed principally in creation of labour-intensive, low-return micro-enterprise activities. In contrast, in regions where rural incomes are growing rapidly, growth in enterprise activities is predominantly demand driven, reflecting the increased need for services and the diversification of consumption into more non-food items, many of which will be produced in the rural areas. As wages rise, the structure of small enterprise activity is likely to shift from low return into higher return activities. With improvements in rural infrastructure and incomes, manufacturing tends to become more concentrated in somewhat larger workshop-scale enterprises located mainly in rural settlements and towns (Haggblade & Hazell 1989, Haggblade & Liedholm 1991).

The progress of NTFP activities tends to reflect these broader trends. Of the two largest activities recorded in the surveys in eastern and southern Africa, employment in woodworking was growing 10 times as fast (30.6% per year) as employment in grass, cane and bamboo activities (3.1%). The latter are low input and output processes tied to agricultural demand, based on a simple technology, primarily single-person production units, and subject to competition from alternative products. It could be argued that they thus show many of the characteristics of activities that grow when the lack of alternatives forces more people to engage in them but that are unlikely to prosper as the economy grows. Many woodworking units, though, seem better able to respond to growing demand, as they are relatively high-input and -output activities confronting growing urban as well as rural demand, and employing flexible technologies that facilitate expansion of individual enterprises. This seems to be borne out by the observation that, at the time of the surveys, about 80% of jobs existing in grass, cane and bamboo activities came from new start-ups. In woodworking, in contrast, 55% of jobs came from expansion of existing enterprises (Arnold et al. 1994).

Comparable analysis of the range of NTFP activities found in southern Ghana (table 1) suggests that many forest product activities are 'activities of last resort'. Most are characterized by ease of access and low capital or skill thresholds needed to enter. Participants in such activities are consequently likely to find themselves in oversaturated markets that offer very low returns to labour. Few are able to expand beyond the single-person (or at best family-based) operation, operating from the homestead. They are thus activities that are likely to be abandoned by those involved in them if more attractive options become available. If correct, this interpretation clearly has important implications for the selection of NTFP options to promote.

Changes in the raw material base

The progressive domestication of a naturally occurring commercial product usually reflects pressures to bring the source of supply under closer control. This response may be to rising costs, irregularity of supply from wild sources, problems of quality, etc. In this section these issues are examimed as they relate to NTFPs and the balance between forest and non-forest sources of supply that is emerging.

Table 1. Change and factors influencing change in forest products activities, Ghana forest zone

Product	Change[1] (a\b)	Demand[2] (a\b\c)	Features[3] (a\b\c)	Problems[4] (a\b\c)	Viability[5] (a\b)
Akpeteshie production	++\++	+\+\+	:\+\+	–\:\:	:\+
Carpentry	++\++	+\:\:	:\+\+	–\+\:	+\+
Charcoal production	++\++	:\+\–	:\+\+	:\:\:	–\–
Honey	++\++	:\:\+	:\:\:	:\:\:	:\:
Medicines	+\++	:\:\+	:\:\+	+\+\–	:\+
Palm wine	+\++	+\–\:	:\:\:	–\:\:	:\:
Mushrooms	++\+	:\+\+	:\:\–	+\:\:	:\:
Chewsponge	++\:	:\:\–	–\:\–	–\:\–	:\:
Carving	+\+	:\:\+	:\+\+	–\+\:	+\+
Baskets	+\+	+\:\–	:\:\+	:\–\:	+\:
Firewood	+\:	:\+\–	–\:\–	:\:\:	–\+
Sponge	:\+	:\:\–	–\:\–	:\:\–	:\:
Pestles	:\:	:\:\–	:\:\–	:\:\–	:\–
Bushmeat	:\+	:\:\:	–\+\+	:\:\–	+\–
Wrapping leaves	:\:	:\–\–	–\:\–	:\:\:	:\:
Snails	:\:	:\–\–	–\:\+	:\–\:	–\–
Cane products	:\:	+\–\:	–\:\:	:\+\–	–\:
Mats	–\:	+\:\:	–\:\–	:\–\:	+\:
Raffia	–\:	:\:\–	–\:\:	:\:\:	–\:

Source: derived from Townson 1995b

1 a overall rate of change in employment: > +10% pa = ++; +5–10% = +; 0–+5% = :; < 0% = –
  b share of enterprises that grew: > 30% = ++; 15–29% = +; 0–14% = :
2 a perception of growth in own business: high proportion growing = +; other = :
  b perception of change in number of enterprises: growing = +; declining = –; other = :
  c motivation for startup: good prospects = +; no alternative = –; other = :
3 a mainly single person units = –; other = :
  b substantial share employ capital = +; other = :
  c substantial share need skills = +; most report no skills = –; other = :
4 a finance a problem for high proportion = –; other = :
  b raw material supply a problem for high proportion = –; for some :; for few = +
  c government regulations a problem for a substantial proportion = –; other = :
5 a main reason for closure: business failure = –; personal = +; other = :
  b future plans: high proportion to expand = +; high proportion to switch = –; other = :

Raw material 'shortages'

Reports of worsening NTFP supply situations have been widespread. Complaints about raw material supply problems feature prominently, for example, among forest product producers included in small enterprise surveys. More of these producers report supply as their main problem now rather than at start-up (Fisseha 1987, Arnold et al. 1994). Much of this can be attributed to rising costs rather than, or as well as, physical depletion.

The increasing dependence of rural people on wage labour reduces the amount of time they have available for other activities and raises the opportunity cost of labour. Recent studies have revealed that the poor are often unable to devote as much labour to gathering or trading NTFPs as in the past. This was found, for example, in Orissa, India (Fernandes et al. 1988), parts of Indonesia (Peluso 1989), the Gambia (Madge 1990) and Vietnam (Nguyen Thi Yen et al. 1994).

The opening up of rural areas itself expands the range of employment options open to rural people, encouraging a move away from some of the more marginal and often isolated and arduous forest-product activities on which they previously depended. For example, improved links between producer and market areas in the Amazon have made agriculture more attractive, contributing to the decline in the numbers engaged in collecting and selling forest products (Browder 1992, Richards 1993).

Changes that reduce physical or economic supplies of particular products may thus be part of broader changes that cause or encourage a shift away from the products altogether, rather than a move to producing them in a more controlled and less costly manner. Some of these trends are evident even where supply remains abundant. A recent study in West Malaysia, for instance, found 279 species present that had been used as foods, medicines, etc., in the past. Of these, only 71 were still being used by local people, and only 11 (10 of them fruits and vegetables) were being sold in nearby markets (Lim & Jamaluddin 1994).

In addition to rising costs that reduce economic access to a resource, many gatherers and producers of NTFPs face other restrictions on their access. As growing commercial demand increases the value of particular forest products, the poor may find themselves excluded from access to the resource. In the Orissa case referred to above, for example, use of trees on village common land was progressively monopolized by the rich and powerful as market demand for NTFPs grew, forcing the poor to collect from further afield (Fernandes et al. 1988).

Producers often face forest policies and practices that focus on conserving the forest resource and on protecting the rights of those licensed to harvest timber. This commonly results in policy prescriptions relating to use of non–timber products that are generally restrictive rather than enabling. Such policies are typically pursued through systems of licensing, fees and other measures designed to limit rather than encourage production and sale of such products (Dewees & Scherr 1996).

Non–forest sources of supply

Rising costs and increasing constraints on access to supplies off-farm are reflected in a marked concentration of production on or close to the farm. A study in a forested area in Sierra Leone, for instance, found that only 14% of all hunted or collected foodstuffs and 32% of the medicinal plants came from the forest; the rest came from fallow and farm bush areas (Davies & Richards 1991).

Similarly, in southern Ghana nearly half of those surveyed reported the farm bush as being their most important source of NTFPs, and a quarter stated their main source to be the farm. Though these magnitudes need to be viewed with some caution, as people are sometimes reluctant to report what they harvest from reserved forests, it does appear that the most important activities draw on forests for little, if any, of their supplies (table 2). A large part of the NTFP activity in the area is thus presently based on farm resources. These resources are, however, mainly naturally occurring stocks, retained during clearance or regenerating on fallow areas. Only some of the oil palm is of planted origin. The forests are a major source of raw materials for some of the smaller activities such as canes, chewsponge and sponge, and for particular forest products such as snails, mushrooms and wrapping leaves.

The structure of NTFP activity is also strongly influenced by the demand for labour in agriculture and its relative attraction as a source of income. A number of products, for instance, are dominated by groups and individuals who have migrated into the

Table 2. Number and share of participants dependent on reserved forests as their most important source of raw materials, Ghana forest zone

	Number of participants dependent on reserved forests as their most important source of raw materials	Proportion (%) of participants dependent on reserved forests as their most important source of raw materials	Ranking of activity participants (all by number of sources of raw materials)
Bushmeat	8343	25	2
Wrapping leaves	8328	31	4
Snails	6688	35	7
Chewsponge	4719	47	10
Mushrooms	3721	23	9
Baskets	3247	14	6
Medicines	2994	12	5
Sponge	2935	38	12
Akpeteshie	2832	12	1
Pestles	1463	39	15
Canes	1425	39	16
Carving	1409	51	18
Raffia thatch	1043	6	8
Mats	332	4	11
Honey	253	4	13
Palm wine	0	0	14
Firewood	0	0	3
Charcoal	0	0	17

Source: derived from Townson 1995b

area and therefore have only limited access to land. Similarly, some activities are dominated by young men who still do not have their own farms, while other activities (e.g., charcoal production) are concentrated in areas where new farms are being cleared (Townson 1995b).

There are also many situations where people have actively manipulated a naturally occurring resource in order to encourage and maintain components of particular value. The babaçu palm in northeast Brazil has long been integrated into local farmers' shifting cultivation system (May et al. 1985). Farmers in the floodplain forests of the Amazon area manage them to favour the economically more valuable species they contain (Anderson & Ioris 1992). In West Kalimantan, forest areas adjacent to communities with improved access to markets have been managed in favour of 'orchards' of the wild fruit tree durian (Padoch 1995, Peluso 1994).

However, the West African evidence suggests that, in at least some situations, the choice by farm households of which farm-based NTFP activities they concentrate upon is largely dictated by the availability of labour and which activities can be based on and integrated with their agricultural activities. It is therefore likely that the tree products most in demand from off-farm sources will provide only limited guidance to which trees farmers wish to establish on-farm. In selecting trees to be grown on-farm as a source of commercial products, it will therefore be important to understand how each responds to the range of needs that farmers usually try to meet through tree management.

Tree crops and farmer management decisions

As off-farm tree production declines, farmers may maintain or grow trees to maintain supplies of tree products to meet the growing demand for tree products, to help maintain agricultural productivity, or to contribute to risk reduction and management (Arnold & Dewees 1995). In most farm systems, trees are present for a combination of more than one of these purposes. Multistrata homegardens, for example, incorporate a variety of woody perennials that contribute to nutrient recycling and soil protection and yield produce that supplements output from other parts of the farm system. Reliance on home gardens also helps to spread farm work, output and income more evenly throughout the year (Ninez 1984).

Three factors in particular may influence farmer decisions about tree management to produce saleable products:

- the influence of market opportunities and constraints
- the relationship between tree crops and different factor endowments and needs
- the roles of trees in risk management

Market opportunities and constraints

Research suggests that most farm-level tree management is primarily to meet household needs. Trading in tree products usually develops as local markets emerge for fruits, fuel and other tree products or shortages. Alternatively, trading can develop as increasing demands on the time of household members leave less time for gathering what is needed to meet household needs. In addition, rising cash incomes allow some households the option of purchasing rather than gathering or growing tree products. Households that are managing tree stocks to provide themselves with such products will sell what is surplus to their needs, or will sell more of their output, to generate additional income (Arnold & Dewees 1995).

Markets for tree products can be important to small-scale, resource-poor farmers at this stage in their integration into a market economy when the costs and risks involved are low (e.g., there are low costs of entry, early returns, market channels that serve small-scale as well as large-scale producers), and production systems can be developed incrementally without putting other parts of the farm system at risk. For example, farmers in an area studied in western Kenya, who had increasingly been growing trees to meet their household needs for poles, fruit and fuelwood, expanded their production of these products for sale to local markets as these markets developed. This has become an important part of overall cash strategies of many households, with sales within communities or between neighbours still predominating (Scherr 1995).

Production for urban and industrial markets is more likely to be practised by farmers in areas where the process of agrarian transition has evolved further towards greater involvement in commodity markets and where there has been an evolution towards an entrepreneurial approach to agriculture based on cash crops. Farmers are likely to enter the market for tree products where they lack other income opportunities, as was the case with black wattle in central Kenya (Dewees 1993) or where returns from tree crops appear to be more attractive or stable than from alternative crops, as was the case during the phase when farmers were adopting eucalypts in north India (Saxena 1992).

In these markets, however, farmers can encounter forms of competition and policy constraints that can make it difficult for them to compete. In many situations urban markets for most NTFPs are still being supplied by mining natural stocks, with producers paying little if anything for the raw material, so that the cost of the product delivered to the market consists mainly of labour and transport. In addition, in many countries supplies of some products come from state forests and plantations and are sold at administered prices. Private producers are also frequently subjected to controls on harvesting, transport and sale, designed to protect against illegal felling for sale from state forests. Resulting cumbersome and costly bureaucratic procedures lead to private producers having to depend on intermediaries to market their produce.

Different combinations of market factors affect farmer development of tree stocks to supply urban wood fuel markets in different ways (table 3). In the Sudan, production by farmers is simply not practical in competition with the low-cost supplies from wood generated through agricultural land clearing. In both central Kenya and northern India, on the other hand, the cultivation of trees as wood cash crops did emerge—but then was curtailed in the face of competitive and policy constraints (Dewees and Saxena 1994a). Unless such impediments can be reduced or removed, urban and industrial markets are likely to be less important than local rural markets in most tree-growing situations.

Factor availability and allocation

The varying role of trees in different situations often reflects differences in the availability of the different factors of production—land, labour and capital. Where the amount of arable land is the limiting resource, trees, as a land use that produces low returns per unit of area, are generally restricted to homesteads, boundaries and other niches where they do not compete with the agricultural crops. However, in some agroforestry systems tree outputs complement or supplement crop outputs, thereby increasing total returns per unit of area. Homegardens, with their vertically layered structure of trees, shrubs and ground cover crops making effective use of space above and below the soil surface, provide a notable example of this.

As farm households have increasingly come to depend on income earned from employment off-farm, labour rather than land is widely becoming the main resource limitation determining farmer options. As the growing of trees requires lower inputs of labour to establish and maintain than most other crops, such shifts in the ratio of labour to land may encourage greater reliance on tree crops (table 4). Thus, in central Kenya a study found that it was households with fewest resident adult males that were most likely to retain or establish black wattle woodlots, in preference to using the sites for the growing of the much more labour (and capital) intensive crop of tea (Dewees 1993). In north India it was the more asset-rich households (with significant off-farm income) seeking to minimize labour supervision requirements that were most likely to grow eucalyptus as a crop (Saxena 1992).

Although trees require less capital than most crops to establish and maintain, they can lock up this capital (and the underlying land) for periods of several years, with little if any intermediate return. The experience of farm forestry in north India demonstrated that tree crops may therefore be an option mainly for those who do not rely on that land for household self-sufficiency—such as large-scale farmers or those with sufficient off-farm income (Saxena 1992).

A tree crop that can be appropriate in one set of factor circumstances could therefore be unsuitable in another. Furthermore, these circumstances are often changing, sometimes quite rapidly. Thus, better functioning factor markets, giving increased access to capital and other inputs, could trigger a move away from extensive and site-enhancing uses of tree cover towards the adoption of more valuable crops and intensive land uses.

Containment of exposure to risk

Trees can contribute to risk containment in a number of ways. Trees are widely included in farm systems because they help to even out seasonal peaks and troughs in flows of produce and income and in demands on farm labour. In systems where trees

Table 3. Comparison of wood product markets, and their operation and impact in providing incentives for farmers to cultivate and manage trees

Characteristics of markets and systems of production	Country case		
	Sudan	Kenya	India
Type of wood and tree product markets	charcoal	wattle bark, charcoal, fuelwood, building poles	building poles, fuelwood, pulpwood
Sources of supply that meet market demands	agricultural land clearance	farmer-grown *Acacia mearnsii* woodlots	farmer-grown eucalyptus woodlot
Competing sources of supply	none	plantation-grown wattle for bark and charcoal, land clearance for charcoal, eucalyptus woodlots for building poles and fuelwood	government-grown timber supplies
Time scale and impact of markets on farmer tree growing	never provided any incentive for tree growing	long-term farmer response allowing scope for the emergence of new markets for tree products	short-term farmer response resulting in overproduction and market collapse
Other incentives not directly linked to markets	none of relevance; some irrigation is made available for eucalyptus and *Acacia nilotica,* but it is not economic to grow these species for charcoal on any scale	seed packets and technical advice provided by colonial government and tanning extract companies; before independence, scope for cultivation of other cash crops was limited by legislation	subsidized seedlings and technical advice provided
Earliest adopters of trees growing innovations	no adopters	earliest adopters were landed and wealthy, though later adopters included small-scale farmers as well	earliest adopters were landed and wealthy, later spread to other farmers; some planting financed by urban capital
Comparative advantage of sustainable production systems	only comparative advantage would be in terms of proximity to urban markets; high costs of production mean that it is unlikely sustainable systems of production could be competitive	land-tenure constraints before independence encouraged households to plant trees to establish land rights; trees also favoured by households with labour supervision problems or with low demands for income	low costs of labour and supervision *vis à vis* annual crops; low profitability of other crops; markets for other crops thought to be more unstable than markets for tree products
Bioeconomic constraints to the adoption of tree-growing innovations	low productivity and high costs of growing trees in an arid environment	high opportunity costs for land (tea and coffee more lucrative than trees)	planting on field boundaries caused competition with other crops
Policy constraints to the adoption of tree-growing innovations	no clear policy constraints; bioeconomic constraints are more critical	movement controls on charcoal, price controls, paraffin subsidies	movement controls; large-scale and heavily subsidized government production for the most lucrative markets limited farmer access to them
Characteristics of the ways markets operate	single entrepreneurs control most aspects of the market production and delivery system; heavily integrated and sophisticated markets	more segmented market operation, with transporters providing the crucial link between rural producers and urban markets	movement controls favour the emergence of village agents, who have the dominant role in linking producers with centres of demand

Source: Dewees and Saxena 1994a

Table 4: Trees and land and labour allocation

- Tree planting may be seen as a feasible land-use option when the opportunity costs of using household labour on-farm are high because there are good wage opportunities in other labour markets.
- Where household labour resources are constrained, problems with supervising and hiring in labour to cultivate annual crops more intensively can act as incentives for households to plant or to maintain trees instead of other crops.
- Labour-to-land ratios are often determined by demographic changes in household composition, with older households having a smaller resident labour force on which to draw. The outcome can be the adoption of less labour-intensive forms of land-use, such as tree growing.
- The need to intensively cultivate a holding may be less amongst older households with fewer residents, which may instead be more dependent on savings or on wage remittances from non-resident children for their support. Trees may be planted to maintain a productive crop on land that will eventually comprise the household's inheritance.
- The quality of land within a holding, as well as across holdings in a given agroecological zone, may be highly heterogeneous. This, in turn, may mean that some holdings, or some parts of some holdings, require much more labour to cultivate than others. Trees may be planted in these areas to even out labour demands.
- The sale of land that is in surplus of the household's immediate needs may be undesirable because of intergenerational concerns and the need to retain resources that can be passed on to the next generation. Renting out surplus land may be undesirable because it might jeopardize the tenure holder's long-term rights of ownership. In these circumstances, trees may be planted and maintained, as an alternative to letting the land lie fallow.

Source: Dewees and Saxena 1994b

form a substantial part of farm output (e.g., where homegardens are well developed), tree products are also important in diversifying farm output, thus reducing the exposure of the farm household to price falls or failure on the part of individual crops (Ninez 1984). Farmers also tend to favour trees with multiple uses, as these provide them with more flexibility in responding to changing household needs and market conditions, over single-product species such as eucalypts.

In agricultural systems where other forms of accumulating and holding capital, such as livestock herds, are not available, trees may serve this purpose. As they can be harvested and sold whenever the owner chooses, they are particularly appropriate as a flexible reserve that can be called down in times of emergency, or to fund exceptional financial outlays, such as weddings or the purchase of land (Chambers & Leach 1987). Farmers in arid areas also exploit the resistance of certain trees and woody shrubs to drought to create a buffer to be drawn on in periods of low rainfall. Trees may also be present in part because they help protect crops and contribute to maintaining soil fertility.

Farmers will use trees that complement or supplement existing crops in different ways and plant them in locations where they do not compete with crops. Trees and tree formations that help protect crops and farm land are likely to be favoured in the allocation of land. Thus the cultivation of *Prosopis cineraria* as an intercrop in Rajasthan reflects its value in enriching the soil and protecting the adjacent pearl millet against wind, as well as its value as a source of fodder (Jodha 1995). In contrast, the fact that the eucalypts planted around fields caused substantial reduction in the yield of nearby crops was a factor in the decision of farmers in Uttar Pradesh to discontinue cultivation of these trees on their cropland (Saxena 1991).

It is important to recognize the above distinctions in the role of trees in farm strategies. Farmers apparently use lower implicit discount rates in making decisions about activities that can contribute to risk minimization—or to meeting self-sufficiency needs—than they do to income-generating activities. In other words, farmers may accept low yields from trees that enable them to reduce their exposure to risk but expect much higher yields from trees they grow as cash crops.

The adoption or non-adoption of tree crops may also be determined by whether or not they contribute to the farmer's security of tenure. When rights to use of land may be established or secured by planting trees on or around the property, this may encourage people to plant trees (or lead landowners to prohibit their tenants from doing so). Where the state is empowered to appropriate forest or woodland areas, people are frequently unsure about their rights to grow trees—and are likely to be reluctant to do so.

The most important factor affecting tree growing in many systems appears to be the existence or absence of rights of exclusion—in particular, exclusion of grazing on the household's fallow fields. Where this is discouraged (e.g., because livestock management is important) or where it cannot be enforced, tree growing is unlikely to take place. Where farmers can exercise this degree of control, economic factors are probably more important than land tenure in determining decisions about growing trees (Cook & Grut 1989, Godoy 1992, Shepherd 1992, Warner 1993).

Conclusions

The adoption of a commercial NTFP activity within an agroforestry system is conditioned by a range of economic as well as physical factors. For some, the scale or nature of the product or process may not lend itself to domestication at the farm level. For others, farm-level production may not be practical or competitive or will not be compatible with other aspects of multiple-objective systems for the livelihood of the farm household. Conversely, some species that are adopted primarily for other reasons may provide commercially exploitable NTFPs as a by-product (e.g., the oils distilled from leaves of eucalypts grown to produce wood).

One aspect likely to require close attention in the process of identification of viable products and activities is the extensive and often rapid change that is occurring in NTFP use. Production and use of many products will decline in face of adverse market or cost developments. There is a danger of focusing on 'sunset' products just because they are important to many people at present. Doing so may adversely affect the producers' ability to respond to more favourable and appropriate options as they arise. At the same time, shifts in broader economic parameters will open up potentials for other products, which may not be recognized in good time if attention focuses just on the present and the past.

A second important aspect is the dual impact that increasing exposure to market forces can have on the place of tree crops within farming systems. Access to markets can mean not only expanded commercial opportunities for tree products but also increased access to fertilizers and other inputs that could permit more intensive land uses. It needs to be kept in mind, therefore, that increased wealth, or improved functioning of land, labour and capital markets that would enable farmers to respond more efficiently to imbalances in factor availability, could be accompanied by a reversal of some of the current shifts towards more tree cover on farms.

A third key aspect is that farmer responses to NTFP market opportunities are often distorted by policy barriers. Higher priority should be given to changing policies and practices that presently constrain farmers' access to markets and that depress market prices for their tree products. These commonly include lack of market information, poorly functioning trading systems serving small producers, competition from subsidized supplies from state forests and plantations, fuelwood prices depressed by subsidies to alternative fuels, and restrictions on private harvesting and trading of some tree products. Removing or reducing such barriers could often be more effective and efficient than subsidies to induce tree planting and husbandry (Dewees & Scherr 1996).

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References

Anderson A.B. & Ioris E.M. 1992. The logic of extraction: resource management and income generation by extractive producers in the Amazon. In: *Conservation of neotropical forests*, ed. K.H. Redford & C. Padoch. New York, Columbia University Press.

Arnold J.E.M. & Dewees P.A., eds. 1995. *Tree management in farmer strategies: responses to agricultural intensification*. Oxford University Press, Oxford. 292 p.

Arnold J.E.M., Liedholm C., Mead D. & Townson I.M. 1994. *Structure and growth of small enterprises using forest products in southern and eastern Africa*. OFI Occasional Papers no. 47, Oxford Forestry Institute, Oxford, UK; Growth and equity through microenterprise investments and institutions, Gemini Working Paper no. 48, Bethesda, Maryland, USA.

Beer J. de & McDermott M. 1989. *The economic value of non-timber forest products in Southeast Asia*. Netherlands Committee for IUCN, Amsterdam.

Browder J.O. 1992. The limits of extractivism: tropical forest strategies beyond extractive reserves. *Bioscience* 42 (3):174–182.

Chambers R. & Leach M. 1987. *Trees to meet contingencies: savings and security for the rural poor*. Discussion Paper 228. Institute of Development Studies, University of Sussex, Brighton, UK.

Cook C.C. & Grut M. 1989. *Agroforestry in sub–Saharan Africa: a farmer's perspective*. Technical Paper 42. The World Bank, Washington.

Davies A.G. & Richards P. 1991. *Rain forest in Mende life: resources and subsistence strategies in rural communities around the Gola North Forest Reserve (Sierra Leone)*. A report to ESCOR. Overseas Development Administration, London.

Dewees P.A. 1993. *Social and economic incentives for smallholder treegrowing: case study for Murang'a District, Kenya*. Community Forestry Case Study 5. FAO, Rome.

Dewees P.A. & Saxena N.C. 1994a. Wood product markets as incentives for farmer tree growing. p 198–241. In: *Tree management in farmer strategies: responses to agricultural intensification*, ed. J.E.M. Arnold & P.A. Dewees. Oxford University Press, Oxford.

Dewees P.A. & Saxena N.C. 1994b. Tree planting and household land and labour allocation: case studies from Kenya and India. p 242–270. In: *Tree management in* *farmer strategies: responses to agricultural intensification*, ed. J.E.M. Arnold & P.A. Dewees. Oxford University Press, Oxford.

Dewees P.A. & Scherr S.J. 1996. *Policies and markets for non-timber tree products*. EPTD Discussion Paper No. 16. International Food Policy Research Institute, Washington.

Falconer J. 1990. *The major significance of 'minor' forest products: the local use and value of forests in the West African humid forest zone*. Community Forestry Note 6. FAO, Rome.

Falconer J. 1994. Non–timber forest products in southern Ghana: main report. Republic of Ghana Forestry Department and Overseas Development Administration, Natural Resources Institute, Chatham.

Falconer J. &. Arnold J.E.M. 1989. *Household food security and forestry: an analysis of socioeconomic issues*. Community Forestry Note 1. FAO, Rome.

FAO. 1987. *Small-scale forest based processing enterprises*. Forestry Paper 79. FAO, Rome.

Fernandes W. & Menon G. 1987. *Tribal women and forest economy*. Indian Social Institute, New Delhi, India.

Fernandes W., Menon G. & Viegas P. 1988. Forests, environment and tribal economy: deforestation, impoverishment and marginalisation in Orissa. Indian Social Institute, New Delhi, India.

Fisseha Y. 1987. Basic features of rural small-scale forest-based processing enterprises in developing countries. In: *Small-scale forest based processing enterprises*. Forestry Paper 79. FAO, Rome.

Godoy R.A. 1992. Determinants of smallholder commercial tree cultivation. *World Development* 20(5):713–725.

Gunatilake H.M., Senaratine D.M.A.H. & P. Abeygunawardena. 1993. Role of nontimber forest products in the economy of peripheral communities of Knuckles National Wilderness area of Sri Lanka. *Economic Botany* 47(3):275–281.

Haggblade S. & Hazell P. 1989. Agricultural technology and farm–nonfarm linkages. *Agricultural Economics* 3:345–364.

Haggblade S. and Liedholm C. 1991. *Agriculture, rural labor markets, and evolution of the rural nonfarm economy*. Gemini Working Paper No. 19. Growth and Equity through Microenterprise Investments and Institutions (Gemini) Project, Bethesda, Maryland, USA.

Hecht S.B., Anderson A. & May P. 1988. The subsidy from nature: shifting cultivation, successional palm forests and rural development. *Human Organization* 47(1):25–35.

Hopkins, J.C., Scherr S.J. & Gruhn P. 1994. Food security and the commons: evidence from Niger. Draft report to USAID. IFPRI, Washington.

Jodha N.S. 1990. Rural common property resources: contributions and crisis. *Economic and Political Weekly, Quarterly Review of Agriculture* 25(26).

Jodha N.S. 1995. Trends in tree management in arid land use in western Rajasthan. In: *Tree management in farmer strategies: responses to agricultural intensification*, ed. J.E.M. Arnold & P.A. Dewees. Oxford University Press, Oxford.

Kamara J. N. 1986. *Firewood energy in Sierra Leone: production, marketing and household use patterns*. Verlag Weltarchiv Studies no. 9. Hamburg, Germany.

Leach M. & Fairhead J. 1994. The forest islands of Kissidougou: social dynamics of environmental change in West Africa's forest–savanna mosaic. Report to ESCOR. Overseas Development Administration, London.

Liedholm C. & Mead D.C. 1993. *The structure and growth of microenterprises in southern and eastern Africa*. Gemini Working Paper no. 36. Growth and Equity through Microenterprise Investments and Institutions (Gemini) Project. Bethesda, Maryland, USA.

Lim H.F. & Jamaluddin I. 1994. *The uses of non-timber forest products in Pasoh Forest Reserve, Malaysia*. Research Pamphlet no. 113. Forest Research Institute, Malaysia.

Madge C. 1990. Money, medicine and masquerades: women, collecting and rural development in the Gambia. PhD thesis, University of Birmingham, UK.

May P.H., Anderson A. & Frazo M. 1985. Babaçu palm in the agroforestry systems in Brazil's mid-north region. *Agroforestry Systems* 3(39):275–295.

Nguyen Thi Yen, Nguyen Quang Duc, Vu Manh Thien, Dang Duc Phuong & Ogle B.A. 1994. Dependency on forest and free products for food security: a pilot study in Yen Huong Commune, Ham Yen District, Tuyen Quang Province, North Vietnam. Working Paper 250. Swedish University of Agricultural Sciences, Uppsala.

Niñez V.K. 1984. *Household gardens: theoretical considerations on an old survival strategy.* Potatoes in Food Systems Research Series, Report No. 1. International Potato Center, Lima, Peru.

Padoch C. 1988. The economic importance and marketing of forest and fallow products in the Iquitos Region. In: *Swidden-fallow agroforestry in the Peruvian Amazon*, ed. W.M. Denevan & C. Padoch. Advances in Economic Botany 5. New York Botanical Garden, New York.

Padoch C. 1995. Creating the forest: dayak resource management in Kalimantan. p 3–12. In: *Society and non-timber forest products in tropical Asia*, ed. J. Fox. East–West Center Occasional Papers, Environment Series no. 19. East–West Center, Honolulu, Hawaii.

Peluso N.L. 1989. The role of non-timber forest products in shifting cultivation communities and households: current knowledge and prospects for development. Field Document No. II–2, Government of Indonesia/FAO Project UTF/INS/065/INS: Forestry Studies, Jakarta.

Peluso N.L. 1994. Fruit trees and family trees in an Indonesian rainforest: property rights, ethics of access, and environmental change. Paper prepared for the Agrarian Studies Seminar, Yale University, 28 January 1994.

Richards M. 1993. *Commercialization of non-timber forest products in Amazonia*. NRI Socio-economic Series no. 2. Natural Resources Institute, Chatham, UK.

Saxena N.C. 1991. Crop losses and their economic implications due to growing of eucalyptus on field bunds: a pilot study. *Agroforestry Systems* 16(3):231–245.

Saxena N.C. 1992. Adoption of a long-gestation crop: eucalyptus growers in north–west India. *Journal of Agricultural Economics* 18(3):257–267.

Scherr S.A. 1995. Tree growing to meet household needs: farmer strategies in western Kenya. p 141–173. In: *Tree management in farmer strategies: responses to agricultural intensification*, ed. J.E.M. Arnold & P.A. Dewees. Oxford University Press, Oxford.

Shepherd G. 1992. Managing Africa's tropical dry forests: a review of indigenous methods. ODI Agricultural Occasional Paper 14. Overseas Development Institute, London, UK.

Siebert S. and Belsky J.M. 1985. Forest product trade in a lowland Filipino village. *Economic Botany* 39(4):522–533.

Townson I.M. 1995a. *Forest products and household incomes: a review and annotated bibliography*. OFI Tropical Forestry Papers 31. Centre for International Forestry Research, Bogor, Indonesia, and Forestry Research Institute, Oxford.

Townson I.M. 1995b. *Patterns of non-timber forest products enterprise activity in the forest zone of southern Ghana*. Report to the ODA Forestry Research Programme. Oxford Forestry Institute, Oxford.

Warner K. 1993. *Patterns of tree growing by farmers in eastern Africa*. OFI Tropical Forestry Papers 27. Oxford Forestry Institute, Oxford, UK, and International Centre for Research in Agroforestry, Nairobi, Kenya.

Domestication of valuable tree species in agroforestry systems: evolutionary stages from gathering to breeding

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Abstract

The domestication of a plant species involves its manipulation and cultivation for specific uses. Through breeding and selection this process can result in rather uniform plant populations with a narrow genetic base. The cultivation of such selected varieties is the last stage in an evolutionary continuum in people–plant interactions. In this evolutionary process a progressively closer interaction between people and plant resources takes place with increasing inputs of human energy per unit of exploited land.

Three dimensions of domestication may be distinguished, i.e., domestication of the biophysical as well as the human environment and domestication of the plant species. The recognition of these different dimensions is of particular importance with respect to the domestication of tree species, because commercial tree utilization usually starts with the exploitation of trees from the wild in natural forests. The domestication of the forest environment involves, in the first instance, the change from uncontrolled utilization of the wild tree products to their controlled exploitation. The second phase consists of the purposeful cultivation of wild trees in either a resource-enriched natural environment or in indigenous agroforestry systems such as forest gardens. The cultivation of domesticated trees in either agroforestry systems or commercial tree-crop plantations is the last stage of this domestication process.

These three stages of domestication are associated with specific socioeconomic and ecological conditions. During the first stage of domestication of the forest environment the management practices are, in first instance, directed at defining user rights. In the second stage, management practices with biological objectives are also undertaken. These focus at the manipulation of the growing conditions of the tree and of the tree's morphological characteristics. During the third stage of plant domestication the genetic constitution of the tree population is also modified. The recognition of various phases of forest and tree domestication provides for a better understanding of the different options for the production of commercial tree crops in agroforestry systems, under location- and time-specific conditions. It also illustrates that efforts to domesticate commercial forest resources should be focused both on the manipulation of morphological characteristics of a tree (its environment) and on the modification of the tree's genetic characteristics.

Introduction: the nature of plant domestication

The concept of plant domestication is interpreted differently by various scientists (Leakey & Newton 1994). Some have defined it in a relatively narrow sense as a human-induced change in the genetics of a plant, to adapt it to human agroecosystems; this process ultimately culminates in the plant's inability to survive in natural ecosystems (Harlan 1975). Others have defined plant domestication in a broader sense, as a process of naturalization of plant species towards specific human-induced growing conditions, during which an increased adoption for specific uses normally takes place. For instance, Prance (1994) states that extraction of non-timber products from the forests may be considered as the initial phase of domestication of valuable tree species. During the domestication process, wild plants are first brought to some form of management. In a later stage of the process, the wild plants are actively cultivated. Only in its final phase does the process involve the selection and breeding of selected genotypes resulting in rather uniform plant populations with a narrow genetic base.

The concept of plant domestication can thus be interpreted in a restrictive sense as a process of changing of the biological characteristics of a species, or in a more extended sense as a process of change in plant exploitation practices, which brings with it changes in the plant's morphology and genetics, as well as in its growing environment. Some authors (Chase 1989) have even extended the concept of domestication from the conventional biological definition to a more inclusive one, i.e., the process of increasing human–plant interactions. According to this interpretation, domestication not only involves a change in plant characteristics and the biophysical environment, it also involves adaptations in human activities with respect to the use and manipulation of valuable natural resources. The various dimensions involved in the process of domestication can be clarified by relating it not only to plant species but also to landscapes: 'A domesticated landscape is one that has been modified by humans from its highly biodiverse state to a state that may still have high biodiversity, but which contains a greater concentration of resources useful to humans' (McKey et al. 1993).

Such an integrated concept of domestication within the landscape seems particularly apt when we consider agroforestry. Many agroforestry systems develop as a result of the gradual modification of forests, by enriching them with useful crops. Such enrichment not only involves agricultural crops; in many cases it also concerns trees producing non-timber forest products (NTFPs). The first phase of domestication of NTFP trees involves a process of concentration of naturally occurring useful tree resources in natural forests. In subsequent phases, also, new species may be introduced into these forests. At first, this will take the form of transplanting of wildlings or seeding of wild species. But gradually selected varieties will also be introduced. As a result, the natural forests gradually change into a mosaic of managed forests and agroforestry systems (Posey 1985, De Jong 1995, Wiersum submitted). The process of domestication can therefore be considered as an evolutionary process, from gathering to breeding, during which changes at the level of both the landscape system and the plant species occur. Concomitantly, a progressively closer interaction between the tree resources and people takes place. The domestication of NTFP trees in agroforestry systems thus involves a coevolution of human society and nature (McKey et al. 1993, Dove 1994), with the combined processes of natural and cultural selection creating a great diversity of human-influenced agroforest types.

This coevolutionary process consists of various stages along a nature–culture continuum. These stages can be associated with specific socioeconomic and ecological conditions (Wiersum submitted). To understand under what conditions farmers are interested in incorporating commercial NTFP trees in their land-use system, it is necessary to understand the specific characteristics of these different stages. This will allow identification of the kind of domestication practices that offer the most scope under specific socioeconomic conditions and for given agroforestry systems. In this paper an analytical model will be presented, to contribute towards a better understanding about various options for incorporating NTFP trees in agroforestry systems under location- and time-specific conditions. The process of domestication of NTFP trees in agroforestry systems is represented by several phases in tree management with associated ecological and institutional conditions; these phases are arranged sequentially along a gradient of increasing input of human energy per unit of exploited land.

Production of non-timber products in agroforestry systems

The potential of tropical forests to provide a variety of non-timber forest products is at present widely acknowledged (e.g., Beer & McDermott 1989, Falconer 1990, Plotkin & Famolare 1991, Nepstad & Schwartzman 1992, Ros-Tonen et al. 1995). Such products include a variety of food products as well as diverse commercial crops such as gums, resins, rattan. In the past it was often assumed that mainly tribal people who were engaged in traditional methods of forest resource use, such as gathering and swiddening, collected such products for their subsistence. But it is increasingly acknowledged that there exists a long history of commercial trade in non-timber forest products (Dunn 1975), coupled with an active management of these products (e.g., Anderson 1990, Dove 1994). When considering the production of non-timber forest products, it is therefore not appropriate to assume a dichotomy between the gathering of NTFPs from wild trees in a natural forest and the cultivation of domesticated NTFP trees in an agroforestry system. Rather, attention should be focused on the various phases of domestication and on the creative role of human culture in regulating tree resources for human use (Hladik et al. 1993, Wiersum submitted).

Agroforestry is a generic name for a variety of land-use systems in which trees are purposively combined with agricultural crops and/or livestock (table 1). With respect to NTFP trees, a wide range of agroforestry and other forest systems may be distinguished (Olofson 1983, Anderson 1990, Gomez-Pompa & Kaus 1990, Wiersum submitted):

- Native forests in which NTFPs are protected: Specific areas or specific tree species in native forests that are favoured and protected because of their value for providing useful materials.
- Resource-enriched native forests: native forests, either old growth or fallow vegetation, whose composition has been altered by selective protection and incidental or purposeful propagule dispersion of food and/or commercial species.
- Reconstructed natural forests: (semi-) cultivated forest stands with several useful planted trees, together with tolerated or encouraged wild species of lesser value, and non-tree plants (herbs, lianas), composed of mainly wild species.
- Mixed arboriculture: cultivated mixed stands, almost exclusively of planted, and often domesticated, tree species.
- Interstitial trees on croplands: either naturally regenerated and protected trees, or planted and sometimes domesticated trees scattered over agricultural fields.
- Commercial plantations with associated agroforestry practices: plantations of domesticated tree crops that are (temporarily) intercropped with food plants or grazed by livestock.

This categorization is a first approximation of the varied and often complex agroforestry systems incorporating NTFP trees. The different categories are not discrete: gradual transformations from one category to another may take place. Many of these systems are indigenous in nature, and they have gradually evolved in response to changing conditions. Such changes may involve a variety of ecological, socioeconomic, cultural and political factors. The four most important changes (Gilmour 1990, Shepherd 1992, Arnold & Dewees 1995) that may affect agroforestry systems are—

- changed ecological conditions, such as resource depletion or land degradation
- changed technological conditions caused by the introduction of new agricultural

Table 1. Examples of different agroforestry systems incorporating NTFP tree species

Main types	Examples
Gathering of non-timber products in natural forests	
Individually claimed trees	tree marking, e.g., Southeast Asia (Persoon & Wiersum 1991)
Resource-enriched natural forests	
Enriched natural forests	enriched rainforest groves in Amazon (Posey & Balée 1989, Anderson 1990) and S.E. Asia (Jong 1995)
Enriched fallows	fallows enriched with fruit/tree crops in S.E. Asia (Foresta & Michon 1993, Salafsky 1995) and Amazon (Posey & Balée 1989, Denevan & Padoch 1987)
	palm fallows in Amazon, W. Africa and Indonesia (Anderson 1987)
	rattan fallow cultivation in Borneo (Weinstock 1983)
Reconstructed (natural) forests	
Forest gardens	Ifugao woodlots, Philippines (Olofson 1983)
	mixed damar gardens, Sumatra (Mary & Michon 1987)
	mixed fruit and rubber gardens, Borneo/Sumatra (Salafsky 1995)
Mixed arboriculture	
Homegardens	pantropical (Landauer & Brazil 1990)
Smallholder plantations	pre-Hispanic cacao plantations Mexico (Gomez-Pompa & Kaus 1990)
	mixed damar/coffee gardens, Sumatra (Mary & Michon 1987)
	mixed rubber gardens, Indonesia (Dove 1994, Salafsky 1995)
Interstitial trees on croplands	
Fruit tree cultivation	farmed parklands, semi-arid West Africa (Pullan 1974, Raison 1988)
	interstitial trees on croplands in Asia (Olofson 1983)
	fruit trees on bunds along rice-fields, S.E. Asia (Grandstaff et al. 1986)
Commercial plantations with associated agroforestry practices	
	intercropping in commercial tree-crop plantations (Nair 1983, Wessel 1992)
	livestock grazing in commercial tree-crop plantations (Payne 1985)

and forestry techniques
- changed economic conditions, such as development of new markets and increased commercialization, changed demands for forest products and changed opportunities for off-farm employment
- changed sociopolitical conditions, e.g., population growth and migration, in-

creased interaction with other ethnic groups, changed tenure conditions including gradual privatization or nationalization of forest lands, development of state organizations for forest management and rural development

These changes increase pressure on forest and tree resources. In several cases, this has resulted in deforestation and forest degradation. But in other cases, farmers have reacted by modifying their management strategies, e.g., by intensifying the cultivation of valuable tree species (Dove 1994, Arnold & Dewees 1995). For instance, management for fruit production may evolve from collecting wild fruits in the forest, through their cultivation in enriched fallows and home gardens, to fruit production in orchards (Verheij 1991).

Such changes in indigenous agroforestry systems demonstrate that many local communities have been actively engaged in domesticating the landscape as well as valuable tree species. Efforts to stimulate the further adoption of domesticated NTFP trees in agroforestry systems will be most successful if they build upon and strengthen such indigenous processes of domestication. This is possible only when a good understanding exists about the various dimensions of domestication in agroforestry systems, as well as the specific characteristics of the various phases during this process. To obtain such understanding, it is useful to consider the various dimensions of tree management in more detail.

Management of trees in agroforestry systems

Often, the concept of forest or agroforest management is used with respect to the conscious manipulation of the environment to promote the maintenance or productivity of forest resources (e.g., Anderson 1990). Such a definition is not complete, however; it limits management towards the implementation of certain technical activities. It does not incorporate the notion that management includes not only the execution of activities but also the process of making and effecting decisions about the use and conservation of agroforestry systems, as well as organizing the management activities (Wiersum submitted). Agroforestry management can therefore better be conceptualized as referring to the total set of technical and social arrangements involved in the protection and maintenance of agroforestry resources for specific purposes, and the harvesting and distribution of the products.

Technical management practices

To date, most studies on domestication of NTFP trees in agroforestry systems have concentrated on the scope for either improved regeneration practices or selection and breeding of specific NTFP species (Leakey & Newton 1994). This illustrates that many researchers interpret the process of NTFP domestication as involving basically a change in biological properties of NTFP trees, rather than as a process of change in human–plant interactions. When domestication is considered in this more inclusive perspective, it becomes clear that management practices in agroforestry systems do involve more than purposeful regeneration of selected tree species. Management practices also include the stimulation of the production of the required products and the protection of valuable tree species against damaging agents (Gomez-Pompa & Kaus 1990, Campbell et al. 1993, Wiersum submitted).

When considering how and to what extent domestication relates to these various management practices, it is important to recognize that it is not correct to assume that planting trees is the first stage in agroforestry management. Although this is true when bare land has to be replanted, it is not the case when agroforestry systems are developed in existing natural forests. In the latter case, the first phase of management consists of protecting valuable tree species through controlled harvesting techniques. Such controlled utilization of forest products involves not only biologically oriented practices but also the definition of user rights (Gilmour 1990). If ample forest resources are present, there is no interest in forest protection or tree planting practices, and management practices may then be confined to defining use rights. But if forest resources are perceived as becoming scarcer, management may be intensified by also implementing biologically oriented practices that limit overexploitation, e.g., limiting the harvested amounts or harvesting rotationally. This management may further be intensified by the execution of practices aimed at increasing the presence or productivity of the desired species. Measures may also be developed to favour the useful species indirectly by manipulating the biophysical environment and removing less desirable competitors.

Thus, management practices consist of a group of deliberate activities for the conservation and possible enhancement of useful forest resources and the controlled utilization of those resources. These practices may be directed at influencing either the forest resource directly or its biophysical and social environment. Much variation in the kind and intensity of management practices may occur between various agroforestry systems, depending on the kind of resources being considered and on the kind of management system. As indicated earlier, gradual transformations from one system to another may take place. During this progression, valuable tree species are gradually segregated from the natural forest and cultivated in increasingly specialized agroecosystems. Concomitantly, the vegetation structure becomes increasingly systematized, with randomly spaced trees of random age giving way to even spacing of even-aged trees. Furthermore, the propagation methods change from using seeds to using clonal material, and the location of regeneration units changes gradually from a forest environment to open-field conditions.

Organization of forest management

Agroforestry management involves not only carrying out resource management practices but also the process of making decisions about: (1) the objectives of management, (2) the kind of activities to be carried out by various persons, and (3) the distribution of products. In addition, management also requires the existence of a control system that ensures that the proposed activities are carried out as planned. In most studies on tree domestication no attention is given to such organizational aspects. It seems to be assumed that the production of NTFPs takes place within clearly delineated management units and under a clearly defined management authority. In many cases, however, this is not necessarily the case. In many instances agroforestry development is planned in areas that are characterized by a pluriformity with respect to land and tree tenure (Fortmann & Bruce 1988, Fortmann & Nihra 1992). Several agroforestry systems are managed not by private owners but by local communities who act cooperatively in managing agroforestry systems as a common resource. Such agroforestry systems are subject to individual use, but not to private ownership. The utilization of these resources is governed by a set of regulations on independent user rights of members of a specific user group (Messerschmidt 1993). For such common-property forest management regimes to function properly, there should exist a local forest management institution with the following characteristics (Gibbs & Bromley 1989):

- a structure for group members to make decisions on the required resource management practices
- group control over the behaviour of the group members, which ensures that the planned management practices are carried out

- control over the distribution of collected forest products
- ability to exclude outsiders

The common-property management regimes are mostly characterized by regulations defining user rights and measures for controlling overexploitation. Often no measures for stimulating biological production are included (Gilmour 1990). But when the management is further intensified by investing labour to increase productivity, the tenure regime often shifts from common-property rights to private ownership rights (Shepherd 1992).

Evolutionary stages in the process of tree domestication in agroforestry

According to the basic principles of agroforestry management, the process of domestication of valuable tree species in agroforestry systems may be characterized as a general evolution from extraction of products from the natural forests under common property regimes to the cultivation of domesticated tree crops on private lands. This evolutionary process thus involves both technical and ecological changes as well as institutional changes. Although examples of different stages of this evolutionary process have been described by various authors, to date the systematic comparative analysis of the various stages of domestication has received little attention.

In an attempt to improve understanding about the evolution in forest–people interactions, Wiersum (submitted) has developed a model in which various forest exploitation and management activities are arranged along a gradient of evolutionary stages in people–forest relations. This model was based on a model by Harris (1989) in which various stages in exploitation of agricultural crops were arranged sequentially along a gradient of increasing input of human energy per unit of exploited land. On the basis of the principles of forest management, three major categories of forest management practices may be discerned. These categories can be conceived as representing progressive phases with respect to the input of human energy per unit of exploited forest, i.e.—

- controlled utilization of forest resources
- protection and maintenance of forest stands
- purposeful propagation of valuable forest components through the regeneration of wild or domesticated trees

Consequently, three major thresholds may be postulated between the various phases of forest–people interactions (table 2). The first is between uncontrolled and controlled procurement of wild tree products in the natural forests. As indicated above, the control of forest utilization primarily involves the definition and control of use rights; this requires social transaction costs with respect, for example, to time spent on mobilization, decision making and control. Control measures with a biological objective are developed in the second instance. The second threshold is between controlled procurement of wild products and purposeful regeneration of valuable tree species. And the third threshold is between the cultivation of wild and domesticated tree species; the domesticated trees may be propagated through genotype or phenotype variants.

A gradual transformation of the natural ecosystem into an agroecosystem occurs concomitantly with this increasing input of human energy per unit of exploited forest land. In addition, the human intervention in the reproductive biology of tree species intensifies (table 2). This process of progressively closer interaction between people and forest resources is associated with various socioeconomic trends. In the first place, the socioeconomic conditions relating to forest utilization change: increasing sedentarization, increasing population density, and a gradual shift from a subsistence economy to commercialization. In the second place, the complexity of the indigenous rules and regulations change, with common property rights gradually becoming changed into private land and tree tenure rights. Thus, the forests and trees are incorporated in an increasingly more complex cultural environment (table 3).

This model should not be regarded as an explanatory model indicating unidirectional and deterministic trends, in which the various phases represent preordained steps on a ladder of increasingly 'advanced' stages of general societal development (cf. Harris 1989). In effect, in many areas different agroforestry types may coexist, with each type occupying a specific landscape (e.g., Posey 1985) or tenurial niche (Fortmann & Nihra 1992). As agroforestry systems are mostly a component of an integrated farming system, the evolutionary trends are anything but straightforward. Depending on their role in the local farming systems the management practices may be either intensified or deintensified in response to agricultural intensification (Belsky 1993) or to more general changes in socio-economic conditions (Balée 1992). Nonetheless, the model may assist in clarifying the various stages in the process of the domestication of valuable tree species in agroforestry systems. It illustrates the various phases in the process of domestication of forest resources and identifies the general relations between tree management practices and ecological and institutional conditions. This information can assist in assessing what kind of activities might be considered when stimulating further domestication of NTFP trees in various categories of agroforestry systems (table 1).

Table 2. Major categories of indigenous forest/tree utilization and management practices

Threshold	Utilization system	Plant-exploiting practices	Ecological effects
	uncontrolled procurement of wild tree products	casual gathering/ collecting	incidental dispersal of propagules, no transformation of natural vegetation composition and structure
Controlled utilization	controlled procurement of wild tree products	more or less systematic gathering, collecting	same
		systematic collection with protective tending of valuable tree species	reduction of competition, limited transformation of forest structure composition
Purposeful regeneration	cultivation of wild trees	selective cultivation by transplanting of wildings and/or dispersal of seeds, vegetative propagules in forest environment	purposeful dispersal of propagules to new habitats, practical transformation of forest structure, composition
		tree-crop cultivation (possibly in combination with annual crops)	land clearance, total or almost total transformation of forest structure, composition
Domestication	production of domesticated trees	cultivation of domesticated trees in tree-crop plantations	propagation of genotype and phenotype variants, land clearance and soil modification inputs of fertilizer and pesticides

Table 3. Institutional arrangements in indigenous forest and tree management and utilization practices

Utilization system	Socioeconomic conditions	Indigenous institutions with respect to utilization
Uncontrolled procurement of wild tree products	segmented societies, low population density, subsistence economy	open acces
Controlled procurement of wild tree products	low population density, incipient social stratification at community level (often coupled with formal state regulations and dual economic system)	common property rights, sometimes priority rights to valuable tree species
Systematic collection of wild tree products and protective tending of valuable tree species	increased social stratification and incipient commercialization at local level (often coupled with formal state regulations and dual economic system)	combined common property rights on forests and private priority rights on claimed trees
Selective cultivation of wild trees	increased population density and socioeconomic stratification	priority rights to forest plots for tree planters
Tree-crop cultivation	medium-high population density, increased incorporation in market economy	private land and tree rights
Production of domesticated trees in plantations	high population density, fully commercialized resource use	private land and tree rights

Conclusion

The domestication of a plant species involves manipulating and cultivating plants for specific uses. Domestication of NTFP trees in agroforestry systems is a multifaceted process in which a progressively closer interaction between people and plant resources takes place. This process consists of three dimensions:

- acculturalization: the incorporation of trees in an increasingly complex cultural environment through the formation of management entities and the formulation of rules and regulations for resource utilization and management.
- modification of the biophysical environment: the protection and stimulation of production of useful trees in natural forests, the partial clearing of natural forests, followed by the planting of useful wild species; also the manipulation of the biophysical environment to stimulate production of the valuable tree species.
- modification of a tree's biological characteristics: the manipulation of its morphological and genetic characteristics.

The utilization of tree species usually starts with the exploitation of trees from the natural forests. Gradually, uncontrolled utilization of the wild tree products is changed to controlled exploitation. Subsequently, wild trees may be purposefully cultivated in either a resource-enriched natural environment or in agroforestry systems, such as forest gardens. The cultivation of selected varieties of trees in either mixed tree plantations or commercial tree-crop plantations is the last phase of this domestication process. Each of these phases is characterized by specific conditions with respect to the ownership and management responsibility, as well as ecological conditions.

The recognition of these various stages of the domestication process is important for understanding the scope for domestication of commercial NTFP tree species in agroforestry systems. It allows better understanding of the various options for the production of commercial tree crops under different ecological and socioeconomic conditions. It demonstrates that the willingness of farmers to adopt commercial cultivation of NTFP trees in agroforestry systems depends not only on access to markets but also on prevailing management conditions. It illustrates that efforts to domesticate NTFP trees in agroforestry systems should focus on both technical and institutional aspects of agroforestry management as well as their interrelations. It also illustrates that efforts to domesticate tree resources in a biological sense should focus not only on modification of a tree's genetic constitution but also on options for modifying a tree's morphological characteristics and its biophysical environment.

References

Anderson A.B. 1987. Management of native palm forests: a comparison of case studies in Indonesia and Brazil. p 155–167. In: *Agroforestry: realities, possibilities and potentials*, ed. H.L. Gholz. Martinus Nijhoff, Dordrecht, Netherlands.

Anderson A.B. 1990. Extraction and forest management by rural inhabitants in the Amazon estuary. p 65–85. In: *Alternatives to deforestation: steps towards sustainable use of the Amazon rain forest*, ed. A.B. Anderson. Columbia University Press, New York.

Arnold J.E.M. & Dewees P.A., eds. 1995. *Tree management in farmer strategies: responses to agricultural intensification.* Oxford University Press, Oxford.

Balée W. 1992. People of the fallow: a historical ecology of foraging in lowland South America. p 35–57. In: *Conservation of neotropical forests, working from traditional resource use*, ed. K.H. Redford & C. Padoch. Columbia University Press, New York.

Beer J.H. de & McDermott M.J. 1989. *The economic value of non-timber forest products in Southeast Asia.* IUCN, Amsterdam. 175 p.

Belsky J.M. 1993. Household food security, farm trees, and agroforestry: a comparative study in Indonesia and the Philippines. *Human Organization* 52(2):130–141.

Campbell B., Grundy I. & Matose F. 1993. Tree and woodland resources—the technical practices of small-scale farmers. p 29–62. In: *Living with trees, policies for forestry management in Zimbabwe*, ed. P.N. Bradley & K. McNamara. World Bank Technical Paper No. 210. World Bank, Washington, DC.

Chase A.K. 1989. Domestication and domiculture in northern Australia: a social perspective. p 42–54. In: *Foraging and farming, the evolution of plant exploitation*, ed. D.R. Harris & G.C. Hillman. Unwin Hyman, London.

Denevan W.M. & Padoch C., eds. 1987. Swidden-fallow agroforestry in the Peruvian Amazon. *Advances in Economic Botany* 5:1–107.

Dove M.R. 1994. Transition from native forest rubbers to *Hevea brasiliensis* (Euphorbiaceae) among tribal smallholders in Borneo. *Economic Botany* 48(4):382–396.

Dunn F.L. 1975. *Rain-forest collectors and traders: a study of resource utilization in modern and ancient Malaya.* Monographs, Malaysian Branch Royal Asiatic Society No. 5. Kuala Lumpur. 151 p.

Falconer J. 1990. *The major significance of 'minor' forest products: the local use and value of forests in the West African humid forest zone.* Community Forestry Note No. 6. FAO, Rome. 232 p.

Foresta H. de & Michon G. 1993. Creation and management of rural agroforests in Indonesia: potential applications in Africa. p 709–724. In: *Tropical forests, people and food. biocultural interactions and application to development,* ed. C.M. Hladik, A. Hladik, O.F. Linares, H. Pagezy, A. Semple & M. Hadley. Man and Biosphere Series 13. UNESCO & Parthenon Publ., New York.

Fortmann L. & Bruce J.W. 1988. *Whose trees? proprietary dimensions of forestry.* Westview Press, Boulder, Colorado, USA. 341 p.

Fortmann L. & Nihra C. 1992. *Local management of trees and woodland resources in Zimbabwe: a tenurial niche approach.* O.F.I. Occasional Papers No. 43. Oxford Forestry Institute, Oxford. 34 p.

Gibbs C.J.N. & Bromley D.W. 1989. Institutional arrangements for sustainable management of rural resources: common property regimes and conservation. p 22–32. In: *Common property resources; ecology and community-based sustainable development,* ed. F. Berkes. Belhaven Press, London.

Gilmour D.A. 1990. Resource availability and indigenous forest management systems in Nepal. *Society and Natural Resources* 3:145–158.

Gomez-Pompa A. & Kaus A. 1990. Traditional management of tropical forests in Mexico. p 45–64. In: *Alternatives to deforestation: steps towards sustainable use of the Amazon Forest,* ed. A.B. Anderson. Columbia University Press, New York.

Grandstaff S.W., Grandstaff T.B., Athakette P., Thomas D.E. & Thomas J.K. 1986. Trees in paddy fields in northeast Thailand. p 273–292. In: *Traditional agriculture in Southeast Asia, a human ecology perspective,* ed. G.G. Marten. Westview, Boulder, Colorado, USA.

Harlan J.R. 1975. *Crops and man.* American Society of Agronomy/Crop Science Society of America, Madison, Wisconsin. 295 p.

Harris D.R. 1989. An evolutionary continuum of people–plant interaction. p 11–26. In: *Foraging and farming, the evolution of plant exploitation,* ed. D.R. Harris & G.C. Hillman. Unwin Hyman, London.

Hladik C.M., Linares O.F., Hladik A., Pagezy H. & Semple A. 1993. Tropical forests, people and food: an overview. p 3–14. In: *Tropical forests, people and food. biocultural interactions and application to development*, ed. C.M. Hladik, A. Hladik, O.F. Linares, H. Pagezy, A. Semple & M. Hadley. Man and Biosphere Series 13. UNESCO & Parthenon Publ., New York.

Jong W. de. 1995. Recreating the forest: successful examples of ethnoconservation among Dayak groups in central West Kalimantan. p 295–304. In: *Management of tropical forests: towards an integrated perspective,* ed. O. Sandbukt. Occasional Papers of SUM 1/95. Centre for Development and the Environment, University of Oslo, Norway.

Landauer K. & Brazil M., eds. 1990. *Tropical home gardens.* United Nations University Press, Tokyo. 257 p.

Leakey R.R.B. & Newton A.C., eds. 1994. *Domestication of tropical trees for timber and non-timber products.* MAB Digest 17. UNESCO, Paris. 94 p.

Mary F. & Michon G. 1987. When agroforests drive back natural forests: a socioeconomic analysis of a rice/agroforest system in South Sumatra. *Agroforestry Systems* 5:27–55.

McKey D., Linares O.F., Clement C.R. & Hladik C.M. 1993. Evolution and history of tropical forests in relation to food availability—background. p 17–24. In: *Tropical forests, people and food. biocultural interactions and application to development,* ed. C.M. Hladik, A. Hladik, O.F. Linares, H. Pagezy, A. Semple & M. Hadley. Man and Biosphere Series 13. UNESCO & Parthenon Publ., New York.

Messerschmidt D.A., ed. 1993. *Common forest resource management: annotated bibliography of Asia, Africa and Latin America.* Community Forestry Note No. 11. FAO, Rome.
Nair P.K.R. 1983. Agroforestry with coconuts and other tropical plantation crops. p 79–102. In: *Plant research and agroforestry,* ed. P.A. Huxley. ICRAF, Nairobi, Kenya.
Nair P.K.R. 1984. Fruit trees in tropical agroforestry systems. Working Paper, Environment and Policy Institute. East–West Center, Honolulu, USA. 89 p.
Nepstad D.C. & Schwartzman S., eds. 1992. *Non-timber products from tropical forest: evaluation of a conservation and development strategy.* New York Botanical Garden, New York. 164 p.
Olofson H. 1983. Indigenous agroforestry systems. *Philippine Quarterly of Culture and Society* 11:149–174.
Payne W.J.A. 1985. A review of the possibilities for integrating cattle and tree crop production systems in the tropics. *Forest Ecology and Management* 12:1–36.
Persoon G.A. & Wiersum K.F. 1991. Anthropology in a forest environment. p 85–104. In: *Contemporary anthropology in the Netherlands: the use of anthropological ideas,* ed. P. Kloos & H.J.M. Claessen. VU University Press, Amsterdam.
Plotkin M. & Famolare L., eds. 1991. *Sustainable harvest and marketing of rain forest products.* Island Press, Washington, DC.
Posey D.A. 1985. Indigenous management of tropical ecosystems: the case of the Kayapó Indians of the Brazilian Amazon. *Agroforestry Systems* 3:139–158.
Posey D.A. & Balée W., eds. 1989. *Resource management in Amazonia.* Advances in Economic Botany No. 7. New York Botanical Garden, New York.
Prance G.T. 1994. Amazonian tree diversity and the potential for supply of non-timber forest products. p 7–15. In: *Tropical trees: the potential for domestication and the rebuilding of forest resources,* ed. R.R.B. Leakey & A.C. Newton. HMSO, London.
Pullan. 1974. FarmEd parklands in West Africa. *Savanna* 3(2):119–151.
Raison J.P. 1988. *Les 'parcs' en Afrique: état des connaissances, perspectives de recherches.* Document de travail Centre d'études Africains. EHESS, Paris.
Ros-Tonen M., Dijkman W. & Lammerts van Bueren E. 1995. *Commercial and sustainable extraction of non-timber forest products: towards a policy and management oriented research strategy.* Tropenbos Foundation, Wageningen, Netherlands.
Salafsky N. 1995. Forest gardens in the Gunung Palung region of West Kalimantan, Indonesia. Defining a locally developed, market-oriented agroforestry system. *Agroforestry Systems* 28(3):237–268.
Shepherd G. 1992. *Managing Africa's tropical dry forests: a review of indigenous methods.* ODI Occasional Paper No. 14. Overseas Development Institute, London. 117 p.
Verheij E.W.M. 1991. Introduction. p 15–56. In: *Edible fruits and nuts,* ed. E.W.M. Verheij & R.E. Coronel. Plant Resources of South-East Asia No. 2. Pudoc, Wageningen, Netherlands.
Weinstock J.A. 1983. Rattan: ecological balance in a Borneo rainforest swidden. *Economic Botany* 37:58–68.
Wessel M. 1992. Development of tree crop production systems in the lowlands of the humid tropics and its relevance to agroforestry. Wageningen Agricultural University, Department of Agronomy, Tropical Crops Communication No. 19. 15 p.
Wiersum K.F. Submitted. Indigenous exploitation and management of tropical forest resources: an evolutionary continuum in forest–people interaction. *Agriculture, Ecosystems and Environment.*

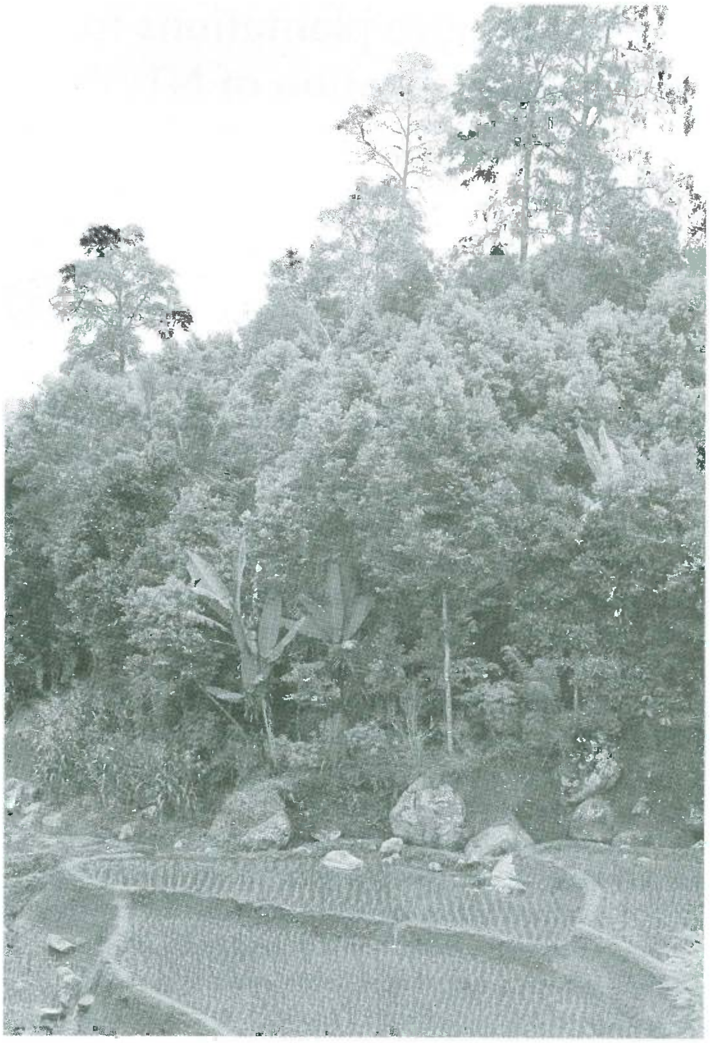

Plate 16. *A complex agroforest based on rubber and cinnamon in Sumatra in close proximity to paddy rice. (photo: R.R.B. Leakey)*

Plate 17. *The traditional parklands agroforestry system of the Sahel after the millet harvest. The principal tree species here in Mali are* Vitellaria paradoxa *(shea nut or karité) and* Parkia biglobosa *(néré). (photo: R.R.B. Leakey)*

Agroforests as an alternative to pure plantations for the domestication and commercialization of NTFPs

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Abstract

NTFP exploitation has recently emerged as a promising alternative to timber extraction in natural forest management. The domestication and the commercialization of these NTFPs tend to emerge as an alternative strategy to their extraction from natural forests.

Incorporating NTFPs in production systems is not a new practice in the tropics. Various forms of agroforestry associations have developed around NTFPs and form the very basis of a suite of indigenous agricultural practices. This agroforestry path to domestication is not commonly considered, in spite of an increasing amount of academic interest in indigenous forest-like plantation models. Furthermore, it is only in recent years that agroforestry research is considering the prospects of these indigenous systems for forest species. To date, nothing in terms of species improvement, for instance, has been done towards the integration of NTFPs into a multistrata or multispecies system, although these are important considerations that need to be taken into account.

In Southeast Asia, and particularly in Indonesia, complex agroforestry systems for the management of forest resources have been developed for centuries by local people ranging from the production of locally consumed fruits to highly valuable industrial products, such as resins and latexes. This agroforest pathway is presented here as an elaborate process of total transfer, of both selected forest resources and a true forest structure from the sphere of 'nature' to that of 'agriculture'. This process can thus be analysed as a particular domestication strategy, which could integrate conventional species domestication techniques—selection, reproduction and plantation practices—to an original form of ecosystem 'domestication'. Prospects for further developing this agroforest strategy for the domestication of forest species, particularly NTFPs, are then discussed.

The social, economic and institutional implications of such an integration of NTFP resources to agricultural development are also analysed, based on various examples of agroforest development and focusing on the efficiency of this 'appropriation' strategy by smallholder farmers, for the acquisition of forest riches.

Introduction

Domestication of forest species for purposes of commercial cultivation seems to have bright prospects. Forestry definitively needs to find an answer to the exhaustion of wild resources while at the same time rationalizing the production of marketable NTFPs. There is great demand for new crops and new markets. Sustainable development has to mitigate the effects of deforestation by increasing the planting of trees on cleared lands, and tropical farmers have to find substitutes for the natural resources lost through deforestation.

However, domestication is neither a fast nor an easy process. It took centuries of farmers' work to develop a range of food crop varieties and decades of scientific research to create productive clones of industrial tree crops. Can foresters or farmers wait another 50 years to tame wild rattans, or before they efficiently produce natural resins or marketable 'forest fruits' from improved and domesticated trees? Can we wait for agroforestry research to spend several more decades testing efficient tree–crop associations for forest domesticates and making them acceptable to smallholder farmers?

Modern plant domestication relies on relatively sophisticated techniques. But it should not be restricted to only a set of techniques. Domestication is also, and primarily, a strategy. Domestication techniques are selected on the basis of economic choices and by the initial preference for a given cropping system within a given farming system. In discussions on domestication, this latter aspect is often neglected, probably because of the historical background of the present scientific community. Modern agricultural and forestry science evolved in Europe, in a pastoral and cereal-growing civilization, which influenced most of the present agricultural paradigms and agroecosystem models. Our perceptions of domestication and agricultural development are deeply influenced by a tacit preference for cereal-based models, which may not be the most useful for the domestication and development of tropical forest resources.

The design of the agroecosystem in which domesticated species are grown is as essential as the choice for particular plant selection, breeding and reproduction techniques. This is particularly important when switching from annual crops to trees and from fields to forests. Most 'modern' agroecosystems in the world relate to a single agricultural model: intensive, highly specialized stands of homogeneous crops. However, other available models exist, which should be examined under the new perspective of domestication of tropical forest species. Especially important among these are the native farming systems in the tropics, for which there is academic information already. This presentation will concentrate on the implications that ecological models in such native systems might have for the design of novel domestication strategies for NTFPs, particularly in agroforestry.

An 'ecosystem' perspective of the domestication of forest species could change the approach chosen and lead to changes in techniques and processes. It is essential to understand that the importance of an ecosystem approach to domestication goes far beyond biological or technical considerations. It also has obvious sociopolitical and institutional dimensions. The common preference of governing elites and scientists for the plantation model of domestication for commercial forest resources in the tropics did not only change the face of forest landscapes and national economies. It also deeply affected forest communities and their socioeconomic life. It is essential to analyse in the context of NTFP domestication, this indirect link between the choice of a particular domestication strategy and the fate of local populations. Domestication is part of a resource appropriation process, and resource appropriation by a powerful faction of the population might lead to dispossession of the weaker faction. This aspect of domestication will be examined in the light of the Indonesian history in forest resource management.

From natural resources to cultivated crops

Food crop domestication and agroecosystems

The process of domestication and cultivation of food crops has followed two totally divergent routes: 'agriculture' and 'horticulture', taken in their etymological sense—the cultivation of 'ager' (open fields) and the cultivation of 'hortus' (gardens) (Barrau 1970). Several ethnobotanists and anthropologists (Haudricourt & Hedin 1943, Sauer

1952, Geertz 1966, Barrau 1967) have suggested that relating these 'grain' and 'garden' models to existing cropping systems will help to focus further discussion.

'Agriculture' refers to the 'grain model' developed for cereal domestication in ancient Mesopotamia and around the Mediterranean, and also in ancient rice civilizations from India to China. 'Ager' (literally the tilled or totally cleared field) conquered the forest and is the central platform for domestication and the 'home' of domesticates. It represents a highly specialized and artificially uniform open field, devoted to grain crops, largely disassociated from the pre-existing environment. It involves a massive population of genetically homogenous plant cultivars. The grain model relies on highly specialized and segregated technical knowledge relating to monocultures as well as to intensive use of chemical and mechanical inputs. These are associated with very high energy consumption and minimal labour inputs at the field level. Genetic specialization and manipulation culminate in the widespread use of hybrids, which totally depend on people for their production and regeneration. The grain model perfectly relates to the productionist mentality of modern agriculture. Initially devised for food crops, it has deeply influenced modern commercial tree cropping: both tropical plantation agriculture as devised by European colonialists (e.g., rubber, oil palm, cocoa, or cinchona) and commercial fruit culture in temperate regions. Both situations replicate a modern corn field biologically and technically, as well as in ideology.

'Horticulture' refers to the management of 'hortus', the garden, which can be characterized by high plant diversity, including tuberous perennials and trees, in somewhat chaotic combinations and configurations. The garden model involves diverse production, from many food crops. Domestication in the hortus, whether in temperate or tropical regions, has operated through the treatment of plants as individuals. It developed countless cultivars of fruits, tubers and vegetables. In the tropics, 'hortus' can be a swidden, an anthropogenic forest, or a homegarden. Management in the garden model plays intensively on ecosystem interfaces and fully benefits from natural vegetation dynamics. Devised for multipurpose production like indigenous agriculture in the tropics, as well as for an optimum management of ecological and economic risks, the garden does not comply with the urgent need for 'productivity' in agriculture. Temperate gardens are nowadays devoted mostly to production for home consumption or to leisure, whereas their tropical relatives are neglected or even denigrated by official agricultural services.

In the one-track mind that characterizes modern rural development, the grain model is considered as the only model that is valuable for efficient agricultural production. Agroforestry research and extension represents the only consistent scientific framework through which the hortus model could be further developed. But this requires innovative approaches, especially as far as domestication and cultivation models are concerned. The open-field preference has often led to reductionist approaches to domestication, which we have to re-examine in the light of agroforestry development. Does domestication unavoidably come down to adapting a wild species to grow in industrial plantations? Are tropical gardens confined to the production of, at best, semi-domesticates? What new perspectives can agroforestry bring to domestication?

Domestication: which models for forestry?

Domestication and cultivation have long been the prerogative of agriculture (here in its widest sense: management of fields and gardens), while worldwide, forests remained the domain of hunting and gathering in support of agriculture. Until roughly the beginning of the 19th century, tropical and temperate forests were managed mainly for integrated, multipurpose use. These practices more or less maintained forest composition, providing for grazing, hunting, gathering, and wood or timber production. Some species selection did happen, creating useful genotypes that could be substituted for wild ones in niches within the pre-existing biotic community. Among other examples are productive chestnuts and sweet acorn varieties in the Mediterranean countries, and peach palm and Brazil nuts in the Amazon Basin.

Rationalization of forest production and forest culture did not really appear before the industrial era. This coincided with more focused demands for specific forest products: fuel for metallurgy, timber and pulp. The development of scientific forestry induced a strict partition between agricultural and forest development. Productivism applied to forestry created new models of intensive wood production, inspired from the grain model in agriculture, with the multiplication of highly homogeneous, specialized, and productive plantations of pine in the north and of acacia and eucalyptus in the tropics. Today's commercial forestry in the tropics, dominated by the imperatives of wood supply, follows a bipolar model: products are either extracted from natural, more or less managed natural stands, or cultivated in highly specialized plantations.

The monoculture preference stands as the recognized option for domestication strategies for timber trees. Domestication and cultivation techniques devised by forestry research for tree species follow the rules of specialization, uniformity and intensification that have proven efficient for grain crops, simplifying the structure and the function of the cultivated 'forest' to the extreme. But how far does this model extend to NTFPs?

What happened in the domestication and cultivation of tropical NTFPs?

Domestication of non-timber forest products in the tropics developed under three different situations.

The indigenous perspective

The history of management, selection and cultivation of useful forest species by indigenous people for subsistence purposes is as old as that of humankind's use of forest ecosystems. In terms of domestication, the process of interaction between farmers and forests gave rise to a whole range of modified tree varieties, which most authors classify as 'managed species' or 'semi-domesticates'. However, scientists commonly recognize that true domestication occurred through the transfer of edible forest species—primarily fruits and nuts—to agriculture through various types of garden (see for example Clement & Villachica 1994, Sastrapradja 1975). These forest domesticates are presently considered as true agricultural or horticultural crops.

Though not often acknowledged in the literature, commercial gathering of forest products by local people also went along with plant selection, integrated management and even cultivation. This simple domestication developed interesting models of true 'forest culture', which relate to the hortus model and will be discussed further. These models have unfortunately remained neglected in most discussions and are almost never included in development programmes, even in agroforestry.

Colonial interventions

Tropical NTFPs acquired a new dimension during the expansion of the colonial era. This started with the high demand for spices (nutmeg, cinnamon, vanilla), coffee or cocoa, which created a new but highly specialized commercial perspective. These cash crops boomed with the rise of the industrial era, which needed new products, such as latexes and resins. For some products, a demand boom and the need for increased control over the resource or over product quality led to domestication through intensive cultivation. The process of domestication and cultivation developed by the colonial plantation managers induced a true movement of disassociation between forest resources and forest ecosystems. Most of the new economic forest resources were transferred to plantation agriculture, through vast estates that reached their peak in the second half of the 19th century and the early 20th century, with oil palm, rubber, cinchona, coffee, tea and cocoa. In transferring forest resources to agriculture, the colonial plantations did not attempt to innovate; they followed the grain model, creating huge areas of specialized, artificial and productive tree monocultures.

New focus on NTFPs

The commercial interest in NTFP declined after World War II, because of the fall of colonial powers and the rise of petrochemical industries, which developed substitutes for natural products. However, a new focus on NTFP exploitation has recently emerged. NTFP extraction is now considered a promising alternative to timber extraction in natural forest management. The justification for this revived interest is not based entirely on economics, although new markets for natural products have emerged, such as phytochemicals in pharmaceutical industries or wild substances in food industries, that have triggered economic interest in NTFP. The other justifications have been ecological and sociopolitical. Ecological interest has focused on reduced disturbance to the forest ecosystem *vis à vis* timber extraction practices—while sociopolitical interests have centred around the promotion of new development models for indigenous forest people and the promotion of 'fair trade' for natural products.

For some of the most coveted products, development through domestication and commercialization tends to emerge as a strategy competitive with extraction from natural forests. Thus, despite the debate about developing new and better models for the domestication and cultivation of useful tree species in farmlands, there is a good probability that the conventional monocultures will persist. This is already obvious for rattan production in Indonesia and Malaysia, where specialized plantations have been established under the strict control of forestry services, and for the Brazil nut in Brazil, where private investors have established large plantations that severely compete with the activities of smallholder farmers and extractivists.

Consequences of NTFP domestication and commercialization for indigenous people: lessons from the past

The era of colonial trade and management had two major consequences for forest people: the displacement of their effective control over the collection and trade of forest resources and passage of the resources either to the governing elite or to private colonial entrepreneurs. This resulted in the local forest communities being overlooked and in the consequent transfer of the commercial benefits to private and commercial planters. This 'dispossession process' continued through most postcolonial governments and is still common today when a traditional forest resource encounters a commercial boom (Dove 1993a). This abuse of native rights commonly starts with restrictions over harvesting practices, develops when traders are acknowledged monopolistic rights for gathering, and culminates with plantation development. This process has political support and is a practical consequence of commercial interests.

The history of natural rubbers in the Amazon and Southeast Asia perfectly illustrates this dispossession process, which transferred control over the resource—from native collectors to powerful traders and then to planters. Caoutchouc (para rubber from

Hevea brasiliensis) was traditionally collected and used by Amerindians in the Amazon Basin. In Southeast Asia, especially Sumatra and Borneo, other wild rubbers (*Ficus elastica* and *Willughbeia* spp.) were harvested and traded by local swiddeners before the 17th century. Commercial interest in Europe and the United States for wild rubbers boomed in the second half of the 19th century, but until 1900, both elastic and non-elastic rubbers remained supplied exclusively by wild species through latex extraction. As prices rose, the control of the rubber areas in Amazonia became concentrated in the hands of the political-economic elite, who 'exerted an absolute rule over native rubber tappers' (Coates 1987). At the same time in Indonesia, the Dutch colonial government progressively restricted exploitation by local tappers, first through imposing a licence to tap the trees, then through granting all tapping rights to foreign concessionaires (Dove 1994). Another period of dispossession of native tappers started with the cultivation of the Amazon rubber tree in Southeast Asia in 1877. By 1913, the supremacy of the wild caoutchouc came to an end and the local tappers in the Amazon virtually stopped working. Cultivated rubber production in the Far East, through large estates, had captured the market (Coates 1987).

Such examples are numerous, starting from the Dutch VOC taking possession of local nutmeg production and trade in the Moluccas in 1621 to the present Indonesian seizure of the birds' nests caves of the local Punan in East Kalimantan, who had owned and managed them sustainably for centuries. To get full control of the nutmeg trade, the Dutch established specialized nutmeg plantations worked by imported slaves while destroying nutmeg trees in surrounding islands. Nobody except VOC was allowed to grow and trade nutmeg any more (Warburg 1897).

What are the prospects for domestication of forest species through agroforestry?

Forestry in the tropics is still looking for technical and economic as well as socially accepted models. Can it escape from the bipolar model of extraction in natural forests on one hand and monospecific specialized plantations on the other? Can domestication of forest trees help to alleviate this situation, or will it contribute to increase the present movement of segregation between forest and agricultural development? Who will benefit from domestication of NTFPs: foresters, planters, or smallholder farmers? How can rural development efficiently and sustainably incorporate the so-called minor forest resources into farmlands?

Agroforestry is often cited as the most favourable means of providing positive answers to such questions. But what type of agroforestry is the best for NTFP development? Is agroforestry research able to fully integrate and develop the potential offered by these 'new' crops? Can it generate 'new' models of agroecosystems, combining both agricultural and forest qualities in an economic as well as ecological perspective? Most agroforestry research until now has concentrated on simple associations, trying to introduce a single tree or shrub species into former grain-model systems. Most agroforestry research has promoted fast-growing trees or shrubs, not old-growth forest species. Agroforestry has been more 'agro' than 'forestry' oriented, more crop than tree based. When dealing with NTFP domestication and cultivation, agroforestry research definitely has to innovate. It has to give new preference to tree-based systems and to look for new ecosystem models (see Leakey 1996). There is room for innovative experimental research. However, a reanalysis of current management practices of forest resources by smallholder farmers might help. Can we find, in indigenous systems, management models that fully integrate forest resource management into farmlands? Can these models inspire novel domestication and cultivation strategies for forest species and thus a new phase of agroforestry development?

NTFPs in indigenous agroforestry practices: a long history of coevolution

Incorporating forest resources in farming systems is not a new practice in the tropics; various traditional forms of agroforestry have developed around NTFPs, constituting the very basis of indigenous agricultures in tropical America, Africa (see Boffa, this volume) and Southeast Asia. Beside fruit-dominated gardens, indigenous farmers have integrated true forest culture into farmlands, and these forms are usually closely associated with shifting cultivation. These 'cultivated forests', which often complement subsistence food cropping in annual fields, are established after total removal of the original vegetation, and they constitute complex, tree-based agroforestry systems, which fully deserve the name of 'agroforests'. Why have they been overlooked in agroforestry research? Perhaps it is a consequence of their appearance: they do not look like cultivated ecosystems and have mainly been mistaken for natural forests.

A focus on Indonesian practices

Many true 'agroforests' in Indonesia have evolved around fruit and nut trees (Michon 1985). But there are other systems that have evolved from former extractive practices in natural forests, through the deliberate incorporation of non-food forest tree species that farmers have cultivated for products to be marketed in international trade.

Among the commercial forest products, cinnamon (*Cinnamomum burmanii* (C.G. & Th. Nees) Bl.) was probably the first to have been incorporated into indigenous agricultural systems. In the central highlands of Sumatra, indigenous stands have been established for more than two centuries. Some form specialized, homogeneous gardens, but others, established on steep slopes, associate cinnamon trees as an understorey with higher canopy trees grown for fruits or timber (Aumeeruddy 1993, Michon 1985). Similarly, benzoin *(Styrax)* is known to be managed as a fallow crop in what represents a true rotational agroforestry system in Laos (Kashio 1994). Such rotational systems were also mentioned in North Sumatra as long ago as the 18th century (Marsden 1783). However, other cultivation practices also developed through more complex and permanent agroforestry systems, which associate benzoin trees in a mix of useful timber and fruit trees (Simanullang 1988, Watanabe 1990).

In western Borneo, swiddeners have, for at least 150 years, established highly diversified tree gardens that integrate oil-producing dipterocarps (11 *Shorea* species) together with tens of other fruit and nut species as well as rattans, latex-producing trees and timber species (Momberg 1992, Sundawati 1993, de Jong 1994). In Central and East Kalimantan, rattan, which has traditionally formed the bulk of trade in forest products, has been incorporated into shifting cultivation systems for more than 100 years. Rattan gardens mix the cultivated palms with planted fruit and timber trees, as well as with numerous other useful species that have established spontaneously (Weinstock 1983, Godoy & Feaw 1989, Fried & Sardjono 1992). A century ago in the south of Sumatra, swidden farmers started cultivating damar trees (e.g., *Shorea javanica* K. & V.) for resin production (Dunn 1975) and have established more than 20 000 hectares of complex forest-like agroforests, associating damar with numerous other fruit and timber tree species (Michon 1985, Michon et al. 1993). Native rubber trees also happened to have been planted in complex gardens, but rubber agroforestry really developed with the incorporation of the para rubber tree in local swidden systems at the beginning of this century. The Amazon rubber tree found its ecological niche in complex tree gardens in Southeast Asia, where it is grown with numerous other species, either planted or spontaneously established. It soon replaced native rubbers in the economic niche of the local swidden farmers (Pelzer 1945, Dove 1993b, Gouyon et al. 1993).

All these agroforests result from farmers' needs and their deliberate choice to improve production and control, or sometimes to protect or even restore useful forest resources. They all present important common features (Foresta & Michon 1991): (1) most of them concern true old-growth forest species, not fast-growing pioneers, (2) they have all evolved from swiddens, through the systematic introduction of trees in cleared lands, (3) most often, they start as specialized plantations that evolve into a permanent mixed stand of planted tree crops and useful spontaneous resources, and (4) they exhibit forest-type structure, including a predominance of large trees, a multi-layered vertical configuration and a closed-cover canopy. Some of these indigenous systems, like the dipterocarp agroforests, hold structural as well as functional characteristics typical of a primary forest ecosystem, with the predominance of big trees, a high species richness, a high ecological complexity, and a closed nutrient cycle. Others, like the rubber agroforests that cover the lowlands of Sumatra and Kalimantan, are more like secondary forests, with dense stands of smaller trees and a rapid turnover of species. These agroforests combine important income-generating strategies based on forest resources and diversified subsistence strategies, but they are not isolated management units: they always complement other agricultural activities, such as food cropping in open fields. Lastly, they rely on local representation and knowledge systems evolved from former forest traditions; they are maintained by simple techniques and integrated practices and are controlled by a well-defined social and tenurial system, which includes rights as well as duties.

How can these indigenous agroforest models contribute to the domestication and cultivation of NTFPs?

Ecosystem domestication: a new perspective?

The current concept of tree domestication (Leakey & Newton 1994) appears poorly adapted to characterize and critically analyse most of the above-mentioned examples of integrating forest resources into agricultural farming systems. 'Domestication' usually focuses more on selection and propagation techniques, making too little reference, if any, to the concepts and strategies developed for the integration of wild resources direct into the farming system. This last point is nevertheless essential when dealing with the domestication of wild forest species. The pre-eminence of the grain model has obscured analyses from other perspectives. Is the conventional model of domestication the best choice for trees that have evolved in a highly diverse and structurally complex environment?

Usually, domestication has intentionally disassociated the resource from its natural habitat. Transfer of the candidate species to an artificially prepared environment has been seen as essential, to allow increased human control of the plant, as well as to induce and efficiently select useful genetic variations (Narr 1956). But should the artificial cultivated environment be fundamentally different from the natural one? Although a very artificial environment has proven its efficiency in cereal domestication, as well as in colonial tree-crop development (Purseglove 1974) and modern forestry plantations for wood production, there is seemingly no satisfying theoretical answer for NTFPs.

The domestication strategy exhibited in the Indonesian agroforest examples partly relies on conventional plant species domestication techniques (selection, reproduction and planting practices), but it does not involve crop management in highly specialized stands, which are quite different from the original conditions in which the wild species had evolved. Nor does it involve a major modification of the structural and biological features of the tree species, in which trees are selected to allow their adaptation to homogeneous monocultural conditions. Rather, the agroforest model relies on an artificially induced reconstitution of a true forest-like ecosystem, simulating the basic principles of a natural silvigenetic succession, which allows the selected species to establish, grow and reproduce as in their original habitat.

Establishing an agroforest is conceived as a specialized tree-planting process aimed at controlling and concentrating the selected forest resource; but this process is achieved through the integration of the resource with natural vegetation and through several successional stages that lead to the gradual reconstruction of a diversified forest structure (Michon 1985). The forest tree seedlings are introduced into the forest clearing with other short- or medium-cycle crops (e.g., rainfed paddy, vegetables, coffee bushes, pepper vines) and receive the care given to the crops. After the abandonment of these food crops as the tree canopy closes, the planted trees are strong enough to grow along with secondary vegetation and overcome competition from pioneers. The subsequent tree fallow then freely develops with little damage to planted trees.

The structure of the agroforest becomes more complex over the years, as the consequence of a particular form of management that maximizes the use of natural production and reproduction processes in order to minimize the rarest economic factor: labour. In a maturing agroforest, plant species regenerating from the neighbouring forests, through natural dispersion, can establish while forest animals find shelter and feed. Through selection, farmers favour economic resources, but non-economic resources are allowed to reproduce. And after several decades of such a balance between free-functioning and integrated selection, the mature phase of the agroforest resembles a natural forest more than a conventional tree plantation.

This ecosystem-analogy strategy has proved efficient for quick acclimation of a true forest tree species. For example, forest farmers in Sumatra have succeeded in what most foresters dream about, but have failed to achieve: the establishment, maintenance, and regeneration of a healthy dipterocarp plantation at low cost and on a huge scale (Michon & Bompard 1987). This is a unique example for the whole forestry world. Dipterocarp agroforests rely on selected and planted forest trees; they exhibit high-density stands and good productivity, but they are also characterized by good ecological sustainability, low-cost establishment and easy regeneration over years. This is quite uncommon in conventional plantation forestry.

The agroforest domestication process allows the maintenance of biological diversity in the qualities of the tree, as it does not focus on the selection of single-purpose varieties: the multipurpose dimension of the wild species is not lost through domestication, as usually happens in the conventional process. Low-canopy varieties of durian (*Durio zibethinus* Murr.) or rambutan (*Nephelium lappaceum* L.) selected by plant breeders produce nothing else but fruits, but damar or benzoin trees domesticated for resin production by local farmers in Sumatra are still good timber producers. This multipurpose dimension is also maintained at the ecosystem level. In the plantation model, what is not the crop is a weed. In the agroforest, self-established species are integrated as economic and ecologically beneficial resources or kept as potentially useful species.

But the most original point is how natural biological processes are utilized to support the artificial domestication and cultivation process. In the agroforest, natural vegetation dynamics are channeled, first to speed up and secure the integration of slow-growing trees in the cultivated system, then to maintain a continuous balance between obsolescence and the regeneration of the cultivated stand. Besides domesticating forest species, the agroforest allows the restoration of integral biological and ecological processes, which determine the overall survival and success of the cultivated ecosystem. These natural processes schematically replace the high technology and energy inputs of forest plantations. Here, it is the agroecosystem that adapts to the plant characteristics. In this sense, agroforests constitute an original attempt of 'ecosystem domestication', through the full utilization of natural ecosystem dynamics to the benefit of a selected, artificially established population of trees. Through this, the agroforest domestication strategy proves to be successful in assimilating the problems associated with the long-term management of forest tree species—or vines, as in the case of rattan. Long-term maintenance and renewal of forest plantations is technically difficult and is invariably costly. The agroforest not only achieves a simple transfer of forest resources and structures. It also guarantees the renewability of these resources and structures, and of the related economic returns.

However, the agroforest strategy, empirically devised by swidden farmers all over the Indonesian archipelago, bears important weaknesses that could be solved by integrated research. The population of cultivated trees in the agroforest is usually genetically rather diverse, which affects the productivity of the crop. Though farmers do select the best producing individuals for reproduction, they cannot reliably capture genetic variation. Vegetative reproduction methods remain simple, and sanitary control in nurseries could be improved. Technical research aimed at these weaknesses could reorient NTFP domestication for agroforestry in two ways. First would be the development of improved plant material specially designed for a complex, forest-like environment, rather than for conventional monocultural plantation conditions. Plant selection and breeding could be aimed at taking advantage of the 'forest' characteristics of the species for both ecological and economic benefits and adapting them to farmers' technical, as well as energetic standards. The second direction for research would be to test high-yielding plant varieties—wild or improved—in agroforest conditions, as is being done by ICRAF in jungle rubber agroforests. This would expand the agroforest model to new areas and improved plant material into existing systems.

Agroforest domestication: a socially empowering strategy for farmers

The analysis of the agroforest domestication process should not be restricted to its technical or ecological aspects. While the transfer of the wild resources of nature to the cultivated lands of agriculture is an essential process—capturing variation in natural genetic characteristics, increasing population density, stimulating cross breeding, or escaping from natural competitors and pests—it must always integrate these with major economic and sociopolitical or policy implications. This could, in future NTFP business, enable smallholders to do more than extract products from wild ecosystems, as they do now.

From the forest to the fields: who owns the resource?

By switching from the management of wild resources in traditional extractive systems to their adoption as new crops in farming systems, farmers often aim at maintaining or re-establishing their traditional authority over the forest resource base. This is obviously important when, because of overexploitation or deforestation, wild economic resources are vanishing from natural forests, or when commercial demand increases. But it might also be an important option for native farmers when politically induced dispossession threatens their livelihood.

In most ideologies and political regimes of tropical countries, agriculture secures social and legal rights over land or natural resources for smallholders better than does forestry. Integrated forest management, as empirically conceived by indigenous forest tribes all over the planet, however sustainable or profitable it is, has never been seriously considered by the governing elites and their technical councils. This is reflected in the widespread lack of legal recognition of native rights and traditional property regimes concerning forest lands and resources in tropical countries. To gain official support, native resource management systems have to evolve in a way that complies with the conventional models. Domestication and plantation are important steps in this process; transferring wild resources to cultivated lands is both a symbolic and a political act of appropriation. But beyond this conceptual aspect lies the legal context of appropriation. Most forest lands in the tropics, and the resources they contain, are under state control; they are 'public goods'. This usually prevents any evolution towards 'privatization' and facilitates tacit 'appropriation' of profitable forest resources, traditionally controlled by indigenous people, by those who are close to power. Private property—for either collective or individual owners—is more readily acknowledged and expected on agricultural land. Thus, cutting the forest and planting trees might be enough to secure, if not property rights, at least the right to claim for such rights. In Indonesia, establishing agroforests has often been a major strategy for land and resource appropriation; establishing production structures and property rights that will be transmitted to further generations is an essential aspect in this particular domestication and cultivation process (Michon et al. 1994).

For example, farmers in Sumatra initially planted damar-producing dipterocarp trees, in response to the depletion of wild damar trees and the need to establish a profitable forest-based economy. But as their relations with forest authorities deteriorated, the establishment of agroforests became a strategy for legal resource appropriation. Thus, presently agroforests are also established as a claim against the closure of forest lands and resources to local communities. Through domestication and tree growing, farmers claim that they have purposefully restored and protected not only damar but the entire forest resource, in the middle of agricultural territory, upon which they hold a firmer control and rights (Michon et al. 1993).

'Global forest resource' appropriation is an essential component of the agroforest domestication strategy. Specialized plantations might secure the appropriation of a given forest resource, but the agroforest strategy goes far beyond that: as it recreates forest structures, it allows the restoration of the landscape in a form that conforms better to the farmers' rights and interests (Michon et al. 1996). In Indonesia, therefore, the relationship of local populations with forest resources is now more closely associated with one or more types of agroforest than with the natural forest. This allows them to maintain an economy and an associated lifestyle that remain in continuity with their forest culture, from which the agroforest directly evolved; but it places it firmly in an agricultural context. The agroforest, therefore, clearly opens the way for other novel models of improved resource management in forest lands throughout the tropics.

Domestication and cultivation: knowledge and capital

The choice for a particular domestication and cultivation strategy is as important as the transfer of forest resources to farmlands, in determining who holds the authority over a particular resource. Domestication and cultivation integrate technical knowledge and capital investments as well as technical, labour or energy inputs; all of these may be inaccessible to smallholder farmers. Colonial plantations have clearly demonstrated how domestication can adversely affect indigenous 'managers' of NTFPs. Will indigenous farmers be similarly spoiled when NTFP domesticates are made available by research institutes through markets or credit schemes? This seems likely when capital-intensive processes of crop establishment and maintenance lie far beyond smallholders' financial and technical capacities, and when the high productivity from plantations leads to a fall in prices of natural products and to the economic collapse of any business collecting those products. The domestication of NTFP through these sophisticated techniques and modern knowledge might only intensify the exclusion of smallholders from the management of forest resources. In contrast, however, the domestication of NTFPs through the agroforest strategy will probably be better integrated into indigenous populations, as it relies on simple techniques, is based on local knowledge shared by every farmer, and does not imply high energy inputs.

In the process of NTFP domestication, the evolution of rubber cultivation in Indonesia illustrates how plantation and agroforest development can have totally divergent effects on smallholders. Technical and financial constraints associated with the plantation model put rubber cultivation out of the reach of smallholders. Thus, intensive rubber cultivation in colonial estates led to the exclusion of native tappers, in both Amazonia and Southeast Asia. However, when swidden cultivators in Sumatra and Borneo adopted the para rubber plantation techniques to their production system by planting rubber trees in their swiddens, the trees grew with the fallow vegetation and soon evolved into a forest-like rubber garden. The trees were tapped if the prices appeared interesting, and they created an agroforest system that was much less demanding in labour and technical inputs than the current estate model. This production system soon became much more competitive than the estate plantations, and since 1945 it has gained the largest share in Indonesian rubber production. Through the rubber agroforests, former indigenous rubber collectors, evicted by the plantation owners, regained their place in the rubber trade and their share in the benefits of rubber development (Pelzer 1945, Dove 1993b, Gouyon et al. 1993).

The forest preference in NTFP domestication: some economic considerations

Domestication should not be disassociated from the global economic strategy of farmers. Future NTFP plantations, whatever their model, will be part of lands claimed and developed through agricultural techniques. They will be integrated into agricultural territories and agricultural production systems. They will support the local agricultural economy.

The advantages of the agroforest model did not, until now, succeed in reliably capturing the trade of products from highly commercial species. Short-term benefits are usually much higher when trees are grown in systems conforming to the plantation model. But so too are the risks and the energy consumption, with all its global ecological and economic consequences. The agroforest model, which by contrast emphasizes economic and ecological sustainability, should thus be evaluated in terms of long-term productivity, energy efficiency and economic security. It may then prove to be much more 'productive' and 'profitable' than the currently accepted models.

Agroforests, in contrast to trees crop estates, allow of numerous tree resources to grow together and to diversify the farmer's income. If encompassed in the framework of agricultural strategies, agroforest development represents a process of forest conversion that does not go along with economic reductionism and that does not irreversibly close the economic potentialities formerly linked to the presence of natural forest. On the contrary, through the restoration of biodiversity in the agroforest, farmers maintain a whole range of economic choices for both the present and the future. Maintaining these options appears indispensable in view of the need for sustainable development. This multipurpose aspect must be kept in mind if systematic research on the domestication of NTFPs for agroforestry systems is to be carried out. An important aspect to consider in this respect is the potential for timber production. Timber will probably become a strategic commodity for farmers in the near future, with potential benefits that might be much higher than those provided by NTFPs. Many NTFP species also have good timber, but species domestication options, and the agroecosystem design, will unavoidably influence the capacity of the candidate forest species to produce quality timber. Investing in NTFP plantings will unavoidably lead farmers to some degree of specialization for a given product. However, opting for 'multipurposeness' in domestication and keeping in mind other potential forms of production, at both the species and the agroecosystem level, will help to avoid the irreversibility of future economic and ecological choices by smallholders.

Conclusion: domestication: technique or strategy?

As a domestication strategy based on forest resources, agroforest development represents an interesting alternative to the two common options devised for non-timber forest product management: harvesting from natural stocks or domestication for specialized plantations. Like specialized plantations, agroforests secure the conservation and multiplication of the planted-forest resources and increase the income-generating capacity of the forest. But they also ensure the restoration of a diverse forest ecosystem, as well as its integration into local agricultural production systems, while allowing local communities to maintain authority over its management. Plantations fail on several of these scores.

NTFP domestication through agroforestry should not confine itself only to technical considerations. Besides field experiments, agroforestry research for NTFPs should focus on devising new strategies for better integration of forest resources into farmland, into rural economies and their related sociocultural, political and institutional systems.

Until now, agroforestry research has never really dealt with long-lived trees, nor with true forest resources. Experimenting with long-lived trees obviously requires much more time than with fast-growing species, and new experimental designs will have to be found. The integration of NTFP forest resources in better forms of land use will require not only new forms of experimentation but also new forms of conceptualization and implementation.

Agroforests still lie on the margins of the conventional agroforestry research, despite the growing academic information about them. However, they touch the very heart of agroforestry, where ***forests*** and ***agriculture*** really meet and where forest structures and agricultural logic intersect. But agroforests are too close to forests for agriculturalists and too much embedded into farmers' activities for foresters. This probably explains why conceptualization of agroforests is still denied by agriculture and forestry research. To deny their conceptualization is also to deny their existence and more importantly their future and then impact on future land use and forest resource management strategies. May the current research trends in domestication and commercialization of NTFPs give new opportunities for further development and integration of the agroforest concept.

References

Aumeeruddy Y. 1993. Agroforests and protected forest areas: indigenous representations and agroforestry practices around Kerinci National Park, Sumatra, Indonesia. Ph.D. thesis, Université Montpellier II, France. 438 p.

Barrau J. 1967. De l'homme cueilleur à l'homme cultivateur. *Cahiers d'histoire mondiale* 10(2):275–292.

Barrau J. 1970. *L'Homme et son environnement végétal en région tropicale humide: L'exemple Malayo-Océanien*. Faculté de Lettres–Museum d'Histoire Naturelle, Paris. 48 p.
Clement C.R. & Villachica H. 1994. Amazonian fruits and nuts: potential for domestication in various agroecosystems. p 230–238. In: *Tropical trees: the potential for domestication and the rebuilding of forest resources*, ed. R.R.B. Leakey & A.C. Newton. HMSO, London.
Coates A. 1987. *Commerce in rubber: the first 250 years*. Oxford University Press, Singapore. 380 p.
Dove M.R. 1993a. A revisionist view of deforestation and development. *Environmental Conservation* 20(1):17–24.
Dove M.R. 1993b. Smallholder rubber and swidden agriculture in Borneo: a sustainable adaptation to the ecology and economy of the tropical forest. *Economic Botany* 47(2):136–147.
Dove M.R. 1994. Transition from native forest rubbers to *Hevea brasiliensis* (Euphorbiaceae) among the tribal smallholders in Borneo. *Economic Botany* 44(4): 382–396.
Dunn F.L. 1975. *Rain-forest collectors and traders: a study of resource utilization in modern and ancient Malaya*. Monographs of the Malaysian Branch of the Royal Asiatic Society 5. Royal Asiatic Society, Kuala Lumpur. 151 p.
Foresta H. de & Michon G. 1991. Agroforesteries indonésiennes: systèmes et approches [Indonesian agroforestries: systems and approaches]. Communication to the workshop 'Which agroforestries for ORSTOM?' ORSTOM, Paris. 14 p.
Fried S.T., & Sardjono M.A. 1992. Social and economic aspects of rattan production, middle Mahakam region: a preliminary survey. *GFG Report* 21:63–73.
Geertz C. 1966. *Agricultural involution. the process of ecological change in Indonesia*. University of California Press, Berkeley. 176 p.
Godoy R. & Feaw T.C. 1989. The profitability of smallholder rattan cultivation in central Borneo. *Human Ecology* 16(4):397–420.
Gouyon A., Foresta H. de & Levang P. 1993. Does 'jungle rubber' deserves its name? An analysis of rubber agroforestry systems in southeast Sumatra. *Agroforestry Systems* 22:181–206.
Haudricourt A.G. & Hedin L. 1943. *L'homme et les plantes cultivées*. Paris.
Kashio M. 1994. Report on a mission to Laos. FAO RAPA, Bangkok. 6 p.
Jong W. de 1994. Deforestation and reforestation in a Dayak village in West Kalimantan. Communication to the Third Biennial International Conference of the Borneo Research Council. 17 p.
Leakey R.R.B. 1996. Definition of agroforestry revisited. *Agroforestry Today* 8(1):5–7.
Leakey R.R.B. & Newton A.C., eds. 1994. *Tropical trees: the potential for domestication and the rebuilding of forest resources*. HMSO, London. 284 p.
Marsden W. 1783. *The history of Sumatra*. Oxford University Press, London. 479 p.
Michon G. 1985 De l'homme de la forêt au paysan de l'arbre: agroforesteries indonésiennes. Ph.D. thesis, USTL., Montpellier, France. 272 p.
Michon G. & Bompard J.M. 1987. The damar gardens *(Shorea javanica)* in Sumatra. p 3–17. In: *Proceedings of the Third Round-table Conference on Dipterocarps*, ed. A.G.J.H. Kostermans. UNESCO, Paris.
Michon G., Foresta H. de & Levang P. 1994. New face for traditional commons. Forest conversion and the redefinition of common property and individual rights through agroforest development in Sumatra, Indonesia. Communication to the 5th Conference of the International Association for the Study of Common Property Resources, Bodo, Norway. 13 p.
Michon G., Foresta H. de & Aliadi A. 1996. Damar resins, from extraction to cultivation: an 'agroforest strategy' for forest resource appropriation in Indonesia. p 454–459. In: *Ethnobiology in Human Welfare*, ed. S.K. Jain. Deep Publications, New Delhi.

Michon G., Foresta H. de & Aliadi A. 1993. Reinventing the forest: damar *(Shorea javanica)* extraction and cultivation in Sumatra, Indonesia. Unpublished report, 48 p.

Momberg F. 1992. Indigenous knowledge systems: potentials for social forestry development. Resource management of land: Dayaks in West Kalimantan. MA thesis, Institute for Geography, Freie Universität, Berlin. 212 p.

Narr K.L. 1956. Early food producing populations. In: *man's role in changing the face of the earth*, ed. W.L. Thomas. Chicago.

Pelzer K.J. 1945. *Pioneer settlement in the Asiatic tropics*. International Secretariat Institute of Pacific Relations, New York. 290 p.

Purseglove J.W. 1974. *Tropical crops*. Longman Group Limited, Harlow. 719 p.

Sastrapradja S. 1975. Tropical fruit germplasm in Southeast Asia: the Indonesian case. p 33–46. In: *Southeast Asian plant genetic resources*, ed. J.T. Williams, C.H. Lamoureux & N.Wulijarni-Soetjipto. Biotrop, Bogor, Indonesia.

Sauer C.O. 1952. *Agriculture origins and dispersals*. American Geographical Society, New York. 175 p.

Simanullang B. 1988. Benzoin farmers: an anthropological study about benzoin production in Desa Aek Nauli, North Sumatra. MA thesis, Universitas Sumatera Utara, Fakultas Ilmu Social dan Ilmu Politik. 108 p.

Sundawati L. 1993. The Dayak garden systems in Sanggau, West Kalimantan: an agroforestry model. MSc thesis, Georg-August University, Göttingen. 95 p.

Warburg O. 1897. *Die Muskatnuß. Ihre geshichte, botanik, kultur, handel und verwerthung sowie ihre verfalshungen und surrogate*. Zugleich ein beitrag zur kulturgeschichte der Banda-Inseln. Leipzig, Germany.

Watanabe H. 1990. Lessons from traditional forest management in which non-wood forest products are mainly harvested in Southeast Asia. *Agricultures Internationales* 1:140–143.

Weinstock J.A. 1983. Rattan: ecological balance in a Borneo rainforest swidden. *Economic Botany* 37(1):58–68.

Plate 18. *A damar* (Shorea javanica) *agroforest in Sumatra. Planted by farmers and intercropped with rice, coffee and other crops, the damar trees are tapped for resin. These agroforests are highly productive and profitable, while also providing many of the environmental services of tropical forests.* *(photo: R.R.B. Leakey)*

Plate 19. *Resin flowing from the tapping point of a* Shorea javanica *(damar) tree.* *(photo: R.R.B. Leakey)*

Production and commercialization of gum arabic in Sudan

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Abstract

This paper presents details of the methods used over the years to establish the vast agroforestry resources that enabled the Sudan to supply about 85% of the world's demand for gum arabic from *Acacia senegal* (L.) Willd.

The methods maintaining the gum gardens, tree tapping and gum collection are described. Indications of recent annual tonnages, the main uses of gum arabic, the international specifications that have to be met and trends of production are given. Exportation from Sudan is the monopoly of the Gum Arabic Company, which exports to its appointed agents throughout the world. Some agents simply distribute the gum as received, to their clients, but others process the gum in a range of ways necessary to satisfy the specific requirements of the commercial end-users operating in their own country, or in other countries from which they have secured a sales contract.

Introduction

The gum arabic of commerce is a water-soluble exudate. The major source (95%) is *Acacia senegal* (L.) Willd. (hashab), with the remaining 5%, from *Acacia seyal*, sold as an entirely separate product (gum talha). Both tree species grow in various plant communities in the drier parts of Africa and Asia (Seif el Din 1969). Commercial use of gum arabic can be traced back to around the year 2000 BC, when the Egyptians used it in foods, adhesives, colours and paint industries. The term 'gum arabic' was coined by European traders, who imported the products from Arabian ports such as Jeddah and Alexandria, and most gum traders of the time were associated with Arab countries. The trade was routed along the Nile from Sudan to Alexandria and later in 1906 to Suez on the Red Sea when the railway was constructed to link Port Sudan to Khartoum. The main ports of disembarkation were Trieste in Italy and Marseilles in France, from where the gum arabic was distributed to the rest of Europe.

Until the first two decades of the present century, Sudanese gum arabic was mainly produced in the central parts of the country, when the principal world market was Ed Dueim town on the White Nile. When in 1912, the railway was extended westwards to El Obeid, the gum arabic production was extended to Kordofan and Darfur, where the principal gum-producing trees of *Acacia senegal* are the dominant component of the woody vegetation on light sandy soils. Because of the remarkably good quality of the gum from these new areas, the end-users of gum arabic often requested to be supplied with 'Kordofan gum'. This new terminology was applied to distinguish the gum that was purely from *Acacia senegal* as opposed to that from other areas, which was occasionally adulterated with exudations from other trees.

The annual gum arabic exports from the Sudan ranged from about 2000 to 7000 tons during the last two decades of the 19th century and subsequently grew to reach the maximum of 62 000 tonnes in 1968/69. During its long history, the gum trade in the Sudan witnessed some major setbacks. The first was in the period of the Mahadia wars

(1881–1898), the second during World War II (1941–1945), and the third resulted from the prolonged drought in the Sahel of 1968–1975 and again from the relatively short-lived drought of 1983–1985. The last two droughts caused the exports to drop from an annual average of 45 000 t (Seif el Din 1995). From 1983 to 1991, gum production began to increase steadily back to its normal levels (fig. 1), thanks to the return of normal rainfalls in the gum belt. Despite this increase of production, exports of gum arabic are

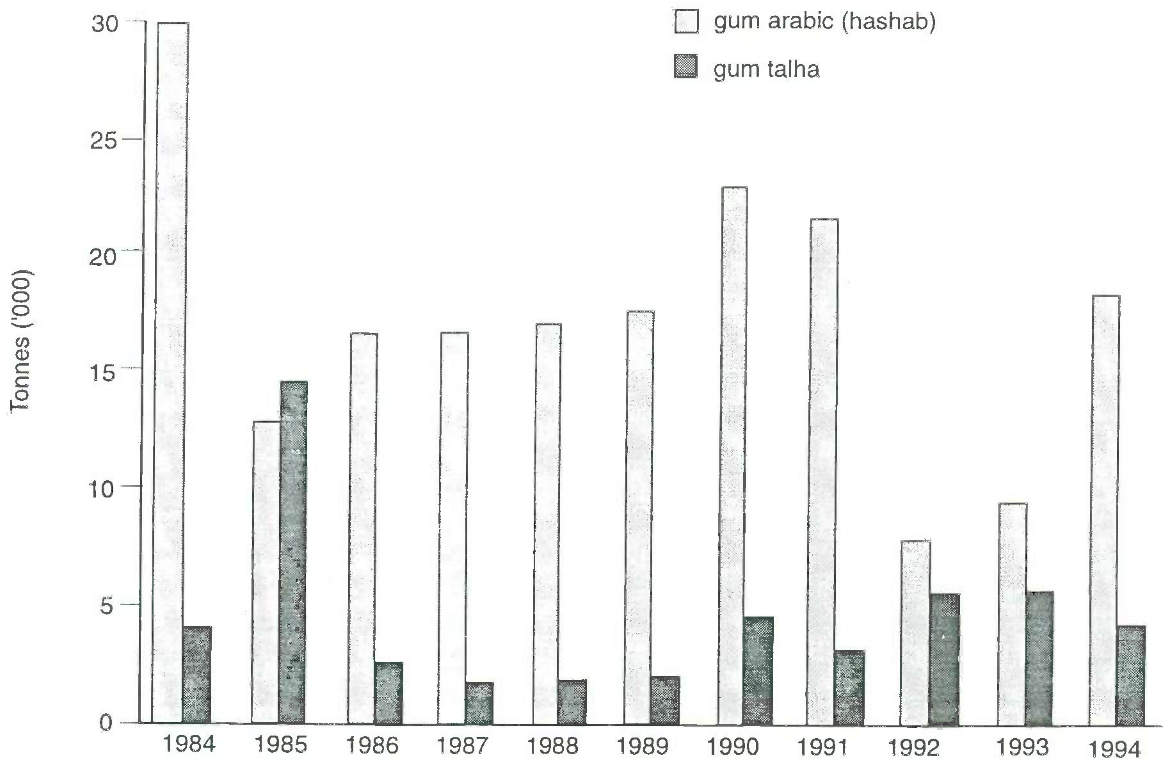

Figure 1. *Exports of gum from the Sudan. The difference between the production figures in table 2 and these export figures probably relates to the export of gum from existing stocks in drought years. Source: Forestry National Commission.*

reviving at a relatively slow pace, because of the confusion caused by the short supplies for world consumption during the drought years. Similar adverse production and export situations have been faced in other gum-producing countries in Africa, such as Chad, Nigeria, Niger and Senegal. In all cases, Sudan remained the supplier of some 70–90% of world consumption of gum arabic, as indicated in table 1.

Gum arabic and its uses

Gum arabic is one of several natural gums and one of four principal exudates that ooze from trees and harden upon exposure to air (Glicksman 1969). It has been described in various reports and laboratory analyses as forming an aqueous solution of up to 50%; colourless and free of taste and odour, these solutions do not readily interact with other chemical compounds. Because of these attributes gum arabic has been used in a wide range of industries, particularly in food preparation. For the people who tap and collect gum arabic in the producing areas, the gum is principally an export crop, with very limited use in its native areas.

Gum arabic from Sudan is obtained or tapped from *A. senegal* trees, from which pieces of bark 10–30 cm long and 2–4 cm broad are removed to form wounds. The gum exudes in the

Table 1. World gum arabic production (tonnes) 1966–1978

Origin	Production	Percentage
Sudan	39 922	78.3
Senegal	2 784	5.5
Nigeria	2 610	5.1
Mauritania	2 480	4.9
Mali	1 018	2.0
Ethiopia	873	1.7
Chad	597	1.2
Tanzania	350	0.7
Niger	323	0.6
Total	50 907	100

Source: Seif el Din 1995

form of small droplets on the wounds that steadily grow in size until they become nodules of 2–5 cm diameter. These nodules are ready to be picked for sale after about 4–6 weeks.

Subsequent pickings are available at intervals of 1–2 weeks. Whereas the biosynthesis of the gum appears to be an internally controlled physiological process, the growth of the nodules seems to be more closely related to the physical environment of the tree (Seif el Din 1969). However, the exudation of gum talha from *Acacia seyal* trees occurs in the hot dry season, without the tree being tapped.

The main gum-producing regions of the Sudan are those falling in the *Acacia senegal* savanna-on-sand vegetation type, which covers most of Kordofan and Darfur states and parts of White Nile state. The clay plains of east and central Sudan contribute only about 25–30% of the total production of Sudanese gum arabic. In 1995, Kordofan produced 49.3% of the gum arabic from Sudan, Darfu 23.4%, eastern Sudan 7% and central Sudan only 0.3%.

As outlined above, the average production in the predrought years (1968–1974) was about 45,000 t an^{-1}. This amount, however, fluctuated widely from one year to another, owing to various factors such as the rainfall, pests, the local prices of gum arabic compared with those of other crops, and the general socioeconomic stability of the gum belt (table 2). Almost all the gum produced from Sudan is destined for export, but should production exceed world demand, the excess is kept as a buffer stock that

Table 2. Production of gum arabic during the last five seasons 1990/91–1994/95

Season	Production (tonnes)	Export price f.o.b. Port Sudan (USD)
1990/91	12 061	2 300
1991/92	7 329	2 550
1992/93	11 410	4 500
1993/94	33 458	4 000
1994/95	estimated 40 000	4 200
1995/96	estimated 30 000	3 500 *

Source: Gum Arabic Co. Ltd. 1995
* reduced to USD 2200 in May 1996

offsets deficits in years of low production. It can thus be observed that, in any one year, gum exports might be greater than current year's production and vice versa.

The uses of gum arabic are a function of its physical and chemical properties. As indicated above, it is practically colourless, tasteless, odourless and readily soluble in water, to give aqueous solutions of low viscosity. Other properties such as rheological behaviour, pH, electrolytes, ageing, compatibility and emulsifying properties have been detailed by Glicksman (1969). Chemical analyses have shown that gum arabic from *A. senegal* is a very complex compound containing D-glucuronic acid, D-galactose, L-arabinose, L-rhamnose and 4-0-methyl-D-glucuronic acid (Anderson 1966).

The main uses of gum arabic are in the food industries (see Hulse, this volume), particularly confectionery, which uses about 60% of world consumption. It is also used in flavourings and in pharmaceutical preparations as a building and emulsifying agent. Other industrial products that use technical grades of gum arabic include adhesives, textiles, printing, lithography, water colours, paints, paper sizing and pottery glazing.

Because of the stringent regulations imposed on all food additives, gum arabic, like all other food ingredients, is subjected to extensive toxicological research by countries, organizations and users of the produce. Most concerned in this regard are the US Food and Drug Administation, the British Pharmacopoeia, and the FAO/WHO Joint Expert Committee on Food Additives (JECFA), all of which aim to protect the consumer of processed foods containing additives, and thus ensure the safety of gum arabic from toxicological hazards. To achieve this end, gum arabic must conform to certain chemical specifications, and these must be adhered to, by both the producers and the processing enterprises. Among these requirements are that the gum arabic has to have a specific optical rotation of –26 to –34 degrees and nitrogen content of 0.24–0.41% (Anderson et al. 1990, 1991). These characteristics and a whole list of other specifications are met only by gum arabic from *A. senegal* (L.) Willd. var. *senegal* (Brenan 1983) and not by gum talha from *Acacia seyal*.

Sustainability of gum production

Commercial gum arabic is the product of *A. senegal* var. *senegal*, which is widely distributed on the African continent as well as in Arabia, Pakistan and India (Brenan 1983). Three other varieties of *A. senegal* are recognized—var. *kerensis*, which seems to be restricted in its distribution to the East African countries of Ethiopia, Somalia, Uganda, Kenya and Tanzania, and var. *leiorhachis* and var. *rostrata*, both of which seem to be restricted to eastern and southern Africa. It is reported that gum exudates from these three varieties are distinctively different from the true gum arabic of var. *senegal*. Because of the strict safety regulations against toxicity, gum talha from *A. seyal* is no longer acceptable, as it does not conform to the agreed specifications.

A. senegal var. *senegal* is the only variety that is being cultivated for gum production in Sudan, as well as in some other Sahelian countries. It is incorporated in the famous agroforestry system known as the bush-fallow system of shifting cultivation, described by Seif el Din (1981). In this system the gum trees are encouraged to grow on farm plots during the fallow period, during which they improve soil fertility, so ensuring adequate crop production when cultivation is resumed. The tree, which protects the soil from erosion and improves its fertility, also provides the farmer with gum as a cash crop during the dry season. This system ensures optimum and sustainable utilization of the natural resources, since both the gum production and the crop cultivation form productive components of the system. Added to this is the fact that animals graze under the gum trees during the dry season without harming the trees. When the trees are felled to allow cultivation, the wood is used for fuel, for building materials and for building fences around farm plots.

This agroforestry system has, however, undergone substantial deterioration, particularly in the main gum-producing areas in Kordofan and Darfur, as a result of the recurring droughts. Tree mortality was widespread, and especially severe in the northern parts of those regions, resulting in partial or total collapse of the bush fallow system. In view of this, the government has started a project, assisted by the United Nations Sudano-Sahelian Office, to restock the gum belt in Kordofan and Darfur. In this project farmers are provided with seeds and seedlings to plant in their own fields. Similar activities are also being carried out elsewhere in the gum belt, spearheaded by the Forest Extension Unit of the Forest National Corporation (FNC).

Because of the importance of gum arabic for the economy of Sudan, the forest service has adopted a strategy of establishing plantations of *Acacia senegal* inside forest reserves to act as buffer plantations. There are at present about 30 000 feddans (12 500 ha) in Blue Nile, Kassala and Kordofan regions, and these are annually rented out to gum tappers on a share-cropping basis. Furthermore, gum plantations constitute a considerable part (30–40%) of the FNC annual tree-planting programme. The Sudanese governments also decreed that all the mechanized farming schemes should plant trees on 10–15% of their area to act as shelterbelts, using *Acacia senegal* var. *senegal* as the main species.

The gum trade

In Sudan, gum buyers do not have contacts with the growers, farmers, tappers or collectors but buy competitively at auction. The farmgate price is fixed by the Sudanese government each October to induce villagers and others to go out to tap the trees and thereafter collect the gum. In years in which there is a surplus and 'buffer stocks' accumulate, the farmgate price is lowered to discourage maximum production. In years of shortage, the opposite applies. The Sudanese merchants licensed to buy at auction must, by law, pay the grower, farmer, tapper or collector immediately after the auction. The minimum price that can be paid at auction is the farmgate price, i.e., the official base price. Gum arabic that, for any reason, is not bought by an independent licensed buyer must be bought by the official Gum Arabic Company at the official base price.

After the merchants buy at auction, they have the gum cleaned and graded by hand in their sheds by young female employees. The grades used are:

Hand-Picked Selected (HPS)
Cleaned and Sifted (CAS)
Cleaned Natural
Red Gum
Gum Siftings
Gum Dust

These grades are then delivered to Port Sudan and sold to the Gum Arabic Company at prices fixed for each grade to allow the buyer, cleaner and grader a margin of profit after the costs of transportation have been met. A 40% export tax is levied by the government when the gum is loaded on to a vessel at Port Sudan for export. The sole permitted exporter, the Gum Arabic Company, ships worldwide to its official appointed agents (one per country), who get 1.5% of the selling price as a discount or commission. A further 0.5% is retained by the Gum Arabic Company to finance research and promotional activities. The agents do not normally hold stocks of gum; they simply arrange contracts for the gum to be delivered from Port Sudan direct to an end-user.

In recent years there has been a growing belief that the present monopolistic exportation by the Gum Arabic Company, introduced in 1967–1968, should be deregulated so that any Sudanese person could buy direct from the farmer or collector and then export the gum to any end-user in any country. This view is becoming more strongly held because the present system, intended to ensure the quality of Sudanese production, is being abused by active smuggling of gum to Chad, Nigeria, Ethiopia, Uganda, Kenya and other countries to avoid the 40% export tax.

Gum arabic produced by countries other than Sudan is cheaper but generally of lower quality, because the cleaning and grading are not as effectively and strictly regulated, because gums from any botanical species may be intermixed in a very variable way, and because other countries have no planted stands of *Acacia senegal* var. *senegal* such as those forming the basis of Sudanese gum arabic production, as a result of the extensive agroforestry developments over many years.

Warm Seas Ltd. is an international multibusiness company involved in the gum trade. There are five divisions, including marketing, consulting, and international trading. Throughout its history, Warm Seas has served over 450 multinational companies. The group employs about 350 staff worldwide and has offices and affiliates in 25 countries around the world. Its main offices are in Sudan, the UK, the USA, France, Germany and the United Arab Emirates.

Warm Seas has been operating successfully for over 20 years, using London as its headquarters. It has developed a strong business in Africa and the Middle East. The group now operates in Africa, Europe, the USA and Asia. Warm Seas through its quality service has built excellent relationships with some of the major food and beverage companies in the world. Warm Seas has equipped its food processing plant in Europe with the latest technology in food processing and continues to deliver total quality service to its customers around the world.

Conclusion

Gum arabic has remained an important cash crop for Sudanese peasants in the arid and semi-arid areas over thousands of years. Its production is going to remain, for a long time to come, a peasant industry for millions of smallholders in areas where other income-generating activities are not available. The gum tree itself is essential in sustaining the farming system, and thus, whether it produces gum arabic or not, farmers will encourage its growth on their lands. This undoubtedly will ensure sustainability of gum supplies to the world market. Sudan, in this respect, has the advantage that the gum tree *Acacia senegal* var. *senegal* occurs naturally over the large area known as the Gum Belt, which covers 40–50% of the total area of the country.

Because the tree grows in almost pure stands of natural bush and groves of pure gum gardens, Sudan will continue to offer on the world market the highest grade of gum arabic with the required specifications. Other countries that could do the same are those in the Sudano-Sahelian zone of Africa such as Chad, Nigeria, Mali and Senegal.

References

Anderson D.M.W., Hirst Sir Edmond & Stoddart J.F. 1966. Some structural features of *Acacia senegal* gum (gum arabic). *Journal of the Chemical Society* Section C, p 1959–1966.

Anderson D.M.W., Brown D.D.M., Morrison N.A. & Wang W. 1990. Specifications for gum arabic (*Acacia senegal*) analytical data for samples collected between 1904 and 1989. *Food Additives and Contaminants* 7(3):303–321.

Anderson D.M.W., Millar J.R.A. & Wang W. 1991. Gum arabic *(Acacia senegal):* unambiguous identification by 13C-NMR spectography as an adjunct to the Revised JECFA Specification and the application of 13C-NMR spectra for regulatory legislative purposes. *Food Additives and Contaminants* 8(4):405–421.

Brenan J.P.M. 1983. Present taxonomy of four species of *Acacia* (*A. albida, A. senegal, A. nilotica,* and *A. tortilis*). p 97–110. In: *Manual on taxonomy of* Acacia *species*. FAO, Rome.

Glicksman M. 1969. *Gum technology in the food industry*. Academic Press, New York and London.

Gum Arabic Co. Ltd. 1995. Gum arabic in the Sudan. Workshop on Gum Arabic, 2–3 October 1995, El Obeid, Sudan.

Seif el Din A.G. 1969. The natural regeneration of *Acacia senegal* (L.) Willd. MSc thesis, University of Khartoum, Sudan.

Seif el Din A.G. 1981. Agroforestry practices in the dry regions. p 419–434. In: *Proceedings of Kenya National Seminar on Agroforestry*, ed. L. Buck, P. Huxley, F. Owino & D. Ngugi. ICRAF and University of Nairobi, Nairobi, Kenya.

Seif el Din A.G. 1995. Gum arabic production in the Sudan. Agricultural Insurance Workshop in the Sudan Sheikan Insurance and Reinsurance Co. Ltd., Khartoum, Sudan.

Domestication and crop development of *Duboisia* spp. (Solanaceae)

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Abstract

Tropane alkaloids have always played a significant role in ethnomedicine as well as orthodox medicine. Formerly, the main sources were the genera *Datura*, *Brugmansia*, and *Atropa* of the Solanaceae family, but recently the Australian genus *Duboisia*, especially the species *D. myoporoides* and *D. leichhardtii*, have become an important source. *D. myoporoides* is a small tree of the rainforest areas of the eastern coast of Australia; *D. leichhardtii* prefers a slightly drier habitat further inland. Dried leaves are used for the extraction of the pharmaceutical products.

It was during World War II that *Duboisia* leaf was collected in quantity and this new source of pharmaceutical products gained in importance. Research activities decreased after 1945 and ceased about 1954, leaving a few plantation trials involving several hybrids between *D. myoporoides* and *D. leichhardtii*. In the following years, what little effort continued in further crop development came mainly from individual growers.

In the mid-1960s Boehringer Ingelheim, a German pharmaceutical company and the main buyer of *Duboisia* leaf, decided to resume the work done in Australia during the war. Available hybrids, as well as new accessions from the natural populations, were screened and a breeding programme was established. The selection criteria used were alkaloid pattern and content, leaf yield, shoot regrowth from stumps, drought resistance, insect resistance, wind resistance, and suitability for mechanical harvest. Simultaneously, research was initiated to develop techniques for vegetative propagation and for weed and pest control, while improvements in cropping and fertilizer use were achieved through experimentation. In addition, machinery for planting, maintenance and harvesting was adapted or designed.

Since 1980, raw material of *Duboisia* for export has been derived from cultivated plants only, and production has proven to be profitable.

Introduction—the tropane alkaloids

The family Solanaceae provides numerous medicinal plants. A prominent group is the tropane alkaloids, containing the main genera—*Datura, Brugmansia, Atropa, Hyoscyamus*. These have played significant roles in ethnomedicine and religious practices of the Old and New World and are now also important in orthodox medicine.

The main tropane alkaloids used in orthodox medicine are atropine (dl-hyoscyamine) and scopolamine (hyoscine). Atropine as a parasympatholytic dilates the pupils of the eyes; it also serves as an antidote against toxins such as phosphoric acid esters like E 605. Formerly scopolamine was used mainly in association with morphine as an analgesic at childbirth and as a hypnotic agent in certain mental disorders. During World War II, scopolamine was found to be of great value in the treatment of bomb shock and against sea- and air-sickness. Demand increased, and since access to the traditional sources was restricted, new sources were sought, leading to interest in the exploitation of *Duboisia* species.

Duboisia myoporoides and *D. leichhardtii*

The genus *Duboisia* comprises three species: *D. myoporoides* R. Br., *D. hopwoodii* F. Muell. and *D. leichhardtii* F. Muell., discovered in 1802, 1861 and 1867, respectively. The occurrence of these woody representatives of the Solanaceae family is restricted to Australia and New Caledonia (*D. myoporoides* only). *D. myoporoides* occurs along the east coast of Australia in frost-free areas with an annual rainfall exceeding 550 mm. The occurrence of *D. leichhardtii* is restricted to a relatively small, drier inland region in South-East Queensland. Both typically are found as isolated trees at the edge of the forest. Because of their corky bark they easily withstand bush fire, and when felled they sucker profusely, which enables them to regenerate quickly in disturbed areas (Barnard, 1952). In about 1880, scopolamine and hyoscyamine were identified as the main active principles of pharmaceutical importance in the leaves of *D. myoporoides* and *D. leichhardtii*. In *D. hopwoodii*, nicotine and related compounds were found prevalent.

Duboisia myoporoides and *D. leichhardtii* are trees that grow up to about 14 m tall. The wood is extremely light and the stem bark very corky (hence its local name 'corkwood'). The leaves are glabrous, broad-lanceolate to obovate in *D. myoporoides*, while in *D. leichhardtii* they are narrower, more lanceolate (6–10 cm long) and light green. Because of its narrower leaf, *D. leichhardtii* appears less leafy. Both species flower profusely in spring, with small, white, typically solanaceous flowers in cymose panicles. The fruit is a small globular berry about 5 mm in diameter, containing up to 15 or more seeds.

In 1940 collection of *Duboisia* from the wild commenced. Commercial production of scopolamine began in 1941, that of hyoscyamine/atropine in 1942 (Barnard 1952). Propagation of plants and plantations was limited in the early years because of the abundance of naturally occurring trees when land was cleared and burnt. For the harvest of *Duboisia* leaf for extraction, the trees are cut, the complete branches with the leaves are air dried and then the dry leaves removed (traditional method), or the fresh branches are chopped, the leaf separated from the wood chips and dried artificially (common industrial method). The stumps normally regrow and can be harvested again after about 12 months. The first large-scale plantations did not occur until the late 1950s, and then they were mainly from seedlings transplanted from natural germination in the wild.

Plant-related research initially focused on plant propagation, on identification of alkaloid-rich genotypes, and the elucidation of the reasons of alkaloid variation (Barnard & Finnemore 1945). These activities gained a new dimension when, in the area where the habitats of *D. myoporoides* and *D. leichhardtii* overlap, intermediate types were found that appeared to be natural interspecific hybrids. Artificial hybridization experiments started, and by 1945 the first hybrid plants were established in the field (Groszman et al. 1949, Hills et al. 1954a, b, c). After the end of World War II, commercial alkaloid extraction and government-supported research continued until about 1954 when the export embargo on *Duboisia* leaf was lifted. Commercial extraction was no longer competitive in the international market; research was considerably reduced if not ceased. Exportation of *Duboisia* leaf from collection of wild material and increasingly from cultivation commenced and continued with a steadily growing level, one of the main buyers being Boehringer Ingelheim.

Domestication and crop development of *Duboisia* spp. did not lead to an agroforestry production system. However, this minor forest species turned into a commercial plantation crop in a relatively short time and may well serve as an example for the problems and opportunities to be expected in similar projects. In other new medicinal crops, agroforestry may be the appropriate production system.

Research and development by Boehringer Ingelheim

In 1951, Boehringer Ingelheim, producer of pharmaceuticals and fine chemicals with a long tradition in alkaloid extraction, launched Buscopan®, a derivative of scopolamine. This compound is a potent spasmolytic and analgesic, lacking the psychotropic effects of scopolamine. Demand for raw material increased considerably, and to secure the supply of high-quality raw material the company decided to develop its own plantations. In the late sixties its R&D work on *Duboisia* started.

Selection of starting material

The plant population present in the existing plantations showed considerable variation. In addition to seed-propagated stands, clones were present derived from early hybridization work and from superior natural sports. After establishing appropriate facilities for analysis, some 20 future parent plants were selected from this highly variable population, together with a small number of pure *D. myoporoides* and *D. leichhardtii* specimens.

Propagation

Insufficient germination and extremely low striking rates of cuttings were common problems encountered by the *Duboisia* growers. Consequently, seed germination trials were established, which confirmed the existence of a seed dormancy period and led to seed pretreatment methods, which resulted in a germination rate of 80–90%. Similarly, after a series of vegetative propagation trials, methods were optimized with respect to plant parts used, season, cutting techniques, disinfection, applications of rooting hormones, substrate, potting material, greenhouse climate and hardening off procedures. Standard striking rates of 90–99% were achieved. More recently, a method for tissue culture propagation has been established and implemented.

Plant breeding

Only conventional breeding methods were applied. Special techniques of controlled crossing of *Duboisia* have been developed, the most important point being the synchronization of flowering. In the course of a continued crossing programme, genotypes were identified that carried useful and highly heritable traits, thus building up a pool of parent plants. Out of more than 12 000 progeny from controlled crosses, about 20 individuals have been cloned for commercial cultivation.

Selection criteria (in the order of the stages of selection) were alkaloid content, alkaloid pattern, ease of vegetative propagation, regrowth potential, leaf yield, stability of alkaloid pattern, drought resistance, wind resistance, frost resistance, insect and nematode resistance, and suitability for mechanical harvest.

Alkaloid pattern stabilization

Unexpected changes were frequently found in alkaloid content and pattern. For example, strong genotype x site interaction and declining alkaloid content of ageing trees were observed. These and similar phenomena made clonal selection, as well as yield estimates, unpredictable. Therefore, the patterns of various alkaloids (scopolamine, hyoscyamine and some other accompanying minor alkaloids) from *Duboisia* hybrid individuals and clones were assessed with respect to—

- variation between genotypes
- variation within hybrid progenies of crosses
- intraclonal variation
- variation over several generations of clonal propagation
- variation over productive life cycle (up to 10 years)
- seasonal variation
- variation between locations
- effects of fertilizer, soil types, and water supply

As a result, clones were identified in which the genetic traits of alkaloid content were stronger than usual, so that the impact of environmental and other factors was reduced and alkaloid yield became more predictable. Harvesting has been closely adapted to seasonal variations in alkaloid content.

Cultivation

Duboisia cultivation practices used to be rather extensive with wide spacing, little or no use of fertilizer and utilization of suboptimal soil types. These factors kept yields low. With the aim of more intensive land use, crop requirements were assessed in field trials with respect to soil type, soil nutrients, fertilizer application, cover crops and planting density. High importance was given to weed control, this being a major cost factor. In cooperation with the regional distributors, herbicides were tested for use with *Duboisia* and eventually registered. Setbacks, such as accumulation of subcritical amounts of residues over a long time, led to the identification of a well-balanced weed control system, which combined mechanical weeding with an essentially minimum level of herbicide application.

Plant protection

As has to be expected when establishing pure stands of plants normally growing in biologically diverse natural stands, insects and parasites feeding on them became pests. However, appropriate crop rotations and the selection of tolerant clones have resulted in the reduction of these problems. For example, nematode populations have been reduced to an acceptable threshold level by this method. Similarly, the incidence of a weevil 'stem borer', whose larvae mine the trunk, has been greatly reduced after clones with a different type of bark were introduced, while another damaging insect, the 'flea beetle' *Psylliodes parilis*, is currently under investigation and cultural practices to reduce its impact are in sight.

Harvesting

Harvesting of *Duboisia* used to extend over the whole summer period, but through studies of the seasonality of alkaloid content, it became possible to define clone-specific periods of maximum alkaloid content. Special high-capacity harvesting machines have been developed that eliminate the need for protracted manual harvesting and allow the harvest to take place when alkaloid contents are high.

Processing

Leaf-drying capacity must match harvesting capacity. Dryer systems were tested and developed for increased drying quality and throughput, and for the avoidance of dust from dried plant material. This has helped to minimize the exposure of workers to the pharmaceutically active substances.

Achievements and factors of success

A number of *Duboisia* hybrid clones have been developed that are superior to the common 'standard' hybrid in scopolamine content (about double), improved growth characteristics, predictability of quality and yields, and lower susceptability to soil nematodes and stem borers.

Cultural practices have been improved with respect to labour requirements, use of agrochemicals and soil conservation. There is a better understanding of insect population dynamics, leading to a more rational use of pesticides. Health hazards originating from the plant material have been greatly reduced.

Today *Duboisia* is a commercially viable crop, which contributes considerably to exports from the region and is the main source of raw material for tropane alkaloid production worldwide.

Several factors contributed to the progress achieved:

- There was basic knowledge of the plants and their cultivation available from farmers and research institutions that provided the starting point for Boehringer Ingelheim´s domestication efforts.
- Rapid progress was made in quantitative analysis of alkaloids and its use in a high-capacity analytical laboratory. This was a precondition for an efficient screening of plant material.
- The combination of commercial farming and R&D activities provided the indispensable immediate feedback and long-term continuity that are necessary when dealing with plantation crops. From identification of suitable parent plants to the first commercial harvest of a new clone takes at least 8–10 years.
- Considerable support, especially in phytopathology, was granted by the Queensland Department of Primary Industries. Research on insect biology was carried out at the University of Queensland.

References

Barnard C. 1952. The duboisias of Australia. *Economic Botany* (1):3-17.

Barnard C. & Finnemore H. 1945. Drug plant investigation: 1. Progress report. *Journal of the Council for Scientific and Industrial Research (Australia)* 18(4):277–285.

Groszmann H.M., Kelenyi G.P. & Rodwell, C.N. 1949. Hybrids between *Duboisia mycoporoides* and *D. leichhardtii*. *Queensland Journal of Agricultural Science* 6(3):1–8.

Hills K.L., Bottomley W. & Mortimer P.I. 1954a. Variation in the main alkaloids of *Duboisia myoporoides* R.Br. and *D. leichhardtii* F.Muell.: 2. *Duboisia myoporoides*. *Australian Journal of Applied Science* 5(3):258–275.

Hills K.L., Bottomley W. & Mortimer P.I. 1954b. Variation in the main alkaloids of *Duboisia myoporoides* R.Br. and *D. leichhardtii* F.Muell.: 3. *Duboisia leichhardtii*. *Australian Journal of Applied Science* 5(3):276–282.

Hills K.L., Bottomley W. & Mortimer P.I. 1954c. Variation in the main alkaloids of *Duboisia myoporoides* R.Br. and *D. leichhardtii* F.Muell.: 4. Interspecific hybrids. *Australian Journal of Applied Science* 5(3):283–291.

Utilization of local fruit in wine making in Malawi

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Abstract

Wine was made from the following indigenous and exotic fruits of Malawi: katope *(Syzygium owarience)* in December–January, guava *(Psidium guajava)* in January–April, chidede *(Hibiscus sabdariffa)* in June–September, bwemba *(Tamarindus indica)* in July–October and mango *(Mangifera indica)* in September–January. For katope and chidede, hot water extraction was carried out and the pH adjusted to pH 3.5. All the musts were treated with pectolytic enzyme to destroy pectins, which inhibit the clarification of the wine. White cane sugar, wine yeast nutrient and commercial wine yeast were added to all the juice extracts. Aerobic fermentation was carried out for two days at 25°C in an open container. Fermentation started 2 hours after the yeast was mixed with the ingredients. After two days, anaerobic fermentation continued at the same temperature (25°C) until the wine was ready for bottling. The first racking occurred one week after the start of anaerobic fermentation, and subsequent rackings were at two-week intervals. Completion of fermentation and therefore the clarification of the wine occurred 4–6 months after the fermentation process started. The alcohol content of the wine ranged from 14 to 16%. The white guava gave the highest alcohol content and produced a dry wine. Mango and bwemba also produced white wines, chidede produced a rosé wine, and katope produced a red wine. The flavours of the wines were characteristic of the fruit used. The average Malawian palate preferred the semi-sweet wines.

Introduction

The African continent has many indigenous shrubs and trees, fruit-bearing varieties among them. A number of these fruit shrubs and trees, mostly the exotic ones, have been domesticated, and some are grown under agroforestry farming systems. The fruits produced by many of the indigenous shrubs and trees are edible. They grow and ripen within a very short period of the year, which leads to an overabundance of the fruit at that time, when the supply usually exceeds the demand. This situation is aggravated by the lack of storage facilities for fresh fruit or of fruit-processing facilities. In addition, some of the fruits, although edible, are not very palatable, contributing to their underutilization.

Producing wine from these indigenous fruits is one way to utilize the excess fruit or to improve its palatability. Wine has been made from the fruit of palms (Herzog et al. 1995), sour cherry (Vondracek et al. 1981), *Rosa roxburghii* (Liu-Jiunian 1982), cashew apple (Rao 1985) and bamboo (Mgheni 1983), among many indigenous others. The most common commercial wine is traditionally made from grapes.

In Malawi, Williamson (1975) documented many useful plants, among them katope (*Syzygium* spp.), bwemba *(Tamarindus indica* L.), guava *(Psidium guajava* L.), chidede *(Hibiscus sabdariffa* L.) and mango *(Mangifera indica* L.), all producing fruit at different times of the year. Wine making from indigenous fruits in Malawi was at one time commercial, and Mulunguzi wine was made from masuku or wild loquat *(Uapaca kirkiana* Muell. Arg). Unfortunately production stopped, and no one in Malawi makes country wine on a commercial basis any more.

This study examined wine production from some fruits of Malawi throughout the year: katope (December–January), guava (January–April), chidede (June–September), bwemba (July–October) and mango (September–January). No attempt was made to use masuku in this study.

Materials and methods

Fruit

All the fruits were bought within Malawi. Katope was purchased in Lilongwe; guava was bought from the Bunda College orchard; chidede was harvested around the Bunda area in Lilongwe; bwemba was purchased in the Machinga area on the road to Mangochi; and the mangoes were purchased in Ntcheu District on the way to Balaka. The fruits purchased were fresh except for the bwemba fruits, which were dried.

Juice extraction

Juice was extracted by covering the fruit with 2 litres of boiling water per kilogram of fruit. The mangoes and the bwemba were peeled before they were scalded. The scalded fruit was cooled in a covered glass or plastic container, crushed, placed in a nylon juice extraction bag, and squeezed.

Pectin destruction

Pectolytic enzyme (pectolase) was added to the extracted fruit juice to help clarify the wine, as all the juices tended to be high in pectin. The enzyme was left to incubate with the juice for 24 hours.

pH monitoring

The pH of the resulting juice was determined using a narrow-range pH paper. The aim was to obtain a pH of around 3.5, which is an acceptable acidity for wines. Where necessary the pH was adjusted with either lemon juice or citric acid, or with potassium carbonate (K_2CO_3).

Aerobic fermentation

After the pH was adjusted, cane sugar from Malawi was added, as the sugar content of the fruit was low. The maximum alcohol produced in the absence of additional sugar would have been about 5%. The sugar added at fermentation was aimed to produce an alcohol content of 11–12%. Also added were wine yeast from a starter and wine yeast nutrient. The yeast was left to ferment aerobically for 48 hours at room temperature (25–27°C), during which time the must was stirred every 12 hours.

Anaerobic fermentation

After the 48 hr of aerobic fermentation, the must was poured into 25-litre scalded containers of glass or plastic, where anaerobic fermentation occurred over many months. The gas trap contained boiled water.

Racking

The first racking was usually one week after the start of the anaerobic fermentation with more racking following at longer intervals (two weekly rackings on the average), until fermentation stopped and the wine had cleared. Clearing normally started during the 4th month of fermentation, but some wines took up to 6 months to clear.

Bottling

Bottling was carried out after the wine had stopped fermentation and the wine had cleared. The best time for bottling was usually 6 months after fermentation.

Results and discussion

Acidity

The pH of katope and chidede extracts were acidic (pH 1.5) and had to be adjusted with K_2CO_3. Once adjusted, the pH remained the same until the end of fermentation.The pH of the other fruit (i.e., mangoes, guavas and bwemba) were normal for wine production (pH 3.5): *S. owariense* 2.5 ± 0.5, *P. guajava* 3.5 ± 0.5, *H. sabdariffa* 1.5 ± 1.0, *T. indica* 4.0 ± 0.5, *M. indica* 3.5 ± 0.5.

Fermentation

The yeast used in these fermentation trials was very active at 25–27°C, and fermentation started 2 hours after it was added. All the wines stopped fermenting after the alcohol content was above 12%. It was difficult to have clarity in the wine during the early part of fermentation. Katope tended to ferment faster (3.5 months) than the other fruits and was also faster in clearing. The slowest fermenting fruit was the mango, which took 5 months to clear. The seasonal temperatures influenced the rate of fermentation, which was faster during the hot season (August–December).

Alcohol content

Fermentation and clearing took longer in katope and white guava than in the other fruits. The mean alcohol content after the wine stopped fermenting was *S. owariense* 14% (range 12–16%), *P. guajava* (white) 16% (12–18%), *P. guajava* (red) 14% (16–18%), *H. sabdariffa* 12% (12–14%), *T. indica* 14% (12–14%), *M. indica* 14% (12–16%).

Colour of wine

Wine colour was related to the colour of the fruit pigment: *S. owariense*, red wine; *P. guajava* (white), white; *P. guajava* (red), white; *H. sabdariffa*, rosé; *T. indica*, white; *M. indica*, white. The intensity of the rosé and the red colour depended on how long the pectolase had been used to destroy the pectin; the longer the juice was incubated with the pectolase the deeper the colour of the wine.

Sweetness or dryness of wine

Although generally the sweetness of the wines depended on the quantity of cane sugar added to the must, the white guava normally gave a dry wine and the red guava a sweet wine. This must depend on the other sugars present in the red guava, which were not fermented by the yeast. This observation has also been made in white peach and red peach wines.

Wine preference

Although this has not been quantified yet, the majority of Malawians ask for wine that is either semi-sweet or sweet. On the other hand, expatriates normally prefer dry wine.

Cultural differences in preference is of course an important consideration when the market for wines is being developed.

Commercialization

Commercial production of wine is possible from any of these locally available fruits. The fact that some of the shrubs and trees have found their way into agroforestry systems will make the fruit readily available for wine production. There is great potential in Malawi for commercial production of country wine. So far, the wine has advertised itself. Other fruits that have been used include peaches (*Prunus persica* L. Batsch), bananas (*Musa paradisiaca* L.), tangerines (*Citrus reticullata* Blanco), oranges (*Citrus sinensis* (L.) Osbeck), lemons (*Citrus limon* (L.) Burm), papayas (*Carica papaya* L.) and grenadillas (*Passiflora edulis* Sims). The commercial production of Mulunguzi wine from *Uapaka kirkiana* fruits in Malawi has been suspended currently.

To make commercial production of country wine in Malawi feasible, the following are needed: a reliable supply of wine yeast, yeast nutrient and pectolase; wine bottles and corking materials; and the availability of large-scale equipment for commercial production.

References

Herzog F., Farah Z. & Amado R. 1995. Chemical composition and nutritional significance of wines from the palms *Elaeis guineensis* and *Borassus aethiopum* in the V-Baoule, Côte d'Ivoire. *Tropical Science* 35:30–39.

Liu-Jiunian. 1982. Studies on the stability of chaosihua rice wine (using glutinous rice and fruit of *Rosa roxburghii* as raw material. *Food and Fermentation Industries* 3:43–51.

Mgheni A.S.M. 1983. Bamboo wine from *Oxytenanthera braunii*. *Indian Forester* 109 (5):306–308.

Rao M.S.S. 1985. Scope for development of alcoholic beverage from cashew apple. *Acta Horticulturae* 108:160–164.

Vondracek J., Blazek J. and Kloutvor J. 1981. Evaluation of sour cherry varieties. *Zahradnictvi* 8(4):249–260.

Williamson J. 1975. *Useful plants of Malawi*. University of Malawi and Montfort Press, Limbe, Malawi. p 129–227.

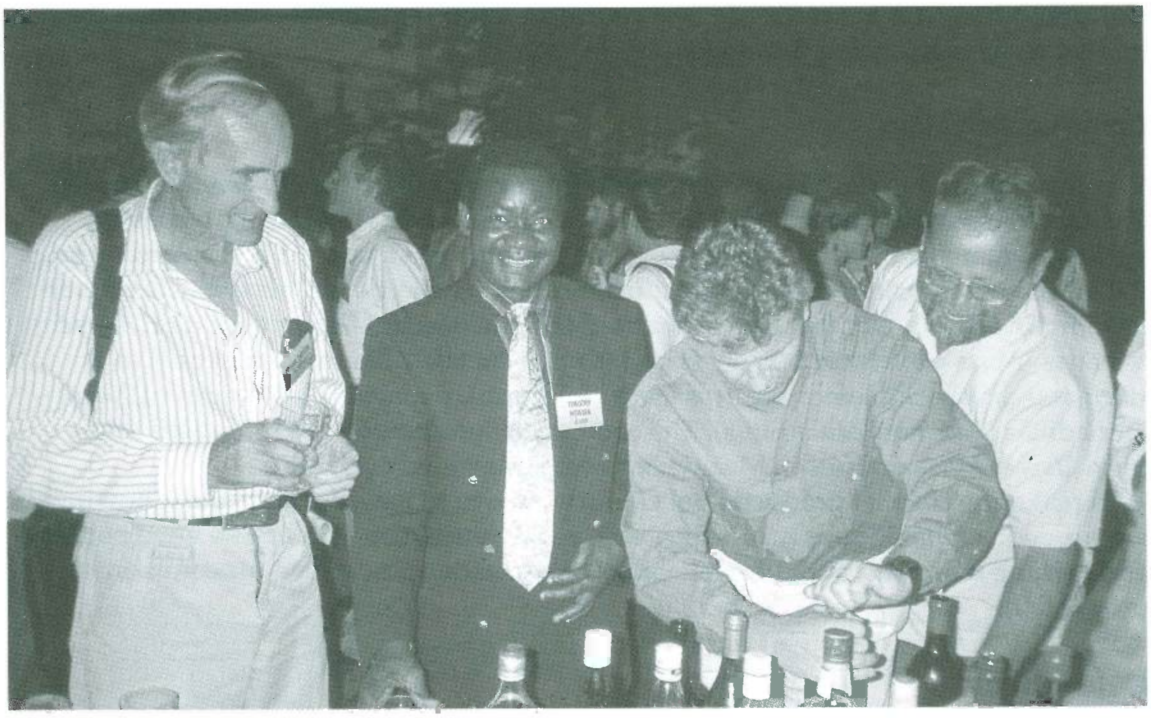

Plate 20. *Tasting wines from fruits of Malawi during the conference poster session.*
(photo: A.B. Temu)

Domestication of the bush mango (*Irvingia* spp.): some exploitable intraspecific variations in west and central Africa

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Abstract

Irvingia gabonensis and *Irvingia wombolu*, the eating and the cooking types, respectively, of bush mango, have been identified by the International Centre for Research in Agroforestry as priority wild fruit tree species for domestication. With information on farmer trait preference, and in collaboration with national agricultural research systems, rangewide germplasm collections have been made. Germplasm banks have been established for genetic conservation and for early assessments of progeny variation. These trials, together with observations on mature field-grown trees, are revealing substantial intraspecific phenotypic differences.

Morphological variations in vegetative and reproductive characteristics, including fruit quality attributes, have been found. Much of this intraspecific variation in the *Irvingia* species of west and central Africa provides opportunities for genetic improvement by genotypic selection and vegetative propagation. This could promote the domestication process of this important wild tree as a crop for agroforestry. This genetic improvement needs to go hand in hand with the commercialization of the bush mango's products to provide means for farmers to supplement their other forms of income and to help develop permanent land-use options, based on improved materials, as an alternative to slash-and-burn agriculture.

Introduction

The natural forests of west and central Africa are rich in natural resources and have tremendous biodiversity (FAO 1983), particularly in trees that provide food, fuel, fibre, medicines and various other products, including construction and building materials. *Irvingia gabonensis* Baillon and *Irvingia wombolu* (Vermoesen) produce edible fruits and seeds (fig. 1). The sustainability of these natural resources has been the concern of various workers (National Research Council 1991), particularly with the continued clearing and selective exploitation of forests (Palmberg 1984). This situation is causing substantial loss in germplasm and also degradation of particular genepools (Gale & Lawrence 1984). The need for conservation, domestication and development of sustainable production systems, such as are possible through agroforestry, has been emphasized if the environment is to recover from this degradation process. The genetic benefits obtained from the domestication of mango (*Mangifera indica* L.), *Citrus* spp., breadfruit (*Artocarpus altilis* (Z) Fosb.) and avocado (*Persea americana* Miller) in the tropics has shown that large genetic gains are possible and suggests that similar opportunities may await the native wild fruits of west and central Africa.

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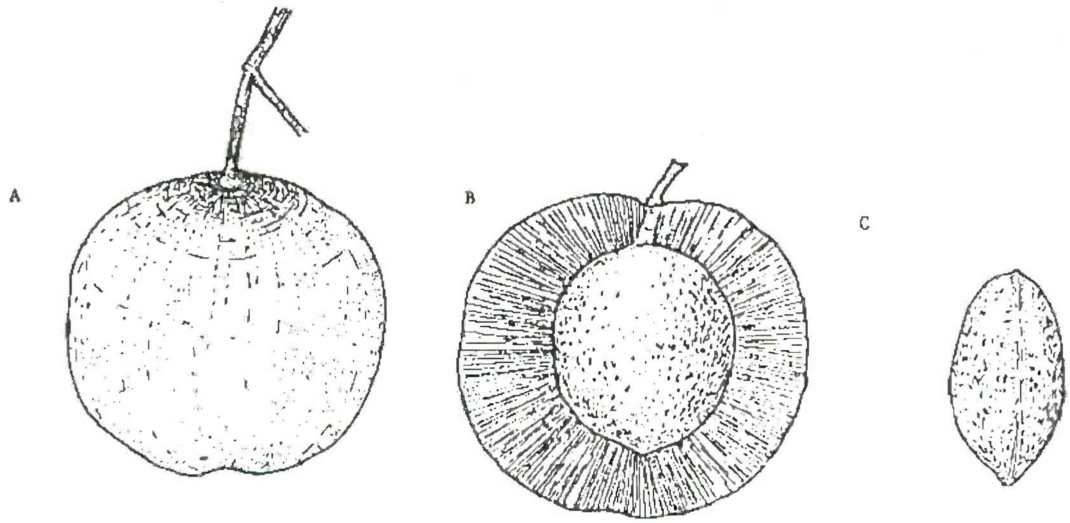


Figure 1. Irvingia gabonnensis: *(a) whole fruit, (b) vertical section and (c) extracted seed covered by hard and fibrous endocarp.*

The *Irvingia* domestication programme arose from the identification of farmer's priorities and trait preferences (Ladipo et al. 1995) using ICRAF's guidelines for priority setting among candidate species (Franzel et al. 1996, Jaenicke et al. 1995). The next step is to study the array of variation available in the species. This is done over the natural range of the species (fig. 2), with particular reference to those traits identified by farmers as being the characteristics appropriate for genetic selection. Consequently, the desirable inherent variation as observable phenotypic characteristics is identified and ready for selection.

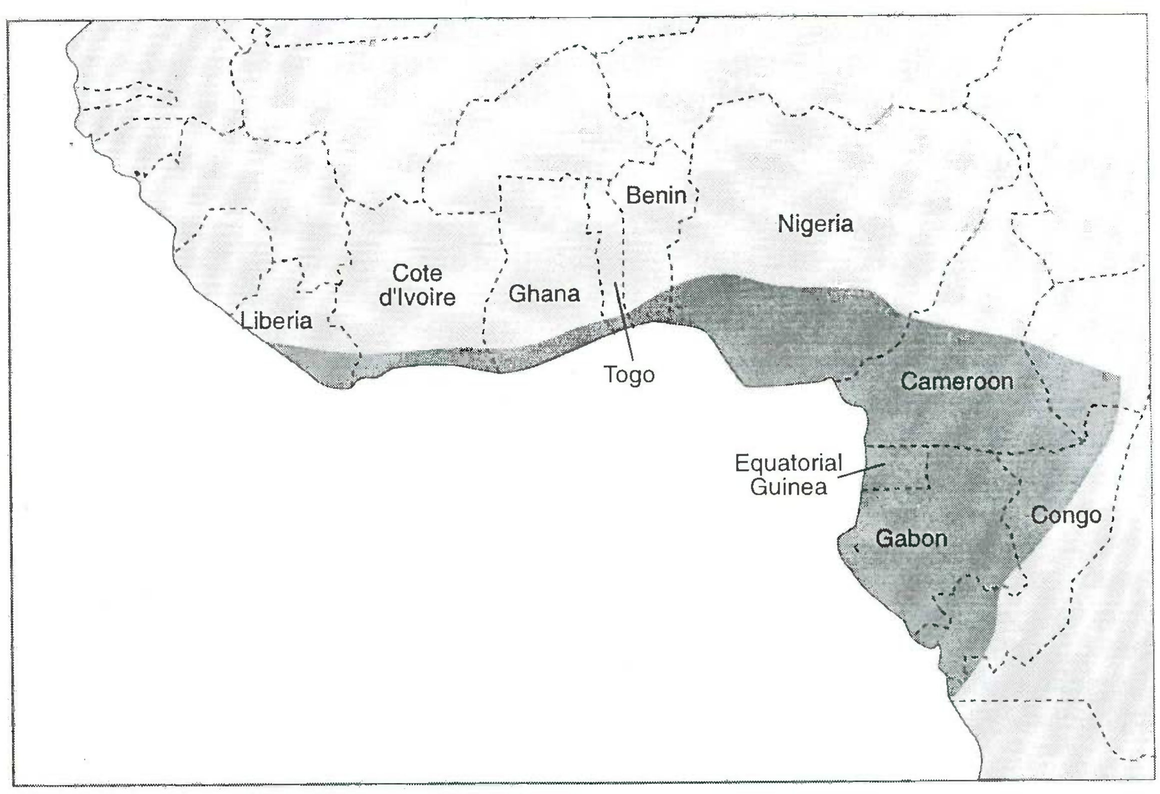


Figure 2. Natural distribution of Irvingia gabonensis *in West and Central Africa.*

The International Centre for Research in Agroforestry (ICRAF) has organized, with its national agricultural research system (NARS) partners, a systematic collection of good quality seeds from Ghana, Nigeria, Cameroon and Gabon, with emphasis on southeast Cameroon and northern Gabon, the centre of diversity of the trees *Irvingia gabonensis* and *Irvingia wombolu* (Ladipo et al. 1994, 1995).

It is well known that considerable variation exists within and between populations of tropical trees (National Research Council 1991). The patterns and extent of genetic diversity in forest trees are strongly determined by their mating systems and geneflow. However, very little is known about these aspects of *Irvingia* spp., except that in *I. gabonensis* the flower is hermaphroditic. Controversy, however, exists about the level of outbreeding. Ujor (1995) has reported low levels of inbreeding, while recent work by Ladipo (unpublished) indicates 100% outbreeding. This indicates that *I. gabonensis*, like other tropical trees, is highly heterozygous.

Intraspecific variation in *Irvingia* species

An important step in a tree improvement programme, particularly in the case of wild species, is definition of the selection criteria. The type and intensity of selection will depend on the pattern of variability within and between populations (Bawa 1976), and variability is the building block for trait improvement through breeding or genetic selection.

An individual or a population's expression of its genetic composition represents an interaction with its environment. This determines the phenotypes of the individual plants and thus their observable morphological characteristics. Most of these characteristics are influenced by a large number of genes. The influence of a single gene on such polygenic traits may be very small. However, the expression of rare recessive genes may result in a trait that is important for the development of a potentially valuable cultivar.

Very little information exists on inter- or intraspecific variations in many of the tropical tree species that are candidates for domestication, including the *Irvingia* species. Variations are reported below for crown shape, leaf colour, phenology and various fruit characteristics observed between populations and individual trees of *Irvingia gabonensis* in west and central Africa (table 1).

Table 1. Variation in fruit yield in 1995 between some 5-year-old Irvingia gabonensis *trees planted in Onne (southeast Nigeria)*

Tree no.	Fruits produced in 1995 (no.)
T 18	33
T 32	152
T 48	32
T 56	38
T 91	118
T 92	126
T 120	105
T 133	125
T 156	145
T 160	4
T 162	207

Variation in fruit production

The flowering and fruiting process consists of a series of sequential stages, all of which must proceed unhindered for a successful fruit harvest (Sedgley & Griffin 1989). The key steps are floral initiation, flower development, pollination, fruit set, fruit development and seed set. Fruit set may depend on the availability of pollen and the efficiency of pollinators, but seed set, which is the development of viable seeds from the ovules of pollinated flowers, depends on endogenous factors and their interaction with the environment. All these factors are under genetic control but can be manipulated by management factors. The success of seed set affects the variation in seed viability and thus germination.

Tree-to-tree variation in fruit yield has been observed over 2 years from a plot of *I. gabonensis* planted at the International Institute for Tropical Agriculture's (IITA) high-rainfall research station at Onne in Nigeria in 1990. For example, trees 160 and 162 produced 6 and 162 fruits in 1994 respectively. In 1995, these two trees produced very similar numbers of fruit and represented the extremes in terms of fruit yield among a small group of trees (table 1). Trees with a good yield of high-quality fruits are obviously potential candidates as future cultivars for agroforestry systems, and hence the selection and mass propagation of these individual trees is a key component of the domestication programme.

Variation in fruit sweetness

Chemical changes during ripening usually involve the conversion of starch to sucrose and reducing sugars. The extent of this conversion affects the sweetness of ripe and mature fruits (Alston 1992) as well as their retention on the tree.

During the *Irvingia* germplasm collections, it was specified that only mature and ripe fruits, as identified by colour and a slight shake of the mother-tree, should be collected. One hundred mature fruits were collected from each tree (where possible). Their sweetness was assessed by 'tasters', who tasted four fruits of each tree. Fruits were divided into three categories: very sweet, sweet and not sweet. Most were assessed as sweet (table 2), but substantial variation in fruit sweetness between accessions was observed in this exercise.

Table 2. Classification of accessions (by number) for fruit sweetness in Irvingia gabonensis *collected in Cameroon (C)*

Very sweet	Sweet	Not sweet
C 58	C22, C27	C44
C 61	C54	
C 59	C37	
	all other 1994/95 collections	

These simple and practical relevant results can be followed up by the more precise and technically sound method used, for example, to assess sweetness in apples (Alston 1992), in which the standard indicator bromocresol green is applied on the cut surface of the fruit to determine the level of sugar content.

Fruit colour

Fruit pigmentation is a major attribute in fruit marketing. For example, red apples have greater consumer appeal than green ones (Sedgley & Griffin 1989). The major pigments responsible for fruit colours are chlorophyll, carotenoids and anthocyanins. The chloroplasts in green immature fruits generally lose chorophyll on ripening and increase other pigments (Goodwin & Goad 1970). In many fruits, the carotenoid content varies, depending on cultivar or genotype, conferring variation in orange and yellow colouration in fruits. Increase in vacuolar concentration of anthocyanin as fruits ripen confers red colouration (van Buren 1970).

In the wild, fruit colour is thought to influence the interest of biotic dispersal agents. *Irvingia* fruits change from green to yellow as fruits ripen. The mature fruit colour has, however, been found to vary from tree to tree (table 3). This immense variability in colour is a resource that can be utilized for colour selection. The resulting consumer appeal should enhance the commercialization process of this wild fruit.

Table 3. Fruit colour, in Irvingia *accessions collected in Nigeria (A or B), Cameroon (C) and Gabon (G) in 1994/95,*

Colour type	Colour	Colour code*	Accessions
1	green	29–C–8 29–B–8 28–B–8	T30 T16 A24 C48
2	greenish yellow	1–B–8	A23 C44 B15 A8
3	yellow a/b	2–A–6/8	A27
4	brownish (cork) yellow a/b	4–C–4/5	G4
5	bright reddish yellow a/b	4–A–7/8	A22 A13 A19

* as defined in the *Metheun handbook of colour* (Korneup & Wanscher 1984)
T = tree

Variation in seed cracking

Similar to the case of already domesticated tropical nut trees, the endocarp of *Irvingia* needs to be cracked open (shelled) to extract the cotyledons (kernels), which are used as thickening agents in soups and stews. In Nigeria, these kernels are called *ogbono* in Ibo (Okafor 1978) and *apon* in Yoruba.

From Gabon to Cameroon and Nigeria, people utilize different techniques to extract *Irvingia* kernels. They can be extracted from fruits in the fresh state, or fruits can be fermented and the kernels extracted wet. Alternatively, they can be fermented and sun dried before extracting, packaging or marketing. All these methods are difficult and hazardous. The whole operation also takes a lot of farmers' time: it is estimated to involve over 288 hours in 3 months—time that could have been spent on other farm activities (Ladipo 1995).

During the 1995 *Irvingia* collections in Gabon, a tree (G28) was found in Bibas, in the north of Gabon, whose nuts split open naturally. The farmer who owned the tree well recognized the advantage of these self-splitting fruits (D. Boland, pers. comm). Fruits were collected from it and divided into three groups; one was processed and spread out to dry while the other two groups were sent to Onne in Nigeria and M'Balmayo in Cameroon for germination and the establishment of living genebanks. After 70–72 hours, 93% of the seeds from G28 had split open, exposing intact cotyledons while none of the seeds from six other accessions in Gabon split at all. This useful trait is an early splitting of the hard endocarp, a process that usually takes place much later during germination.

Variation in fruit shape and quality

In the domestication of *I. gabonensis*, special attention needs to be placed on fruit shape and form. Spherical fruits are the most common, but a range of other shapes has been recorded (fig. 3). For example, in Cameroon, accession C44 showed an unusual rectangular fruit shape, which was later found to occur also in Nigeria and Gabon. Piriform fruits are also found fairly frequently. This character was recorded for all mother trees in the passport data forms of each accession collected by ICRAF.

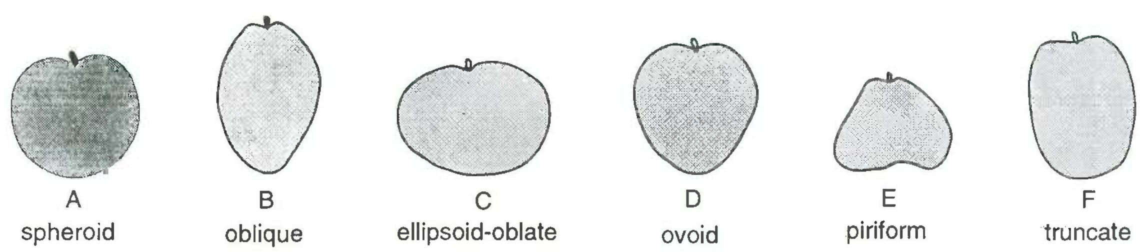


Figure 3. Variation in fruit shapes of Irvingia gabonensis.

In Onne (southeast Nigeria), fruit malformation or 'dimpling' was observed on some trees. Observation over 1 to 3 years has shown that this characteristic is repeated and is thus probably heritable. However, such deformations could be caused by insect or disease attack. Fruits from suspect trees in Onne were therefore examined *in situ* throughout their developmental stages. Sample fruits were cut open but did not reveal disease or insect attack at any stage. Cell collapse or failure of cells to divide during development could be responsible for this malformation, but this characteristic requires more investigation. In fact, it is important to identify this and other characteristics that can reduce the value or quality of *Irvingia* so that they can be eliminated early in the improvement programme for this species.

Variation in flowering and fruiting phenology

The time at which fruits ripen for harvest is a major determinant of the annual schedule of management practices in orchards. It also affects the profitability of the commercial crop (Sedgley & Griffin 1989).

The first stage in the flowering process is floral induction or evocation (Sedgley & Griffin 1989). It is not known what triggers this process in *Irvingia* species, but a substantial variation was observed in the number of floral flushes within the population of 182 trees planted in 1990 (table 4), with most trees not flowering at this age or flowering only once a year, but with a few flowering 2–4 times.

During the 1994 *Irvingia* germplasm collection in Cameroon, a large diversity in fruiting time was observed (see Fondoun et al. 1994). Maturity of fruits was early in the

Table 4. Variation in the number of floral flushes in trees of Irvingia gabonensis *4–5 years old at Onne, Nigeria*

No of flushes	1994	1995
Single	59	72
Double	10	11
Triple	8	10
Quadruple	6	7
Total	83	100

southwest and littoral regions, while fruiting was late in the central, eastern and southern regions of the humid lowlands of Cameroon (see fig. 4).

Fruit maturity in *I. gabonensis* can be in July–August (early) and August–September (late). However, some out-of-season fruiting seems to occur. In Onne (southeast Nigeria) trees T53, T126 and T162 fruited in February (4 months before general fruiting).

In the moist tropical forests of Gabon, Equatorial Guinea and southern Cameroon, field exploration confirmed the existence of indigenous knowledge about fruiting times and showed that trees of *Irvingia gabonensis* can flower and produce fruits twice a year. During the 1994 and 1995 collections, there was an opportunity to ask farmers who have lived all their lives in the forest about other variations. The Pygmies of the Dja Forest (Cameroon) and the Ibos of southeast Nigeria, in particular, have a lot of indigenous knowledge about their local fruit trees. In this area, some trees produce fruits in January–February and again in June–August. This is quite different from most other areas, which produce fruit only once a year, and indeed, sometimes even only every other year, as was reported by farmers for some trees in the littoral region of Cameroon. Ake Assi and Okafor (unpublished) have also observed trees that flower and fruit more than once a year in Ivory Coast and in Nigeria, respectively.

If variations of this type can be captured in domesticated varieties, the commercial viability of the crop would be greatly enhanced. Research is therefore needed to understand the genetic basis of this characteristic, so it can be effectively utilized in *Irvingia.*

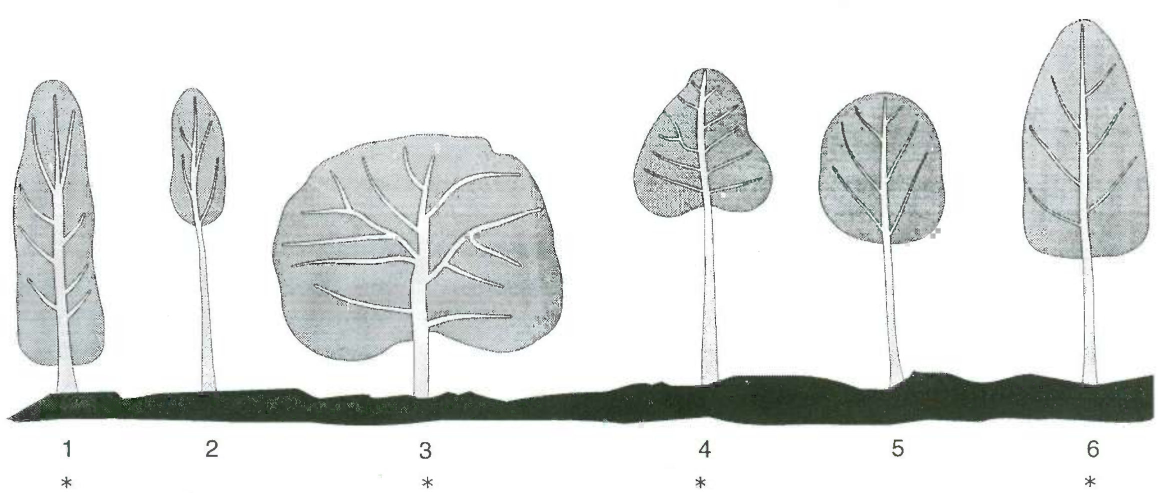


Figure 4. Variation in crown shape of Irvingia gabonensis *(* = Principal types)*

Variation in precocity

Precocity in plants is known to be under some degree of genetic control, with considerable variation in the time taken for trees to reach maturity and start fruiting. *Irvingia gabonensis* is generally said to commence flowering after 10–15 years, but Ladipo and Anegbe (1995) have reported variation in the commencement of flowering in young *I. gabonensis* in southeast Nigeria. This has also been indicated by farmers who reported that fruiting could commence much earlier in a precocious tree genotype. Near Ibadan, Adedeji (pers. comm.) reported that two of his three *Irvingia* trees began to fruit at year 6. Within a 182-tree plot of *I. gabonensis* planted in 1990 at Onne, 83 trees flowered in 1994; 100 trees subsequently flowered in 1995 (45%), with many of the same trees flowering and fruiting a second time.

Polyembryony

Polyembryony is the formation of more than one embryo in an ovule. It can be an advantage, as it is a form of clonal propagation, the nucellar embryos being identical to those of the female parent. Sedgely and Griffin (1989) have reported that polyembryony is under genetic control in some fruit tree crops. In *I. gabonensis* the level of polyembryony was found to differ between some accessions collected in the wild. Accessions that showed polyembryony in Ibadan also showed high levels of polyembryony in M'Balmayo, Onne, and Ibadan (see table 5), indicating that it is probably an inherent characteristic in these accessions exhibiting this trait. Assessment of six kernel samples of *Irvingia*, however, revealed that the weight of the two kernels from a polyembryonic fruit were about equivalent to the weight of the single kernel of normal fruit from the same accession. Therefore, from a production point of view, there seems to be little reason to select for this characteristic. However, the trait could be useful for research purposes.

Table 5. Incidence of polyembryony (percentage of fruits examined) in some Irvingia *accessions (A = Nigeria, C = Cameroon)*

Accession no.	Nursery sites			Average (%)
	Ibadan (%)	Onne (%)	M'Balmayo (%)	
C41	6.7	6.7	10.0	7.8
A28	4.0	6.7	4.0	5.0
A29	12.0	5.0	10.0	9.3
A12	3.3	6.7	3.3	4.4

Variation in crown shape

The form and shape of tree crowns can vary substantially and is probably due to genetic variation in apical dominance and apical control. Ladipo et al. (1991) identified genetic variation in apical dominance as the process determining clonal variation in the production of branches and branching frequency of *Triplochiton scleroxylon* K. Schum. trees and thus differences in their branching habit and crown form. In fruit trees, horticulturalists further manipulate tree form by pruning and mechanical treatments to promote flowering and improve fruit yields (Quinlan & Tobutt 1990). Branching and form traits are incorporated into breeding and selection programmes (Alston 1976), as they can be of substantial value for orchard development.

For agroforestry, substantial attention needs to be given to the crown attributes of trees, particularly their size and density, as affected by the numbers of branches, branching angle and branch retention, since crown form will affect the extent to which the tree shades interplanted crops.

Domesticated *I. gabonensis* acceptable for both agroforestry and intensive orchard management may eventually be required. This might involve the need for different crown and bole forms. These potential differences therefore need to be considered as selection criteria for improved cropping efficiency and to meet cultural and commercial needs.

Okafor (1974) described interspecific crown variations and delimited *Irvingia gabonensis* into two varieties (var. *excelsa* and var. *gabonensis*). Harris (1993) has more recently reclassified these varieties as species *I. wombolu* and *I. gabonensis*, respectively. This reclassification was based on fruit and crown form characteristics.

Isolated mature (10–25 years) trees of *I. gabonensis* have been assessed for their crown characteristics over the last 4 years in Cameroon, Gabon and Nigeria. Considerable variation is apparent (fig. 4). The genetic nature of these differences needs to be confirmed. Pruned and plantation trees were not included because of the possibility that their crown form results from competition in a forest type situation. It is not known, however, whether these assessed trees have been isolated throughout their life.

Foliar colouration

Colour change in the leaves of tropical trees is not uncommon as the leaves expand and mature (Longman & Jeník 1987).

In *Irvingia gabonensis* young leaves are usually pale green and sometimes pink. Field and nursery observations have shown that some trees of *Irvingia gabonensis* have red leaves (Okafor pers. comm., Ujor 1995) even as mature trees. In our collections, accession B40 (Nigeria) showed this characteristic in 14 out of its 30 seedlings. To a lesser extent, this leaf colouration was also observed in the progeny of four other accessions, in the M'Balmayo Field Station of IITA in Cameroon. This phenomenon occurs only in *I. gabonensis* and not *I. wombolu*. Red-leaved genotypes might have potential as cultivars for amenity plantings as the characteristic could be captured clonally by vegetative propagation.

Establishment of genebanks

Accessions of *I. gabonensis* collected in Nigeria, Cameroon and Gabon in August 1994 and January 1995 were divided into three lots for establishment in live genebanks within this subregion (table 6). In Nigeria two genebanks were established, one at Ibadan in collaboration with the National Centre for Genetic Resources and Biotechnology (NACGRAB), and one in Onne in collaboration with the International Institute of Tropical Agriculture (IITA). A third genebank was established at M'Balmyo in Cameroon in collaboration with IRA (Institut de Recherche Agronomique).

Table 6. Accessions of conserved germplasm of Irvingia *spp. in west and central Africa (Nigeria and Cameroon) in 1995*

Site	Accessions conserved (no.)		NARS and CG
	Bank 1	Bank 2	
Ibadan (Nigeria)	5	60	NACGRAB
Onne (Nigeria)	9	50	IITA
M'Balmayo (Cameroon)	7	55	IRA/IITA

Conclusions

The National Academy of Sciences (1975) and others have suggested the need to promote minor crops, while Leakey and Newton (1994) have emphasized the need to exploit their genetic diversity and to domesticate them for agriculture, agroforestry and forestry. ICRAF sees domestication as an opportunity to make agroforestry systems more attractive to farmers and to alleviate poverty, while at the same time promoting tree planting with indigenous trees, diversifying land-use systems and developing dynamic agroecosystems. The combination of domestication strategies with an improved policy environment and techniques to alleviate soil fertility depletion are seen by ICRAF as an opportunity to develop better land-use practices in sub-Saharan Africa (Sanchez & Leakey in press). This is urgent as tropical forests are still being destroyed and their genetic resources continue to be eroded. This paper has enumerated substantial phenotypic variations in *Irvingia* species, which could be exploited to ensure their successful genetic improvement and domestication. Vegetative propagation (see Ladipo 1995) and selection provide quick and reliable means to capture this genetic variation and to domesticate tree species (Leakey & Jaenicke 1995). This approach would enhance the efforts already carried out by farmers, selecting for crops that fit their specific ecosystems and to provide their needs.

Further study is required of the genetic variability in *Irvingia* species and to confirm their origin and values. We suggest further work on the following issues:

- Continue to study *Irvingia* breeding systems.
- Continue to collect and conserve more accessions, including the utilization of *in situ* techniques.
- Continue to identify variation in phenotypic characteristics and initiate corresponding chemical and analytical studies to determine descriptors of fruit quality.
- Undertake molecular genetic studies within and between populations to elucidate patterns of genetic variation.
- Conduct cytological studies to provide information on chromosome numbers, etc.
- Continue to develop propagation techniques, especially for mature tissues (see Ladipo in prep).
- Develop field trials on station and on farm to test performance of putative cultivars
- Investigate management and genotype interactions to develop production systems

The germplasm and knowledge already assembled indicate that domesticated. varieties offer the potential to enhance the fruit quality, including nutrition, environment and economy of the region.

References

Alston F.H. 1976. Dwarfing and lethal genes in apple progenies. *Euphytica* 25:505–514.

Alston F.H. 1992. Flavour improvement in apples and pears through plant breeding. *Phytoparasitica* 20:33–41.

Bawa K.S. 1976. Breeding of tropical hardwoods: an evaluation of underlying bases, current status and future prospects. p 43–59. In: *Tropical trees: variation, breeding and conservation*, ed. J. Burley & B.T. Styles. Academic Press, London.

FAO. 1983. Food and fruit breeding forest species. p 172. In: *Examples from East Africa.* FAO Forestry Paper No. 44/1. FAO, Rome.

Fondoun J.M., Kengue J. and Ndung'u J. 1994. *Irvingia* germplasm collection in Cameroon. Unpublished report. ICRAF, Nairobi, Kenya.

Franzel S., Jaenicke H. & Janssen W. 1996. *Choosing the right trees: setting priorities for multi-purpose tree improvement.* ISNAR Research Report No. 8. ISNAR, The Hague. 87 p.
Gale J.S. & Lawrence M.J. 1984. The decay of variability. p 77–85. In: *Crop genetic resources: conservation and evaluation*, ed. J.H.W. Holden & J.T. Williams. IBPGR, Rome, and John Allen and Unwin, London.
Goodwin T.W. & Goad L.J. 1970. Carotenoids and trite + penoids. p 305–368. In: *The biochemistry of fruits and their products*, vol. 1, ed. A.C. Hulme. Academic Press, New York.
Harris D.J. 1993. A taxonomic revision and ethnobotanical survey of the Irvingiaceae in Africa. D.Phil. thesis. University of Oxford. 274 p.
Jaenicke H., Franzel S. & Boland D.J. 1995. Towards a method to set priorities amongst species for tree improvement research: a case study from West Africa. *Journal of Tropical Forest Science* 7:490–506.
Korneup A. & Wanscher J.H. 1984. *Metheun handbook of colour*, 3rd ed., rev. by Don Pavey. Metheun. p 16–136.
Ladipo D.O. 1995. Management and genetic improvement of MPTS in humid lowlands of West and Central Africa. Annual report to ICRAF.
Ladipo D.O. In preparation. Vegetative propagation of *Irvingia gabonensis* from marcotts.
Ladipo D.O. & Anegbe P. 1995. Flowering and fruiting in field grown bush mango (*I. gabonensis* and *I. wombolu*) in southeast Nigeria. Paper presented at the 23rd Annual Conference of the Genetics Society of Nigeria, 14–18 May 1995. 9 p.
Ladipo D.O., Adewusi H., Fatokun H.K., Adebisi A. & Obisesan K. 1995. *Irvingia wombolu* (syn. *I. gabonensis* var. *excelsa* Okafor). Germplasm exploration and collection in southern Nigeria. ICRAF report on genetic resources collection activity in HULWA. ICRAF, Nairobi. 13 p.
Ladipo D.O., Britwum S.P.K., Tchoundjeu Z., Oni O. & Leakey R.R.B. 1994. Genetic improvement of west African tree species: past and present. p 239–248. In: *Tropical trees: the potential for domestication and rebuilding of forest resources*, ed. R.R.B. Leakey & A.C. Newton. HMSO, London.
Ladipo D.O., Leakey R.R.B. & Grace J. 1991. Clonal variation in apical dominance of *Triplochiton scleroxylon* K. Schum in response to decapitation. *Silvae Genetica* 40(3/4):135–140.
Leakey R.R.B. & Jaenicke H. 1995. The domestication of indigenous fruit trees: opportunities and challenges for agroforestry. p 15–26. In: *Proceedings of 4th International BIO-REFOR Workshop*, ed. K. Suzuki, S. Sakurai, K. Ishii and M. Norisada. BIO-REFOR, Tokyo.
Leakey R.R.B. & Newton A.C. 1994. Domestication of 'Cinderella' species as the start of a woody-plant revolution. p 3–6. In: *Tropical trees: the potential for domestication and rebuilding of forest resources*, ed. R.R.B. Leakey & A.C. Newton. HMSO, London.
Longman K.A. & Jeník J. 1987. *Tropical forests and their environment*, 2nd ed. Longmans, London. 185 p.
National Academy of Sciences. 1975. *Underexploited tropical plants with promising economic values.* NAS, Washington DC., 188 p.
National Research Council. 1991. *Managing global genetic resources: forest trees.* National Academy Press, Washington, DC., 228 p.
Okafor J.C. 1974. Varietal delimitation in *Irvingia gabonensis* (Irvingiaceae). *Nigerian Journal of Forestry* 4:80–87.
Okafor J.C. 1978. Development of forest tree crops for food supplies to Nigeria. *Forest Ecology and Management* 17:1–11.
Palmberg C. 1984. Genetic resources of arboreal fuelwood species for the improvement of rural living. In: *Crop genetic resources: conservation and evaluation*, ed. J.H.W. Holden & J.T. Williams. IBPGR, Rome, and John Allen & Unwin, London.

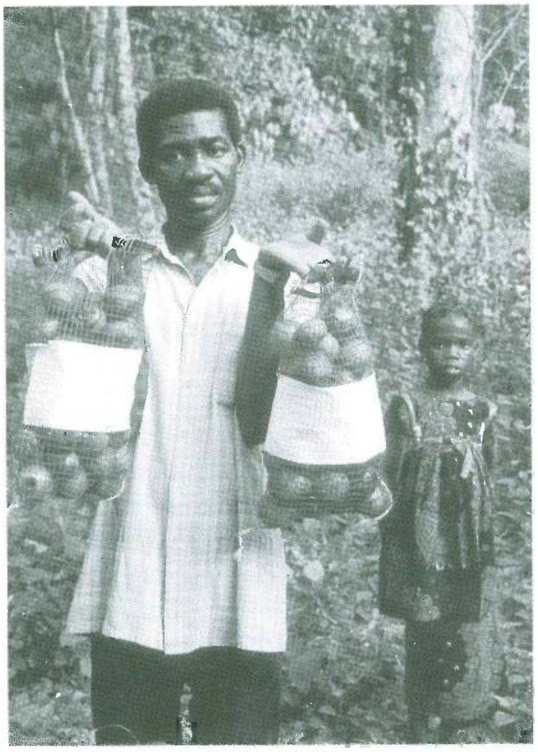
Quinlan J.D. & Tobutt K.R. 1990. Manipulating fruit tree structure chemically and genetically for improved performance. *Horticultural Science* 25(1):60–64.

Sanchez P.A. & Leakey R.R.B. In press. Land-use transformation in Africa: three determinants for balancing food security with natural resource utilization. In: *Proceedings of the Fourth Congress, European Society of Agronomy, 7–11 July 1996, Wageningen, The Netherlands.* 15 p.

Sedgley M. & Griffin A.R. 1989. *Sexual reproduction of tree crops.* Academic Press, Sydney, Australia. 378 p.

Ujor G.C. 1995. Reproductive biology of *Irvingia gabonensis* (O'Rorke) Bail in southern Nigeria: phenology, floral biology and varietal characteristics. PhD thesis, University of Ibadan, Nigeria. 355 p.

van Buren J. 1970. Fruit phenolics. p 269–304. In: *The biochemistry of fruits and their products*, vol. 1, ed. A.C. Hulme. Academic Press. New York.



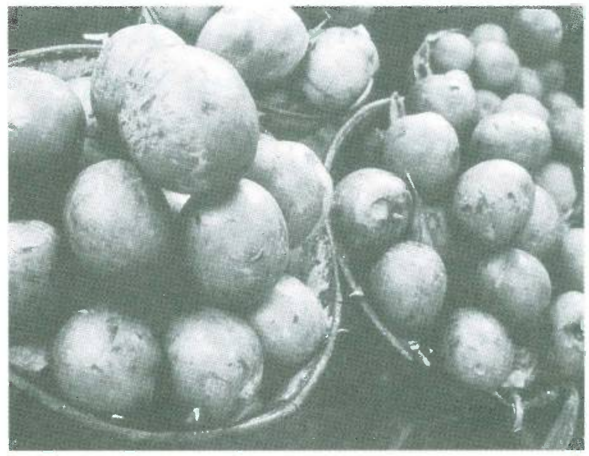


Plate 21. *A germplasm collector showing fruits of* Irvingia gabonensis *collected in southwest Nigeria.* (photo: D. Ladipo)

Plate 22. *Fruits of* Irvingia gabonensis *(bush mango), one of the priority indigenous tree species for domestication.* (photo: D. Ladipo)

Plate 23. *Variation in colour and size of mature fruits of* Irvingia gabonensis *collected in southeast Nigeria.* (photo: D. Ladipo)

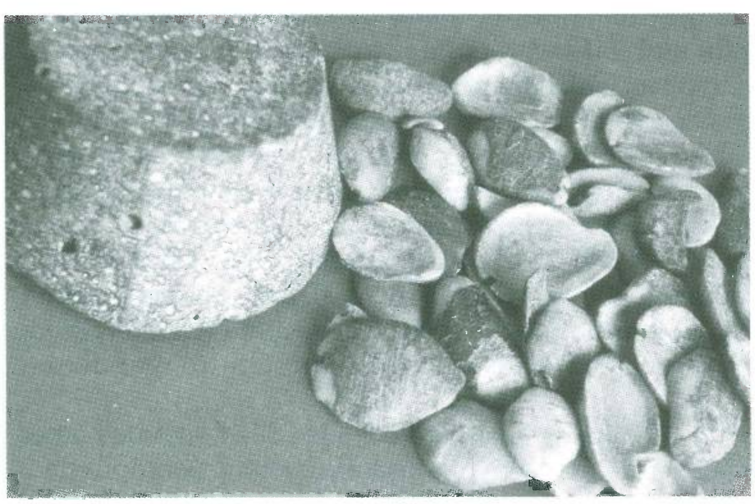


Plate 24. *Kernels (processed and unprocessed) of the seeds of* Irvingia gabonensis *(bush mango). These are used to thicken so ups and stews and are widely traded in West Africa.* (photo: R.R.B. Leakey)

Domestication of mushrooms from the miombo woodlands: current status and crucial issues for agroforestry

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Abstract

The miombo woodlands harbour a diversity of tree species producing valuable non-timber forest products. While most of these can be domesticated in human-created ecosystems, others may be specific to natural ecosystems. The depletion of natural forests and woodlands jeopardizes the continual existence of many of these non-timber forest products. For instance, some mushrooms that obviously occur in natural woodlands or forests do not normally occur in converted lands. This paper focuses on the status of mushrooms in the miombo woodlands and the current effort in Tanzania towards their domestication through harnessed symbiosis with trees in agroforestry systems. The crucial issues involved are highlighted.

Introduction

The miombo woodlands constitute the commonest woody vegetation in many eastern, central and southern African countries. In Tanzania, they constitute the largest single vegetation type (Temu 1979) and differ from other woodlands in that they are dominated by the genera *Julbernardia* and *Brachystegia (Leguminosae–Caesalpinioideae)* (Lind and Morrison 1974). Trees in these genera together with those in *Afzelia* and *Isoberlinia* (Leguminosae–Caesalpinioideae) and *Uapaka* (Euphorbiaceae) (Högberg & Nylund 1981, Högberg 1982, Alexander & Högberg 1986, Munyanziza & Kuyper 1995) make the miombo woodlands unique in that they are symbiotically associated with a variety of mushroom-producing fungi that make ectomycorrhizal symbiotic associations with tree roots (Munyanziza 1994). In addition there are saprophytic fungi and others that have symbiotic associations with termites, which are important in this ecosystem. Thus there are three broad groups of desirable mushroom-forming fungi:

- Ectomycorrhizal fungi, forming symbiotic associations that benefit the plants in terms of increased capacity for nutrient and water uptake. This results from enhanced efficiency by fungal hyphae, which increase the volume of soil exploited. The fungus, in exchange, gets energy from its host (Harley & Smith 1983). While some plants can live in the absence of the fungal partner, at least under amended (fertilized) environments, mycorrhizal fungi cannot live in the absence of the host. In poor, dry tropical soils, however, mycorrhizal associations are vital for plant growth and survival (Munyanziza 1994). The normal reproductive cycle of mushroom-producing mycorrhizal fungi involves the following stages: (1) spore germination, (2) mycelium growth, (3) infection of the specific host, and (4) fruiting-body (mushroom) production and sporulation. Without the right host the fungus does not reach stages 3 and 4.
- The saprophytes, which do not need living hosts and colonize dead organic matter that they decompose. They are hence involved in nutrient recycling. Saprophytic

mushrooms can thus occur in agricultural land, in pastures, and of course in woodlands and forests.

- The termitomyces, which live in symbiosis with termites. Termites culture the mycelium of the fungus in their nests and feed upon it and spread it. This relationship is obligate for both partners (Härkönen et al. 1995). Termitomyces constitute a delicacy in eastern and central African countries (Ryvarden et al. 1994).

In addition to these desirable fungi there are also a few undesirable parasitic fungi. These parasitic fungi live at the expense of their host. An example is *Armillaria mellea,* which fructifies on living trees. Parasitic fungi are harmful and therefore not welcome in agricultural or forest plantations. The point is not how to domesticate them but how to control them.

The unique ecosystem of the miombo woodlands is currently undergoing several forms of degradation related to human activity. Such activities include making charcoal, collecting fuelwood for home use, making bricks and especially clearing land for agriculture (Chidumayo 1987a, b; 1989, 1991). The rapid depletion of this ecosystem and its major tree genera has many implications, such as—

- Ecosystem-specific products will be lost.
- Tree-specific microorganisms will be lost some time after the removal of their tree partners. Among the most vulnerable organisms are the symbiotic mushroom-producing ectomycorrhizal fungi. When a species is in such danger, there are two possible options: (1) protection in its natural range or (2) domestication and multiplication in human-created ecosystems. Domestication can also be triggered by market opportunities. The aim of this paper is to discuss the status and the crucial issues in the domestication of mushrooms occurring in the miombo woodlands.

Increased interest in non-timber forest products

Intensive forest management has usually focused on timber as the main or the sole end product of forest operations. Thus all activities tend to be aimed at maximizing wood production and neglecting other forest components (Mikola 1970, 1980). This can lead to a failure to achieve sustainable production. Among the non-timber forest products attracting more and more interest for their economic potential and role in environmental protection are wild edible mushrooms (Pegler & Piearce 1980). In several countries, mushrooms are now included in forest resource inventory for their economic returns as a criterion for environmental health. While collected traditionally by local people in the wild, mushrooms have recently attracted scientists, donors and politicians (Härkönen et al. 1993, Ryvarden et al. 1994). Probably this reflects the fear that current land use is unsustainable.

Current land-use activities in miombo woodlands

People in the miombo woodlands have limited alternatives for energy and limited possibilities for income generation. In the process of converting land for agriculture, forestry, and other land uses the original vegetation is usually replaced by few a selected species not generally native to the area. In agriculture, these are maize, tobacco, beans, etc., while in forestry the species dominating plantations are eucalypts, pines and cypress. In agroforestry systems, trees given priority have mostly been those fixing nitrogen and with other multiple uses (Kamara & Maghembe 1994). In the miombo woodland areas the tree species composition of plantations, agroforestry and farms have a bearing on the quantity and species of mushrooms found, since the host–symbiotic relationship determines which species occur. Current interest in the domestication of indigenous miombo fruit trees for agroforestry could have benefits for mushroom production (Maghembe 1994).

Domestication of mushrooms in agroforestry: status and crucial issues

Domestication of the saprophytic mushrooms is probably the easiest of the three types described. The main requirements are the right substrate and an adequate physical environment. This group of fungi has been domesticated on a commercial scale in Europe, some Asian countries (Oei 1991) and recently also in some African countries. Mushroom eating in Tanzanian rural areas relies exclusively on collection from the wild. Species commonly eaten belong to a few genera, most of which live in symbiosis with termites or trees. *Amanita, Cantharellus, Lactarius* and *Russula* are ectomycorrhizal; *Auricalaria* and *Coprinus* saprophytic; and *Termitomyces* symbiotic with termites (Härkönen et al. 1995). Most of the mycorrhizal mushrooms eaten in Tanzania grow in mutualistic association with a few tree genera occurring in the miombo woodlands, as described above.

In Tanzania, there is a growing interest in the domestication of edible mushrooms but there is still a lack of appropriate simple techniques for doing it. Tanzania has, however, been chosen to coordinate mushroom cultivation in sub-Saharan Africa.

Mushroom growing in Tanzania is confined at the moment to academic institutions, where trials have been initiated in the laboratory or in the glasshouse. No trials exist in rural areas. The following issues have to be borne in mind when planning the domestication of mushrooms in agroforestry:

- Ectomycorrhizal fungi: The presence of ectomycorrhizal fungal inoculum in agricultural and agroforestry systems does not necessarily mean the production of mushrooms. A number of factors may affect vegetative growth of the fungus and the production of fruiting bodies.
- Termitomyces: These, living in symbiosis with termites, have not yet been domesticated. So far, they cannot be domesticated in isolation from their termite partners. They occur both in forest lands and in agricultural and agroforestry systems. The conversion of forest lands to agriculture or agroforestry is likely to have an effect on termitomyces.
- Saprophytes: Saprophytic mushrooms can be grown on a wide range of dead organic matter, from sawdust to entire logs. The yield, however, will depend upon (1) the nature of the substrate, (2) air humidity and temperature, (3) moisture of the substrate and (4) other competing organisms. The use of inoculated logs for mushroom cultivation outdoors has been practised in Asian countries with varying success (Oei 1991). Inoculated logs are used in Europe for mushroom cultivation (Y. Claassen pers. comm.). With the introduction of indoor cultivation, mushroom yield has been significantly improved (Oei 1991).

With declining land productivity and increasing interest in organic farming, the cultivation of edible saprophytic mushrooms offers prospects for using agricultural residues and sawdust. Residues used for mushroom cultivation can be reused in agriculture and agroforestry for soil conditioning, as fertilizers or as animal feed.

- Parasitic mushrooms: The cultivation of edible parasitic mushrooms is a risky venture since one would be building up the disease inoculum, which can shift to crops.

The right host, at the right time

The right host is essential to have symbiosis. Not all trees form ectomycorrhizal associations (Lapeyrie & Högberg 1994); in fact, in the tropics about 95% of the tree species form endomycorrhizas that do not form mushrooms (Mason & Wilson 1994). Clearly in the domestication of mycorrhizal fungi for mushroom production on trees in agroforestry systems, the tree component has to be a species forming ectomycorrhizas. A number of exotic species (e.g., pines and eucalypts) do form ectomycorrhizas (Mikola 1970, Munyanziza & Kuyper 1995), as do many of the indigenous miombo trees.

A further complication is the recognition that ectomycorrhizal fungi develop an ecological succession in forest plantations (Mason et al. 1987, Termoshuizen 1991). Thus mushrooms associated with seedlings (early-stage fungi) are different from those associated with adult trees (late-stage fungi). For increased mushroom diversity and sustained production, the domestication of mycorrhizal mushrooms will mean the creation of an agroforestry system having trees of different species and age groups supplied with the right spectrum of fungal partners.

Soil disturbance and chemicals

Mycorrhizal formation, especially mushroom formation, is sensitive to soil disturbance (Amaranthus 1992). Soil disturbance in agroforestry systems may take the form of compaction by machinery, weeding by hand, by hoe or by machine. Whatever the form, the mycelial network will be disturbed. Similarly, chemical weeding, which is often done in forests or agroforestry (Amakiri 1977), may have consequences on mycorrhiza fungi and hence on mushroom production (Iloba 1980). The same holds for other chemicals that may be used, for example, to control pests and diseases. Fungicides are obviously undesirable if mushroom production is part of the system. It is also well known that inorganic fertilizers may negatively affect mycorrhizal formation (Arnebrant 1994, Arnebrant & Söderström 1992). Where mushroom cultivation is envisaged chemical fertilizers should be avoided or used with caution.

Organic matter manipulation

The amount of organic matter available in forest stands influences the types of mycorrhizae present on tree roots (Harvey et al. 1976). In the Netherlands, Baar (1995) observed that organic matter manipulation (removal or addition of litter) in stands of Scots pines stimulated mushroom production in some fungal species while inhibiting it in others. In the miombo ecozone, farmers increasingly use miombo litter as a mulch in agroforestry systems. Depending upon the amount used, this litter may influence the number and quantity of mushrooms produced in such systems. The domestication of mushrooms in agroforestry will require a clear understanding of the ecology of the intended mushroom species.

Conclusions

Mushrooms constitute an important resource yet to be exploited on a commercial scale to alleviate poverty, food insecurity and environmental degradation in developing countries through their links with agroforestry. Traditionally gathered for household consumption, they have won international attention. However, their future is uncertain given the rate of destruction of their natural habitat. The domestication of edible saprophytic mushrooms in artificial conditions is, however, gathering some momentum in a few African countries. The domestication of edible mushrooms living in symbiosis with other organisms (trees and termites) is yet to start and needs to build on the understanding of the relation between the partners and the environment under which this relation can be optimized. Domesticating edible mushrooms in agroforestry will diversify the farmer's possibilities and increase food security but will require special management of agroforestry systems. This will depend especially on incorporating appropriate tree species in agroforestry systems, practising limited soil disturbance, understanding carbon dynamics and avoiding excessive use of inorganic fertilizers and chemicals.

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References

Alexander I.J. & Högberg P. 1986. Ectomycorrhizas of tropical angiospermous trees. *New Phytologist* 102:541–549.

Amakiri M.A. 1977. Effect of herbicides on microbial populations and activities in soils under teak (*Tectona grandis* L.) plantation. *East African Agricultural and Forestry Journal* 42(4):420–426.

Amaranthus M.P. 1992. Mycorrhizas, forest disturbances and regeneration in the Pacific Northwestern United States. p 202–207. In: *Mycorrhizas in ecosystems*, ed. D.J Read, D.H. Lewis, A.H. Fitter & I.J. Alexander. CAB International, Wallingford, UK.

Arnebrant K. 1994. Nitrogen amendments reduce the growth of extramatrical ectomycorrhizal mycelium. *Mycorrhiza* 5:7–15.

Arnebrant K. and Söderström B. 1992. Effects of different fertilizer treatments on ectomycorrhizal colonization potential in two Scots pine forests in Sweden. *Forest Ecology and Management* 53:77–89.

Baar J. 1995. Ectomycorrhizal fungi of Scots pine as affected by litter and humus. Ph.D. thesis, Wageningen Agricultural University, The Netherlands. 139 p.

Chidumayo E.N. 1987a. A shifting cultivation land use system under population presssure in Zambia. *Agroforestry Systems* 5:15–25.

Chidumayo E.N. 1987b. Woodland structure, destruction and conservation in the Copperbelt area of Zambia. *Biological Conservation* 40: 89–100.

Chidumayo E.N. 1989. Land use, deforestation and reforestation in the Zambian Copperbelt. *Land Degradation and Rehabilitation* 1:209–216.

Chidumayo E.N. 1991. Wood biomass structure and utilisation for charchoal production in a Zambian miombo woodland. *Bioresource Technology* 37:43–52.

Harley J.L. & Smith S.E. 1983. *Mycorrhizal symbiosis*. Academic Press, London. p 483.

Harvey A.E., Larsen M.J. & Jurgensen, M.F. 1976. Distribution of ectomycorrhizae in a mature douglas-fir/larch forest soil in western Montana. *Forest Science* 22:393–398.

Härkönen M., Buyck B., Saarimäki T. & Mwasumbi L. 1993. Tanzanian mushrooms and their uses. 1. Russula. *Karstenia* 33:11–50.

Härkönen M., Saarimäki T. and Mwasumbi L. 1995. Edible mushrooms of Tanzania. *Karstenia* 35 suppl. (ed. S. Stenroos), Helsinki.

Högberg P. 1982. Mycorrhizal associations in some woodlands and forest trees and shrubs in Tanzania. *New Phytologist* 92:407–415.

Högberg P. and Nylud J.E. 1981. Ectomycorrhizae in coastal miombo woodland of Tanzania. *Plant and Soil* 63:283–289.

Iloba C. 1980. The use of chemicals for weed control in forest tree nurseries. p 121–123. In: *Tropical mycorrhiza research*. ed. P. Mikola. Clarendon Press, Oxford.

Kamara C.S. & Maghembe J.A. 1994. Performance of multipurpose tree and shrub species 28 months after planting at Chalimbana, Zambia. *Forest Ecology and Management* 64:145–151.

Lapeyrie F. & Högberg P. 1994. Harnessing symbiotic associations: ectomycorrhizas. p 158–164. In: *Tropical trees: the potential for domestication and the rebuilding of forest resources,* ed. R.R.B. Leakey & A.C. Newton. HMSO, London.

Lind E.M.& Morrison M.E.S. 1974. *East African vegetation.* Longman, London.

Maghembe J.A. 1994. Out of the forest: indigenous fruit trees in southern Africa. *Agroforestry Today* 6(2):4–6.

Mason P.A. & Wilson J. 1994. Harnessing symbiotic associations: vesicular arbuscular mycorrhizas. p 165–175. In: *Tropical trees: the potential for domestication and the rebuilding of forest resources,* ed. R.R.B. Leakey & A.C. Newton. HMSO, London.

Mason P.A., Last F.T., Wilson J., Deacon J.W., Fleming L.V. & Fox F.M. 1987. Fruiting and succession of ectomycorrhizal fungi. p 253–268. In: *Fungal infection of plant,* ed. G.F. Pegg & P.G. Ayres. Cambridge University Press, Cambridge.

Mikola P. 1970. Mycorrhizal inoculation in afforestation. *International Review of Forestry Research* 3:123–196.

Mikola P. 1980. Mycorrhizae across the frontiers. p 3–10. In: *Tropical mycorrhiza research,* ed. P. Mikola. Clarendon Press, Oxford.

Munyanziza E. 1994. Miombo trees and mycorrhizae: ecological strategies, a basis for afforestation. Ph.D. thesis, Wageningen Agricultural University, The Netherlands. 193 p.

Munyanziza E. & Kuyper T.W. 1995. Ectomycorrhizal synthesis on seedlings of *Afzelia quanzensis* Welw. using various types of inoculum. *Mycorrhiza* 5:283–287.

Oei P. 1991. *Manual on mushroom cultivation. techniques, species and opportunities for commercial application in developing countries.* Tool, Amsterdam, and CTA, Wageningen, The Netherlands. 249 p.

Pegler D.N. & Piearce G.D. 1980. The edible mushrooms of Zambia. *Kew Bulletin* 35:475–491.

Ryvarden L., Piearce G.D. & Masuka A.J. 1994. *An introduction to the larger fungi of South Central Africa.* Boabab Books, Harare, Zimbabwe. 200 p.

Temu A.B. 1979. Fuelwood scarcity and other problems associated with tobacco production in Tabora region in Tanzania. *Division of Forestry Record No.12.* University of Dar es Salaam, Morogoro, Tanzania. 22 p.

Termoshuizen A.J. 1991. Succession of mycorrhizal fungi in stands of *Pinus sylvestris* in the Netherlands. *Journal of Vegetation Science* 2:255–264.

Development of *Coleus forskohlii* as a medicinal crop

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Abstract

Coleus forskohli, belonging to the family Labiatae (Lamiaceae), grows wild in arid and semi-arid regions of India. In a targeted plant screening programme at Hoescht AG the species was discovered to have pharmacological activities of lowering blood pressure and producing positive inotropic activity. The pharmacological activities were attributed to forskolin, a labdane diterpene, located in root tubers. Forecasts of the requirements of forskolin for drug development indicated the need for a sustained supply of root material in quantities that would threaten the survival of the species in nature. Concern for species conservation and a sustained supply of the root material led to consideration of developing *C. forskohlii* as a medicinal crop. The focus of the development studies was the increased yield of root tubers and forskolin. The development research entailed studies on natural species populations, evaluation of intraspecific variation, identification of suitable agroclimatic regions, standardization of growth conditions, and genetic improvement of elite genotypes. As a consequence of this development, *C. forskohlii* is now being cultivated as a source of forskolin.

Introduction

Development of a new medicinal plant in the pharmaceutical industries generally is taken up subsequent to the drug development. Our strategy at Hoescht AG in the case of *C. forskohlii* differed from this standard strategy in that the crop development and the drug development activities were concurrent. Although the development activities were spread over 13 years, the species was commercialized in 1986, subsequent to identification of the superior strain and suitable agroclimatic zones:

- discovery of *C. forskohlii* as a potential drug (1974–1981)
- natural habitats and intraspecific variation (1982–1985)
- collection of germplasm and its evaluation (1983–1985)
- identification of suitable agroclimatic regions (1985–1986)
- optimization of growth conditions (1985–1987)
- genetic improvement (1989–1994)

Discovery of C. *forskohlii* as a potential drug

Coleus forskohlii Briq. (synonyms, *C. barbatus* Benth., *Plectranthus forskohlii* Willd., *P. barbatus* Andr. and *P. comosus* Willemse), belonging to the family Labiatae, was collected in 1973 from Dehra Dun in North India for targeted pharmacological screening. The collection rationale was its phylogenetic relationship to a medicinal herb, *C. amboinicus* Lour. Methanol extract of root tubers exhibited blood pressure lowering and positive inotropic activities in animal models (de Souza 1977). Bioactivity-guided purification of the active extract provided an active labdane diterpene forskolin (Bhat et al. 1977). Subsequent research revealed forskolin to have many more pharmacological activities, namely, antiglaucoma, antiplatelet aggregation, antiinflammatory, antithrombotic (Rupp et al. 1985,) and a biochemical activity of adenylate cyclase stimulant increasing intracellular cyclic AMP (Metzger & Lindner 1981, Seamon et al. 1981). As a consequence, demand increased for forskolin as a bioactive molecule for drug development and as a research tool for the study of the cyclic AMP dependent physiological phenomena. The increased demand warranted synthesis of the forskolin molecule or a sustained supply of the plant source. Since total synthesis of forskolin is not a practical route for meeting the demands of the compound, the latter option was considered. Concern for the sustained supply of the root material and conservation of the natural *C. forskohlii* led us to develop the species with increased root production and forskolin content.

Natural habitats and intraspecific variation

C. forskohlii grows wild on sun-exposed arid and semi-arid hill slopes of the Himalayas from Simla eastward to Sikkim and Bhutan, Deccan Plateau, Eastern Ghats, Eastern Plateau and rainshadow regions of the Western Ghats in India (fig. 1). Latitudinal and altitudinal range for the occurrence of the species is between 8 and 31° N and 600–800 m respectively. The species was studied for its ecological preferences in its native habitats throughout its distribution range excluding Eastern Plateau, Sikkim and Bhutan. Before the botanical studies were undertaken, the species was studied in the regional floras and herbarium specimens were examined in seven zonal herbaria of the botanical survey of India at Dehra Dun (Himalayan flora), Allahabad (Central India flora), Shillong (northeastern India flora), Jodhpur (Rajasthan flora), Pune (western India flora), Coimbatore (southern India flora) and Port Blair (Andaman and Nicobar group of islands flora), as well as at the Forest Research Institute, Dehra Dun and the Blatter Herbarium in Bombay. Eleven representative ecogeographic areas were selected for habitat and population studies (fig. 1); between 1982 and 1985, 27 botanical trips were made for the purpose. Coleus-growing areas in the Himalayas in Uttar Pradesh were visited every month from April to December, and the other areas were visited at least twice during the blooming period. The following is the summary of the observations made on different populations and habitats of *C. forskohlii* (Shah 1989).

- *C. forskohlii* is a subtropical and warm temperate species naturally growing at 600–1800 m elevation.
- The species grows on sun-exposed hill slopes and plateaus in arid and semi-arid climatic zones.
- The species inhabits loamy or sandy-loam soil with 6.4 to 7.9 pH.
- The species is herbaceous with annual stems and perennial rootstock.
- Populations from different ecogeographic areas vary greatly in their morphology.
- Growth habit is strikingly variable: erect, procumbent or decumbent (fig. 2).
- Shoot height varies from 15 to 120 cm.
- Lamina length varies from 1.5 to 15.5 (fig. 3).
- Inflorescence length ranges from 3 to 40 cm.
- Root morphology in different populations is fascinatingly diverse, being tuberous, semi-tuberous or fibrous (fig. 2).
- Fresh root yield in different populations ranges from 1 to 500 g per plant.
- Forskolin content in roots varies from 0.07 to 0.58% of dry matter within and between populations.

Collection of germplasm and its evaluation

Initially 30 inter- and intra-populational ecotypes, including 2 cultivars (11 from the Himalayas, 18 from peninsular India and 1 from Sri Lanka) were collected for evalua-

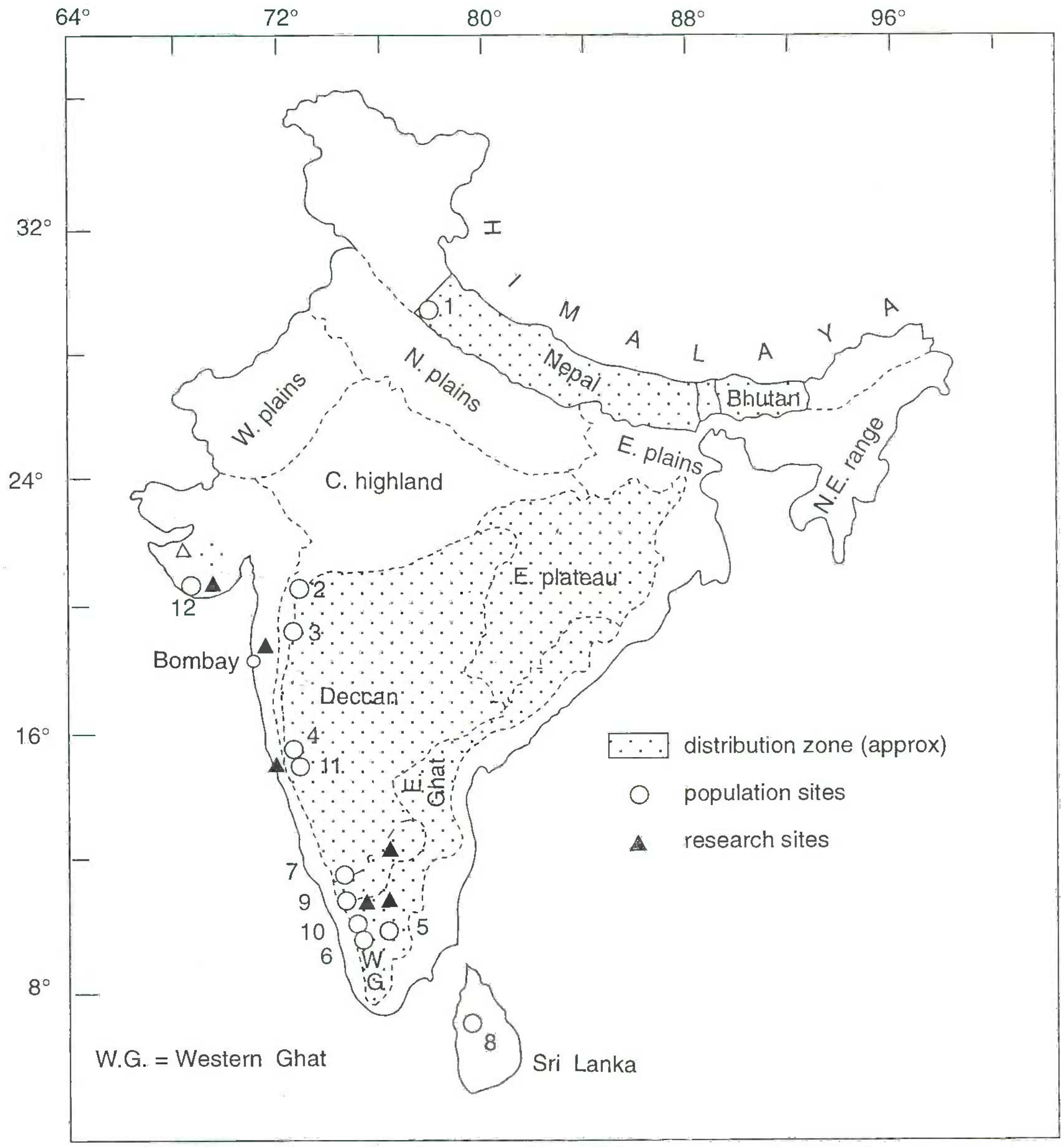

Figure 1. Distribution of Coleus forskohlii and research sites on the Indian subcontinent.

tion of root yields and forskolin content. Clones of these diverse ecotypes were grown vegetatively under uniform cultural conditions and at a single site on our factory campus in Bombay. This transplanting experiment proved the ecotypes to be genetic in nature. Based on growth habit, root and shoot morphology, root production, forskolin content and geographic location, the number of genotypes was reduced to 12—a manageable number for evaluation. Original locations of the 12 genotypes are shown in figure 1. Evaluation studies performed in Bombay identified a non-flowering cultivar to be superior in both parameters—forskolin content (about 0.4%) and root tuber yield (300–500 g plant^{-1}, and rarely 2000 g plant^{-1}). The other two varieties that were superior for one of the two parameters were a naturally growing variety, superior for forskolin content (about 0.4%) but with poor root tuber production, 50–200 g plant^{-1}, and another cultivar with poor forskolin content of about 0.1% or less but root tuber production as good as that of the non-flowering cultivar. These three cultivars were selected for further evaluation.

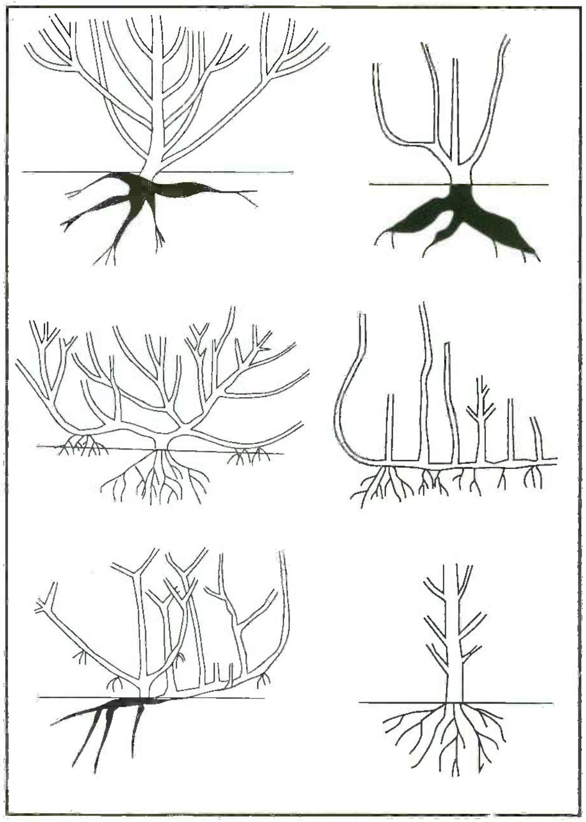

Figure 2. Diverse growth forms of Celus forskohlii.

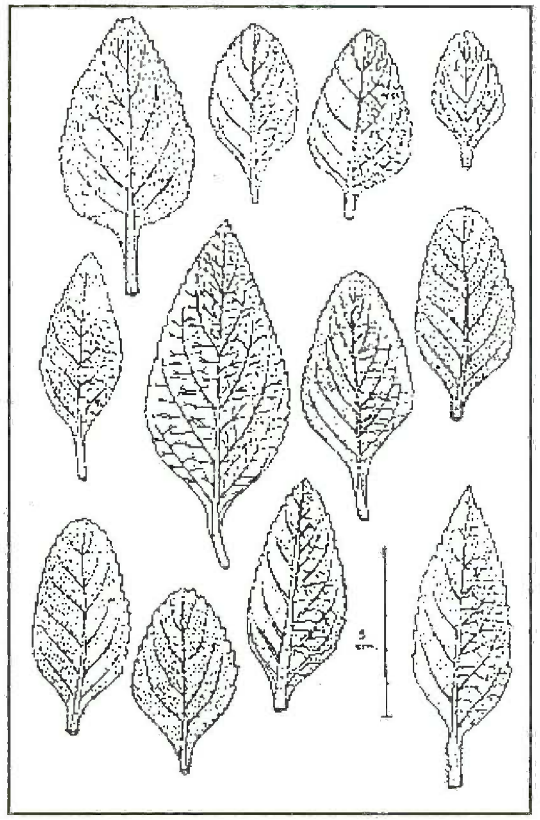

Figure 3. Leaf variation in Celus forskohlii.

Identification of suitable agroclimatic regions

Suitable agroclimatic regions for commercialization of *C. forskohlii* were identified by the pilot cultivation at the sites listed in table 1, having different agroclimates. The investigation included the superior non-flowering cultivar variety and one or both of the two the varieties characterized above.

The three cultivars under investigation at the sites (table 1) reacted differently to the range of agroclimates. Forskolin content improved by 80–100% under the agroclimatic conditions of Bangalore and Salem, demonstrating these areas suitable for commercialization of *C. forskohlii*.

Table 1. Cultivation sites in India for Coleus forskohlii

Cultivation sites	Latitude	Longitude	Elevation (m)
Veraval (Gujarat)	20°54′ N	70°22′ E	20
Jamnagar (Gujarat)	22°27′ N	70°02′ E	23
Bombay (Maharashtra)	19°07′ N	72°51′ E	15
Bicholim (Goa)	15°25′ N	73°47′ E	62
Bangalore (Karnataka)	12°58′ N	77°35′ E	921
Coimbaore (Tamil Nadu)	11°00′ N	76°58′ E	409
Salem (Tamil Nadu)	11°39′ N	78°10′ E	278

Optimization of growth conditions

A project with the Olericulture Department of the Tamil Nadu Agricultural University at Coimbatore was sponsored to determine optimal growth conditions: spacing, fertilizer (NPK) needs, planting time and harvest period. Cultural practices adopted for the experiment were as those followed in Gujarat, where the species is cultivated as a minor crop (site 12). Root tubers are consumed as a pickle in Gujarat and certain parts of Karnataka (site 11). The summary of the various trials is as follows.

- Experiments tested three levels of spacing (20, 40 and 60 cm) between the plants and 60 cm between the ridges. The dry root tuber yield after 5 months of growth was 3.2 kg, 2.9 kg and 2.6 kg per unit area respectively, the yield being proportional to the number of plants per unit area. No significant influence of planting density was observed on forskolin or root yields.
- Thirty combinations of NPK were tried. A combination of 40 kg of nitrogen, 60 kg of phosphorus and 50 kg of potash was found to be optimal for maximum dry tuber yield. Enrichment of forskolin was not observed with this combination.
- Under Coimbatore conditions, June–July were found to be optimal months for planting the cuttings of *C. forskohlii* in terms of maximum dry tuber yield per unit area. The optimal period for harvesting tubers was 5.5 months later. December–April were found unsuitable for planting *C. forskohlii*. Leaving the crop unharvested beyond 5.5 months led to reduction in tuber yield.

Genetic improvement

Studies on genetic improvement (hybridization and polyploidy studies) of *C. forskohlii*, supported by Hoechst, were conducted at the Medicinal Plant Division of Indian Institute of Horticultural Research at Bangalore, under the supervision of Dr R. Krishnan. Altogether 34 varieties—11 autotetraploids of diploids, 11 intervarietal hybrids, 11 autotetraploids of the hybrids, and 1 grafted variety—were developed over a period of 5 years from 1989 to 1994. An autotetraploid of the superior variety registered an increase of 23.1% in forskolin content, 1.3% over its diploid progenitor in pot studies. This tetraploid, using diploid progenitor as the check variety, was evaluated in a multilocational trial at four sites—three in Tamil Nadu and one in Karnataka for forskolin accumulation and root tuber yield. Percentage increases of forskolin in the tetraploid varied from site to site, being 2.3. 15, 17.7 and 51%. The root tuber yield, however, was decreased by 47.8, 46.1, 14 and 36.7% at the respective sites, indicating unstable growth characteristic of the autotetraploid and thereby making the autotetraploid unsuitable for commercialization. The diploid cultivar thus continues to be the variety of choice by the farmers.

Major accomplishments

- Through selection of a high forskolin-yielding variety and the determination of conditions for its optimum cultivation, forskolin yield has been increased eightfold.
- Natural resources of *C. forskohlii* were conserved through the development of a strategy to secure the plant source concurrently with the drug development, instead of the usual practice of postdrug development.

Acknowledgements

I wish to thank Dr W. Badziong, our former research director, and Dr P. Hammann, the present director, for permission to present this paper; Dr Bansi Lal, head of the Chemistry Department, for the encouragement; and my coworkers Mr S.N. Godbole, Mrs S. Mulye, Mr R. Pereira and Mrs Indira Sai for their assistance in preparation of the presentation.

References

Bhat S.V., Bajwa B.S., Dornauer H., Souza N.J. de & Fehlhaber H.W. 1977. Structure and stereochemistry of a new labdane diterpenoid from *Coleus forskohlii* Briq. *Tetrahedron Letters* 19:1669–1672.

de Souza N.J. 1977. In: *Proceedings of the Third Asian Symposium on Medicinal Plants and Spices*, Colombo, Sri Lanka. UNESCO. p 83–92.

Metzger H. & Lindner E. 1981. *IRCS Medical Science* 9:99.

Rupp R.H., de Souza N.J. & Dohadwalla A.N., eds. 1985. *Proceedings of the International Symposium on forskolin: its chemical, biological and medical potential.* Hoechst India Limited, Bombay 400 080. p 19–30.

Seamon K.B., Padgett W. & Daly J.W. 1981. *Proceedings of the National Academy of Sciences*. U.S.A. 78:3363.

Shah V.C. 1989. Biosystematic studies on *Coleus barbatus* (Andr.) Benth. Ph.D. thesis. University of Bombay, Bombay, India.

Non-timber forest products marketing: field testing of the marketing information system methodology

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Abstract

Despite their overall economic importance, studies have shown that the proportion of the final sale price of non-timber forest products (NTFPs) received by the local level of producers or processors is extremely small. The main reason for the low profitability of NTFP enterprises is the lack of an organized information system to help individual producers organize production and distribution, determine appropriate prices, select markets, follow supply and demand, or promote merchandise.

An evaluation of the two marketing information system (MIS) field test sites in Uganda of the Forests, Trees and People Programme revealed that MIS had a significant positive impact on the two communities. The information on product sales was used in both communities to adjust production and stocking levels and product lines and, in the process, increase the profitability of their enterprises. MIS was also used to change product mix and to target different market niches.

The impact of MIS seems to have been greater in the community (Masaka) that participated the most in the design of the system. They had the greater appreciation of the potential value of MIS.

Introduction

Non-timber forest products (NTFPs) have received increasing attention and are making significant contributions to local economies. In India, for example, the NTFP sector provides over 30 million jobs (Koppell 1993). The continued importance of NTFPs as a source of income and employment for the people at the grassroots has led many people to initiate or increase production and to harvest NTFPs for various markets.

Studies have shown that, despite the overall economic importance of NTFPs, the proportion of the final sale price that the small-scale collector, producer or processor gets is extremely small and, therefore, that profitability is low. The main reason why NTFP enterprises are not more profitable is the lack of an organized information system to help individual producers organize production and distribution, determine appropriate prices, select markets, follow supply and demand or promote merchandise. Even when there is market information, it is frequently not disseminated to local small-scale producers.

In 1992, the Forests, Trees and People Programme (FTPP) developed guidelines for the creation of local-level marketing information systems (MIS) for NTFPs. The objective of developing MIS was to assist producers increase the income they derive from their small-scale NTFP enterprises, while at the same time learning about marketing, the production chain, simple accounting and new production processes. This knowledge should also increase the leverage and market power of the local producers and sellers.

Development of a methodology for the local design and operation of MIS was initiated in 1992 in the Philippines (3 sites) and tested in the Solomon Islands (2 sites), Bangladesh (1 site), Uganda (2 sites) and Peru (1 site) in 1993.

The range of participants, the kind of information they collected and the type of products for which they collected information varied widely. In the Philippines, Bangladesh and the Solomon Islands, farmers and swidden cultivators focused on marketing information about cultivated and gathered agricultural and forestry products, including tree leaves, fruits, nuts and lianas. In contrast, in Uganda, participants were groups of small traders and producers of baskets, mats, chairs, stools and bags derived from NTFPs. The MIS was structured to collect and analyse information on sales from the stalls and determine consumer preferences.

Definitions

Markets are potential outlets for products. They include places and institutions where people are interested in selling or purchasing a given product or service.

Marketing encompasses all the activities involved in determining and meeting the needs and interests of customers, to maximize profits. Marketing involves finding out what the customer wants and helping to set up the production/marketing system which supplies that demand and maximizes income' (Dixie 1989).

Marketing information includes all the data that help those involved in production and selling to determine and meet the needs and interests of the consumer.

Marketing information system (MIS) is an organized procedure for gathering and analysing information. It involves collecting, analysing and distributing predetermined types of marketing information (table 1) for informed decision-making and increased bargaining power.

Table 1. Content of a marketing information system

- Prices for products
- Price differences—retail, wholesale, farmgate
- Explanations for changes in price or demand
- The names and locations of traders
- The volume, quality and packaging requirements of various markets and traders for different products
- Price variations by market for products
- Sales and marketing channel alternatives (direct sales, middlemen, cooperatives, wholesalers, retailers, marketing boards)
- Distribution channels that exist (transportation alternatives, storage facilities)
- Promotion opportunities (product shows, advertisements, incentives, packaging)
- Terms of payment alternatives (barter, credit, cash, labour)

Non-timber forest products (NTFP) include all tangible products, natural, crafted or processed, derived from forests or any other land under similar use, other than timber (Chandrasekharan 1995).

Steps taken in creating local-level MIS for Uganda

Selection of sites in Uganda

The following factors were used to determine whether a given site was suitable for the establishment of MIS:

- Expression of local needs and interest in using marketing information: local interest is

necessary to ensure the collection of reliable data and its sustained utilization in an MIS.
- A level of production above the subsistence level: where families and individuals produce solely to meet their own needs, there is no relevant market about which to gather information.
- Producers of NTFP have physical access to data and information: if the source of information is far away, travel costs could prevent its collection.
- A high level of 'community' spirit: to establish a cooperative, locally run and managed information system, local people must work together.

Using the above criteria, two participating communities were selected, one in Mukono town, 10 km east of Kampala (Mukono handicraft seller), and one in Masaka, 80 km west of Kampala (Bamuna supermarket).

Getting baseline information

One of the two participating communities (Masaka) proceeded through the entire design process before starting to collect data. Using participatory rural appraisal (PRA) methods, it made each design decision as a group. Using the checklist presented in table 2, it obtained baseline information about the goods that are produced in the area, production levels, use and sales of various NTFP.

Table 2. Forest and tree products questions about the NTFPs to be covered by the MIS

Which non-timber forest products are harvested/produced in the area?
- During which season are these products produced?
- Are they or could they be produced/harvested on a sustainable basis for the foreseeable future?
- During which season are they used?
- Who uses these products?
- How are these products used?

Are there any products that are not produced or sold that could potentially be produced/sold in the future?
- If so, why are they not currently sold?

What happens to the products after they are sold?
- Are local people aware of where the products are ultimately used?

What problems are currently faced in attempts to sell non-timber forest products?
- How are local people trying to solve these problems?

Designing the system

Having gathered the relevant information, the community proceeded to design the MIS. Each design decision was discussed by the community to ensure that all the relevant considerations were thought about.

The primary design decisions made during the PRA exercises addressed the following points:
- what are the goals and objectives of the MIS?
- who would benefit from the information (the target user group(s))?
- what types of data should be gathered?
- what are the sources of information?
- who should analyse the information and how?

- how should the information gathered be communicated?
- what are the training needs of the community?

Implementing the system

Once the design process was completed, implementation of the MIS commenced. Adaptations to the design were made during the process of implementation. The implementation stage consisted of organizing collection and analysis of information, establishing the monitoring and evaluation structure, and instituting the training programme.

The importance of local participation in the design process

Active participation of users in the design, operation and evaluation of the MIS is crucial to the success of the system. This is because the overall goal of any MIS is to serve the needs and interests of the target (user groups). Involving local people in the design process ensures that the information gathered and that the approach taken to data collection are appropriate given local circumstances. It also increases local ownership of the MIS and commitment to its sustained operation.

To test these assumptions, the second participating community (Mukono group) did not go through the whole design process. The group met with the local field test facilitator twice, was given predesigned forms and was taught how to collect marketing information. This community used the information collection forms designed by the Masaka group (table 3). Training in analysis and use of the information took place once data collection had started.

Table 3. Bamuna supermarket data collection sheet

Items sold	No	Size	Colour	Types of customer	Other items needed
Mat					
Basket					
Large basket					
Tray					

Findings of the study

Using MIS, producers and sellers of non-timber forest products were able to determine which products sell best, and hence which products to offer for sale in future (introducing new products and eliminating others). The information also indicates the product quality and quantity that are most in demand by the customers (table 4, for example from Bamuna).

At the end of every month, the numbers of items of each type sold were analysed and discussed by the participating stalls and producers. The results showed that there was a high demand for baskets, followed by trays and mats. It was advisable, therefore, to invest more in baskets than in mats. In the basket sales, small baskets were preferred. A total of 76 small baskets were sold in one month compared with 41 large baskets sold in the same period. However, the demand for large trays was higher than that for small ones. Colour also influenced customer choice. Tourists preferred brightly coloured baskets and trays while local people preferred plain ones. Tourists were the main purchasers of all the handicraft items sold. The handicraft producers should therefore target the tourists specifically.

Table 4. Bamuna supermarket—NTFPs sold during August 1993; overall sales of different products

	Sold			Size preferences		
	Tourists	Locals	Total	Small	Large	Total
Mats	5	14	19	6	13	19
Trays	18	10	28	18	10	28
Baskets	72	45	117	76	41	117

Colour preferences

Mats	No. sold	*Small baskets*	No. sold
Plain white	8	Red	1
Green + purple	6	Purple	10
White + red	3	Purple+red	10
White + green	2	Red+green	9
		White	26
		Green + purple	3
		White + orange	7
		Yellow + green	1
		White + purple	2
		Green	4
		Orange + yellow	2
		White + green	1
Total	19		76
Trays		*Large baskets*	
Purple+green	6	Orange + green	6
Yellow+green	3	Green	3
Purple+yellow	3	Red + white	1
Purple+red	5	Green + purple + red	25
Green+red	6	Green	2
Red+yellow	4	Green + purple	1
White	1	Purple	1
		Purple + red	2
Total	28		41

Impact of MIS on participating communities

An evaluation six months after implementing MIS found that it had had a significant impact on business practices and marketing in both sites. Additionally, the MIS had improved the general confidence of participating groups and their willingness to collaborate on other projects.

A secondary objective of the project was to determine if the level of community participation in the design of the MIS had had an impact on its effectiveness. The MIS was designed according to the community choices in Masaka while in Mukono the facilitator designed the information collection system without community involvement but based on the Masaka information.

Masaka site

At Masaka, the introduction of the MIS led to significant changes in business practices. The impacts of the MIS are arranged of their importance to participants:

- **Improved ability to respond to consumer interests**

Participants cited this as the most beneficial effect of the MIS. Increased market transparency has increased their knowledge of the products and product attributes customers desire.

Using MIS information, Masaka participants changed the range of products offered, introducing some products, eliminating others, the specifications of those products, the items requested from producers, and the level of quality demanded from production.

Participants noted that the most important change in approach to business was that the seller now asked customers what other products, colours, shapes and sizes they would like to have available. In Masaka, participants wanted to have more information on how products were used once they were purchased so that they could change specifications according to the end use. For example, the raw materials used could be adapted to meet specific uses.

- **Increased ability to target market segments**

Through the information collected, Masaka traders tried to target their market more specifically. For example, the colour preferences of tourists could be matched to the market and influence production accordingly.

- **Ability to work together**

Participants found that discussing the marketing information together gave them the opportunity to discuss business, so that a movement towards collaboration in purchasing and ordering was developed.

- **Price-setting ability**

Masaka used analyses of sales to improve price setting in response to levels of demand.

Mukono site

At Mukono the MIS, once again, had an impact on business practices, but the order of importance of the factors affecting impact was slightly different from that at Masaka. According to participants, the following are the most important changes:

- **Improved ability to respond to customer interests**

Mukono participants also felt that the MIS was most helpful for deciding what to stock and produce. However, they did not use the information to expand or change their product lines, although they did use it to place orders and buy new materials. Mukono participants did not, however, follow who was purchasing the different items. Their ability to target specific markets was therefore more limited than that of Masaka.

- **Ability to set prices**

Like at Masaka, the people of Mukono used sales information to determine prices.

- **Ability to work together**

The Mukono participants formed a traders' organization, following the initiation of the MIS. Although this group was more resistant to working together, their organization did move towards greater collaboration and, for example, purchased some raw materials in bulk.

- **Decreased cost of production**

Participants felt that a side effect of the MIS, through bulk purchasing of raw materials, was a decrease in the costs of production.

From these limited results it can probably be concluded that the group that had been involved in the design of the MIS had the greater feeling of ownership of the project and thus gained the most.

Programme shortcomings

The programme was generally a success; however, some significant shortcomings were identified:

- **Limited community inclination to independently expand and adapt the system to changing needs**

The facilitator was the driving force behind the evolution of the MIS. Although communities are able to collect and use marketing information, they seem either unwilling or unable to make adjustments to the system on their own. Some attention therefore needs to be devoted to ways to construct the MIS to encourage greater self-help. Perhaps with time and increased self-confidence, community willingness and ability to adapt the MIS will grow.

- **Limited capacity to sustain MIS without external support**

The communities would like to continue to operate MIS; however, without continued support and facilitation, it seems this may not happen. It is therefore important to consider how to make marketing information systems more sustainable. Both communities are very interested in continuing to work with FAO and Makerere University to develop their marketing potential and business operations.

References

Chandrasekhran. 1995. Terminology, definition and classification of forest products other than wood. p 345–380. In: *Report of International Expert Consultation on Non-Wood Forest Products, Yogyakarta, Indonesia.* FAO Non-Wood Forest Products no. 3. FAO, Rome.

Dixie G. 1989. *Horticultural marketing: a resource and training manual for extension officers.* FAO Agricultural Services Bulletin no. 76. FAO, Rome.

Koppell C. 1993. Establishing marketing information system field test sites in the Philippines and the Solomon Islands, June 1993 (trip report). FAO, Rome.

Plate 25. *Handicrafts from non-timber forest product raw materials, at Mukono, 10 km along Kampala–Jinja road, Uganda.* (photo: A.Y. Banana)

Croton megalocarpus, the poultry-feed tree: how local knowledge could help to feed the world

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Abstract

The high cost of protein sources for poultry has led researchers to direct increased attention to non-conventional feeds. Although most plant leaves are good sources of protein, their use by non-ruminants is limited by the high fibre content and, in some cases, the presence of toxic factors or metabolic inhibitors.

Laboratory analysis and results of experiments involving animals show that ground seeds of *Croton megalocarpus*, a species indigenous to eastern African montane forests, could be a major ingredient of commercial poultry feeds. Trees of this species already form an important component of agroforestry systems in the region, providing timber and charcoal. The tree provides good shade and has been used as a boundary marker. Its potential as a feed for poultry has been recognized by only a very few local people. The typical local management system for poultry and cultural beliefs could have attributed to this.

First observations on *C. megalocarpus* revealed that the scarce literature on this species was incorrect in many details. It was found that trees generally start flowering during the fourth year and potential seed yields of mature trees are assessed at 25 kg per year. Enormous variance has recently been observed in different components of seed production (e.g., frequency of flowering, number of flower spikes, number of female flowers per spike, number of seeds per fruit, weight of seeds), and this indicates that, through selection and breeding, yields could be considerably increased.

Introduction

As the world population grows, increasing the food supply becomes an ever-more-urgent priority. In the year 2040 the world community will have to produce 500% more food than it is doing at the moment. According to the participants (Consultative Group on International Agricultural Research and national research organizations) of a conference, 'Ecoregional approaches for sustainable land use and food production', there should be enough carrying capacity to fulfil the demand for more food. One requirement identified during this meeting was the need for good analytical research of regional production systems. Increased integrated efforts and attention on the local farming systems should result in improved concepts of food production. Indigenous technical knowledge of animals and plants not conventionally regarded as domesticated is expected to be a major component of the successful accomplishment of this difficult task.

Agricultural research has boosted crop and animal yields worldwide, yet the skewed distribution of scientific and technological capabilities robs the poorest areas of the world, most in need of scientific and technical knowhow, of the ability to develop their agriculture to the fullest. Experience has shown that no single body of knowledge alone is sufficient to provide the will and direction to overcome hunger and malnutrition. No firm formulas developed in the industrialized nations can satisfy the ecological, cultural and social diversities that characterize the world's regions. On the other hand, new combinations of cross-disciplinary and multisectoral knowledge have the potential to design strategies for feeding and providing nourishment to the peoples of the world. This is the concept behind the new efforts to promote the domestication of indigenous tree crops (Leakey & Newton 1994).

The ongoing and future work proposed here for the development of new poultry feeds attempts to contribute to meeting this challenge. It shows that through a participatory approach to farming systems development, localized technical knowledge has enormous potential to provide food in a much larger part of the world.

Poultry production in developing countries

In most areas of the world, there are fewer religious or social taboos associated with poultry than there are with pigs and cattle. Thus poultry products provide an acceptable form of animal protein for most people, with the exception of strict vegetarian vegans.

Table 1. World population (millions) of farm animals, birds and humans in selected regions (1987)

	Cattle	Sheep & goats	Pigs	Chickens	Humans
Developed	412	576	347	2642	1228
Developing	865	1084	493	3394	3769
World	1277	1660	840	6036	4997

More than 90% of the world's poultry flocks consist of chickens (FAO 1982, cited in Smith 1993). The actual number of poultry in the world is very large (table 1) and the number far exceeds in quantity (although not of course in total weight) the combined total of sheep, goats, pigs and cattle. The contribution that poultry makes to the supply of animal protein varies from area to area.

According to an FAO survey in 1970 of 90 countries, 69% of the population had available an average of less than 30 g per day of animal protein, and 19% had 10 g or less. Even in those countries that apparently have more than enough animal protein to meet everyone's needs, these figures almost certainly give an unrealistic picture of the actual situation. It is irrefutable that in the poorest countries the consumption of animal protein by the richer people is considerably greater than that of the poorest, who eat few, if any, animal products. Furthermore, lactating women and young children, who in East Africa form nearly 60% of the population (Balldin et al. 1993) need a greater proportion of animal protein than adult men who, in fact, eat the most.

Inequality of animal protein distribution among the people of poor countries could radically be changed through supply of poultry products. This is technically possible because poultry are able to adapt to most areas of the world; their cost is low, their generation interval short, and rate of productivity high. A poultry enterprise can produce meat within 8 to 10 weeks and eggs within 4 months.

Over the last 40 to 50 years rapid changes have occurred within the poultry industry, especially in developed countries. Selection and cross-breeding techniques have enabled the production of a laying fowl that will provide up to 280 eggs a year and a meat-type chicken that will weigh over 2 kg at 7 weeks of age, having been fed on only 4 kg of a balanced diet.

Before 1930, the method of keeping poultry in the developed countries was similar to the way free-range, scavenger poultry flocks are kept in developing countries today. Therefore the question arises, can the developments in intensive poultry production be profitably adopted by developing countries?

Many governments in developing countries have encouraged the development of large-scale modern poultry enterprises. Beyond the capital development, the constraints are those associated with their operation. For example, a major problem arises when scarce foreign exchange has to be used to import poultry feed, and to a lesser extent, vaccines and drugs. To produce 1 kg of broiler carcass requires 2–3 kg of a balanced feed, while a laying bird requires up to 50 kg of a similar diet over a year.

The foodstuffs used for poultry feeds are often of a quality that could be fed directly to hungry humans. Intensive poultry production is thus appropriate when a country has surplus vegetable foodstuffs or an export-based economy (Smith 1993). Consequently, in the developing world, governments would be better advised to pursue a policy encouraging free-range poultry production. Although this system of production appears primitive, it can be very efficient because the inputs are very low. With good management, free-range hybrid poultry under subsistence farming conditions in Zimbabwe have produced 170 eggs per bird per year when the diet of the birds was supplemented with maize alone (Huchzermeyer 1973). The question we must therefore ask now is: are there other sources of food suitable for poultry that would not normally be used for human consumption?

Poultry nutrition

Because poultry are monogastric, they are unable to manufacture essential amino acids or the B vitamins, and they cannot exist on high-fibre diets. The diet of birds must contain the materials essential for the processes of maintenance, production and reproduction. The essential nutrients can be grouped as water, carbohydrate, fats and oils, protein (amino acids), vitamins and minerals.

The energy in the diet, necessary for production (meat, eggs) and for the maintenance of vital functions and body temperature, is largely in the form of carbohydrates; fat and amino acids are also required. The synthesis of protein in the body tissues requires an adequate supply of about 20 different amino acids, 10 of which cannot be synthesized by the bird and must therefore be provided in the diet.

Foodstuffs commonly used in poultry diets in the tropics can be classified into five broad classes:

- cereals and cereal by-products (maize, sorghum, millets, wheat, rice, maize bran, wheat bran, rice bran)
- other energy foods (cassava, sugar, molasses)
- animal proteins (fish meal, meat and bone meal, feather meal, blood meal)
- plant proteins (soya bean, groundnut, cottonseed, sunflower seed, linseed)
- mineral supplements

Foods containing high levels of protein (e.g., soya beans, groundnuts, sunflower seeds) are expensive to purchase, while energy foods (e.g., cereal by-products) are often plentiful and relatively cheap.

The most commonly used animal protein for poultry diets is fish meal. It is a high-quality protein food, rich in all the essential amino acids, but fish meal is in limited supply in most developing countries.

The high and increasing prices for animal feed have compelled researchers in developing countries to direct their attention to non-conventional feeds, with particular emphasis on protein substitutes. Plant leaves are commonly processed into leaf meals for non-ruminant animals. Among the leaf meals, leucaena *(Leucaena leucocephala)* and cassava *(Manihot esculenta)* leaf meals are most popular (Limcango-Lopez 1990). Other species reported on are *Trema orientalis*, *Morus indica*, *Moringa oleifera*, and *Sesbania rostrata*. In China, pine needles are one of the main leaf fodders. Leaf meal is produced industrially and used widely in animal feed, especially for pigs and poultry, mainly to supplement vitamins and trace minerals (Zaichun 1990).

The use of leaf meal as feed is limited by its high fibre content and, in some cases, the presence of toxic factors or metabolic inhibitors. Consequently, levels higher than about 5–10% have detrimental results on survival and production (Yoshida 1944, Springhall & Ross 1965, Labadan et al. 1969, Ross & Enriquez 1969, Lopez et al. 1978, Sazon 1988, Cariaso 1988, Ash et al. 1992).

In Kenya, however, a real breakthrough has been made in identifying a local poultry feed supplement. The Kenya Woodfuel and Agroforestry Programme (KWAP), implemented by ETC Kenya Consultants, has in close collaboration with farmers exploited indigenous knowledge on a species that can be named the 'poultry-feed tree'.

The potential of the poultry-feed tree in animal nutrition

The seeds of the poultry-feed tree, *Croton megalocarpus* Hutch. (Euphorbiaceae), are reportedly eaten by birds and squirrels (Noad & Birnie 1989) and can be used for poultry (Nicholson 1992). These seeds contain oil and protein, believed to be 30 and 50% respectively (Teel 1984). Analysis at the laboratories of the East African Tannin Export Company in Eldoret, however, showed an average of 32% oil and 18% protein. Croton oil is also reported to be a powerful cathartic, occasionally used in medicine (anon. 1958).

Croton megalocarpus is indigenous to East Africa. Its range is the semi-arid and subhumid highlands, at altitudes between 1200 and 2450 m, with an annual rainfall of about 800 to 1600 mm and average annual temperatures varying between 11 and 26°C. Trees of this species are found in forests and often on farms, where they play a mayor role as boundary markers, windbreaks, shade trees and fuelwood producers.

The few reports on the use of croton seeds as poultry feed are restricted to the Nyeri and Kakamega areas of central and western Kenya respectively. In all cases the seeds are fed as seasonally available supplements to the diet of free-range poultry flocks. Little is known about feeding ratios and productivity of these birds.

Preliminary results of experiments by KWAP with ground croton seeds partially replacing commercial chick and layers mash show that up to 50% of commercial feed in the diet of highly productive hybrid layers can be substituted by croton seed meal, with no adverse effects on production or hatchability of eggs. Additionally, a 10 to 15% saving in food consumption was observed when croton seed meal was included in the diet.

In the case of chicks, feeds were formulated using commercial feeds and croton seed meal. One-day-old layer chicks were fed on a 10% croton seed diet, and the level of croton in the feed was gradually increased to 25% for one-week-old chicks and maintained at that level. Feed intake, feed efficiency, body weight gain and growth rate of the chicks over a 12-week period were very satisfactory (table 2). Birds slaughtered after this experimental period did not show any internal abnormalities.

Table 2. Growth of layer chicks fed with croton seed meal in the diet

Week	Croton seed in diet (%)	Food conversion ratio (%)	Weekly growth rate (g)
1	10–20	50	26.0
2–4	25	26	48.5
5–12	25	22	117.5

Agroforestry as a more sustainable land-use practice

Agroforestry refers to land-use systems in which trees or shrubs are grown in association with agricultural crops, pastures or livestock and in which there are both ecological and economic interactions between the trees and other components of the system. Generally, economic factors of agroforestry systems are more important to farmers, but possible negative ecological interactions could be offset by getting an important product or service from the tree (Thijssen et al. 1993a).

At the present time, agricultural scientists and policy-makers, researchers, development workers and extension staff in developing countries are giving increased attention to the use of locally available resources, and economic and ecological reasons have led to a reassessment of the technologies used in agriculture. The practice of low external input and sustainable agriculture' has led to remarkable improvement of agricultural systems (ILEIA 1989). Practices such as the use of unconventional animals and plants in food production receive much more attention than in the past. Experts expect a great impact from these practices, especially in the arid and semi-arid rainfed areas and other areas that so far are considered to have a low production potential, because of their alleged low resource base.

The rapidly expanding interest in agroforestry in recent years, witnessed by the myriad of research and development activities, leaves no doubt that agroforestry as an approach to land development is now accepted by most scientists and development specialists. Increased concern at the highest international policy levels about the sustainability of agricultural development, in the light of the apparent rapid depletion of the natural resource base, has brought agroforestry even further into the limelight.

The tree component can play its beneficial role through the production of useful commodities (e.g., fruits, fodder, firewood, wood products) and by providing certain environmental services such as shade, erosion control and windbreak. The main assumptions are that trees can diversify the range of products obtained from a piece of land and can influence the microclimate favourably for crop growth and animal production while exploring better the three-dimensional character of the soil through the tree's extended root system, its vertical growth and its perennial existence.

The poultry-feed tree in an agroforestry context

Production figures for seeds of the poultry-feed tree are not available. Egli and Kalinganire (1988) report that in Rwanda it flowers and produces fruits every two years, while evidence from Kenya suggests that this species produces fruits every year. Potential seed production for a tree is still unknown but it is generally described as 'abundant'. Preliminary observations, however, indicate that 25 kg of seeds per tree per year is feasible.

There seems to be large variability in the major components of seed production (frequency of flowering, number of flower spikes, number of female flowers per flower spike (1–5), fruit diameter (1.7–3.8 cm), seeds per fruit (1–4), seed weight (0.67–1.18 g). This indicates that significant improvements in seed yield could be achieved through selection and breeding of new varieties. The effects of management on seed production are not known, but different pruning regimes could also benefit seed production, as flower buds are borne at the end of branchlets.

Propagation of this species is by seed, which germinates readily within about 10 days. Contrary to reports that seeds lose viability fast because of the high oil content (Teel 1994), germination percentages can be as high as 80% after the seeds have been stored one year in a plastic container. No reports are available on vegetative propagation.

Croton megalocarpus (i.e., 'croton with the big seeds') is a hardy and fast-growing tree (table 3) that can reach 35 m or more in height. It usually forms a flattish crown and has horizontal layers of branches. Young plants thrive well even in harsh climatic conditions, and it is not browsed by livestock nor attacked by termites.

Table 3. Growth characteristics of Croton megalocarpus *in East Africa*

Region	Altitude (m)	Age (years)	Height (m)
Rwanda, Rwerere area	2300	2	3.1
Rwanda, Rangiro area	1900	5	11.7
Rwanda, Ruhande area	1750	43	20.2
Kenya, Maseno area	1500	1	1.7
Burundi, Karuzi area	1620	0.5	0.7

The poultry-feed tree is characterized by its multipurpose functions on the farm. Because seeds are available and propagation is simple, it is often planted to demarcate boundaries where it plays roles as a live fence and a windbreak, and reduces soil and water erosion. Younger trees coppice well after pruning, so this species is often used as a hedge around home compounds or fields. In the Kenyan coffee-based land-use system of Embu District, for instance, more than 10% of the farms have croton hedges, with an average length of 70 metres (Thijssen et al. 1993b). However, when managed as a hedge this species is unlikely to produce fruits.

Older trees have been reported to be competitive with crops (Noad & Birnie 1989, Thijssen et al. 1993a). The species is therefore often confined to certain niches on the farm such as roadside boundaries, woodlots and paddocks. In grazing areas crotons are valued as shade trees for animals. As a shade tree, croton can even be found on home compounds, in markets and at bus stops along the road. Where trees are grown within crop areas the annual extensive leaf fall combined with high levels of nitrogen and phosphorus in the leaves (Niang 1993) give it potential to improve soil fertility and serve as a source of mulch in, for instance, coffee plantations.

Products obtained from *C. megalocarpus* are timber, building poles and fuelwood, while first-class charcoal can be made out of the wood of this species (Thijssen et al. 1993a). The well-dried nuts are reported to be used in some areas together with charcoal in cooking stoves. Nut shells could be used as mulch in vegetable gardens (one 30-litre bucket can cover an area of 2.25 m^2) and as a component of potting mixtures for plants. The croton flowers are bee forage while the seeds, bark and leaves of the tree are reported to have medicinal value (anon. 1958, Kokwaro 1976, Noad & Birnie 1989), including medication for poultry (Charles 1990).

In the Embu area, on the slopes of Mount Kenya, *C. megalocarpus* has been found on 40% of the farms (Thijssen et al. 1993a) at an average density of about 15 trees per farm (excluding trees managed as a hedge). The majority of farms (84%) had between 1 and 10 trees, while 11% contained between 50 and 100 trees. An estimate of the total number of croton trees on farms in the coffee-based land-use system of this area (ca 400 km^2) gives a figure of more than 160 000 trees.

Participatory technology development as the methodology for a research and development project

The change in thinking about agricultural technology has also led to a rediscovery and reassessment of indigenous technical knowledge. An increasing number of publications support and document the argument that farmers have a wealth of knowledge about their own environment. They have developed specific skills to use this environment and are very active and creative in adapting the way they use the environment to achieve their objectives. In line with this, the roles and functions of agricultural researchers and extension workers *vis à vis* work with the farmers is due for reassessment.

Recent literature and meetings on research and extension linkages show the present interest in the development of participatory technology. There are a number of examples where extension and development workers or researchers have successfully worked together with farmers to develop their technology. These examples are increasingly being recognized as pioneers in a powerful approach to development, which needs to be expanded further.

The Kenya Woodfuel and Agroforestry Programme involves participatory technology development for sustainable agriculture. Its first step was building up a relationship of confidence with rural communities and analysing existing land-use systems. Stock was taken through small experiments and literature research, and items were selected for further development. One of these was the poultry-feed tree, from which the last three steps of participatory technology development deserve some special attention. The magnitude of the potential that this species has for many areas in the world has implications for the type of future research and development activities to be undertaken.

The poultry feed tree as a commodity for domestication by participatory technology development

Croton seed meal has enormous potential on both small and larger scales. In the example given of the coffee-based land-use system of Embu District in Kenya, and at a yield level of only 20 kg of seeds per tree by the estimated 60 000 croton trees, every child in that area could be assured of eating at least 200 eggs per year if the croton seeds could form 50% of the diet of chickens. Alternatively, at the yield of 25 kg of seeds per tree, for every kilogram of seeds produced and fed to broilers, every child in the area could eat one whole chicken every fortnight.

For the production of animal feeds, western countries are importing large quantities of protein material from countries where this material could be used as quality food for the exporting nation. Because of the international demand, however, the price of these materials is too high for common people in the producing countries, and exportation generates higher profits for the producers. If the apparent potential is confirmed, croton seed meal could become an alternative source of protein for poultry feeds all over the world. Since this product is not used for human consumption, it could become a new cash crop for farmers and an export product for tropical countries with appropriate growing conditions. At the same time, introduction of croton seed meal on the international market could lower prices of, for instance, soya bean and fish meal.

Currently, distribution of this species is restricted to some areas in eastern and central Africa. To ensure a rapid development of this croton meal technology, information has to be collected through surveys in these areas. Mature trees should be studied to obtain important phenological information and better describe the ecological niche of this species. At the same time components of production and management regimes should be observed. The presence of croton trees on farms will make it possible to assess the interaction of this tree with crops, livestock and soils in an agroforestry context.

The first step to domesticate this species should examine the qualitative aspects of the seeds for poultry feed. This will involve laboratory analysis and should include a check on antinutritive components, while formal animal experiments should prove the potential of croton seed meal for smallholders. Then, in collaboration with national research organizations dietary details can be worked out to assist in the process of development and adaptation of improved rural poultry husbandry and the use of croton seed meal in particular.

The second step involves the economics and adoption of this new poultry feed. Labour implications and financial returns, especially from a gender perspective, will be important factors for study. Recognizing the importance of good relations with local people and the scale of the task to get communities to collect primary information and to spread this approach over eastern and central Africa, locally active organizations have to work in a participatory way. Some local people have a lifetime of experience with this species and their input will enable a thorough characterization of the poultry feed tree. Potentials for local markets as well as international trade also have to be examined.

The third step in the domestication process, which could go in parallel with step 2, involves the selection of high quality and highly productive trees. As stated earlier, extensive variation exists in the different components of production. Possibilities of vegetative propagation by cuttings or grafting has to be explored to enable multiplication of quality genetic material. The breeding of superior varieties is an alternative option if selection does not produce tangible results, but it would be a slower process and thus probably more expensive. This fundamental type of research should be left to specialized institutions and most probably deserves an ecoregional approach.

The fourth phase in the development of this new crop, that of dissemination, will require careful attention. Experimental results and relevant dietary information have to be made available to the people and organizations concerned in the most appropriate way. This information has to find its way to commercial organizations through the media and formal publications. If the crop is to be adopted by smallholders, the messages must be technically sound, economically feasible, socially desirable and environmentally safe. Continuous interaction with the target group, as spelled out in the participatory technology development concepts, should ensure that the messages to farmers are appropriate and that they lead to a high adoption rate of the new technology.

For countries outside the eastern and central African region, dissemination of quality planting material will be a prerequisite for introduction of the poultry-feed tree. Requisition of seeds of different provenances, seed handling and storage, and distribution of the seeds to other regions will be major tasks for any project with the mandate to develop the poultry-feed tree to its fullest potential.

Finally, the potential of croton seed meal as protein feed is not necessarily restricted to poultry, since monogastric animals are more affected by fibre content, the type of amino acids, and feed inhibitors. The first experimental results with croton seed meal are very promising. Experiments with other animals, for example, pigs, could be carried out first by informal surveys, because of the huge financial implications of formal animal research. Again, collaboration with farmers will be of utmost importance.

References

Anon. 1958. A guide to the Nairobi Arboretum. Government Printer, Nairobi. 12 p.

Ash A.J., Petaia L., & Ako H. 1992. Nutritional value of *Sesbania grandiflora* leaves for monogastrics and ruminants. *Tropical Agriculture* (Trinidad) 69(3).

Balldin B., Hart R., Huenges R. & Versluys Z. 1993. *Child health: a manual for medical assistants and other rural health workers*. AMREF, Nairobi. 418 p.

Cariaso E.R. 1988. Feeding value of Mallunggay *(Moringa oleifera)* leaf meal in broiler

diet. Thesis, College of Agriculture, University of the Philippines, Los Banos.
Charles R.A. 1990. *Multipurpose trees and shrubs of the Kathama area.* Kenya Polytechnic, Nairobi. 84 p.
Egli A. & Kalinganire A. 1988. *Les arbres et arbustes agroforestiers au Rwanda.* ISAR, Rwanda. 184 p.
Huchzermeyer S.P. 1973. *Potential of free range chicken in Zimbabwe.* ZARI, Harare. 46 p.
ILEIA. 1989. *Participatory technology development in sustainable agriculture.* ILEIA, Leusden, The Netherlands. 38 p.
Kokwaro J.O. 1976. *Medicinal plants of East Africa.* East African Literature Bureau, Nairobi. 384 p.
Labadan M.M., Abilay T.A., Alejar A.S. & Pungtilan U.S. 1969. The effects of feeding high levels of ipil-ipil *(Leucaena leucocephala)* leaf meal on comb and testes growth of SCWL cockerels. *Philippine Agriculturalist* 53:65–94.
Leakey R.R.B. & Newton A.C. 1994. *Domestication of tropical trees for timber and non-timber products.* MAB Digest 17. 94 p.
Limcango-Lopez P.D. 1990. The use of shrubs and tree fodders by nonruminants. p 61–75. In: *Shrubs and tree fodders for farm animals,* ed. C. Devendra. Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989. IDRC-276e. IDRC, Canada.
Lopez P.L., Sayaboc V.S. & Deanon A.S. 1978. The effect of ferrous sulfate on high ipil-ipil *(Leucaena leucocephala* (Lam) de Wit) leaf meal fed layers. *Philippine Agriculturist* 62:116–129.
Niang A.I. 1993. Selection generale des espèces. AFRENA annual planning meeting held in Kabale, Uganda. ICRAF, Nairobi. 64 p.
Nicholson M. 1992. *Fodder trees for smallholders.* Miti Mingi Mashambani, FINNIDA, Nakuru, Kenya. 55 p.
Noad T. & Birnie A. 1989. *Trees of Kenya.* Nairobi. 308 p.
Ross E. & Enriquez F.Q. 1969. The nutritive value of cassava leaf meal. *Poultry Science* 48:846–853.
Sazon M.A. 1988. Feeding value of *Sesbania rostrata* in layer diets. Thesis, College of Agriculture, University of the Philippines, Los Banos.
Smith A.J. 1993. *Poultry.* Tropical Agriculturalist Series. CTA, Wageningen, The Netherlands. 218 p.
Springhall J.A. & Ross E. 1965. Preliminary studies with poultry rations for the territory of Papua New Guinea. 1. Grower rations with copra, sago and *Leucaena leucocephala. Papua Guinea Agricultural Journal* 17:117–121.
Teel W. 1984. *A pocket dictionary of trees and shrubs in Kenya.* KENGO, Nairobi. 151 p.
Thijssen H.J.C., Murithi F.M., Nyaata O.Z., Mwangi J.N., Aiyelaagbe I.O.O. & Mugendi D.N. 1993a. Report on an ethnobotanical survey of woody perennials in the coffee zone of Embu District, Kenya. AFRENA Report no. 62. ICRAF, Nairobi. 32 p.
Thijssen H.J.C., Murithi F.M. & Nyaata O.Z. 1993b. Existing hedges on farms in the coffee based land use system of Embu District, Kenya. AFRENA Report no. 65. ICRAF, Nairobi. 14 p.
Yoshida R.K. 1944. *A chemical and physiological study on the nature and properties of the toxic principles in* Leucaena glauca *(Linn.).* Hawaii Academy of Science, Honolulu, USA. 2138 p.
Zaichun X. 1990. Availability and use of shrubs and tree fodders in China. p 295–302. In: *Shrubs and tree fodders for farm animals,* ed. C. Devendra. Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989. IDRC-276e. IDRC, Canada.

Market, policies and institutions in NTTP trade: nothing is perfect

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Abstract

New tree varieties and related technological innovations require years to affect smallholders' profits. But policies affecting trade in non-timber tree products (NTTPs) can have immediate effects that are transmitted through markets to prices at the forest or the farmgate. These trade policies also affect incentives to adopt innovations. There have been few studies of the political economy of trade in NTTPs, but substantial literature from development economics and agricultural economics contains relevant insights. The development economics literature of the 1950s and 1960s placed great faith in public institutions to implement policies that addressed market failures and imperfections. In contrast, the 'new political economy' that emerged in the 1970s and 1980s pointed out that policies were a product of political processes that often favour individuals with wealth and power. In this view, 'bad' policy (from an economic perspective) is not a mistake but a product of self-serving influence. Characteristics of NTTPs and their markets make them susceptible to failures in markets, policies and institutions. Although much can be gained from improving basic understanding of these markets, it is naive to think that better information is a panacea.

Introduction

New tree varieties and related technological innovations require years before their potential is expressed in smallholders' profits. In contrast, effects of trade policies are transmitted quickly through markets to prices at the forest or the farmgate. Thus, trade policies can have rapid, powerful effects (for good or ill) on incentives to make the long-term choice to plant and maintain trees. Most devastating are trade restrictions that lead to collapse of farmgate prices, thus destroying incentives necessary for domestication and commercialization of non-timber forest products in agroforestry systems.

There have been few studies of specific features of NTTP trade. However, a substantial literature from agricultural economics, development economics and other social sciences contains some relevant insights. Here, the basic framework of market failures and market imperfections, which provide the textbook rationale for policy intervention, is examined first and is followed by a review of the 'new' political economy perspective, the theoretical basis for a radical reinterpretation of the causes of 'bad' policy. Institutional perspectives that are especially relevant to implementation of policy in developing countries are then discussed. The political economy and institutional perspectives provide a pessimistic picture regarding prospects that trade policy intervention can achieve its formal objectives. The relevance of these general insights to the specific case of NTTPs is assessed in each section. These are framed as hypotheses for further research because of scant NTTP-specific evidence.

The conclusions venture some general observations regarding policy priorities and pitfalls and about the process of policy-making and implementation itself. The paper reflects the fact that the author has had much more experience with these issues in

Southeast Asia than in sub-Saharan Africa. Africa *is* different (and diverse); but its distinctive political and institutional features mean that the cautionary tales regarding policy intervention apply in Africa with equal, or greater, force.

Markets

Market orientation and the degree of government intervention are key policy choices, whether this mix is achieved by design or default. Idealized models, those that purport to represent the perfect market as well as those that assume an omniscient planner, are of limited use as standards for judging these alternatives. The appropriate mix is an empirical question that hinges on the balance of offsetting effects resulting from imperfections in markets, the distribution of political power, and the capabilities of government agencies. Some general insights are available, however, regarding the right mix of activities of the public and private sectors.

The basic case for reliance on agricultural markets

Dahl and Lindblom (1953) provide an analytical framework for judging the comparative advantage of public agencies and private enterprises. Their framework yields three propositions that deserve policy-makers' attention. First, all large organizations, public or private, are 'bureaucracies' and rely heavily on hierarchical techniques for decision-making and control. Second, private enterprises (or independent cooperatives) can be expected to be more efficient than public agencies in responding to the cues of the price system and in holding down costs. This fundamental distinction rests with the structure of incentives: a public agency is controlled by a multilevel bureaucratic organization whereas small private enterprises are controlled largely by markets. Moreover, the locus of decision-making in a bureaucracy is likely to be quite distant from the actual location of production and distribution activities, thereby exacerbating the problems of information management, monitoring and establishing appropriate incentives. The third proposition is that individual proprietorships and other small enterprises differ from both large public agencies and large private enterprises in not having the distinctive characteristics of bureaucracy; small-scale proprietors own the firm and its resources, respond more directly to price and profit signals, and have little need for hierarchical techniques.

Agricultural production (and marketing) in developing countries typically can be undertaken by such small-scale, independent proprietors. Indeed, farms that account for the bulk of agricultural production in developing countries are quintessential private enterprises: large numbers of small-scale, decentralized decision-makers producing similar products. Although agriculture often is cited as approximating the perfect market paradigm, even staple food markets have flaws. Widely dispersed production and limited infrastructure increase transaction costs, risk and uncertainty cloud production and investment decisions, and asset fixity can slow response to changing incentives (Timmer et al. 1983). Nevertheless, the relative efficiency of these small-scale producers is established empirically in agricultural economics literature spanning 30 years (Schultz 1964, Tomich et al. 1995).

The evidence for agriculture in developing countries indicates that in general (1) smallholders are the most economically efficient producers, (2) smallholders produce more output per unit area, (3) smallholders employ more labour-intensive techniques, and (4) although there can be an initial lag, smallholders have no persistent disadvantage in using profitable technologies; from these it follows that (5) there is no fundamental tradeoff between production efficiency and equity (Tomich et al. 1995).

Results from marketing studies indicate that (6) private traders will be more efficient than marketing by state enterprises, from which it usually follows that (7) farmgate prices in developing countries are higher under competitive private marketing than when marketing is undertaken by state enterprises.

A basic hypothesis: are NTTPs really different?

Do the general results for agriculture apply to the specific case of NTTPs? NTTPs share some (but not all) features of agricultural markets in developing countries, including the key feature highlighted by Dahl and Lindblom (1953): small-scale, independent proprietors account for much production. But smallholders' share may be less for NTTPs compared with agriculture overall because large-scale plantations also feature in tree-crop production. The widespread belief that plantations are more efficient tree-crop producers than smallholders in developing countries is refuted in Tomich et al. (1994, also see Hayami 1993). The following hypothesis provides a point of departure:

> ***Hypothesis 1.*** Production and marketing of NTTPs resemble patterns identified for agricultural commodities in developing countries.

This hypothesis is essentially untested and is a full agenda for research in and of itself, although the findings of Amacher et al. (1993) with fuelwood are consistent with this hypothesis. It is entirely possible, however, that while much of agriculture is an operating approximation of the perfect market paradigm, flaws present to some degree in most agricultural markets may have more serious effects in the specific case of NTTPs.

Market failures

Some (potential) failures in NTTP markets may truly set them apart from agriculture; candidates discussed below include environmental externalities and missing commodity markets. Missing markets, lack of property rights, externalities and diverse production sources have been identified as features that distinguish NTTPs (Witcover & Vosti 1995). Public goods can, however, arguably be considered the most important market failure in the agriculture sector of developing countries.

Public goods

Government efforts that generate and disseminate improved varieties and agricultural technology, market reports, weather forecasts, and other useful information and that mitigate natural hazards through flood and disease control are examples of public goods (and services). It is both inefficient and inequitable to rely on markets and the response of private firms to private demands for public goods. Government action is required not because developing countries are well endowed with institutional capacity—indeed, this may be a key constraint—but because there is no effective alternative to government intervention to provide an adequate supply of public goods. Markets fail, in this case, because of two defining characteristics of public goods. First, the use of a public good by one person does not prevent full benefits being enjoyed by others. The second characteristic, which follows from the first, is that it often is difficult to exclude users; hence it may be excessively costly to charge them. This 'free rider' problem is the main reason why private firms operating in a free market will not produce an adequate supply of public goods.

Market price reports and other forms of information are 'pure' examples of public goods. NTTPs differ from other agricultural commodities regarding information only to the extent that systems for public dissemination of market prices and other relevant statistics are relatively undeveloped for many NTTPs. Since costs of dissemination have plummeted with the spread of radios and other electronics and because of economies of scale in collection of data in specific markets, it should be feasible to improve NTTP market information, even for relatively minor products. To have any meaning, these data must be combined with information on standard grades and units of measurement. Definition and dissemination of information on these standards are other public goods.

Up to a point, investments in transportation, communication and other forms of infrastructure also have some attributes of public goods. In these mixed instances, however, it often will be feasible and desirable for individual beneficiaries to contribute to the cost, for example, by paying tolls and other user fees. Better transport and communications reduce transactions costs and improve market information for all commodities, including NTTPs.

Especially in developing countries, investments of human talent and financial resources in agricultural research will not approach socially optimal levels, without financial and administrative support from public agencies. High rates of return to investments on agricultural research (Ruttan 1982) indicate that there has been widespread underinvestment to produce these public goods. Yet these studies, and the results that can be seen firsthand in farmers' fields, are helping to build awareness among policy-makers of the priority that agricultural research deserves.

Consensus on desirability of supplying agricultural research as a public good does not eliminate the hard choices necessary to balance limited government funding and research capacity with the range of agricultural development needs. The returns to such investments are governed, in large part, by the extent of the recommendation domain. Other things equal, it is understandable that staple foods and other production systems that loom large in terms of key policy objectives (growth, employment, food security) get top priority for scarce research resources. Irrigated agriculture is characterized by relative homogeneity of large areas of high-potential land. Under these circumstances, a manageable number of field trials can yield information that is broadly representative of conditions on many farms and rapid diffusion of innovations can occur.

In contrast, impact of research aimed at niche environments and production systems spanning heterogeneous resource bases, circumstances where NTTP-based systems may have a comparative advantage, can be severely constrained. Relevance of experiment station research is limited under conditions like the diverse rainfed farming systems of much of sub-Saharan Africa, as well as the Asian uplands. As a consequence, research and technology dissemination activities aimed at NTTP production systems face uncommon challenges in these difficult settings.

Environmental externalities and global public goods

Production externalities are cases where certain costs or benefits of production by one economic agent accrue to others. The externalities of interest here arise from so-called forest functions, including *off-site* effects of soil erosion and water runoff, as well as effects on local climate. Siltation of reservoirs, flooding and water shortages are examples of negative environmental externalities. Positive environmental externalities include rich alluvial soils (which start as erosion somewhere else!) and watershed functions (water storage, timely rate and pattern of water flow, and good water quality). Hard evidence on these effects is scarce, but tree planting, including NTTP production in agroforestry systems, would seem to be a good substitute for natural forest in supplying these environmental externalities; continuous foodcrop production probably is not.

Forest functions also influence the supply of global environmental public goods through carbon storage and reduction of greenhouse gas emissions (believed to contribute to adverse changes in global climate) and through conservation of biodiversity. Few (if any) land-use systems can rival primary forest as a stock of carbon. However, tree-based systems (including NTTP production and other agroforestry systems, but also timber plantations, oil palm plantations and other monoculture systems) sequester significantly more carbon than either annual crop systems or grasslands.

In Indonesia, low-management-intensity rubber agroforests ('jungle rubber') allow the survival of a considerable part of the original forest biodiversity. These agroforests (which are complex, multistrata agroforestry systems, *not* monoculture plantations) contain considerable biodiversity, since the planted trees are augmented by natural invasion of species from the original forest (Michon & de Foresta 1992, 1994). Besides ecological advantages, including the forest-like environment that retains biodiversity, rubber agroforests are suited to smallholder management. They involve minimal additional investment in labour and capital and typically are established in conjunction with upland food crops. A major issue for further research is whether the introduction of higher yielding rubber germplasm can allow intensification without much loss of the remaining biodiversity (van Noordwijk et al. 1995).

Missing commodity markets

Many NTTPs (coffee, cocoa, nutmeg, mace, cloves, cinnamon, pepper, rubber and damar, to name but a few) have been traded in international markets for centuries. Although the private sector has been a mainstay of world trade in these commodities, local production and marketing has ebbed and flowed in various places at various times, often in conjunction with official intervention (usually with adverse economic results). Jaffee's (1993) survey of 15 cases of developing countries' experience with exporting high-value agricultural commodities found that, for nearly all the success stories, 'the private sector has played a dominant, if not exclusive role in commercial production, processing, and trading activities'.

Public agencies typically are immune to the competitive pressures of the market, which spur cost reduction and efficiency in private trading firms. For this and other reasons, public sector involvement in marketing often drives down producer prices. In the extreme, this can reduce incentives sufficiently for local markets to disappear completely. If a commodity market is missing, policy distortion is a prime suspect.

Since some NTTPs can be harvested from forests as well as being produced in farmers' fields, distorted forestry sector prices can destroy incentives for smallholder production of these NTTPs in agroforestry systems. In cases where no local market exists because of market failure, however, involvement of a public agency or parastatal in intrinsically commercial activities may yield important benefits. The Kenya Tea Development Authority (KTDA), which catalysed rapid expansion of tea production leading to higher incomes for smallholders, is (or was) a notable example. It must be emphasized, however, that KTDA recognized smallholders' capacity to organize tea production at the farm level and concentrated on supplying public goods, such as dissemination of new technology, and on carrying out activities in which economies of scale are important, such as coordinating the timely collection and processing of tea leaves. By matching smallholders' capacity for efficient tea production in their fields with its own ability to achieve economies of scale in processing, KTDA was able to create opportunities that were beyond the grasp of individual smallholders.

Addressing market failures is a general feature of successful public sector intervention in agricultural export promotion, but these must be identified on a case-by-case basis. For example, Jaffee (1993) concluded that 'in the vast majority of focal cases, governments have provided facilities and services which either have public good properties, give rise to [positive production] externalities, or exhibit large economies of scale'. It is worth noting, however, that just as the spice trade emerged in response to international demand, and Kenya Tea Development Authority sells tea in an established world market, Jaffee's success stories each 'faced very favourable international market conditions during their 'take off' stage and for many subsequent years'.

There may also be reasons for a transitional role for a parastatal in the distribution of improved planting material or other new inputs if initial demand is not sufficient to attract private suppliers. However, if input demand increases, private firms ultimately will be more flexible and more efficient. This transition to private trade can occur only if public agencies and private firms eventually compete on equal terms. Preferential access to supplies or subsidized prices can entrench the monopoly position of a government agency and prevent the emergence of an efficient market for agricultural inputs.

If an incipient private market already exists, government intervention can kill it. Early in the analysis of opportunities to disseminate improved planting material to smallholder rubber producers in Indonesia, it was believed that there was no appreciable private sector involvement in rubber propagation. The preliminary recommendation was for government to establish its own nurseries and to market planting material at a subsidized price (Barlow & Jayasuriya 1984a, Barlow et al. 1991). But, as field research considered implementation options, it was discovered that private nurseries already existed. These private nurseries could have been driven out of business if plans had proceeded for public nurseries to supply subsidized planting material. Emphasis shifted from the mistaken view that the problem was a missing input market to efforts to identify means of addressing imperfections in the existing market, with particular attention to imperfect information and to nurturing improvement in quality of privately propagated planting material (Barlow 1994).

It therefore appears that, among possible market failures (public goods, externalities, missing commodity markets), NTTP production in agroforests is most distinctive from other land-use systems in its potential for supplying global public goods. Specifically, to the extent it replicates a forest-like environment, NTTP production in agroforests appears to offer an extraordinary combination of income-generating opportunities with positive environmental externalities and global public goods. The area of these land-use systems will be below optimum in the absence of policies and workable mechanisms to compensate for carbon sequestration and biodiversity conservation.

Unfortunately, appropriate policies and workable mechanisms to address failure of markets to produce optimal amounts of these global public goods require global institutional innovation—a difficult task indeed, particularly for biodiversity conservation (Sandler 1993).

Imperfections in NTTP markets: real or imagined?

A number of market imperfections (flaws in markets that fall short of market failure) may affect production and marketing of NTTPs. On the production side, these include price and yield risk, imperfect information, and interlinked imperfections in markets for land and capital. It is certain NTTP producers face variation in prices and yields. However, there is no *a priori* reason to expect NTTPs to be inherently riskier than alternatives in agriculture. Accumulated experience with crop insurance in developing countries is quite clear: administrative costs far outweigh benefits to producers (Hazell et al. 1986). Thus, NTTP production risk is an issue to be tackled through agricultural research progammes (discussed above under public goods), not through production insurance schemes. Price risk, however, will be taken up below. Information on prices was addressed under the public goods rubric and is the subject of a separate paper in this session. Programmes aimed at imperfections in land and capital markets involve institutional complexities that will be addressed later.

This leaves market imperfections that directly affect NTTP trade as the focus for this discussion. Perhaps the most fundamental requirement for the market to yield an efficient outcome is that there be many buyers and sellers. If everyone is a 'price taker', no single economic agent can influence prices alone. The first two topics in this section concern possible market power. First, as with agriculture, NTTP production usually involves many producers, hence many local sellers; there is less certainty about the number of buyers, raising the possibility of monopsony (or oligopsony) power in local markets. Second, since differences in climate and resource endowments may focus comparative advantage in production of certain commodities in a few countries, there is also the possibility of national monopoly (or oligopoly) power to affect prices received on world markets. Third, price stabilization is taken up as a possible response to the issue of price risk mentioned above. There is a fourth possibility, at least in theory, known as the infant industry argument, which could be invoked to justify trade restrictions to promote 'value added' processing.

Local market power: 'eliminate the middleman'

The statist view of economic development is manifested in the often artificial distinction between formal markets, those influenced by the government and presumed to be relatively efficient, and informal markets beyond the pale of official control and presumed to be partially formed and inefficient. Notions that free markets are imperfect and presumptions that market power allows traders to exploit farmers are often put forward as justification for direct government intervention in agricultural markets.

Although the functioning of local markets for NTTPs is an empirical question rather than an issue of dogma, accumulated evidence for a variety of agricultural commodities indicates the burden of proof must rest with those who think NTTP prices should be determined by government rather than by market forces. Especially in Africa, but also in Indonesia and the Philippines, it has been common for the public sector (or officially designated private firms) to appropriate sole authority for marketing certain export crops and for other essentially commercial activities that are difficult for bureaucratic organizations to manage effectively. Experience with export marketing boards suggests that their inefficiency creates an implicit tax for agricultural producers.

It is conceivable, however, that NTTP production typically is dispersed more widely and encounters greater bottlenecks in transport infrastructure, thereby raising the possibility of dramatic increases in transaction costs, poorer market integration, and limited market information. As a result, a tendency toward local monopsony may exist for NTTP markets that generally is absent for agricultural commodities. Another possibility is that economies of scale in trading or processing a particular NTTP create a natural monopsony. Whether either of these possibilities translates into actual market power can be answered only through empirical research. Appropriate methods are available, but there are few studies that apply them to NTTPs (Witcover & Vosti 1995).

World market power: 'fair trade'

There are cases (e.g., diamonds, petroleum) where export taxes or quotas can create economic benefits for exporting nations. But as a practical matter, international commodity agreements are unwieldy, and there are few agricultural commodities where single countries have sufficient market power for an optimal export tax argument to apply. No country in Africa or Southeast Asia had even 4% of world coffee exports and only Kenya had a significant share (12%) of tea exports in 1987. Among major agricultural commodities, cocoa is perhaps the most plausible case for an optimal export tax for certain African producers. But by any economic measure, the cocoa export taxes of 40–70% imposed in the early 1980s by Ghana, Nigeria and Cameroon were several times the optimum (Imran & Duncan 1988). These policies raised world prices, but they also undermined domestic investment in cocoa. The question of lower tax versus no tax depends most on the subsequent investment decisions of other producers and potential producers (Panagariya & Schiff 1990). Export taxes by West African producers increased incentives for the dramatic expansion of cocoa production by Malaysia and Indonesia, neither of which taxes its cocoa exports significantly nor belongs to the International Cocoa Agreement.

Many agricultural commodities face competition from natural and synthetic substitutes, so even a large share of exports does not guarantee market power for the producing country. For example, Malaysia produced one-third of the world's exports of natural rubber and almost half of the exports of tropical oils in 1987. After accounting for competition from synthetic rubber and other edible oils (and including production in consuming countries that is not exported), Malaysia's share of world supply falls to 11 and 9%, respectively. And, while Madagascar accounted for 70% of natural vanilla exports in 1987, 90% of the US market was synthetic vanilla. Research is under way to produce 'natural' vanilla flavour through tissue culture, which promises better quality at lower cost. Any attempt by Madagascar to raise natural vanilla prices would simply accelerate this research and thereby hasten the demise of its vanilla exports.

Even in cases where there is a valid optimal export tax argument, there should be concern about its incidence. If the NTTP in question is a perennial (as most are), the elasticity of supply is likely to be small, at least in the short run. As a result, the export tax will not only extract monopoly rent from foreign consumers but will also fall (probably even more heavily) on the country's own producers. This problem has been finessed by assuming producers are compensated (which almost never happens in the case of smallholders) or by what Deaton (1992) emphasizes are naive assumptions that (1) farmers do not save and (2) governments invest wisely.

Price risk: 'protecting our farmers'

Many countries impose international trade restrictions in an effort to protect producers (and consumers) from price fluctuations in world markets for staple foods. Instead of raising the average price, as in the preceding topic, the objective here might be to reduce variation around the trend in world markets. Indonesia has used trade restrictions to pursue this policy objective for rice (the staple food) with remarkable success (Timmer 1991). Why not use trade policy instruments to stabilize domestic NTTP prices, thereby reducing producers' risk? Part of the answer rests with the balance between benefits and costs of stabilization. True stabilization (aiming for the same average price, but with lower variance) can be costly, and the economic benefits are controversial (Newbery & Stiglitz 1981, Kanbur 1984).

Value-added processing: 'moving downstream'

The idea has simple appeal: why not process NTTPs before export to increase 'value added', create jobs, earn more foreign exchange, and a host of other fine things? As with Indonesia's ban on raw rattan exports, trade policy instruments, including export taxes or quantitative restrictions on NTTPs, often have been imposed to promote domestic processors of primary products. If these processing activities were profitable, this begs the question of why it was necessary to intervene at all. One answer, in theory if not in fact, is that an 'infant' processing industry may need time to 'learn by doing', to bring costs down enough to compete on world markets.

But prospects are not good that these infants will grow up. When exports are restricted (or banned), the domestic price of the commodity falls. This encourages inefficient processing industries that may even be 'value reducing', in that they consume primary commodities and other inputs that add up to greater value than the processed export.

Policies

To begin, it is worth stating the usually unstated assumption that governments intervene in NTTP markets if (and only if) it is demonstrated that a market imperfection exists. In this view, policy mistakes, unnecessary intervention, or failure to intervene when it is justified results from lack of information or limited capacity for policy analysis. This assumption will seem naive to many. But until only a little over 20 years ago, the perspective that policy mistakes resulted mainly from misunderstanding was a basic (if implicit) assumption of economic development and agricultural policy analysis. Byron (in press) argues that this perspective still predominates in analysis of forestry policy and, judging from a number of presentations at a recent workshop, it is the conventional view of policy failure in NTTP markets too.

The architects of the theory of 'domestic divergences' recognized a broader set of forces operating beyond their theoretical 'first best world'. In practice, however, simplistic interpretations have fed a statist obsession with the market imperfections catalogued in the previous section. After all, who would oppose 'eliminating the middleman', 'fair trade', 'protecting our farmers', and 'moving downstream'? The trade policy instruments that are used to pursue these attractive notions create their own paradox: markets with heavy government intervention, and they tend to diverge the most from allocative efficiency. Furthermore, such government control of agricultural product prices typically reduces farmers' income. These results may be no accident.

The naive view that outcomes really are determined by policy analysis and planners' designs is seductive. Life would be much simpler if reality conformed to that wishful thinking. In this textbook perspective, stressing the role of consistent, rational analysis and the exclusion of everything else, policy-makers begin with a clean slate and act in concert to perform policy analyses and economic appraisals; their objective is the identification of optimal policies, programmes and projects. This view of strategic choice presumes the world is neat enough to allow a 'strategic blueprint' process (fig. 1). The understandable tendency to identify a set of goals and then to attempt to design a blueprint to realize those goals has been a disastrous flaw of much thinking about development strategy (Korten 1980). This 'strategic blueprint' perspective, misleading if considered alone, will provide a point of departure for subsequent discussion of policies and institutions.

What is government's role?

Because of government's power in a wide range of activities, there is a tendency to view government not only as all powerful but also as the primary force in society. The 'strategic blueprint' described above reflects excessive faith in particular governmental

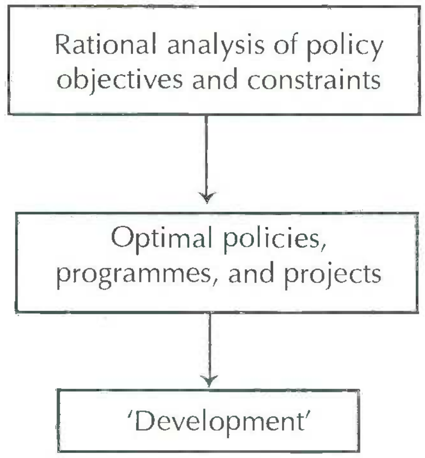

Figure 1. The supposed blueprint approach to agricultural development.

initiatives. As such, it lies at one extreme of the variety of narrow views regarding government's role in the development process. From this perspective, agricultural development is a top-down process with all progress emanating from central governmental planners. At the other extreme are exclusively bottom-up views: that all agricultural development begins through private initiative and people working in village institutions. At best, government is irrelevant in this view; often it is condemned as a barrier to progress.

Each of these narrow views is misleading. On one hand, there are limits placed on the scope of government choice by the distribution of political power (Grindle 1986). Government actions also are constrained by factors determined in the rest of the world through the interactions of international markets, the decisions of foreign aid 'donors', and a variety of other forces that impinge on absolute sovereignty of the state. Opportunities for government action are created and foreclosed through shifts in the international situation and domestic politics. On the other hand, the rate and pattern of development depends on the interacting effects of individual choices *and* government policies and programmes, including development and dissemination of new agricultural technology; public investments in roads and other transport and communication infrastructure; and a host of government decisions affecting the marketing of output, the distribution of inputs, and the allocation of land, water, labour and capital.

Limited time and information as causes of policy failure

One big shortcoming of the 'strategic blueprint' perspective of figure 1 is that there is too much risk and uncertainty in the world to expect any policy to be ideal initially, much less perpetually. Policy failures can stem from misinterpretation of likely effects of government actions or faulty prediction of future conditions (March & Olsen 1976). Much thinking about comprehensive planning has been based on an implicit premise that direct government action could somehow produce outcomes that would be more purposeful, more rational and more benevolent than the allegedly chaotic results of private firms operating in an imperfect market system. The now widely recognized pitfalls of comprehensive planning arise from the difficulties of organizing the information flows in bureaucracies necessitated by the fantastically large number of decisions required to run any economy.

Simon (1985) calls rationality 'bounded' when 'complexity of the environment is immensely greater than the computational powers of the adaptive system'. In a complex system that has contending adaptive forces, policy-makers will 'statisfice', a term coined by Simon to describe the pragmatic approach of 'looking for alternatives in such a way that can generally find an acceptable one after only moderate search' (Simon 1985). Satisficing or seeking answers that are 'good enough', reflects a reasonable response to the burden complexity imposes on policy-makers. As a practical matter, the time spent searching for options must balance the social, economic and political stakes of the issue at hand, with the premium on timeliness of decisions and the limits on time available for policy-makers to attend to details (Simon 1985, Lindblom 1959).

Development policies are intended to cause changes. But even without purposeful change, the 'facts' of the world fluctuate. Climate, commodity prices, international political and financial arrangements, and a host of other external factors are, to varying degrees, beyond control of national policy-makers. Thus, simply because policy choices and their consequences are separated in time, adding a feedback loop between results and analysis is a desirable refinement to a rational approach to policy choice.

Information feedback and active learning are necessary to incorporate lessons from experience and to adapt to changing circumstances (fig. 2). This 'adaptive' perspective is a considerable step beyond blueprints. Nevertheless, this perspective still views strategic choice as a basically rational adaptive process (albeit bounded by time and search costs) and still contributes to a tendency to believe that better forecasting, more thorough planning and more information are the solutions to market imperfections or policy failure.

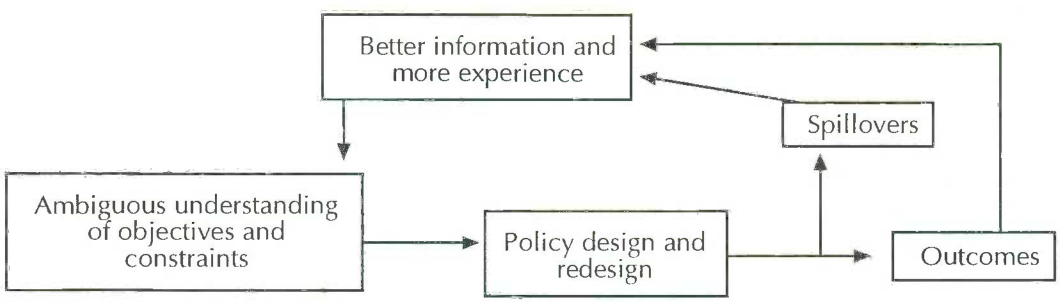

Figure 2. The adaptation cycle approach to policy decision-making.

The 'new' political economy

In place of the naive view of a neutral and benevolent government implicit in the 'blueprint' approach, it is important to recognize that policy-makers are pushed and pulled by lobbies representing narrow group interests, which may have little interest in the social goals of development. Worse still, broad coalitions that come close to representing the interests of society at large are likely to be ineffective because large groups have difficulty in motivating individuals to extend their own effort to win general benefits for the group. This is the 'free rider' problem again. Here it refers to the fact that members of a large economic group, such as small-scale farmers in developing countries, benefit from actions that favour their group whether or not they participate in the organization that achieves those actions. Moreover, the impact of any individual participant on the final outcome will be slight. Hence, there is little incentive for individual members of large groups to join organizations that represent their interests and much less to undertake the substantial effort to organize such a group (Olson 1965).

Government interventions that are intended to overcome market imperfections and to direct resources toward broad social objectives, in practice, are likely to be subverted by smaller groups with concentrated interests. The outcome reflects the familiar paradox: that apparently benign government initiatives create losses because of economic distortions, and they ultimately divert resources from production to unproductive rent-seeking activities, such as the cultivation of government contacts to secure trading licences (Krueger 1974). Rationality prevails in this policy-making process too, but it is a selfish rationality. Policies are seen as products of political processes that favour individuals with wealth and power. In this view, 'bad' policy (from an economic perspective) is not a mistake; it is the intended outcome of influential actors.

This 'new' political economy is the most common approach to relating self-seeking behaviour to the formulation of government policy. In its purest form, the neoclassical tools of optimization are applied to the actions of interest groups as they operate in the political economy. As such, so-called neoclassical political economy, including the 'collective choice' and 'public choice' schools, is a healthy reaction to tendencies to ignore the effect of politics on choice of development strategy or to implicitly assume that government will play the role of a neutral and benign protector of broad social interests (Srinivasan 1985).

The new political economy perspective fits the frequent cases in which concentrated private interests prevail over the common good. For example, it is consistent with substantial evidence of the extent that policies of governments in sub-Saharan Africa have had detrimental effects on the great majority of their farmers, who also happen to be the great majority of their populations. Balisacan and Roumasset (1987) and Olson (1988) develop collective choice interpretations consistent with the broader pattern that agriculture tends to be taxed in low-income countries and subsidized in industrialized countries (Anderson & Hayami 1986).

Moreover, the new political economy provides a basis for understanding governments' apparent preference for interventions that give officials arbitrary power to grant or withhold cheap credit, subsidized fertilizer and other scarce resources. These interventions are a means to enhance a regime's capacity for political control and are familiar elements of the patronage systems that are such common features of the politics of Africa, Asia and Latin America. This ability to grant preferential treatment can be used to secure the support of powerful and influential farmers, who might otherwise provide leadership in championing rural interests. Clearly, a regime's leaders may well attach more importance to political advantages associated with arbitrary controls than to their adverse effects on efficiency and equity.

The government intervention in markets, and the frequent disruption of the efficiency of markets, is not simply a misunderstanding of basic economics (Bates 1981). Similarly, projects in specific locations benefit participants of the locality but not those who are excluded from participation through personal characteristics or through distance. Thus, as Bates and others have argued, there can be a systematic tendency toward market intervention and project planning to build favour with a specific constituency while discriminating against potential opponents. Government intervention in response to all the imperfections in NTTP markets described earlier is susceptible to this tendency.

Policies leading to administrative rationing of trading licences, subsidized credit, fertilizer or other resources cannot only result from concentrated political power but can also magnify the importance of political influence. The arbitrary and discretionary element in the administrative allocation of such resources encourages concentration on highly lucrative but unproductive activities rather than on socially productive, income-generating activities (Bhagwati 1982).

Distortion of prices because of government involvement in activities that can be handled better by the private sector has received the bulk of the attention in the literature on new political economy. There are, however, parallel effects of these choices on a government's capacity to provide the public goods discussed earlier. For example, governments frequently assume operational responsibilities for marketing agricultural commodities that exceed their administrative capacity while they neglect fundamental responsibilities, such as improving, or at least maintaining, transportation facilities. Even public goods and services are not immune to influence from powerful interest groups. In agricultural research, for example, studies have documented biases favouring *latifundia* in Argentina (de Janvry 1978) and large-scale rubber plantations in Malaysia (Barlow & Jayasuriya 1984b). In each case, the large-farm subsector exerted disproportionate influence on national research agendas, and the resulting innovations were not always appropriate for the majority of farmers, who were operating smallholdings.

Limitations of the new political economy perspective

The extent to which concentration of political influence impedes both economic and social objectives depends on circumstances of time and place. It is inaccurate, however, to view those who wield authority in low-income countries as a completely self-serving group. To concentrate solely on the new political economy perspective, which views pursuit of power as a means for elites to serve their own acquisitive interests, is as likely to be misleading as viewing political leaders simply as disinterested servants of society.

The most important limitation of the new political economy perspective is that it does not provide an adequate explanation of the many cases where governments do give priority to broad social and economic goals, rather than respond solely to group interests. There are circumstances where pursuit of collective goals is consistent with the personal interests of influential policy-makers. Certainly, the incentives to promote agricultural development are more subtle than a taste for expensive automobiles or the desire to retain an influential position. But the dominance of agriculture in the economies of developing countries should make agricultural growth a salient issue. For economics ministers, the prospect of continuing in their job may be enhanced, or threatened, by the rise and fall of broad economic aggregates affected by agricultural performance.

Where do NTTPs fit in this political economy?

Despite the rewards of narrowly self-serving behaviour, *some* influential people in developing countries clearly do care about social progress and economic development. Yet there certainly is much truth in Leys (1971) observation that the social structure of low-income countries tends 'to promote a particular type of politics, which is the type least likely to set a high premium on so generalized an objective as national development'. In this political economy, even policy-makers who care about development will have to pick their battles.

> *Hypothesis* 2. NTTP market imperfections and policy failures do not rank high among policy-makers' concerns. As a result, policy intervention in NTTP markets is more likely to be driven by rent seeking than by efforts to address market imperfections.

Since policy failure that undermines food security can translate into political turmoil, policies affecting production and marketing of the staple food typically rank high on the list of policy-makers' concerns. On the other hand, it is clear that no such discipline operates in forestry because inefficiency and missed development opportunities resulting from rampant rent seeking in the forestry sector simply do not pose the same threat to a regime's survival, despite the enormous export earnings that can be lost. Thus, apparent failures in forestry policy can be tolerated or even exploited to political advantage. With few exceptions, NTTPs fall well below food and even below forestry in this hierarchy, whether measured in terms of their contribution to GDP, employment, or foreign exchange balances.

Institutions

Policy failures are not simply an aggregate effect of individual shortcomings in collecting, collating and interpreting information, nor are they always a result of venality, although these weaknesses are contributing factors. Bureaucratic politics and organizational processes weaken links between individual intentions and organizational choices, ultimately affecting policy impact (Allison 1971, March & Olsen 1976). Since scarcity of administrative capacity and analytical skills in the public sector and chronic shortages of government revenues are distinguishing features of many developing countries, the emphasis on policy failure in the previous section must be matched by greater awareness of the serious problems caused by an imbalance between public sector responsibilities and resources. Building the stocks of key human resources can have very high payoff, but it inevitably takes time. Augmenting administrative and analytical capacity is more an outcome of economic development in the long term than a prescription for alleviating immediate constraints.

Policy implementation

Implementing agencies have their own organizational interests and routines, which reflect varying degrees of compatibility with national policy objectives. As Simon (1985) has pointed out, 'the members of an organization . . . for whom plans are made are not passive instruments, but are themselves designers who are seeking to use the system to further their own goals'. Consequently, apparent unresponsiveness to national interests may simply reflect the balance of bureaucratic politics at the level of office clerks, bank tellers and extension agents.

Incentives are only part of the story regarding apparent failures in implementation, however. The range of feasible policy choices ultimately is limited by capacity of organizations to accomplish what is intended. Furthermore, policy changes typically require new routines to be added to an organization's repertoire. The hope that the resulting organizational actions will actually produce the outcomes intended by policy-makers presumes that organizations can 'learn' how to do new things effectively over time.

Examples exist of effective institution building and enhancement of organizational capacity in developing countries. However, prospects are not good that implementation of complex new development policies and programmes can be accomplished with much precision in the first attempt. The actual fit (or misfit) between organizational requirements of a new policy and organizational capacity to create the necessary routines cannot be anticipated adequately; it must be revealed through experience. To the extent that domestication of NTTPs involves new products and programmes, this feature means implementation of NTTP programmes, which will require extra time and will present unforeseen difficulties.

The learning necessary for effective implementation in complex bureaucracies is a chronic blind spot of development policy. Ideally, it is desirable to approach implementation as a process of exploration and learning by doing (Grindle 1980). The feedback loops in figure 3 are a schematic representation of some of the patterns of information flow necessary for implementation in complex organizations. In practice, however, policy-makers have to match pressing policy objectives with institutional capacities that happen to be available at a particular time.

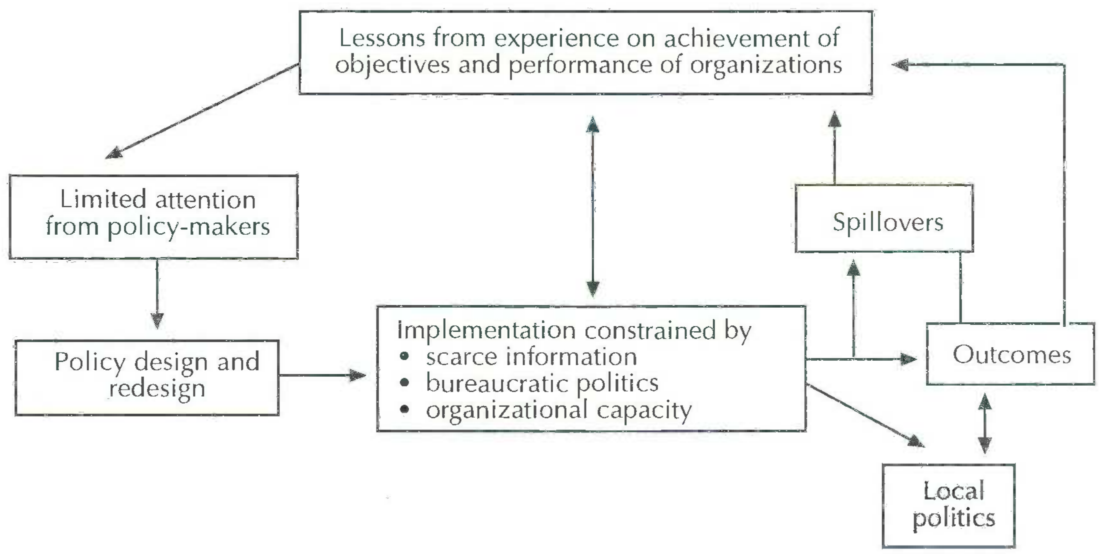

Figure 3. An information cycle for effective implementation of policy-making.

A central dilemma of development lies with the difficulty of institutionalizing capacity to adapt within complex, control-oriented bureaucracies (Rondinelli 1982). In contrast to markets, the hierarchical structure within government bureaucracies is not conducive to adaptive behaviour. Standard operating procedures are but one built-in source of bureaucratic resistance to change. In the view of Nelson & Winter (1982), 'the routines of the organizations as a whole are confined to extremely narrow channels by the dikes of vested interest'. There also is a particular problem of structuring incentives to reveal information from costly mistakes. Since this information almost always shows who is responsible, the incentive for those concerned is to reveal as little information as possible.

Furthermore, individuals with enough power to influence policy directly rarely have sufficient time to attend to the mass of details surrounding implementation. This is an additional source of both bad performance and lack of learning how to improve performance over time. In part, the sad persistence of policy failures reflects the limits that time pressures impose on the amount of attention a policy-maker can devote to any one issue.

Even when high-level attention to implementation of programmes and projects is available, it does not guarantee development policy objectives will be served. Indeed, as discussed earlier, patterns of patronage and special influence can generate a range of ad hoc programmes and projects that have little or no relationship to development. In this context, Grindle (1980) observed that the 'remoteness and inaccessibility of the policy-making process to most individuals', which is particularly pronounced in the political systems of developing countries, means that 'a large portion of collective demand making, the representation of interests, and the emergence and resolution of conflict occurs at the output stage'. This concentration of local political activity at the implementation stage is one more force that weakens links between policy choices and actual development outcomes.

Institutional remedies for imperfections in markets for land and capital

These factor market imperfections are interlinked in a number of ways, including the double bind that poor people often need land titles to get credit and they need credit to buy land. As discussed earlier, subsidized credit programmes, whatever their purpose, have proved inefficient and inequitable (Von Pischke et al. 1983). And fungibility of funds means targeted credit programmes (say for planting specific NTTPs) rarely achieve their objectives. It is especially difficult to administer credit programmes for tree planting (see, for example, Tomich 1991). New thinking on rural finance emphasizes building banking services that respond to rural people's needs rather than credit for a specific commodity or activity. Nurturing these banking institutions takes a long time. All in all, alleviation of capital market imperfections should be viewed as a broader development objective rather than a precondition for domestication and commercialization of NTTPs.

Perceived insecurity in property rights (in trees as well as land) undermines incentives to plant trees and to conserve land. Land registration programmes might be one means of promoting more efficient factor markets. But the costs of formal land titling are substantial and indigenous systems may already provide (albeit informal) relative security of property rights for many farmers (Feder & Noronha 1987, Migot-Adholla et al. 1991). Under these conditions, there will be greater returns to investments in agricultural research than to efforts to grant formal land titles.

Informal property rights become a problem, however, if there is a perception of imminent risk of expropriation. For example, Feder et al. (1988) found insecure tenure had a negative effect on land investment by squatters on state land in Thailand. Overlapping public and private claims, and contested claims generally, undermine incentives for investment and resource management on both sides. Common property is another situation where overlapping claims can arise, but elements of these institutional arrangements for community-based resource management may be superior to private property (Arnold 1992).

> ***Hypothesis 3.*** Since many forms of NTTP production are suited to marginal uplands and degraded forest land, NTTP production often is undertaken on common property or on land involved in contested claims between smallholders and the state. Prevalence of these ambiguous property rights is the key institutional factor distinguishing NTTP systems from the general situation in agriculture. Institutional innovations will be required if these problems on distinctive property rights are to be addressed.

Since the stakes can be high at the local level, programmes to address property rights problems will be vulnerable to political pressure from local interests, especially during early stages of implementation. This is an area where partnership with non-governmental organizations (NGOs) that have invested the time and effort to build grassroots credibility may be one way to compensate for weaknesses in public institutions. But these are areas where many questions remain about what, if anything, government can do locally to improve the efficiency of markets for land and other property rights.

Summary and concluding remarks

Characteristics of NTTPs and their markets make them susceptible to failures in markets, policies and institutions. As with agriculture more generally, government efforts to supply public goods, such as research and technology dissemination, are key elements of an appropriate NTTP development strategy. But because production often spans difficult, heterogeneous agroecosystems, production-oriented research on NTTP systems faces extraordinary challenges. Unlike much of agriculture, these tree-based systems also offer substantial environmental benefits and, *if* the difficult institutional issues can be overcome, hold the prospect for enhanced supply of global public goods.

When market imperfections are identified, it is possible (at least in principle) to seek selective interventions to improve the functioning of NTTP markets, rather than install a government bureaucracy and repress private trade. These selective government interventions include programmes to disseminate information on prices, grading standards, and units of measurement and investments in transportation, communication and other market infrastructure. Systems for collection and dissemination of local prices and other statistics on domestic NTTP markets are relatively undeveloped, even for internationally traded commodities. This lack of information is one potential source of NTTP trade policy failure.

While much can be gained from improving basic understanding of NTTP markets, it is naive to think that better information is a panacea. The context for policy-making in developing countries often combines the most forceful arguments for government intervention (to address both real and imagined market imperfections) with severely limited capacity for effective implementation. Like the mainstream of agricultural and development policy analysis, individuals with an interest in NTTP policy need a sophisticated appreciation of the way these forces shape policy and its outcomes.

A first step is the recognition of the possibility that rent seeking will subvert broader policy objectives. Indeed, it was argued that policy intervention in NTTP markets is more likely to be driven by rent seeking than by sincere efforts to address market imperfections. This is because information on these markets tends to be poor and, in most cases, NTTP market imperfections are not a big concern for policy-makers. This creates opportunities for influential individuals or small groups to influence policy in pursuit of selfish ends. And since NTTP policy failures typically carry few consequences for policy-makers, they have little direct incentive to be vigilant. Moreover, implementation of policies to obtain desired results also depends on the limited capacities of government agencies as well as the limited attention of policy-makers.

The 'blueprint' approach (fig. 1) involves a deterministic coupling of formal analysis, policy choice and actual outcomes. In the perspective depicted in figure 4, this inadequacy is addressed by introducing strategic notions (key ideas about how things work) and policy preferences of influential individuals, policy analysis commissioned by those individuals, bureaucratic politics involving the political and bureaucratic elite, effects on policy implementation resulting from organizational processes beyond direct control of policy-makers, and other direct results and indirect spillover effects. In this political economy, the individual's ideas and policy preferences are expressed or repressed through political influence, persuasive skills and power used in bureaucratic politics, and individual appreciation of organizational processes, luck and timing.

Other characteristics also serve to distinguish this perspective from the blueprint approach. Although both require that policy-makers give attention to detail as a condition of influence, the revised perspective recognizes that a policy-maker's continued attention to a particular detail is especially unlikely because of the multitude of issues competing for that attention. Consequently, implementation has a featured place in the revised perspective, as much because implementation is likely to remain a persistent blind spot for policy-makers as from hopes for improving it (Grindle 1980).

Furthermore, although action and analysis are on equal footing in their *potential* complementarity as sources of useful information, analysis has a subsidiary role in practice. Chronic scarcity of analytical capacity is typical in developing countries. Even when analyses are available, actual lessons of experience based on a legacy of political wins and losses, implementation successes and failures, and other sources of understanding of development experience tend to override abstract analytical lessons.

This is not to say that policy analysis has no prospects for impact—quite the contrary. In contrast to the blueprint approach, which relies solely on formal analysis, results of

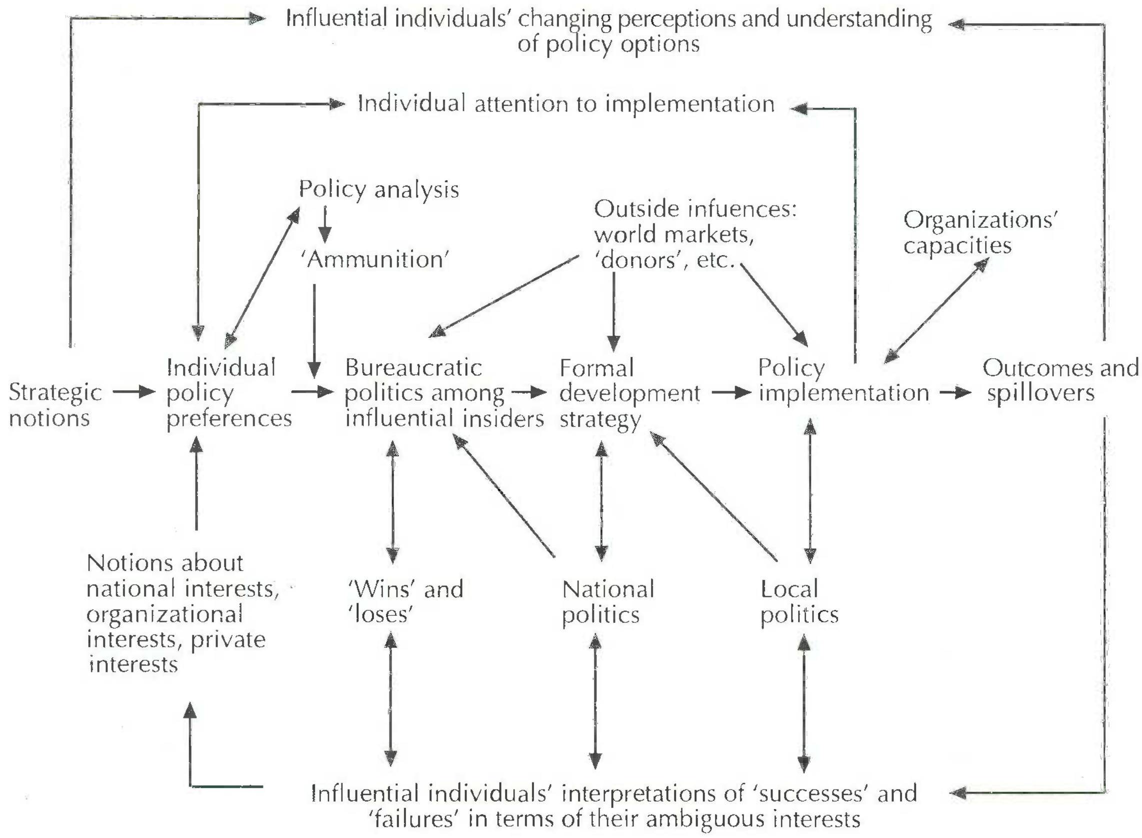

Figure 4. The recommended pragmatic approach to policy-making for agricultural development.

policy analysis also can be inputs to bureaucratic politics. Indeed, since analyses often are commissioned by influential individuals to be used as ammunition, this may be the primary channel for the influence of analysis. If that is true, it has important implications for the priorities, methods and audience for policy research on NTTPs.

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References

Allison G.T. 1971. *Essence of decision: explaining the Cuban missile crisis*. Little Brown, Boston.

Amacher G.S., Hyde W.F. & Joshee B.R. 1993. Joint production and consumption in traditional households: fuelwood and crop residues in two districts in Nepal. *Journal of Development Studies* 30(1):206–225.

Anderson K. and Hayami Y., eds. 1986. *The political economy of agricultural protection*. Allen and Unwin, Boston.

Arnold J.E.M. 1992. Production of forest products in agricultural and common land systems: economic and policy issues. p 433–453. In: *Managing the world's forests: looking for balance between conservation and development*, ed. N.P. Sharma. Kenda/ Hunt Publishing Company, Dubuque, Iowa, USA.

Balisacan A.M. & Roumasset J.A. 1987. Public choice of economic policy: the growth of agricultural protection. *Weltwirtschaftliches Archiv (Review of World Economics)* 123(2): 233–245.

Barlow C. 1994. *The market for new tree crop technology: a Sumatran case*. Department of Economics, Research School of Pacific and Asian Studies, Australian National University, Canberra.

Barlow C. & Jayasuriya S.K. 1984a. Problems of investment for technological advance: the case of Indonesian rubber smallholders. *Journal of Agricultural Economics* 35(1):85–95.

Barlow C. & Jayasuriya S.K. 1984b. *Bias toward the large farm subsector in agricultural research: the case of Malaysian rubber.* Australian National University, Canberra.

Barlow C., Shearing C. & Dereinda E. 1991. Alternative approaches to smallholder rubber development. HIID Development Discussion Paper No. 368. Harvard Institute for International Development, Cambridge, MA, USA.

Bates R.H. 1981. *Markets and states in tropical Africa*. University of California Press, Berkeley, California.

Bhagwati J.N. 1982. Directly unproductive profit-seeking (DUP) activities. *Journal of Political Economy* 90:988–1002.

Byron N. In press. Forest policy analysis in developing countries: which theoretical and methodological issues are important? Paper prepared for IUFRO 20th World Congress, Tampere, Finland.

Dahl R.A. & Lindblom C.E. 1953. *Politics, economics and welfare*. Harper, New York.

de Janvry A. 1978. Social structure and biased technical change in Argentine agriculture. p 297–323. In: *Induced innovation: technology, institutions, and development*, ed. H.P. Binswanger & V.W. Ruttan. Johns Hopkins University Press, Baltimore, MD, USA.

Deaton A. 1992. Commodity prices, stabilization, and growth in Africa. Discussion Paper 166. Research Program in Development Studies, Center of International Studies. Princeton University, Princeton, NJ, USA.

Feder G. & Noronha R. 1987. Land rights systems and agricultural development in sub-Saharan Africa. *World Bank Research Observer* 2(2):143–169.

Feder G., Onchan T., Chalamwong Y. & Hongladarom C. 1988. *Land policies and farm productivity in Thailand*. Johns Hopkins University Press, Baltimore, MD, USA.

Grindle M.S. 1986. The question of political feasibility: approaches to the study of policy space. EEPA Discussion Paper No. 3. Harvard Institute for International Development, Cambridge, MA, USA.

Grindle M.S., ed. 1980. *Politics and policy implementation in the third world*. Princeton University Press, Princeton, NJ, USA. p. 15.

Hayami Y. 1993. Peasant and plantation in Asia. In: *The agrarian origins of commerce and industry*, ed. Y. Hayami & T. Kawagoe. St Martin's Press, New York, USA.

Hazell P., Pomareda C. & Valdes A., eds. 1986. *Crop insurance for agricultural development: issues and experience*. Johns Hopkins University Press, Baltimore, MD, USA.

Imran M. & Duncan R. 1988. Optimal export taxes for exporters of perennial crops. Policy, Planning and Research Working Papers, WPS 10. International Economics Department, World Bank, Washington, DC. p. 21.

Jaffee S. with Gordon P. 1993. Exporting high-value food commodities: success stories from developing countries. World Bank Discussion Paper No. 198. World Bank, Washington, DC. p 56–58.

Kanbur, S.M.R. 1984. How to analyze commodity price stabilization: a review article. *Oxford Economic Papers* n.s. 36(3):336–358.

Korten C. 1980. Community organization and rural development: a learning process approach. *Public Administration Review* 40(5):480–511.

Krueger A.O. 1974. The political economy of the rent-seeking society. *American Economic Review* 64(3):291–303.

Leys C. 1971. Political perspectives. In: *Development in a divided world*, ed. D. Seers & L. Joy. Penguin, Middlesex, England.

Lindblom C.E. 1959. The science of muddling through. *Public Administration Review* 19(2):79–88.

March J.G. & Olsen J.P. 1976. *Ambiguity and choice in organizations*. Universitetsforlaget, Bergen, Norway. p 12–18.

Michon G. & Foresta H. de 1992. Complex agroforestry systems and conservation of biological diversity: agroforestry in Indonesia, a link between two worlds. p 488–500. In: *Harmony with Nature: an international conference on the conservation of tropical biodiversity*, ed. S.K. Yap & S.W. Lee. *Malaysian Nature Journal*, Golden Jubilee Issue.

Michon G. & Foresta H. de. In press. Forest resource management and biodiversity conservation: the agroforestry model. In: *Proceedings of IUCN Workshop on Biodiversity Conservation Outside Protected Areas, Madrid, March 1994.*

Migot-Adholla S., Hazel P., Blarel B. & Place F. 1991. Indigenous land rights systems in sub-Saharan Africa: a constraint on productivity? *World Bank Economic Review* 5(1):155–175.

Nelson R.R. & Winter S.G. 1982. *An evolutionary theory of economic change*. Harvard University Press, Cambridge, USA. p 111.

Newbery D.M.G. & Stiglitz J.E. 1981. *The theory of commodity price stabilization: a study in the economics of risk*. Oxford University Press, New York.

Olson M. 1965. *The logic of collective action*. Harvard University Press, Cambridge, MA, USA.

Olson M. 1988. The treatment of agriculture in developing and developed countries. *Journal of Economic Growth* 3(2):10–15.

Panagariya A. & Schiff M. 1990. Commodity exports and real income in Africa. Policy, Research, and External Affairs Working Paper WPS 537. World Bank Africa Economic Issues Conference, Nairobi, Kenya, June 1990. Country Economics Department, World Bank, Washington, DC.

Rondinelli D.A. 1982. The dilemma of development administration: complexity and uncertainty in control oriented bureaucracites. *World Politics* 35(1):43–72.

Ruttan V. 1982. *Agricultural research policy*. University of Minnesota Press, Minneapolis, USA.

Sandler T. 1993. Tropical deforestation: markets and market failures. *Land Economics* 69(3, August):225–233.

Schultz T.W. 1964. *Transforming traditional agriculture*. Yale University Press, New Haven, CT, USA.

Simon H.A. 1985. *The sciences of the artificial*. MIT Press, Cambridge, MA, USA. p 167, 177, 190.

Srinivasan T.N. 1985. Neoclassical political economy, the state, and economic development. *Asian Development Review* 3(2):38–58.

Timmer, C.P. 1991. Food price stabilization: rationale, design, and implementation. p 219–248. In: *Reforming economic systems in developing countries*, ed. D.H. Perkins & M. Roemer. Harvard University Press, Cambridge, MA, USA.

Timmer C.P., Falcon W.P. & Pearson S.R. 1983. *Food policy analysis*. Johns Hopkins University Press, Baltimore, MD, USA.

Tomich T.P. 1991. Smallholder rubber development in Indonesia. p 249–270. In: *Reforming economic systems in developing countries*, ed. D.H. Perkins & M. Roemer. Harvard University Press, Cambridge, MA, USA.

Tomich T.P., Kilby P. & Johnston B.F. 1995. *Transforming agrarian economies: opportunities seized, opportunities missed*. Cornell University Press, Ithaca, New York. chap 4–5.

Tomich T.P., Roemer M. & Vincent J. 1994. Development from a primary export base. p 151–193. In: *Asia and Africa: legacies and opportunities in development*, ed. D.L. Lindauer & M. Roemer. International Centre for Economic Growth, San Francisco.

van Noordwijk M., van Schaik C.P., Foresta H. de & Tomich T.P. 1995. Segregate or integrate nature and agriculture for biodiversity conservation? Paper presented at Global Biodiversity Forum, Jakarta, Indonesia, 4–5 November.

Von Pischke J.D., Adams D.W. & Donald G., eds. 1983. *Rural financial markets in developing countries: their use and abuse*. EDI Series in Economic Development. Johns Hopkins University Press, Baltimore, MD, USA.

Witcover J. & Vosti S.A. 1995. Workshop on Non-Timber Tree Product (NTTP) Market Research. EPTD Workshop Summary Paper No. 3. IFPRI, Washington, DC. p 4–6.

An introduction to selected FAO programmes related to non-wood forest products

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Abstract

This paper highlights the main features of three major programmes of FAO, the activities of which are closely related to the development of the non-wood forest products sector. The programmes are the Non-Wood Forest Products (NWFPs) Programme, the Agroforestry Programme, and the Forest Products Marketing Programme. Several other programmes of FAO also contribute to the work on the development of non-wood forest products, both within the Forestry Department and in other departments of the organization.

Non-wood forest products programme

General

Non-wood forest products (NWFPs) have featured in one or another of FAO's programme for several decades. In the early stages, they were handled as 'minor forest products' and the emphasis given to them was relatively minor as well. Recently, however, recognition of the significant environmental, economic and social roles of NWFPs have brought them into sharper focus. This development has also been helped by the emphasis on the efficient and sustainable use of natural resources and by the growing consumer interest in natural products.

NWFPs received notable attention at UNCED in 1992, which brought them to the interest of the authorities. Much of the new interest is, however, yet to be transformed into commensurate and consistent action.

FAO invigorated its programme on NWFPs some five years ago and allocated specific resources for the activities related to them. The NWFP programme is currently implemented under the Wood and Non-Wood Products Utilization Branch in the Forest Products Division.

The work carried out under the NWFPs programme of FAO has concentrated on increasing the awareness of their importance, identifying the most relevant issues related to the development of the NWFP sector, and initiating action to collect relevant information. FAO, as an organization with a mandate for global forestry, is also trying to coordinate the activities carried out by various public and private organizations in this area. On the technical side, the main emphasis of FAO's work is focused on resources, including NWFP resource management, harvesting, and marketing to secondary processing industries or final users. Until recently, the programme has concentrated mainly on the development of NWFPs in the tropical areas of the world.

Specific activities carried out recently include organizing meetings, preparing publications, establishing contacts, developing collaborative arrangements and partnerships, and promoting the NWFPs programme in general.

Meetings

FAO has organized and held four regional expert consultations on NWFPs (two for the Asia-Pacific region and one each for English-speaking Africa and the Latin America and the Caribbean region). These meetings were held jointly with other organizations, for example, the Africa meeting was co-sponsored by the Commonwealth Science Council, while US Forest Service co-sponsored the Latin America meeting. In January 1995, an Inter-Regional Expert Consultation was held in Indonesia, which brought together specialists from all the tropical regions. Other meetings were held by utilizing the resources of the FAO regular programme with support from other agencies and forestry field projects. Reports of all the above meetings have been published and copies are available from FAO.

Publications

The NWFPs programme has also published a number of studies that have been prepared by consultants with funding from the FAO regular programme or outside sponsors. The documents include material that highlights the importance of NWFPs in general (e.g., 'NWFPs—the way ahead' and 'More than wood—special options on multiple use of forests') or in specific regions or countries (like the Mediterranean region, the Amazon region, Viet Nam, Tanzania). Also included is an overview of the international trade of NWFPs. There are also a number of monographs to describe specific NWFPs (i.e., 'Nutmeg and derivates', 'Flavours and fragrances of plant origin', 'Gum naval stores: turpentine and rosin from pine resin', 'Natural colourants and dyestuffs', 'Gums', 'Resins and latexes of plant origin', 'Edible nuts', and 'Tropical palms'). Finally, the programme publishes a newsletter, *Non-Wood News,* with a frequency of approximately one issue per year. It was launched in 1994, so at the moment two issues have been published (although the first issue is now out of print). The third issue is with the printers and is due to be available for distribution in March this year. *Non-Wood News* provides an open forum for all readers to exchange information, contacts, announcements of programmes, etc. Its present circulation covers 600 individuals or institutions involved in NWFP activities around the world. *Non-Wood News* is also accessible through an Internet address -http://www.fao.org/WAICENT/faoinfo/forestry/nwnews.

Furthermore, there are other publications on more general production and trade issues that have come out recently in the NWFP Series, i.e., 'NWFPs for rural income and sustainable forestry: general principles and approaches', 'Multiple-use forest management guidelines for the production of NWFPs', 'Income generation from NWFPs in upland conservation', and 'Trade restrictions affecting international trade in NWFPs'.

Collaboration

Successful development of the NWFPs sector means a multidisciplinary approach. Many of the problems associated with the development of this sector are social, i.e., related to the general development of forestry communities. The NWFP programme closely collaborates with a number of interested and involved parties. FAO's NWFP programme has maintained contacts, exchanged information, provided comments, reciprocally attended meetings, etc. These include both UN organizations dealing with specific aspects of NWFPs, like UNIDO, ILO, WHO, UNESCO, UNEP and ITC, as well as other international and regional organizations like IUCN, WWF, CIFOR, ICRAF, WRI, ATI, CS, IIED, IDRC, ICIMOD, CATIE, UK/ODA-NRI, Royal Botanic Gardens-Kew, New York Botanical Garden, Commonwealth Science Council, and Oxford Forestry Institute.

Within FAO, this collaboration involves keeping close contacts with all the divisions of the Forestry Department and a number of other divisions (Plant Production and

Protection, Agricultural Services, Land and Water, Food Policy and Nutrition, and Statistics). Within the Forestry Department, the Agroforestry, Community Forestry, and Forest Products Marketing Programmes have been closely involved in supporting the development of the NWFP sector.

FAO has regional offices in all the main geographic regions where there are regional forestry officers, whose contribution to the NWFPs programme is also significant. They organize specific regional meetings on the topics and prepare and publish related studies.

Future activities

Future NWFPs activities in FAO will be guided by the recommendations of the 1995 Inter-Regional Expert Consultation on NWFPs held in Indonesia. The Consultation specifically requested FAO to:

- develop and provide guidelines for sustainable management of NWFPs
- promote establishment of information networks on NWFPs
- compile a directory of available databases, as well as institutions working on NWFPs
- draft a policy framework on NWFPs, suitable for integration within the overall forest sector policy, to serve as a model to be adapted by countries
- collaborate with relevant agencies/institutions in addressing specific trade issues such as information about the chemical and biological diversity of forests
- develop a system of classification of NWFPs, harmonized with the existing international systems such as the International Standard Industrial Classification of all Economic Activities (ISIC) and the Standard International Trade Classification (SITC) in collaboration with the UN Statistical Office

These recommendations were considered by the 12th Session of the Committee on Forestry which is the main policy-formulating body on forestry matters in FAO, in March 1995. It urged FAO to undertake the necessary follow-up action and to develop a centre of excellence in the area of NWFPs.

Relating to the recommendations made by the Indonesia Expert Consultation, several initiatives in which FAO is collaborating are taking place outside FAO. To give a few examples: the IUCN has expressed interest in developing a framework policy for NWFPs. WWF and ATI would also like to be consulted in this. UNIDO has expressed interest in collaboration in the implementation of field projects on NWFPs. FAO has been asked by WHO to comment on their model monograph of widely used medicinal plants dealing with some 35 plant species.

NWFPs are increasingly gaining worldwide interest, not only in the tropical areas of the world. There are initiatives under development in the boreal forest zone, where NWFPs are seen as of major importance in multiple-use forestry, social development of forest-based rural communities, advancement of sustainability, maintenance of biodiversity, protection of environment, and relations towards the general public.

It is foreseen that NWFPs will remain on the forestry agenda at both national and international levels for quite some time to come.

Agroforestry Programme

FAO's activities in agroforestry are approached from several different perspectives and disciplines: forestry, various types of farming systems (crop-based, animal-based, or mixed-production systems), resource management (soil and water conservation, watershed management) and for particular agro-ecological zones (uplands and mountains, arid zone). It is also treated in a holistic way through farming-systems research and development.

An interdepartmental working group on agroforestry has been established in FAO to ensure in-house coordination and communication between different departments and several divisions in FAO. The activities of various departments and divisions are discussed in a paper presented at the ICRAF-FAO Inter-Regional Meeting on Agroforestry Research, Development and Education for Africa, Asia and Latin America, held at ICRAF, Nairobi, in May 1994.

While agroforestry is diffused throughout FAO, the Forest Resources Division of the Forestry Department provides an institutional home in FAO for a programme that deals specifically with agroforestry development. This programme explores issues related to the role of trees in agricultural systems, and the relationships between forestry and agriculture in changing land-use patterns. The programme focuses on the contributions that agroforestry can make to the livelihoods of farmers, sustainable agriculture, natural resource conservation, and food security. The programme does not have a specific focus on the development of non-wood forest products in agroforestry systems but has encouraged the production of various types of tree products (fruit, nuts, fibre, fodder, etc.) for use by the farm household or for generation of cash income.

The objectives of the programme are to increase awareness and technical knowledge about agroforestry and to strengthen member countries' capabilities in agroforestry development. To date, these efforts have been largely through the field programme. At any one time, FAO supports between 20 and 30 field projects in developing countries focused on agroforestry, or with an agroforestry component. These projects include pilot activities for agroforestry development in a particular area of a country, strengthening of institutions, training to improve knowledge of agroforesty systems, efforts to improve research capacities and the development of extension methodologies and materials.

FAO also supports two regional agroforestry networks, the Asia-Pacific Agroforestry Network (APAN) consisting of 11 countries, and the Technical Cooperation Network in Agroforestry for Latin America and the Caribbean, consisting of 18 countries. These networks promote the sharing of information on agroforestry technologies, research and education programmes, and participatory methodologies of agroforestry planning and implementation. The networks have also organized training courses and meetings and have published various documents. The networks are working to attract international financial support for agroforestry programmes in their respective regions.

The Agroforestry Programme is currently working on improved planning of agroforestry activities, development of a framework for assessing the sustainability of agroforestry, improving economic analysis of agroforestry systems, and incorporating marketing considerations into agroforestry planning. In conjunction with the latter, the Agroforestry Programme collaborated with the Forest Products Marketing Programme and the Community Forestry Programme to develop a document, 'Marketing in forestry and agroforstry by rural people' (see annex).

Forest Products Marketing Programme

The Forest Products Marketing Programme supports, as part of its activities, the work of the NWFP programme. The objective of the Forest Products Marketing Programme is to contribute to the conservation and rational utilization of forest resources, to increase economic and social benefits from the forestry sector and to improve the equitable distribution among the participants in these activities.

Its basic strategy is to develop and strengthen marketing in the forestry sector through: (1) raising awareness of the benefits and importance of efficient marketing, (2) improving the information base, (3) increasing institutional support and capabilities, and (4) improving current marketing practices.

Specific activities include preparating marketing studies, implementing surveys on the needs for marketing training, supporting training activities, preparating case studies and other training materials, strengthening and setting up marketing information systems, organizing meetings, providing backup for field programmes and projects.

Funding for coordination and development of the programme is included in the regular programme budget of FAO. External funding is needed mainly for carrying out specific activities under the programme.

As the programme covers all forest products, only a few examples of NWFPs can be cited: 'A case study on marketing of Brazil nuts' and 'A compendium of computer-based databases of relevance to forest products marketing'. There are also case studies on marketing of wood fuels, for example, the 'Case study on marketing of wood fuels in Senegal'. Jointly with the Agroforestry Community Forestry and NWFP Programmes, the Forest Products Marketing Programme has participated in the preparation of a document, 'Marketing in forestry and agroforesry by rural people'. A condensed description of the document is appended as an annex to this paper.

Specific importance of this conference to FAO's NWFPs and other related programmes

1. We expect to get from this conference some clearer idea of the magnitude and types of demand for NWFP for various end-uses, to be able to inform the countries of their production potential.
2. This conference offers FAO an opportunity to give information about—
    - its role in trying to link in a coordinated manner the various parties interested in the implementation of diverse activities, to avoid duplication of efforts and unnecessary wastage of scarce resources.
    - the database that FAO intends to develop of institutions dealing with NWFPs. This will also indicate any other databases that these institutions may have available.
    - the preliminary work that FAO has done to develop a product classification for NWFPs. This will enable delegates to contribute to its further refinement, whenever it will be done, specifically concerning the products that are of direct relevance to their sectors of NWFPs. The eventual aim of all concerned is, of course, to try to produce a useful classification system, naturally within the limits of the international system of statistics.
3. It provides an opportunity to distribute relevant FAO documents, which are also available from FAO in Rome.

Annex

Introduction to 'Marketing in forestry and agroforestry by rural people'

Rural people practise forestry either as individuals or as organized communities. They comprise forest dwellers and other forest-dependent people who harvest and extract wood and non-wood forest products from the forests, and farmers who practise agroforestry. The forests and farm lands which they use are either owned by them or they have user's rights to these resources.

In several instances, the forest dwellers and farmers live close to the subsistence level and therefore produce mainly for their own and family consumption. They are therefore not accustomed to extensive trading of their products to outsiders. Whenever they have some excess production, above their own requirements, it is sold in the local market place or to middlemen. Farmers and other producers of wood and non-wood forest products who have stable excess production would benefit from improved organization of their marketing activities.

The development efforts among forest dwellers and farmers practising agroforestry aim at increasing their income. It has been noted that many of these activities have concentrated on the development of a resource base and the production systems, without much attention being paid to the development of marketing. A balanced development of forestry and agroforestry systems presumes, however, that all the basic functions from resource management, through raw material harvesting and processing to marketing, get equal and sufficient attention to function in harmony. By making these people more directly involved in marketing of their products, their ability to claim a fairer share of the economic benefits created through forestry and agroforestry activities can be secured.

In order to draw attention to the importance of marketing and to respond to expressed needs for its better understanding in forestry and agroforestry systems, FAO has prepared a document, 'Marketing in forestry and agroforestry by rural people'.

The aim of this document is to increase understanding of the importance of marketing and of how marketing influences the design and management of forestry and agroforestry systems. The document highlights the main features of forest products marketing and marketing management and advises on the steps to be taken in introducing the marketing function in forestry and agroforestry systems.

The document has been written primarily for use by extension workers, community leaders, NGO staff and other field practitioners. Its objective is not to be a 'how-to-do-it' guideline, but rather to increase the interest in marketing and to stimulate awareness of the basic elements involved. Some guidance is, however, given to field practitioners on how to get started when introducing marketing into forestry and agroforestry systems. This document will need a series of guidelines on specific aspects like: How to do marketing at the field level; How to train people for the marketing function; How to set up marketing information systems; and How to carry out marketing studies. Some of these guidelines have been identified, but others still need to be prepared.

WORKING GROUP REPORTS

1. Assessment and monitoring of non-timber forest products

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Introduction

A wide array of products from plants and animals can be classified as non-timber forest products (NTFPs). This working group focused on plants and plant products, as they had been the main focus of the conference. The first step in assessing and monitoring NTFPs is product identification. This is based on reconnaissance and pilot inventories, market evaluation and indigenous knowledge, as well as on an analysis of what scientific knowledge already exists within the region and what might be transferable from elsewhere. For the purpose of this discussion it was assumed that product identification had been done already and that the status of NTFPs would be assessed and monitored by inventories.

It was agreed that the objective of NTFP assessments is to collect information about the distribution, frequency and seasonality of NTFPs so that plans can be made for the sustainable management and utilization of the NTFPs for the improvement of human welfare. It is important to determine, prior to the assessment, for whom the information is being collected—who are the beneficiaries or clients. It is also important to determine that the policies and regulations governing the ownership, management and utilization of NTFPs are conducive to supporting farmers and the rural community and hence the local economy.

Classification of inventories

There is no single technique for assessing and monitoring NTFPs, because of the variety of products. The appropriate methods therefore depend on the objectives of the inventory. The following considerations are important.

- The intended use of the inventory: The purpose may be to identify a management plan for an area, or it may be the conservation of an endangered species, or the development of specific products for marketing and processing.
- Spatial scale: Inventories may be done at a local, district, national or regional scale, depending on their objectives. Local-level inventories are usually management or market oriented, while regional inventories are usually for planning or policy formulation.

Forest inventories are usual oriented towards specific products—most commonly timber, but increasingly also for some non-timber forest products such as bamboo, medicinal herbs, fruits. The incorporation of many different products in one inventory is complicated by differences in species phenology, scale and spatial distribution.

Inventories of non-timber forest products can be purely to determine the quantity of the product available or to determine the quantity used. The latter involves market studies and the flow of products, which can be age or size dependent. In many cases the biophysical resource inventory would focus on individual products (e.g., bark, fruits), while a socioeconomic flow inventory would concentrate on types of product usage (e.g., food, medicines, gums).

State of the art

Some data and information exist on a few selected NTFPs, for some specific locations. However, the data are scattered in several disciplines and institutions. Furthermore, the data were collected for separate and uncoordinated objectives and using very diverse surveying methodologies, ranging from forest inventories, agricultural crop surveys, participatory rural appraisals (PRA) and socioeconomic studies. Consequently, they lack consistency in terms of:

- geographical reference
- units of measurement
- precision of measurements
- data quality

Designers of the inventories had tailor-made them to suit their needs. The data are therefore difficult to manipulate for other interpretations or uses. There is also limited comparability across disciplines and geographic regions.

The group knew of no references that provide guidance on systematic surveys of NTFPs. However, it was recognized that as NTFPs become more significant in the livelihood of local communities, the demand for more precise and comprehensive information will rise. There is, therefore, a need to develop proper inventory technologies to identify, quantify and assess quality of NTFPs.

The group agreed that it is virtually impossible and therefore perhaps futile to search for a generalized technique for NTFP resource assessment because of the major differences in:

- intended use of the survey results
- the groups of NTFPs to be included
- spatial scale
- temporal scale

An added complication arises when products from a single tree can be used for several purposes; the measurements for a given product could be quite different from those required for a different product. An example is bitter kola (*Garcinia kola* Heckel), whose fruit pulp is a food and has medicinal properties, the seed is an edible oil-bearing nut, while the wood is used as chewing sticks for dental health because of their bacterial properties and fibrosity. Clearly, assessments of quality and quantity of fruit pulp are unrelated to those of chewing sticks, while nut quantity is probably related to the amount of fruit pulp (fig. 1).

In this case, the medicinal uses of each of the products are different. How then can resource flows be monitored and assessed? From the user and the market viewpoints, product flows are probably the most useful. These can be captured by product-flow data-capture forms (fig. 2).

Constraints and problems

General conditions affecting NTFP assessments

- There are often restrictive policies concerning the institutions and the products for which they are responsible.

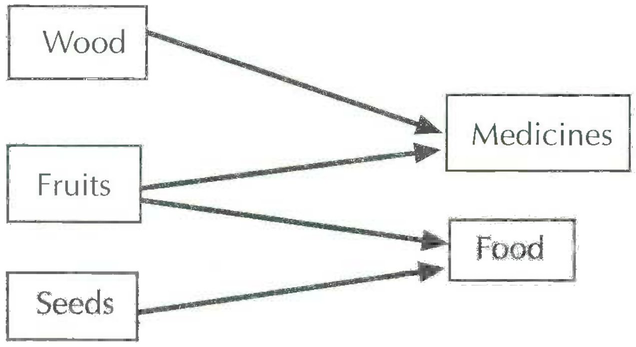

Figure 1. Relationships between products and uses in the West African tree Garcinia kola.

Location/area:								Date
Survey crew name/s:								
Codes to monitor resource flow: supply (sources) A = forest; B = market; C = commercial area; D = state/land; E = farm								
Codes to monitor resource flow: consumption (destinations) F = marketplace; G = process; H = home; K = strategic storage								
Product type	Species 1		Species 2		Species 3		Species 4	
	Quantity	Code	Quantity	Code	Quantity	code	Quantity	Code
Fibre (kg)	25	AF	13	CG	34	BF		
Fruit (no)	72	EF	19	DH	64	AK		
Bark (kg)	32	AK	25	BK	12	DH		

Figure 2. An example of a NTFP product-flow data-capture form. Quantity could be expressed in weight (kilograms), dimensions (length, diameter, volume) or by number of items. Price per unit may also be included in this column.

- The mandates for work on NTFPs often fall across several disciplines and institutions, as well as several land-use categories. This makes inventories difficult to implement although they may be technically well justified.
- The objectives for an assessment of NTFP resources may be unclear regarding what information should be collected, how it should be used and who will be the beneficiaries.
- The role of local communities in the assessment should be clear, as lack of cooperation can hinder work. Cooperation can be enhanced if it is clear what the objectives are and that the local population will benefit.

Organizational problems

Cost is always difficult to treat. An assessment will find sources for funding only if the objectives are convincing. Convincing objectives alone, however, are not sufficient. In the ideal case, the economic or socioeconomic benefit of improved information exceeds the cost of the inventory. But in many cases this situation is not given.

Other organizational problems are logistics and the availability of expertise and training possibilities. In local-scale inventories expertise could be provided by the local communities, if they are involved with the inventory planning from the very beginning.

For regional assessments the question of expertise is much more crucial. Local expertise can also be used in this case, but then it must be guaranteed that the level and quality of knowledge of the local experts are comparable throughout the region. Otherwise data consistency is questionable.

Data consistency and quality problems

One of the central problems identified was the valuation of the products, still missing for many products and in many regions.

The identification of many NTFPs is not easy, for example, identifying aromatic and medicinal herbs. Special knowledge is required, and it cannot be easily transferred in a training course.

Some NTFPs show a clear seasonality. This means that identification is possible only during a particular time of the year when, for example, above-ground shoots indicate below-ground storage organs. This necessitates a large number of field crews and experts to carry out the inventory in the short time period available.

Measurement of quantitative and qualitative characteristics is problematic, as is the standardization of measurements. For example, to measure or estimate the amount of fruit on a fruit tree in terms of either number or weight is extremely difficult as there are fluctuations depending on tree size, climate, water supply and other interacting factors. The same difficulty of measurement holds for medicinal and aromatic herbs, for which there might also be an interest in the content of particular chemicals. Chemical analysis, however, is beyond the possibilities of a regular inventory.

Research issues

Research issues are relatively easy to identify. A classification into the technical and biophysical and the socioeconomic research fields appears reasonable.

On the technical side research into specific inventory and monitoring techniques is necessary, especially statistical aspects (statistical design, field plot design, data analysis techniques). The potential for remote sensing should be analysed. Direct assessment of NTFPs by means of remote sensing is possible for some products (trees, bamboo), but it might be possible to identify indicators with which the occurrence of NTFPs can be estimated in an indirect way. Identification of indicators is another very important research issue, as is the development of modelling techniques.

A review of available, proven or not-proven techniques is needed. Two topics are of utmost importance: participatory inventory techniques and the compatibility of different assessment techniques. In many cases a resource inventory has to be combined with a quantitative market study and maybe also with the results of a questionnaire or the evaluation of official statistics.

Conclusions

Many studies and projects on utilization, management, marketing, etc., of NTFPs are ongoing. The methodology used in specific studies to collect data and to create a database should be spelled out clearly and made available to interested researchers and projects.

We need the knowledge about the status quo of the resource now. Interdisciplinary case studies would be helpful—on single products or sets of products, and on sales both locally

Table 1. Research issues in NTFP resource assessment and monitoring

Biophysical	Cross-cutting	Socioeconomic
• Statistical and field plot design • Assessment of land and plant capability • Potential of remote sensing techniques	• Review of available techniques • Participatory inventory techniques • Compatibility of different techniques • Indicators and modelling techniques • Information system development (needs and potential)	• Demand for and use of inventory data or improved information

Table 2. Expertise needed to address inventory research

Biophysical	Cross-cutting	Social
• Inventory and statistics (forest, range wildlife, crop) • Ecology • Botany and taxonomy • Remote sensing • NTFPs	• Ethnobotany	• Sociology • Environmental economy • Marketing • Village-based research

and regionally. It is difficult to talk in general terms about assessment and monitoring of NTFPs. See tables 1 and 2, summarizing research issues and expertise needed.

The following research needs have been identified:

- Development of product groups; research on inventory techniques by these groups as well as for individual products.
- Interdisciplinary case studies based on:
  - single products
  - sets of different products grouped into compatible classes

  Case studies should first be done locally and regionally. The methodologies tested in case studies should be fully documented.
- Consideration of market information in inventory planning. Product value is an essential ingredient in any inventory planning. In many cases, the market prices for NFTPs are unknown. In the consideration of how much effort can be put into the assessment of a given product, this is a complicating factor.
- Standardization of inventory procedures, especially with regard to units used in product measurement and reporting. This will facilitate comparability as well as regional and global compilation of inventory information.
- Development of predictive models using satellite data and aerial photographs; also the development of models estimating product quantity and quality from measurable tree and stand variables.

2. Indigenous knowledge and ethnobotany

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Introduction

One of the reasons for considering the domestication of trees and commercialization of their products in agroforestry systems is to improve the livelihood of rural peoples. Such improvements could be in production systems, income-generating opportunities and nutritional well-being. The starting point is the knowledge that indigenous peoples already possess.

Indigenous knowledge and technology

The working group initiated discussion by considering the various meanings of indigenous knowledge and indigenous technology. Indigenous knowledge, for example, is cumulative over generations and composed of information on plants, their uses and their growing environment. Such knowledge is dynamic as it changes over time within a particular ethnic group and varies among groups. Indigenous technology is the application of this knowledge to local problems. It is through this technology that progress is achieved. It is recognized that indigenous knowledge is not restricted to particular ethnic groups that have been indigenous to an area but that all types of people, and even animals, possess knowledge of their environment.

Domestication of some species has been a result of such indigenous knowledge and technology. It is a process in which humans have manipulated the characteristics of certain wild species to fulfil their own desires and have brought them under management. The main driving force behind domestication is the need to intensify the uses of particular species. Such needs may be the result of market forces.

Relevance to domestication

The initial steps in the domestication process are normally inspired by and make use of indigenous knowledge; however, there are constraints to capturing and utilizing this local-level knowledge. At times, there is a lack of clarity as to where, or from whom, information can be obtained. Also there can be a reluctance by individuals and communities to share information, as the return of benefits to individuals and communities with knowledge (i.e., their intellectual property rights) is often neither defined nor guaranteed. An alarming erosion of indigenous knowledge is occurring because of the degradation of cultural heritage and the local environment. Western cultural values can influence local cultural norms and cause a breakdown in the transmission of information from one generation to the next. Such cultural changes can be compounded by environmental degradation; for example as species disappear, so too does the knowledge related to them.

Standardization of procedure

The working group agreed that to document indigenous knowledge, procedures should be standardized with guidelines for information gathering. Overall, a systems approach for the gathering of information was advocated that takes into account historical, socioeconomic and biophysical factors affecting availability, production and conservation of plant resources. Resources that have documented past indigenous knowledge include old colonial records, archives, museum collections and the writings of early missionaries. Indigenous knowledge can be gathered from the older generation of a community, but not necessarily solely from them, as knowledge is dynamic and all age groups possess some. Gender balance in gathering of information is also important, as men and women can value and use plants differently. In general, a trust should be built between communities and researchers. Appropriate acknowledgement and reimbursement is required for access to and use of the knowledge, as well as a return of benefits derived from such information. Ideally, local people themselves should be trained to document and preserve their knowledge. Furthermore, there is a need to assert the right of resource ownership by the communities, through approporiate policies, especially land tenure and legislation systems.

Indigenous knowledge can be difficult to utilize because it is often not comprehensively documented and its availability is variable. Even when available, its application is site specific, depending on ethnic groups and ecogeographic zones. The knowledge may not be tested or verified, since, for example, the success of medicinal products may be affected by psychological and cultural factors and not only by testable pharmaceutical ingredients. Furthermore, cures from local healers are often made by mixing products of several plant species together. The processing and isolation of compounds from medicinal plants by pharmaceutical industries may lose the synergy of different ingredients to cure illnesses.

Research priorities

It was noted that smallholder farmers do not necessarily need high-value products, as their main priority is often food security. It is therefore more logical to aim for higher productivity, as opposed to high-value products. The ideal ultimate goal would be to improve and increase productivity by using a diversity of domesticated or semi-domesticated species in agroforestry systems. High-value products are more suited for monocultures, which run counter to the conservation of biological diversity.

To promote indigenous knowledge and disseminate research results obtained from it, the working group suggested that, in addition to publications, audiovisuals, databases, electronic communications and mass media should be utilized and targeted to different user groups. These same methods can also be used to document knowledge. Furthermore, indigenous knowledge should be incorporated in school curricula. Scientists and NGOs should facilitate dissemination to academic institutions through seminars and lectures.

Where possible, working groups such as this one should include those actually possessing knowledge of plants and their environment, such as traditional healers.

The working group proposed that to benefit smallholder farmers and the environment and to improve productivity, the following were necessary in research activities:

- involvement of the communities in all stages of project development including decision making
- in situ and ex situ conservation of species and indigenous knowledge in agroforestry systems
- development of indicators that can be used to evaluate the impact of projects
- protection of farmer interest and the environment

Research constraints

To overcome constraints in retrieval and utilization of indigenous knowledge, the working group proposed the following:

- A comprehensive inventory based on indigenous knowledge of species and their respective products.
- Development and installation of databases containing the inventoried information in a regional bibliographic centre for ease of access and periodic updating. Such databases should encourage the sharing of information of ongoing activities between scientists, to avoid duplication, which not only wastes limited resources, but also burdens the time of local peoples.
- Establishment and promotion of species improvement networks (SIN) on selected priority species, such as those of common regional interest.
- Establishment of national, regional and international networks on the domestication and commercialization of non-timber forest products in agroforestry systems. Direct involvement of rural communities and small-scale farmers in the domestication of species in agroforestry systems and the commercialization of their products through training and technical assistance and by focusing on important species in rural areas.
- Ensuring local control by the communities over access to and use of their knowledge of resources.
- Adding value to indigenous knowledge by complementing it with scientific technology, particularly in the case of developing pharmaceuticals or with coordinating health care programmes with local healers.

Constraints for the development of databases were recognized as lack of financial resources, insufficient technical experience, and lack of goodwill among institutions to share information.

Conclusions

Ordinarily, inventories provide a large number of species with potential for domestication or commercialization. The working group identified a need to objectively select and test these species, as financial and labour constraints would not allow for all species to be promoted. It is recognized that local people's needs, priorities and preferences should be considered when identifying products. In this regard, methodologies of preference and priority ranking have been developed; however, it is uncertain that the priorities identified today will be useful even in the foreseeable future.

With regard to the pharmaceutical industry, the use of indigenous knowledge is not as straightforward as isolating an active ingredient and processing it into a tablet.

It was recognized that research should involve farmers as well as international centres, local institutions, NGOs and universities. In general, holistic testing of information and products was recommended. Provenance trials and species selection for use in different agroecological zones would be necessary. The working group believed that priority in research activities should be given to arid and semi-arid lands, because in the group's opinion those ecosystems are more fragile, causing people there to be more dependent on indigenous fruits and herbal medicines.

3. Product development and management

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Introduction

Inter- and intraspecific variation in tropical species forms the basis for evaluation and development of descriptors. The conservation of germplasm is necessary for such evaluations of species and eventual product development. Provenance testing would guide selection of germplasm for domestication. The best germplasm should have a market and be profitable to farmers.

The working group throughout its discussions kept in mind how the farmer would benefit; therefore, members agreed that domestication should focus on products with potential for increasing food security and economic growth in the context of different agroecological niches and systems. Commercialization and product development can take place simultaneously or in sequence. Product development can be undertaken first while minimizing farmers' risks.

Needs for agroforestry

To encourage farmers to manage trees in agroforestry systems, the following would be needed:

- security of tenure
- guaranteed benefits
- access to credit
- access to appropriate planting material
- access to technologies for production and processing
- access to training (processing, entrepeneurship, etc.)
- access to markets (demand creation, market information systems)
- creation of awareness of value of projects at all levels
- partnerships in project activities

Domestication strategy

Domestication and commercialization will affect household livelihood strategies; for example, how labour is allocated may change from production of staples to production of NTFPs. Trade-offs will have to be made regarding the intensity of domestication, ecological functioning and socioeconomic equity (fig. 1). It is envisioned that the greater the intensity of domestication, the less diverse production systems would be and the fewer people would benefit. The optimal point varies depending on the species and local or national circumstances.

Product development and management are restricted by what is known at the local level; for example, there is a lack of flow of information between producers and consumers. There is little understanding of the dynamics between product and market and of the cultural aspects of production, handling and postharvest processing.

Research priorities

Comprehensive basic research on product and source is necessary. It should be multidisciplinary, including, for example, economics and horticulture. Products should be identified based on local people's needs and utilization. A collaborative research approach should be taken involving the CG system, NARS, NGOs and the private sector. Farmer and researcher participation should be considered at all levels.

Product- and species-oriented networks of research participants should be established utilizing databases, directories of practitioners, bibliographies, etc. Seminars, workshops and newsletters should be encouraged. Assistance from international organizations would be needed to disseminate information, transfer technologies, and encourage exchange of scientists and practitioners. Such exchange of information must also include farmers to keep them abreast of research advances.

Farmer participation in research and product commericialization is necessary to ensure that the farmer will directly benefit. In this respect, the optimal intensity of domestication should be identified (fig. 1). Environmental impact assessments may aid this identification. The management of a diversity of products of high market value and with household uses will aid in improving farmer livelihoods. To increase value to farmers, local processing should be promoted and improved.

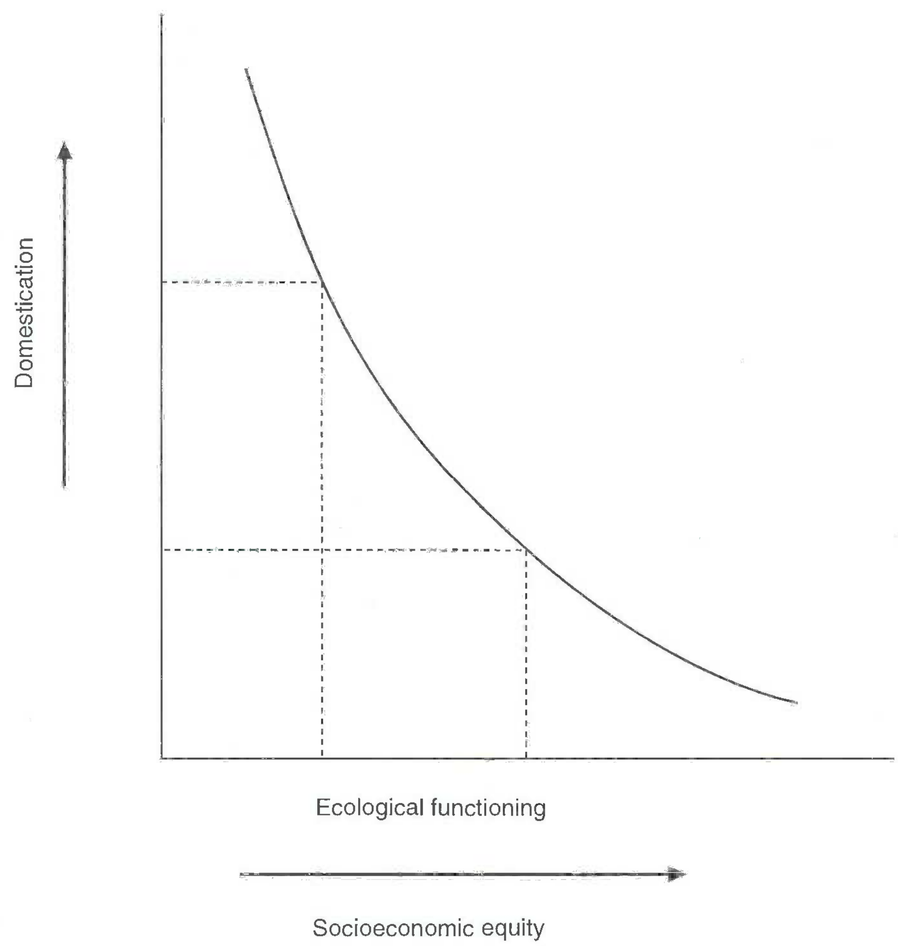

Figure 1. The relationship between domestication of NTFPs, ecological functioning and socioeconomic equity.

Conclusions

A summary model was designed (fig. 2) that integrated botanical research with indigenous knowledge to identify products for market. Those products to be marketed would then be managed either in their natural habitat or within agroforestry systems. Based on farm production budgets and the most efficient management systems, recommendations would be made to implement product development and management. These recommendations would consider production, distribution, marketing and monitoring.

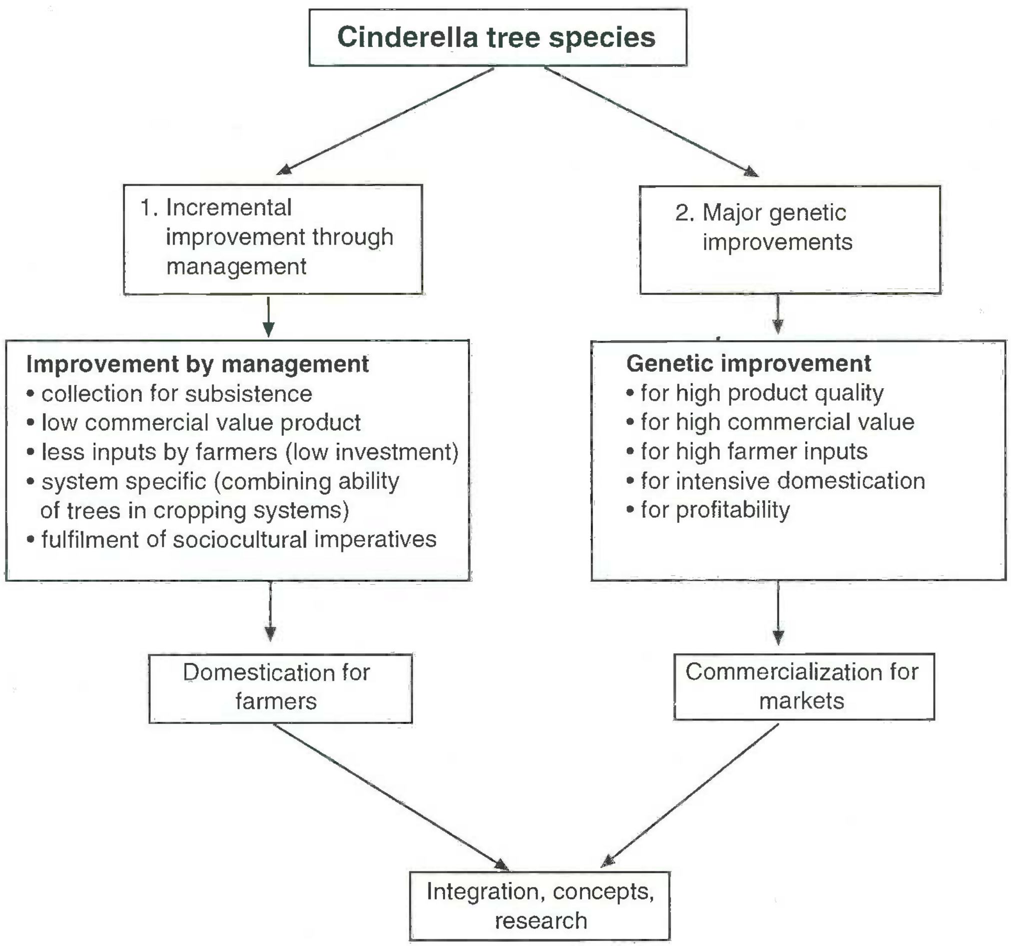

Figure 2. Summary model for product development and management.

4. Product domestication and adoption by farmers

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Introduction

The group defined domestication of NTFPs as a progression from collection and utilization of products, through protection, management and cultivation, and culminating with genetic manipulation. This progression occurs through intensification of investment and genetic control. Two extreme strategies were envisaged: (1) making incremental improvement beginning with in-situ product protection and management and (2) making major leaps in genetic improvement (fig. 1). Domestication activities will usually fall between these two extremes. The first strategy would favour small-scale farmers while the second would be geared toward entrepreneurial establishments. The group recommended that efforts be concentrated on domestication of Cinderella tree species, and that the two strategies be considered, but with special attention to market conditions for specific products.

Research priorities

The group recognized the need to capture previous experiences that were available on domestication and commercialization of Cinderella tree species, particularly in horticulture. The lessons learned should be compiled and used to guide our actions in agroforestry. With that in hand, the proposed areas of research are—

- Characterization of the markets and their appropriateness for small-scale farmers. It should be noted that some markets involve higher risks and distant markets involve higher transport costs. Relating these to product prices and potential benefits to the farmer is crucial.
- Study of the factors that control farmer behaviour in respect to domestication, and how it varies in relation to agroecological, cultural and socioeconomic conditions.
- Research of seed and seedling distribution mechanisms. This is important for the provision of genetic material to users, thus enabling its domestication and adoption.
- Phased development of multistrata agroforests. Experiences from Africa (Chagga homegardens), Asia (rubber agroforests) and Latin America (peach palm forests in Peru) demonstrate a great potential for product diversification and environmental amelioration. Research is needed to establish the appropriate attributes of species for the different phases of agroforest development. This involves developing appropriate system trajectories for particular sets of circumstances.
- Domestication strategies, depending on farmer circumstances. Research should be done on the internal factors (social, cultural, economic) and external factors (institutions, policy, etc.) that promote or inhibit domestication and commercialization. This will provide information on what strategies can work and why.

The concern was expressed that the genetic improvement pathway, if highly successful, might lead to monocultures, rather than to agroforests, although this may depend on the levels of inputs required and the value and volume of the products produced.

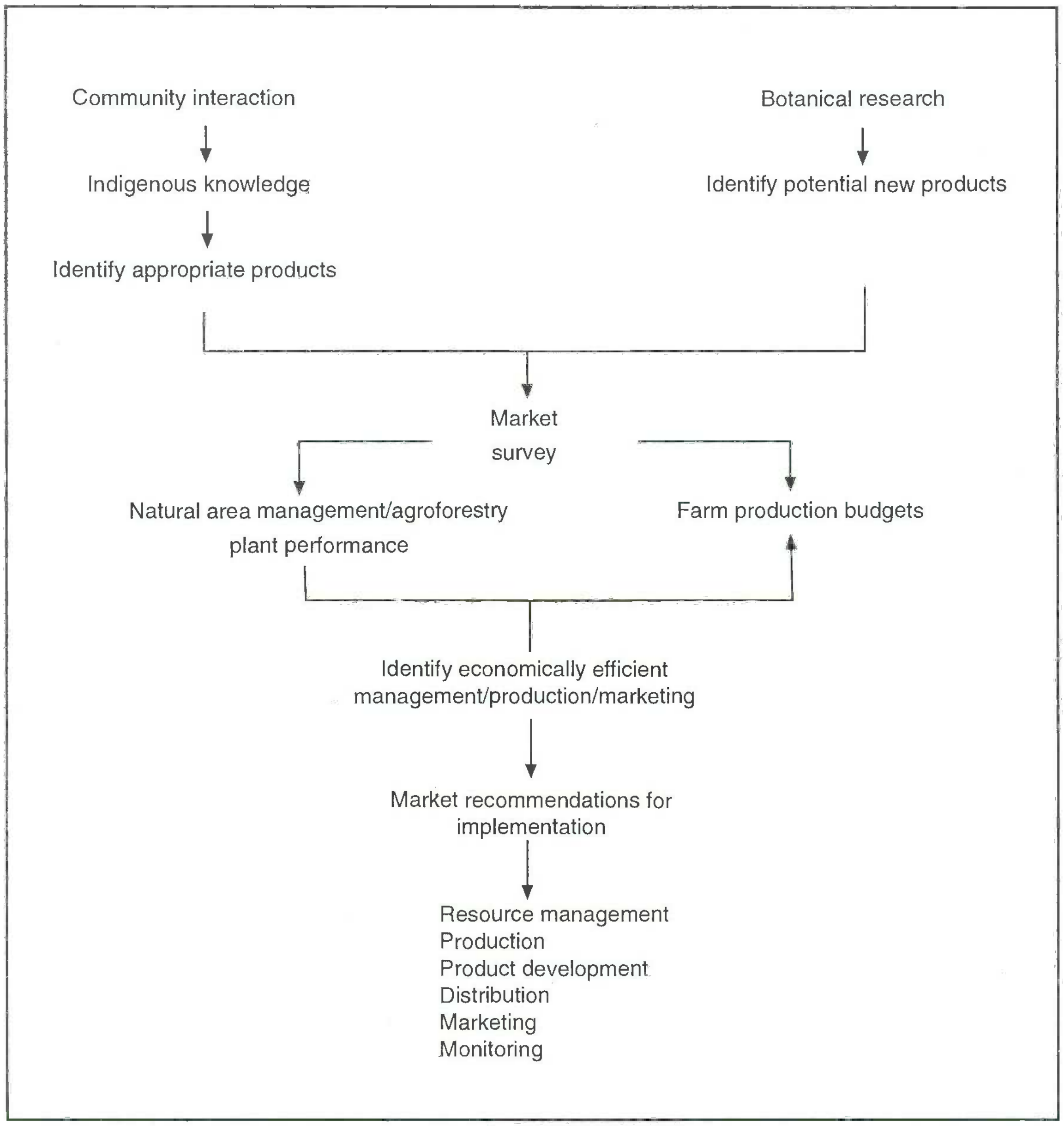

Figure 1. Two pathways in domestication and commercialization of NTFPs. These pathways form two extremes, with many intermediates.

Infrastructure and institutions

For successful commercialization, the products must flow from production centres to the marketplaces. For this to happen, development of infrastructure such as roads, transport and marketing channels is necessary. Policies and financing of such infrastructure should be considered before large-scale domestication is undertaken.

A marketing information system is another area of concern. Information flow (including collection, interpretation and sharing) is important for the success of domestication and commercialization. Systems for improving farmer–researcher dialogue, such as surveys and knowledge-based systems, and for tapping into indigenous knowledge should be emphasized. There is also a need to strengthen links between local, regional and international research and development institutions.

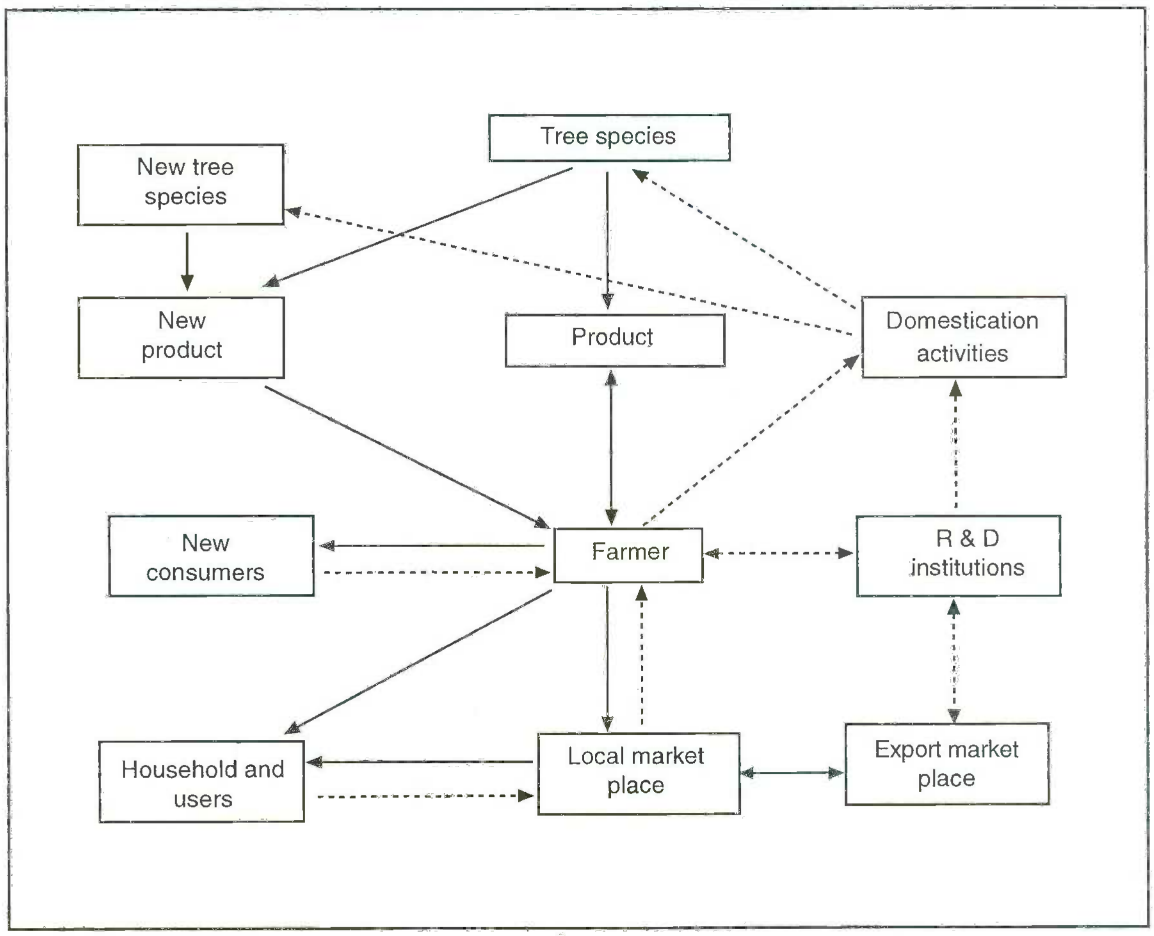

Figure 2. Information flow relevant to the processes in domestication and commercialization of Cinderella tree species. Key: → = product flow; - -> = information flow.

Conclusions

Domestication and commercialization of trees for NTFP products can be for two target groups: resource-poor farmers and commercial entrepreneurs, and these involve different strategies. In agroforestry, it is the farmer-oriented strategy that is most relevant.

5. Policy and institutional aspects

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Introduction

While a number of studies have been conducted on non-timber forest product (NTFP) issues, very few address markets, policies and institutional aspects. Available studies are usually confined to a single commodity or a group of commodities, and in a specific geographic and cultural setting. There is an urgent need to review available studies to draw general conclusions on market, policy and institutional aspects. Particularly there is a shortage of studies on domestication and commercialization of NTFPs in relation to—

- the impact of national forest and forestry-related policies, ranging from land-use policies to industrial policies
- the cross-border effects on neighbouring countries' policies
- the influence of international conventions and trade agreements
- the impact of national, nominal and functional forest laws
- the constraints and possibilities in connection with current institutional arrangements

Research priorities

As interest in non-timber forest products is relatively new, many issues requiring research arise, for example—

- What are the main implications of international conventions on the domestication process? How are these conventions implemented? Are they compatible with national policies?
- How are indigenous hunter-gatherers affected by domestication and commercialization? What are the economic and social implications for them?
- Market research and price information of NTFPs is needed.
- Is there a trade-off between the objective of raising people's income and biodiversity conservation?
- We need to make sure that research targets smallholders and their production constraints.
- How does the business environment for NTFPs compare with traditional alternatives, such as agriculture?
- What works and what does not work: the evaluation of NTFP markets.

Much information exists, but it is not systematized. There is a need for creation and collation of databases to support decision-making. There is an urgent need for creating a monitoring network for collaboration among governments, non-governmental organizations (NGOs), the private sector and international organizations. This collaboration should take place at different levels: national, regional and international. These efforts should involve a three-step approach: identification of issues; decisions on what to do; and decisions on how to do it (collaboration, coordination and implementation).

Dissemination of information

Given the breadth of research areas and the site specificity of conditions, coordination of research and sharing of results are necessary. Information dissemination is crucial. The FAO newsletter is an important tool for communication, but it needs to be published more often. There is a need to identify the relevant institutions at international, regional, subregional and national levels, and to encourage collaboration. Collaboration needs a leader. ICRAF is a leading organization in the tropics, but who is leading in the subtropics and in the temperate forest regions? The International Union of Forestry Research Organizations (IUFRO) and other relevant organizations also could play an important role in coordination. IUFRO, for example, already has member institutions at the national level that are very active. There is a range of channels already existing that can aid in sharing research findings. These include conventional extension organizations, NGOs, the private sector and community leaders. National agroforestry coordinating committees can be used to address NTFP issues. In some cases national NTFP networks also exist. Many actors are dealing with NTFPs: WHO, IUCN, WWF, UNICEF, etc. A small working party would be very useful in identifying the role of the different organizations involved. Lack of workable arrangements for intellectual property rights, however, can be a barrier to sharing information.

Benefits from domestication

It is necessary that the domestication of non-timber tree species in agroforestry systems benefits both the farmer and the environment. Although benefits cannot be ensured completely, prospects for success can be improved. To start, there must be no policy barriers that discriminate against smallholder farmers. Many different actors control different aspects of domestication and commercialization. Researchers have certain roles to play as well as farmers and traders. Since they often operate in isolation, it is necessary to establish mechanisms for the exchange of information among these actors. In such a way farmers can respond better to markets and be kept aware of advances in domestication.

Keeping the improved livelihoods of farmers and environmental conservation in mind, ICRAF, in partnership with national agricultural research systems, NGOs and other institutions, should identify research needs and carry out appropriate research—for example, identifying the potential NTFPs for each country. Through collaboration with farmers and governments, ICRAF could provide tools and information to respond to their development needs. The Centre for International Forestry Research and the International Centre for Research in Agroforestry should jointly convene a workshop focusing on case studies, such as farm studies in different ecological zones. Such studies could contribute to pilot projects to address how domestication would work under farmers' conditions and what would be the environmental externalities. A result of such research should be the production of guidelines for the domestication of NTFPs, for example, what is to be taken into account and how the farmer will benefit.

The concept of domestication involves genetic improvement and cultivation of the species in an agroecosystem. Objectives of domestication are to alleviate poverty, to raise people's incomes, and to provide food security. Genetic erosion is a threat to domestication, but domestication can also conserve a species (with a reduced gene pool). There is therefore a need for parallel efforts towards both in-situ and ex-situ conservation. Moreover, domestication could contribute to biodiversity conservation by reducing pressures for the exploitation of natural forests. The beneficiaries of domestication and commercialization are smallholder farmers, traders and processors.

Commercialization

Investments in domestication have to pay off; therefore, research should target products and species that are economically viable at the commercial level. There is a need to distinguish commodities with a local or national and a regional or international market. But in both cases information about price, market, etc., is necessary. It is also important to analyse the business environment for NTFPs compared with alternative possibilities such as agricultural crops. We do not know much about NTFP markets, and perhaps we can learn from the agricultural sector, for instance about launching a commodity in the market.

There is a relationship between the costs of domestication and the appropriate technical level. Domestication can be associated with value-adding activities in a wide sense, for instance, processing at local level—but is processing a necessary part of domestication? Processing and quality issues can create development, but there are also costs involved in processing and increased quality that need to be considered.

Domestication will create new labour opportunities, depending on what is domesticated and the extent of the domestication. The implications of changes in labour allocation should be monitored and evaluated—for example, what labour quality (skilled and unskilled) and quantity are demanded, how different groups are affected, and how gender issues are taken into account.

Institutional constraints

Legal and other institutional hurdles exist that impede the domestication process—for example, trees of some species are always government property regardless of where they grow. Clarification of land and tree tenure is important. The level of clarity differs according to ownership category. Private ownership poses no problems; however, problems may exist at clan, communal or public level that need to be addressed by research and development. Such hurdles should be identified and removed to provide a legal basis for production and marketing of NTFPs. Standards and agreements for international trade (GATT, ISO, etc.) should be clarified for NTFP producers. Artificial protection does not work. Also, how will structural adjustment programmes affect NTFPs? Southeast Asia is experiencing success as a result of a freer market environment. Genetic and intellectual property rights, as well as licensing of improved varieties, are increasingly serious issues.

Policy-making

The benefits of removing bad policies can be considerable; for example, developing countries cannot afford to support many subsidies. For each market, there may be specific barriers that policy-makers should focus on removing. Policies should focus on public goods, research and extension, information (about price, markets), and infrastructure (roads).

Some specific support systems might be needed to aid participation by the poorest people, but there was no consensus in the group as to how to do this effectively. Providing credit facilities can help avoid dependence on middlemen.

Training

Capacity building is important at different levels for success of domestication and commercialization. Farmers, depending on their objectives, need training in a variety of areas from germplasm conservation and propagation techniques to business management and market information systems. Universities and specialized institutions play an important role in developing products. They need qualified staff for this endeavour. Training for extensionists on NTFPs is also needed. Policy-makers and decision-makers also need to be kept informed of the latest advances in domestication and commercialization.

The World Food Summit will be an important policy forum. Considering the role that NTFPs can play in maintaining and improving food security, it was recommended that NTFPs be recognized during the summit.

Conclusions

The policy and institutional aspects of both the domestication and the commercialization of NTFPs are crucial for the realization of social benefits in the form of food security, poverty alleviation and employment as well as environmental benefits.

Conference recommendation to FAO

During the Domestication and Commercialization of Non-Timber Forest Products for Agroforestry Systems Conference, 19–23 February 1996, the delegates made the following recommendation:

- recognizing that non-timber forest products (NTFPs) have played a traditional role in the feeding of people throughout the tropics;
- recognizing that NTFPs play an important role in food security, especially in dry years;
- recognizing that NTFPs play a crucial role in the health and nutrition of people in the tropical countries;
- recognizing that the sale of NTFPs allows people the freedom to purchase essential inputs in support of agriculture;
- recognizing that through domestication, as defined by Leakey and Newton (1994), many NTFPs can be improved qualitatively and quantitatively to be more attractive to farmers, more marketable and so contribute to the alleviation of malnutrition and poverty . . .

This conference recommends that FAO include edible non-timber forest products, and their domestication, on the agenda of the forthcoming World Food Summit.

Reference

Leakey R.R.B. & Newton A.C. 1994. *Domestication of tropical trees for timber and non-timber products.* MAB Digest 17. UNESCO, Paris. 94 p.

Poster paper abstracts

Aromatic plants of tropical central Africa

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The essential oil obtained by hydrodistillation from leaves of *Lippia multiflora* ssp. *moldenke* growing in Central African Republic has been analysed by GC and GC-MS; its chemical composition is rather atypical in that it contains more than 70% of a rare monoterpenoid compound: 6,7 epoxymyrcene. As far as we know, it is the first time that this compound has been found in an essential oil at such a high level.

Non-timber forest products management problems and prospects: a case study from India

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Non-timber forest products (NTFPs) have always been and continue to be an important element of the forest resources in India; however, they have not received due attention. Sustained development of NTFPs within the socioeconomic sphere of forest management in India offers challenging opportunities for forest managers to improve productivity from the forest. An understanding of resource use, flow and economic returns from various NTFPs is essential prior to arguing for a reorientation of the timber-dominated forest policy.

A case-study approach has been used to examine the trend of out-turn, marketing pattern and contribution of NTFP to the forestry sector in a regional context. Time series analysis was applied to assess the production, nature and extent of commercialization of NTFPs based on secondary data for a 10-year period (1980–89) from one eastern Indian state, Orissa. It was observed that as many as 48 marketable products (bamboo, seeds, leaves, gums, fibres) were harvested from the forest, contributing 54% of the forest revenue, but they were not exploited systematically. Those harvested were mostly exported outside the state, reducing chances of employment generation. Institutional constraints were identified in the collection, and the marketing system, and the need for making value-added products was emphasized. Regression analysis was used to determine the relationship between some influential factors, i.e., physical, economic and institutional, and the production of major non-wood products in the region. The results indicated the need for higher investment in the forestry sector including plantations of NTFP species and suitable procurement prices for better out-turn.

Promotion of non-timber forest products in montane forests of Thailand by agroforestry systems or managed forest

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The montane forests of Thailand harbour a multitude of non-timber forest products, which are used by the local communities. Most of them are collected for subsistence only—

mushrooms, honey or herbal medicine. Only few products are seasonally sold in the market, like the chestnuts of *Castanopsis*. In most cases use and marketing of non-timber forest products is not yet profitable enough to be a means of income for the local population. Development of sustainable but profitable use of these products is a necessity.

The miang gardens of northern Thailand could be a model for other products. Tea trees grow naturally in the montane forests. They are used by Thai villagers to produce green tea (miang). The existing stands are enriched by further tea trees. Some of the undergrowth and canopy is cut to promote growth. A whole village community lives from these 'tea-gardens'. The system of enrichment planting by using natural stands of a non-timber forest product can be a model for other plants, as well. This system could be used for benzoin or some wild species of cinnamon, both of which are overcollected because of high demand.

A traditional agroforestry system exists in southern Thailand on the slopes of Khao Luang. The farmers who developed this system collect various non-wood forest products in the montane forests above. Some of the plants could be incorporated into their forest gardens, to increase productivity.

Bamboo resource in the homestead of Chittagong in Bangladesh

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A sample survey was conducted on the homestead bamboo plantation of Chittagong District in Bangladesh in 1992. The survey covered a total of 14 rural thanas with a sample of 727 ha of land in the district. The district has a variety of bamboos, among which *Bambusa vulgaris*, *Melocanna baccifera* and *Bambusa tulda* are the most common species. The purpose of the survey was to estimate the total bamboo resource, its cultivated area, households with bamboo cultivation, rate of cultivation and harvest and stocking per hectare and per clump.

A stratified two-stage sampling design was followed for the survey. A sample of 900 households was considered for the purpose. The results showed that there were 3694 ha under bamboo cultivation, 937 764 clumps and 48 821 592 culms. About 42% households have bamboo plantations; 5% plant rhizomes and 29% harvest bamboo every year. The number of bamboos per hectare were estimated to be 15 331, with 69 per clump.

The current overall picture of bamboo production in homestead agroforestry systems in Bangladesh is shown on the basis of the survey results. The role of bamboo as determined by its contribution and economic importance is also mentioned. The necessity for assessment and monitoring of the resource is emphasized.

Potential for exploitation of *Eucalyptus* species for non-timber benefits in Kenya

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The genus *Eucalyptus,* which is native to Australia and some islands to the north, consists of over 600 species. The planted *Eucalyptus* are used mainly for pulpwood, charcoal and more recently for sawn timber.

Eucalytpus trees also provide a range of non-timber benefits. These include environmental benefits such as preventing wind erosion, providing shelter for livestock and

reducing waterlogging. *Eucalyptus* species grow rapidly and can survive long periods of adverse conditions. They can thus be used to revegetate degraded areas and reclaim barren, unproductive land.

Another benefit from planting *Eucalyptus* is the extraction of essential leaf oils. By steam distillation of the leaves, most species of *Eucalyptus* yield an essential oil that is used in the pharmaceutical, perfurmery and chemical industries.

In countries like Portugal, Spain and South Africa, eucalyptus oil represents an important value-added by-product and generates much needed additional income and employment opportunities. In these countries, eucalyptus oil extraction in an integrated process, with small oil distilleries found next to plantations managed for pulpwood and sawlogs. In some countries, for example, Swaziland and Zimbabwe, a medicinal-type eucalyptus oil is produced from *Eucalyptus smithii* grown on a coppice system. The oil produced is exported mainly to Australia, France and Germany.

In developing countries such as Kenya, recovery of oil from *Eucalyptus* trees would be a secondary activity with the 'waste leaf' from the felled trees being collected and distilled for oil. At present, eucalyptus oil is being imported to Kenya for use in the pharmaceutical and food industries. Establishing an industry to produce eucalyptus oil would save the country valuable foreign exchange and at the same time supply this much needed essential oil. This would also enhance the prospects of success in *Eucalyptus* planting activities and the use of this tree as an agroforestry species.

Management of two contrasting tree species in domesticated farmed parklands in Burkina Faso

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In the semi-arid regions of West Africa the farmed parklands form one of the most widespread agroforestry systems. Scattered trees are deliberately maintained in a relatively regular pattern on cultivated fields because of their specific use. Most of these species are multifunctional; in addition to their value for environmental protection and products for household consumption they mostly have also a commercial value. The farmed parklands can be considered as a domesticated landscape in which the structure and distribution pattern of the trees are intimately related to human influences. These influences include purposeful cultivation and management but no specific efforts at selection and breeding. The management practices to which the trees are subjected are not uniform but depend on the architectural characteristics and specific functions of the trees. The practices also depend on the tenure status of land on which the trees are growing.

The variety of management practices that may be employed is demonstrated by how two contrasting commercial tree species are handled, i.e., *Parkia biglobosa* and *Detarium microcarpum*. Both species produce edible fruits, but whereas the first is purposefully managed for such production, the second is primarly managed for fuelwood production. The socioeconomic importance of these species is indicated and the purposes and features of the different management practices (such as purpose regeneration, pruning, ringing) are described.

This case study demonstrates that research on tree domestication should focus not only on the posssibilities for selection of trees with certain genetic features but also on the scope for application of specific management practices that are directed at the

manipulation of a tree's growing environment and its morphological characteristics. Local people have traditionally been carrying out a variety of tree management practices in their indigenous agroforestry systems, but still little attention has been given to describe and evaluate such practices in a systematic way. Obtaining a better insight in tree management options should form an essential ingredient in research on the potential for adoption of domesticated tree species in agroforestry systems.

Commercial opportunities: the Nepal–India trade in medicinal and aromatic herbs

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Thousands of tonnes of medicinal and aromatic herbs are harvested each year in the forests and alpine meadows of the Nepal Himalayas. The herbs are sold in roadhead towns in upland Nepal; from there they are transported to wholesalers in the southern part of the country and from there to the main wholesale markets in India. This paper focus on the main commercial species from central Nepal; the trade is analysed with particular reference to distribution of income within the marketing chain. Possibilities for improving current utilization and marketing are discussed.

Tapping of almaciga *(Agathis dammara* (Lam.) Rich.) for sustained productivity of the tree: the Philippine experience

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Tapping almaciga is a veritable economic activity. The resin obtained from the tree *Agathis dammara* is called almaciga resin or Manila copal. Although regarded as a minor forest product, it is one of the leading dollar earners for the country. It is used in the manufacture of varnishes, lacquers, soap, paint, printing inks, linoleum, plastics, waterproofing materials and paper sizing. It also can be used as incense in religious ceremonies, as smudge for mosquitoes, as torches and for kindling fires. However, traditional methods like deep tapping, overtapping and frequent rechipping cause death of many standing trees. Considering the deteremental effects caused by such traditional methods of tapping almaciga, a set of scientific techniques was developed at FPRDI. This has been introduced and adopted by the almaciga resin licensees, farmers and out-of-school youths in various parts of the country. This paper covers two parts: (1) the tapping practices of almaciga in the Philippines and (2) biological consideration in almaciga tapping as essential information geared at sustained resin production.

Screening of potential medicinal plants through ethnobotanical survey

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Despite the progress made in synthetic organic chemistry and biotechnology, the wild flora in developing countries are still the plants used as drugs in modern and tradi-

tional medicines. Plant products have a very good safety record. These drugs contain multiple ingredients of diversified chemical structures. Such a combination of plant constituents often has a synergistic effect, improving the therapeutic action of the known active principals. Most of the ethnobotanical knowledge acquired by local people has been passed on to them by word of mouth from one generation to the next.

In this study, ethnomedicinal information was obtained through interviews with local aborigines of different forest regions of Bangladesh. The plant part used medicinally was as variable as the diseases that the plant is meant to cure. The leaf, shoot, fruit, seed, stem, wood, bark, root and even the whole plant (in some cases) have some medicinal value. Some of the medicinal plants recorded during the present survey were found to have great potential to cure diseases common in this subcontinent. Both farmers and scientists need to know the medicinal and economic value of these plants so this heritage can be used wisely and at the same time conserved for future generations.

Euphorbia tirucalli resin: potential adhesive for wood-based industries

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Euphorbia tirucalli is a common agroforestry species that farmers use as a hedge plant. Its resin was studied for application as an adhesive for wood-based materials. Studies were carried out on various working properties of the resin, and it was found to be comparable with commercial water-based wood glues. Glued wood samples were further tested for shear stress along the bond line. The study indicated that with minor modifications *Euphorbia tirucalli* resin is a suitable adhesive for wood-based materials, especially where cost and availability are the decisive factors.

Non-timber forest products and their production opportunities in Nepal

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Medicinal and aromatic plants, as part of forest products other than fuelwood, fodder and timber, have been usually referred to as non-timber forest products (NTFPs). More than 700 species, constituting some 12% of Nepal's vascular flora, are recorded as medicinal plants. Growing these plants under tree species is a new concept in Nepal. This activity could be seen as an agroforestry system in which forestry practices could be combined with medicinal herbs.

An experiment was laid out to study the effect of a tree crop *(Dalbergia sissoo)* on the yield of an adjoining medicinal herb *(Cymbopogan winterianus)*. A simple alley cropping system was selected with populations of 500, 250 and 125 trees per hectare controlled by uniform tree-row spacing of 10 m. The main aim was to find the effect of the tree crop on the yield of the adjoining medicinal herb.

Data for 3 years on growth and yield of tree and crop indicate that there was no difference in height at the different spacings. There was also no difference in the yield of citronella oil, whether grown with or without trees. The study indicates that small farmers who wish to grow citronella grass for oil production can do so beneath sissoo trees.

Promising new non-timber forest products from southern Senegal

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Local people (Wolof, Fulani and Mandingue) in the Casamance region in southern Senegal depend heavily on the mostly deciduous tropical forest for their livelihood. Crops (maize, groundnut, cotton) are grown on soils cleared from the forest. Cattle graze in the grassy undergrowth. People harvest forest plants for fruits and medicine and other secondary uses. During a 2-year enthnobotanical survey, it was found that some 150 woody plant species were used by the local populations. More than 40 yielded fruits that supplemented the daily diet; some 100 were a source of medicine. The economic potential of some key species that can be used in local agroforestry systems is presented and discussed.

The economic evaluation of rattan in Yaoundé, Cameroon

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A study to evaluate the importance of rattan was carried out in Yaoundé, Cameroon, by investigating the transformation channel.

The results obtained through surveys, interviews and observations revealed that rattan-related activities increased significantly in the last 10 years, which coincides with the period of economic deterioration in Cameroon. The rattan supplied to the city of Yaoundé comes mainly from the surrounding villages. These natural stands are overexploited and are becoming farther and farther from the residential areas.

Rattan-based industry is less developed and interests only a limited number of persons (gatherers, manufacturers, producers . . .). Very little, if any, effort has been made to explore its potential to compete in the international market. It is still a man-dominated sector, which has recorded significant increases as unemployment increased during the period of economic crisis.

Present harvesting techniques are inefficient, wasteful and detrimental to regeneration. If this is considered alongside the rate of deforestation, it becomes evident that to ensure that rattan production is sustainable, artificial plantations need to be created. Also, if rattan products are to enter international markets and compete with those from from Asia, a lot needs to be done in the areas of organization, training and infrastructure.

Indigenous knowledge and native tree species

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The school has developed comprehensive monographic accounts and associated extension manuals on fruiting trees native to the Sudano-Sahelian zone as a contribution toward domesticating them (monographs and manuals on *Balanites aegyptiaca* and *Acacia seyal* have been produced and the manuals translated into Hausa, Swahili, Arabic and French; similar treatments of *Vitellaria paradoxa* and *Parkia biglobosa* are due out during 1996).

Recent experimental work on the ecophysiology of tree–crop combinations with the University of Maiduguri, Nigeria, has found large differences in the ecological combin-

ing ability of trees with staple crops on vertisolic soils. For example *Prosopis juliflora*, naturalized in northern Nigeria, produced twice the woody biomass of the native *Acacia nilotica* subsp. *adstringens* but competed less for water with sorghum when pruned as a result of differences in the root response to pruning, leaf phenology and hydraulic architecture. By selecting trees that have a high ecological combining ability and selecting crops that are manipulable by management, researchers have found that simultaneous agroforestry is practicable even in semi-arid conditions. The research suggests the importance of considering resource capture strategies in the domestication process, if trees are to be used.

This work ties in with research on indigenous ecological knowledge using a novel knowledge-based systems approach. For example, in semi-arid Tanzania it was found that farmers were knowledgeable about the aggressive competitiveness of *Acacia nilotica* with crops. In one farming community in Nepal, farmers have been found to have sophisticated knowledge about fodder value and tree–crop interactions for 90 native species, six of which they have classified to a subspecies level not yet botanically recognized. The Nepali farmers considered six tree crown attributes as important in determining shading and leaf drip effects. Their knowledge of leaf drip erosion was in advance of contemporary science until 1995 and they specified associative tree ideotypes for use in their rain-fed terraced farming. Agroforestry knowledge is now being developed as a means of driving agroforestry research and extension at an institutional level on the basis of analysis of current local and scientific knowledge.

Identification of indigenous fruit trees of the miombo woodlands in Maswa, Tanzania

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A study of wild, indigenous fruit trees was carried out in the miombo woodlands of Maswa District in western Tanzania. Individual interviews were conducted at households in 10 villages and with vendors of wild fruits in towns to study how families use the wild fruits in their daily lives.

Respondents made use of 30 different types of wild, indigenous fruit trees in their homes. *Tamarindus indica* was the priority wild fruit used by 99% of the respondents. Women chose this tree more frequently than did the men. Other important indigenous fruit species were *Cathium burtii, Virtex payos, Vitex mombassae* and *Adansonia digitata*. These fruit trees provided people with multiple products such as wood for constructing homes and domestic tools, fodder for livestock, firewood, medicines for all ailments and diseases such as measles, stomach ache, smallpox, goitre, high blood pressure, scabies and bilharzia, and income from the sales of fruit. Selling wild fruit wholesale was generally done by older people; the age of people selling the fruit retail was much lower. Younger people tended to say that the sale of wild fruit contributed significantly to overall income.

Twenty-three different species of wild, indigenous fruit trees were found growing on respondents' land. The majority of respondents owned their land. Younger people generally had acquired land through buying or inheritance and older people through allotment by the village government. Older people tended to say that wild fruit trees belonged to the owner of the field in which they were growing. The fruit from these trees, however, could be gathered and used by anyone, as reported by 39% of the respondents.

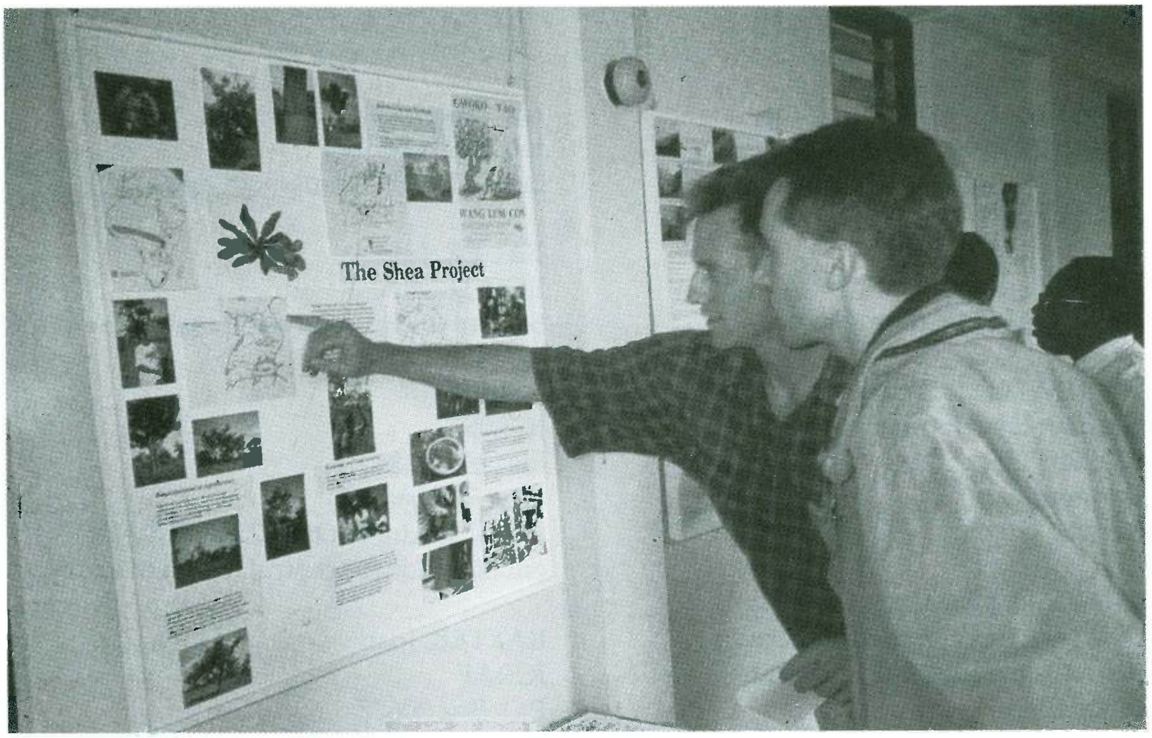

Plate 26. *Conference delegates viewing one of the poster papers.* (photo: A.B. Temu)

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