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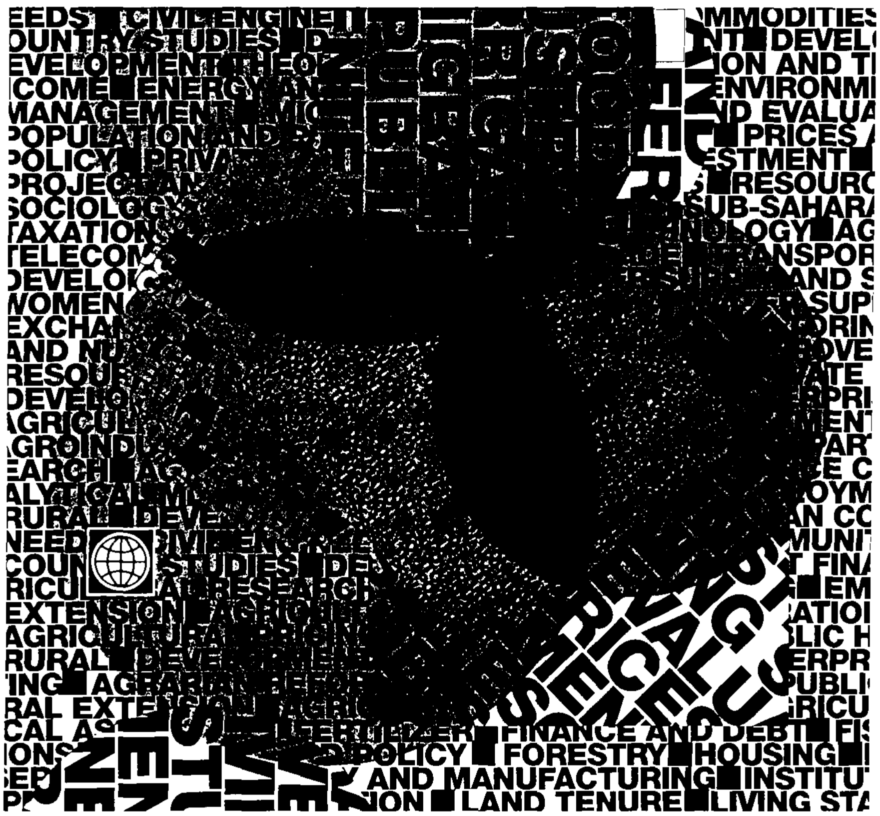
Technologies Related to Participatory Forestry in Tropical and Subtropical Countries

Eric Tamale, Norman Jones, and Idah Pswarayi-Riddihough



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FOREWORD

Important lessons have been learned from the disappointing results of the "social forestry" projects that were initiated in the 1970s. These lessons were in technical, as well as in policy and institutional, domains.

The more recent generation of "participatory forestry" projects explicitly incorporates the lessons learned about the necessary policy and institutional conditions. Frequently, however, these newer projects do not make explicit provision for improved technologies. Sometimes there is no discussion of technology at all, as if policy and institutional changes would be sufficient conditions for success. This is puzzling, since improved technology is also necessary, forest scientists have made significant technological advances, known improved technologies are not being implemented on a wide scale, and technology ought to be more amenable to change than long-standing, professionally-proud institutions.

Thus the focus of this paper, as indicated in the title, is on technologies that can improve the productivity of participatory forestry. Species selection for different end uses is crucial. Improved technologies are illustrated for propagating and managing selected species, determining the spatial arrangement of trees, and obtaining an efficient mix with crops within farms, on contours, and along boundaries. Such techniques will have to be effectively disseminated, and the paper addresses this question too.

I hope that this paper will contribute to much greater recognition of the importance of, and scope for, improving technologies in participatory forestry projects. I look forward to seeing this greater awareness translated into results on the ground.

Alexander McCalla
Director
Agriculture and Natural Resources Department

ABSTRACT

Successful participatory forestry requires adoption of the best possible forest technologies. These include choice of species which farmers need for various end uses, good nursery practices, and postplanting tree management. This paper describes some of these technologies, including indigenous forest technologies, factors influencing the choice of species by farmers and foresters, some of the nursery practices for ensuring good planting stock, better postplanting tree management techniques, and technology for tree improvement. The paper also describes various patterns of intercropping trees in farms, including rotational agrosilviculture; home gardens; trees over crops; alley farming; boundary planting; and silvopastoral systems such as fodderbanks, forest grazing, live fences, and trees over pastures. The species and families of trees commonly grown in Africa, Asia, and Latin America are listed, which indicates a need for research to concentrate on species from four selected botanical families: Leguminosae, Meliaceae, Moraceae, and Myrtaceae.

The paper outlines factors that determine farmers' choice of technologies and describes how modern technologies can be more effectively disseminated. Poor interaction between farmers and local technicians and between local technicians and on-station researchers has created serious communication gaps that need to be bridged using social communication strategies such as social action learning, listening, and iterative extension to create dialogue and mutual understanding. Continuous feedback on and refinement of technologies are needed as new information becomes available. Farmer-oriented, demand-driven, and appropriate research and extension strategies must be adopted.

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EXECUTIVE SUMMARY

In the wake of persistent poverty, fuelwood scarcity, and environmental degradation in many countries, development agencies, including the World Bank, are exploring the best technologies and approaches for enabling local farmers and communities to participate more effectively in and benefit directly from forestry. These approaches are collectively referred to in this paper as participatory forestry. In the past, many forest departments focused on managing forest reserves, whereby foresters acted more or less as police officers and revenue collectors, with little or no acknowledgment of the contribution of forestry to people's income. The concept of social forestry, which emerged in the 1970s, had limited success in involving local people in forestry because project planning and implementation were top-down and technologies were not developed from the farmers' perspective.

World Bank-funded social forestry projects had similar experiences, whereby they neglected certain critical technical issues, such as species identification, desired location and patterns of intercropping, and tree management techniques used. The projects emphasized physical targets, that is, the number of seedlings to be raised and distributed to farmers, and focused less on the quality of planting stock. Some staff appraisal reports mentioned involving local people in projects, but provided no clear mechanisms for how and at what levels such participation would take place. Experience has shown that local people, particularly women, need to be involved in planning, implementing and monitoring projects, supported and empowered through training, secure tenure, and a favorable policy environment to control the forest resources. They should have an economic stake in the use of forests, which requires good prices and secure markets.

Successful participatory forestry requires adopting the best possible forest technologies, including choice of species farmers need for various end uses, good nursery practices, and postplanting tree management. This paper describes some of these technologies, including indigenous forest technologies, factors influencing the choice of species by farmers and foresters, some of the nursery practices for ensuring good planting stock, better postplanting tree management techniques, and technology for tree improvement. The paper also describes various patterns of intercropping trees in farms, including rotational agrosilviculture; home gardens; trees over crops; alley farming; boundary planting; and silvopastoral systems such as fodderbanks, forest grazing, live fences, and trees over pastures. The species and families of trees commonly grown in Africa, Asia, and Latin America are listed, which indicates a need for research to concentrate on species from four selected botanical families: Leguminosae, Meliaceae, Moraceae, and Myrtaceae.

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1. INTRODUCTION

During the last few decades, the need for forestry management systems that directly address the needs of local people and focus on supporting community management of forests have been widely advocated.[1] Persistent poverty, increased fuelwood scarcity, and environmental degradation have all led to a recognition that the emphasis on managing reserved forests or establishing large-scale, capital-intensive industrial plantations has neither been effective nor has it improved the well-being of local people. Since the 1970s, tree planting by and for people (social forestry) on communal land (community or village forestry) or on their farms (farm forestry or agroforestry) has been identified as a potential strategy for increasing the production of tree products, meeting the needs of local people, and protecting the environment.[2] However, many of these forestry projects were designed outside the communities involved and were not well adapted to local needs because of various technical, policy, and institutional weaknesses. This paper focuses mainly on the technical shortcomings.

The World Bank and other development agencies are currently exploring alternative approaches for enabling local farmers and communities to participate more effectively and benefit directly from forestry by giving them greater responsibility for managing forests for their own benefit. These approaches are collectively referred to in this paper as participatory forestry. The concept of participatory forestry is complex, involving more than just encouraging farmers to plant trees on their farms or on communal land. It comprises various socioeconomic factors and technological (silvicultural) aspects. Technical considerations include choosing the right species to meet farmers' needs for various end uses; adopting appropriate technologies for propagating and managing selected species (collecting good seeds, raising high quality planting stock, and using good practices for planting, thinning, pruning, coppicing, and harvesting);[3] ensuring an appropriate spatial arrangement of trees (pattern, lineability, spacing, density, and intercropping); and, obtaining the desired mix with crops inside the farm, on contours, and along boundaries. The adoption and implementation of technology depends on the socioeconomic context, that is, government policies, market structures, land tenure system, institutional arrangements, extension services, and political environment under which farmers and communities practice participatory forestry. Therefore, to design and promote effective participatory forestry, technological and socioeconomic factors have to be analyzed and systematically molded into usable practices.

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[1] "A forestry management system includes a set of technologies for forest establishment, management and use, and the organisational arrangements for implementation of these technologies and distribution of the forest products" (Gilmour and Fisher 1991).

[2] Community forestry refers to the approach in which local communities (villagers or user groups) participate cooperatively in establishing and/or managing of forests on local communal land.

[3] This paper considers appropriate technologies, in this paper, to be those that are scientifically sound (i.e., suitable for good tree growth); economically feasible (i.e., affordable and easily accessible); compatible with the needs, sociocultural beliefs and practices of the local people; and adaptable to their overall production system in a given locality. The term technology includes tools, knowledge, skills, techniques, and practices of forest management.

1.1 Objectives and Rationale

The primary objective of this paper is to examine technologies appropriate for participatory forestry. To develop and implement successful community-based forestry projects, farmers or cooperatives must have access to the best possible technical advice to ensure that good quality trees are planted correctly. Good institutional arrangements and a favorable socioeconomic and policy environment will further this goal. Detailed analysis of these is beyond the scope of this paper, but it will include some references and comments.

The paper's specific objectives are to:

- Review briefly the present situation concerning participatory forestry;
- Provide a general review of tree species farmers have planted in Africa, Asia, and Latin America;
- Discuss ways to improve management and planting stock quality;
- Outline various patterns in which trees are integrated on farms and the kinds of agroforestry systems commonly needed.

The paper is based on information gathered from a review of the general literature on forestry; analysis of Bank reports, including staff appraisal reports, project performance reports, and project completion reports; and interviews with Bank staff. To put the need for improved technologies into perspective in relation to participatory forestry, let us first review the historical background.

1.2 The Concept of Social Forestry

Forestry management has undergone a series of transitions in many countries. Originally, many forest departments, particularly those of colonial regimes, were established with the primary objective of controlling the extraction of forestry products (timber and pulp) from forest reserves with few direct links between forestry and the needs of local people. For the most part, foresters acted as police officers guarding national forest reserves and collecting revenues. Local people's traditional rights to manage and utilize the forest using indigenous knowledge and practices were limited to unreserved forests or usufruct within reserves. Even up to the late 1960s, forest departments in many countries continued to emphasize the creation of forest reserves to conserve forest resources. Increasing populations resulted in the degradation of unreserved forest land and encroachment into reserved forests. The Food and Agricultural Organization of the United Nations (FAO) spearheaded the transformation of traditional forestry practices designed mainly to support industry to include meeting the forestry needs of the rural poor. In its landmark publication, *Forestry for Local Community Development*, the FAO defined community forestry as "any situation that intimately involves local people in a forestry activity" (FAO 1978). This publication argued that community forestry is centered on people's participation, that is, getting local people to plan and execute their own projects on a self-help basis, and emphasized the need to increase the direct benefits of forests to local people.

The World Bank highlighted the involvement of people in its first forest sector policy paper (World Bank 1978), and thereafter refocused its lending from traditional forestry toward projects involving community participation. Between 1978 and 1990, 42 percent of the total Bank lending in forestry was directed to such projects (36 projects totaling US$915 million), compared with a mere 3.7 percent (two projects of US $11 million) in previous years (World Bank 1991). Many other organizations and networks, including the Social Forestry Network of the Overseas Development Institute (ODI); the Forest, Trees and People Program of the FAO and the Forestry/Fuelwood Research and Development project in Southeast Asia (financed by the U.S. Agency for International Development (USAID) and managed by Winrock International), have played significant roles in promoting this concept. Countries in Asia, Africa, and Latin America initiated forestry programs with participatory components. Typical examples include the Forest Village Program of Thailand (see Box 1), the Community Forestry Through User Groups Program in Nepal (see Box 1), the Integrated Social Forestry Program (ISFP) in the Philippines, the Community Fuelwood Plantations in Korea, and the Participatory Forestry Management Program in India.

Box 1 : Forestry Programs with a Participatory Component

The Forest Village Program in Thailand. In Thailand, the Integrated Rural Development Project (IRDP) and the Forest Department adopted a village afforestation approach in which local people were consulted at village meetings. In each area, the authorities sought a local people's organization to implement afforestation work and to be fully responsible for selecting species, raising seedlings, preparing sites, and planting under the technical guidance of forest department agents. Volunteers were selected, and after training in nursery management and plantation establishment provided technical advice to other farmers. Local organizations and the forest department signed contracts that defined objectives, targets, procedures, and conditions. Incentives that included the provision of free, improved fruit trees; planting materials; farm tools; and cash payments (for each good planted tree) were given to encourage farmers. People's participation depended more on direct personal benefits than on involvement in decisionmaking. The local organizations acted as implementation agencies of plans formulated by IRDP & FD (Bastiaanssen and Brinkman 1988).

Community Forestry in Nepal. The Community Forestry Through User Groups Program in Nepal is based on the premise that a management plan for a communal forest can be implemented successfully only if the community feels that it is their plan. The plans are therefore formulated after consultations with the people and their leaders. Foresters provide technical guidance, but the farmers must agree on what tree species should be selected, how many should be planted, when, and where. In this way, the program responds to the people's needs. The plan becomes a contract between the government and the villagers and is signed by the village council chairman (*Pradhan Pancha*) and the chairman of the village forest committee on behalf of the community and the district forest controller on behalf of the government. The process of jointly preparing the management plan has been an effective tool for extension and actively involves the local community and its leaders. (French and Gecolea 1986).

Slowly, forestry management was recognized as a crucial component of rural development and fuelwood began to be acknowledged as an important resource for the well-being of the rural poor. By the 1980s, the focus of forestry management had shifted from "forests for the state" to "trees for the people" (FAO 1983). Different ideas began to emerge, such as social forestry, community forestry and agroforestry (see Box 2) that emphasized the role of forestry in meeting the needs of local people. Social forestry projects encouraged farmers and communities to grow trees on farms, around their villages, or on communal land. This was perceived as a strategy to meet their basic needs, particularly for fuelwood, food, fodder, and building materials, thereby, to some extent, combating the environmental problems associated with the destruction of natural forests.

Box 2: Social Forestry Subsystems

Three major subsystems of social forestry are as follows:

- **Village and community forestry.** In community forestry, organized groups of people living in the same area and having common interests are cooperatively involved in establishing or managing forestry estates. Village forestry involves the establishment of woodlots or the management of small, natural forests on a village's communal land by residents of the village for their own benefit. The work of nursery management, outplanting, field silvicultural operations, and harvesting of the crop is undertaken collectively and the benefits are shared equitably.

- **Farm forestry or agroforestry**. Farm forestry is a form of forestry in which trees are deliberately grown or retained on individual (smallholder) or commercial farmland with crops and/or animals or as pure stands on the farm (farm woodlots). Agroforestry has been defined generally as an integrated land use system in which woody perennials (trees and shrubs) are deliberately grown on the same land management unit as agricultural crops and/or animals in some form of spatial or temporal arrangement.

- **Urban Forestry**. This is another form of social forestry. It involves planting trees in urban centers for shade, aesthetic/ornamental purposes, or for fruits and fuelwood. The trees may be grown in parks, along avenues, in compounds, or in small woodlots in the surburbs.

Source: Kirchoffer and Mercer 1984

Experience from past projects highlights some important points concerning social forestry. First, fuelwood scarcity is rarely a sufficient incentive for people to plant trees: certain forestry projects in Africa specifically designed to increase fuelwood production failed. Second, farmers' participation in selecting tree species for planting is a critical factor for successful implementation (Kerkhof 1990). Where rural people decide to plant trees, they prefer ones that produce saleable products, that is, those that can yield economic benefits. People have cited benefits such as poles, timber, fruits, and fodder as their primary motivation for planting trees. Third, people actively participate in afforestation programs only if they perceive that they will result in tangible benefits. For example, the Social Forestry Program in Java found that to maintain farmers' commitment, the program had to create and provide farmers with an adequate income on a regular, uninterrupted basis (Stoney and Bratamihardja 1990).

Short-term benefits are another feature essential to projects based on community forestry. In northern India farmers grow short rotation trees such as poplar for veneer and matchwood or eucalyptus for poles and pulpwood; in the Philippines farmers grow *Paraserianthesis falcataria* (a very fast-growing tree) for pulpwood and sawlogs; in Sudan, they grow *acacia senegal* to produce gum arabic; and in central Java *Calliandra calothyrus*, a fast-growing leguminous shrub, provides fuelwood. The emerging importance of trees as cash crops raises issues needing attention, namely, farmers' access to markets, which will require market research; price stability and support to enable farmers to take advantage of market opportunities; and the provision of extension services to advise farmers what to grow and how they can obtain good planting stock to produce high quality products for the market (Arnold 1985).

2. THE WORLD BANK'S EXPERIENCE WITH SOCIAL FORESTRY

Bank staff envisaged that by actively involving people in planting trees on their farms, compounds, or villages to meet their basic needs, their quality of life would be raised. However, many projects the Bank funded overlooked certain technical issues relevant to forestry, such as identification of suitable species, the quality of seedlings planted, appropriate locations for planting trees on the farm, and patterns of intercropping, and management techniques. All too often local foresters prescribed technologies because they believed they knew the best species and technologies for farmers. They did not make any serious efforts to identify the indigenous technologies farmers used or to determine how they could be complemented with scientific methods to derive more appropriate technologies. Consequently, projects failed to achieve their goals.

Inadequate attention to the species recommended has been a consistent shortfall. For example, in the India-Kerala Social Forestry Project the casuarina, acacia, and eucalyptus for fuelwood and fodder provided by the project were not the farmers' preference. Contrary to expectations at appraisal, farmers wanted to plant high value timber species such as teak and ailanthus for cash rather than merely meeting their domestic fuelwood needs (World Bank 1994b). Similarly, the Burundi Second Forestry Project revealed a flaw in that rural nurseries provided seedlings to farmers, mainly for trees for firewood, with little analysis of the demand for tree products and the perceived role of trees within the farming system, which resulted in a poor response from farmers (World Bank 1994a). These problems would have been minimized if baseline surveys, monitoring surveys, and feedback through extension had determined farmers' preferences.

A few projects carried out applied research after project inception. For example, in the Ghana Forest Resources Management Project, attitudinal surveys on tree planting were carried out to assess the importance and value of trees to farmers; the extent to which they accepted growing trees with crops; the reasons for planting specific tree species; the perception of the importance of cash income from trees; and the acknowledgment of the role of trees for windbreaks, soil fertility improvement, erosion control, and environmental improvement. An applied research program was initiated covering development of agroforestry technologies, erosion control techniques, terraced farming using trees, alternative species for small timber, live fencing, indigenous fuelwood species, grafting of fruit trees, domestication of medicinal plants, promotion of local fodder species, and development of beekeeping by rural people (World Bank 1993a). Similarly, in the Mali Second Forestry Project, applied research programs contributed significantly to a participatory strategy focused on silvicultural techniques, including the identification of productive gmelina and eucalyptus provenances, the development of techniques for propagating cuttings, the introduction of direct sowing techniques, and the identification of improved thinning regimes. Integrated management of natural forests, including identification of production and regeneration techniques, was examined and a phenology of indigenous species, the impact of fire on natural regeneration, and an evaluation of various management regimes was initiated, followed by the design of agroforestry training and extension programs (World Bank 1993b).

A technical shortcoming in many Bank-funded projects, and also in forest plantation work throughout the developing world, relates to the quality of planting stock. Projects tend to emphasize physical targets, primarily the number of seedlings raised and distributed to farmers, and to pay little attention to the quality of the planting stock and the subsequent crop. While most appraisal reports mention the need for good quality plants, they do not indicate mechanisms for ensuring that high quality planting stock is provided to farmers. Support for modern nursery practices and tree improvement programs has been limited. As a result, many projects provide seedlings of poor physical quality and inferior genetic make up, which results in low survival rates and poor quality tree products.

Evaluation of the social forestry approach has shown that planting forest trees requires more attention both to the selection of species and of the technologies associated with tree growth. It has also proved that merely planting trees provides only marginal benefits to rural communities and has little effect on environmental problems and forest destruction. This has led to development of the participatory concept, which involves not only planting trees, but managing forest lands.

3. PARTICIPATORY FORESTRY

Recently appraised projects, such as the Bhutan Third Forestry Development Project; the Pakistan Northern Resource Management Project; and the West Bengal, Maharashtra, and Andra Pradesh forestry projects in India, include large components on participatory management and institutional strategies and approaches for involving local communities. The Bhutan project has a village forest management system in which villagers will be given responsibility for managing selected traditional forest areas under the technical guidance of the district forest officer. Activities include training foresters and farmers in village forest management, hiring facilitators, helping to organize village institutions for community forestry, developing and implementing village forest management plans, developing systems for sharing forest produce among beneficiaries, and preparing forest extension materials. The project also encourages the establishment of private nurseries by supplying the necessary inputs. In the Pakistan project a social mobilization unit will be set up to interact with communities, help to draw up community resource management plans for each village, and ensure community participation in implementation. Programs are designed to ensure adequate and early returns to farmers as incentives (World Bank 1993c). The Maharashtra and Andhra Pradesh projects both outline means by which planting stock can be improved, and joint forest management committees, which are responsible for micromanagement planning and implementation of the plans, can be formed.

Throughout the tropics and subtropics people's participation in rural development programs has gained importance during the last decade.[4] A number of policy documents, including *The Tropical Forest Action Plan* (FAO 1985), *Our Common Future*, a report by the World Commission on Environment and Development (WCED 1987), and *Agenda 21* (UNCED 1993), emphasized the need to involve local communities in environmental resource management and sustainable development programs. Centralized systems tend to have limited awareness of local circumstances and to make communities dependent on the government for providing goods and services. Thus the need for a viable and sustainable community-based approach to facilitate greater participation in forestry ventures.[5]

Community participation includes many different dimensions of "benefits," and Berenschot (1988) observes that having more participation is not always beneficial, because its value depends on the type of participation, on who participates, when they participate and under what circumstances. Cernea (1989) advises that true people's participation needs precise identification of who "the people" are and how they are organized. Strategies to promote participatory forestry and joint forest management require analysis of all dimensions and functional constituents of local communities as management units. Unfortunately, to some government officials, peoples' participation in projects simply means notifying the community what is planned for them, rather than consulting with people and enlisting their support and cooperation. Some government officials equate participation with mobilizing of people to undertake certain tasks, often not to their direct benefit, merely to implement government plans.

Women constitute an influential group in participatory programs, especially in developing countries, where they often provide most of the manual farm labor, but only in recent years has the role of women in rural development been widely acknowledged. In terms of tree management, women will know the different species that provide the best products for fuelwood, fodder, craft materials, medicines, or tannins. In joint forest management, the collection and sale of nonwood forest products (fruits, medicines, mushrooms, honey, wax, and tannins) will provide women with forest-based income. In addition, nurseries could be subcontracted to women's groups, as has succeeded in the Greenbelt Movement in Kenya and the Uganda Women's Tree Planting Movement.

Interaction between farmers and communities and foresters is a critical factor in participatory forestry. Such interaction was formerly limited to hiring members of the community

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[4] Paul (1987) defined people's participation as "an active process in which beneficiaries (local people) influence the direction and execution of projects rather than merely receiving a share of the project benefits."

[5] The advantages of participation include sharing management responsibilities and project costs with the community, increasing project efficiency and effectiveness, building beneficiary capacity, and empowering communities (Bhatnagar and Williams 1992).

to plant, tend, and protect trees on government plantations.[6] Extension efforts are often restricted to setting up nurseries, distributing seedlings, and establishing of village woodlots, and are often directed toward a few well-off individuals. Farmers and the professional foresters have conflicting interests in reference to the technical aspects of forest establishment and management. Farmers want technologies responsive to their cash and subsistence needs; adaptable to their limitations of land, time, labor, and capital constraints; and flexible enough to adjust to changes in weather or markets. Foresters focus on technologies to meet planned production targets or conservation objectives and need results to enter into their records at the prescribed time rather than to maximize financial efficiencies. The two groups also disagree about tree species. In Usambara areas of Tanzania, foresters and conservationists consider *Maesopsis eminii* unsuitable in catchment areas because it produces only thin litter and does not adequately control surface runoff. Meanwhile local farmers believe the tree creates a good microclimate that benefits their crops and fast growth to produce timber (anonymous 1991). In the Turkana Rural Development Project in Kenya, the assumption that the Turkanas were solely interested in livestock proved wrong when interactive discussions revealed they were also interested in trees and had extensive indigenous knowledge and traditions affecting the use of trees (Kerkhof 1990). In northern India foresters working for a private company recommended the planting of poplars to farmers. Initially the farmers resisted, but as the foresters provided good plants and the match company guaranteed sales, farmers finally realized that they could integrate this species into their program (Piare Lal 1991). In some areas foresters need to learn from farmers, and in others farmers could effectively adopt foresters' professional advice. However, in most developing countries the gap between communities and foresters will not be bridged easily.

A number of factors constrain peoples' participation in forestry, including policy, institutional, and technical factors as follows:

1. **Lack of land tenure security.** Experience with community forestry projects in countries such as India, Kenya, Nepal, and the Philippines and Kenya demonstrates that lack of land tenure security is a major disincentive to tree planting by farmers (Steppler and Nair 1987).

2. **Lack of control over forest resources**. In Uganda, muvule trees (*Milicia exclesa*) belong to the government, while in Honduras and the Dominican Republic all trees belong to the government and individuals need permits to cut trees (Foley and Barnard 1985).

3. **Lack of secure or reliable markets and suitable pricing policies.** The problems of marketing, access to markets, and prices are extremely complex and require extensive research.

4. **Lack of appropriate technologies.** Even when projects provide the desired species, poor quality stock results in low survival rates, unsatisfactory growth, and poor quality products.

[6] The art of dealing with local communities and encouraging their participation in forestry activities is a new phenomenon to traditional foresters that has only recently begun to emerge as an important aspect of forestry.

5. **Long rotation periods**. Resource-poor smallholder farmers need quick returns from annual crops rather than from planting trees, but costs could be offset by affordable credit facilities from financial institutions or industry.

6. **Competition with other land uses for land, labor, and capital**. Tree farming may compromise agricultural production.

7. **Bureaucratic adamancy**. The functioning of bureaucracy in many countries frequently frustrates people's participation in forestry. Although officials may appear sympathetic, they sometimes use their office to jeopardize people's cooperation by reducing the flow of incentives promised to them. For example, in West Bengal the government had promised the community 25 percent of the final yield in exchange for joint management and protection of the forest. However, when a government forest corporation was authorized to harvest the forest, only 6 percent was awarded to the community.

8. **Weak local institutional capacity**. Many local communities lack the necessary resources to implement forestry activities and have to depend on external resources.

Strategies to promote authentic and functional participation by farmers in forestry need to address all the above constraints—a formidable task. Of the nine points, five (1,2,6,7, and 8) will require policy and institutional changes, and point 3 relates to marketing, which may also be linked with policy issues. Only appropriate technologies and rotation periods (points 4 and 5) are biological or genuinely technical problems.

Observations in the field indicate that seedlings planted in agroforestry projects are frequently of poor quality, and thus farmers gain few, if any, benefits. Farmers take great pride in their farms and are intolerant of crops with poor growth, and therefore quickly lose interest in tree crops. This paper emphasizes forest technologies that will improve crop quality, but no matter what species are selected, poor planting stock will result in substandard production and depressed values. During the past two or three decades forest researchers have developed technologies for improving the quality of planting stock. While often associated with large-scale commercial plantations, some of these technologies can be adapted to local conditions for cost-effective production of good quality planting stock. This issue has been chosen because seedlings can be improved significantly with relatively little effort, provided producers are able to differentiate between good and bad plants. Planting stock can be improved without the complexities of reorganizing institutions and policies because its success rests with people in the field, both farmers and foresters. Although technological improvement will not resolve participatory forestry problems, farmers' productivity and incomes will be improved while other issues are being tackled.

4. TECHNOLOGIES RELATED TO PARTICIPATORY FORESTRY

Forest technology has undergone many changes in recent decades because of the increased focus on plantation forestry as opposed to natural forest management. To promote participatory forestry, forestry experts must examine both indigenous forestry practices and modern techniques and develop appropriate and socially acceptable technologies.[7] This section describes some indigenous forest technologies and attempts to compare them with the contemporary scientific knowledge. It discusses factors influencing the choice of species by farmers and foresters, describes technologies for propagation and postplanting management of trees on the farm, and discusses the location and patterns of intercropping of trees on the farm.

In most cases, unlike agricultural crops, technologies for tree species are generalized rather than specific, because the vast number of species planted lack research aimed at their domestication. To identify priorities for research it is expedient to review the biological families favored for agroforestry. Annex 1 presents the families and species of trees commonly grown in Africa, Asia, and Latin America, and Annex 2 lists commonly grown trees by family, genus, and species. These provide some indication of the immense problems scientists face when considering species for participatory forestry ventures. Although these lists are far from complete, they contain more than 200 species, a few represented in more than one region. The most striking point is that the genera of the Leguminosae family represent nearly 30 percent of the total, and if the three other well-represented families, Meliaceae, Moraceae, and Myrtaceae, are added, these four families account for approximately 50 percent of the species listed. If research in different regions focused on species in these four families, rapid technological advances through aggregated studies may be possible.

4.1 Factors Influencing the Choice of Species

The choice of species involves a complexity of socioeconomic and technological considerations, including ecological suitability, usefulness to people, and the costs and benefits associated with establishment and management. Trees in conditions unsuited to them grow poorly and may die. If trees do not provide the products and services farmers desire, they may be abandoned or uprooted. Therefore, foresters and farmers must agree on and develop tree species suited to farmers' needs, with silvicultural requirements and techniques stipulated from the farmers' perspective.

Foresters often overemphasize technical aspects when selecting tree species and neglect farmer's preferences.[8] They focus on trees that are easy to obtain and propagate, such as eucalyptus and teak. Technical factors that foresters consider essential include adaptability of the species to site (agroclimatic and edaphic) conditions, ease of establishment, fast growth rate, and high resistance to pests and diseases. However, characteristics desirable for agroforestry outlined in the literature are that species should be multipurpose and compatible with agricultural crops, able to conserve soil and water and improve soil fertility through nitrogen fixation, deep rooted to minimize competition for water with field crops and not cause hindrance to farm operations, small crowned and have a sparse canopy to minimize shading of crops, good at coppicing and have self-

[7] Social acceptance is a pre-requisite for the adoption of any technology, and will also determine the forest management strategy that is feasible.

[8] Foresters think that farmers are ignorant about tree requirements, while farmers believe that foresters know little about growing trees on farms. This is perhaps true in the sense that until recently, the training of foresters focused more on managing trees in the natural forest and less on farm forestry. Certainly, they know little about indigenous species growing well with crops on farms.

pruning properties, and deciduous in nature. They should also have easily decomposable litter (Narawane 1991; Tewari and Singhal 1991). These features may or may not be compatible with those foresters tend to emphasize, which are often fast-growing exotic species. Foresters have generally ignored indigenous species because they know little about planting them, but farmers prefer indigenous species because many have valuable known qualities and they are familiar with them.[9]

From the local farmers' viewpoint, the choice of species should be dictated by the species' ability to provide for their needs. Forestry projects in Africa, Asia, and Latin America indicated that small farmers seldom wish to plant trees exclusively for one product and prefer multipurpose species. Projects in Africa and Asia designed only to increase fuelwood production met with little success (Kerkhof 1990; Stoney and Bratamihahardja 1990).[10] Other observations from projects have been that farmers prefer to plant tree species and adopt systems they are already familiar with; select trees producing fruit, wood, timber, and/or resins; and plant tree species with fast growth rates, short rotations, and ready sale. Socioeconomic studies in Maharashtra also showed that holding field demonstrations and distributing good quality seed or seedlings played an important role in popularizing agroforestry (Hegde 1988).

In some countries, customary beliefs and the social value of trees also influence farmers' decisionmaking, for example, certain trees are associated with luck, malign spirits, or social taboos. In Zimbabwe, for example, people do not cut trees such as *Parinari curatellifolia*, which are believed to be sacred while trees such as *Tamarindus indica* and *Azanza garckeana* were believed to host spirits (Fortmann and Nhira 1992). In Ghana the Ashanti revere *Milicia excelsa*, in India *Azadirachta indica* has an important role in Hindi religious practices, and many tribal people elect certain trees as shrines, of which perhaps the best known is *Ficus religiosa*. These factors generally influence the retention or planting of such trees on the farm. Gender differences can also influence the choice of species. For example, in Kenya men prefer species with saleable products like fruits, poles, and timber, while women focus on species that produce multiple products for household subsistence, including fruits, fuelwood, fiber, and fodder.

4.2 Indigenous Technologies for Tree Propagation and Management

Farmers use several traditional technologies to raise and maintain trees in their farms or in the forest.[11] These differ from the modern techniques used in state forest management systems or commercial plantations in terms of scale, complexity, inputs required, adaptability to local environments, and other characteristics (see Table 1). Traditionally, farmers have managed small,

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[9] A good example exists in Costa Rica, where the Organization of Tropical Studies has documented that at least six indigenous species will grow well on farms, and farmers are actively planting these with the help of a nongovernmental organization called Foundation for the Development of the Central Volcanic Mountain Range (FUNDECOR).

[10] To many farmers, other alternatives to fuelwood are possible, for example, the use of crop residues for cooking, so they do not bother to plant trees specifically for fuelwood. In fact fuelwood is often collected (sometimes illicitly) free of charge. Generally, farmers also want monetary returns from their trees.

[11] Note that technologies vary from region to region depending on the indigenous knowledge, resources available, end uses of the trees, and sociocultural factors. This section simply gives a general description of indigenous practices as described in the literature.

temporary nurseries with open beds on which they raise bare-rooted seedlings. They select healthy-looking plants and carry them in baskets the short distance to planting sites. Seedlings remaining in the nursery are allowed to grow larger before being outplanted. Rarely do farmers throw away seedlings unless they die. Modern scientific observations prove this inevitably leads to poor quality plants in the field from these subsequent plantings.

An alternative to using seedlings is direct sowing. Farmers have used this method in situations where the supply of seeds is abundant. In East Africa, for example, farmers raise *Maesopsis eminii* by direct sowing. In some instances, farmers plant saplings collected from the forest, known as wildings. Farmers often protect tree seedlings that germinate naturally on their farms, for example, *Parkia* spp. in West Africa; *Faidherbia albida* in eastern and southern Africa; *Balanites aegyptica* in arid zones and elsewhere; *Albizia coriaria*, *Maesopsis eminii*, and fruit trees in Uganda (Tamale 1990); and *Madhuca longifolia* in southern India because of its many uses. Some communities encourage natural regeneration of forests by simply protecting sites from fire and grazing, for example, in Nigeria farmers encourage natural regeneration of *Parkia bicolor* and *Vitellaria peradoxum*.

Table 1: A Comparison of Modern and Indigenous Forest Technologies

Characteristic	Contemporary technologies	Indigenous technologies
Type of forestry	Commonly plantation forestry, high capital input, large scale	Farm forestry, less capital input, small scale
Species	Usually single species Exotic species widely planted Usually single purpose timber or pulp	Varied species Indigenous species preferred Usually multipurpose
Planting stock	Containerized seedlings/cuttings	Bare-rooted seedlings, stumps, and cuttings commonly used. Direct sowing common
Land preparation	Sometimes mechanical	Largely manual
Agrochemicals	Chemical fertilizers, pesticides occasionally used	Agrochemicals rarely used, organic manure or nitrogen-fixing plants often used Wood ash used to control pests
Spacing and lineability	Trees planted in straight lines Equal spacing	Straight lines not important Wider and irregular spacing
Age structure	Usually even-aged	Varying age
Thinning	Systematic, predetermined spacing	Selective when performed
Protection	Artificial fencing, paid labor	Live fencing, stacking
Complexity	More complex, less flexible and adaptable to local changes in environmental factors, market needs	Simple, flexible, and more adaptable to changes

Vegetative propagation (cuttings and grafting) is another practice farmers used to raise domesticated tree crops, such as poplar, mango, and rubber. Propagation of bamboo, poplar, and sisoo is usually from cuttings, either from roots or shoots. They generally use grafting when physiologically mature characters of the species produce the required product, such as fruits or seeds. Unlike cuttings, two plants are involved in producing a single plant, the young rootstock and the mature scion, so care must be taken to ensure tissue compatibility. The method is commonly used for fruit trees such as mango and citrus.

Farmers' traditional tree planting techniques, patterns, and schedules vary from one area to another. Planting normally starts with the onset of rains on cloudy days or in the evenings when stress on seedlings will be lowest. Watering after planting is not common.[12] Seedlings may be planted at irregular spacing and in varying patterns depending on the size and shape of the farm or the intended use of the tree. When planted in or around a crop field, trees are situated in such a way that they do not cast a shadow on crops for most of the day, because most agriculture crops are bred for growing in open conditions. If planted as windbreaks, they are located on boundaries in the direction of the wind.

The use of chemical fertilizers, herbicides, or pesticides is not common for many small landholders. To control pests farmers use wood ash or remove diseased plants and plant parts. In India farmers often prepare decoctions of *Azadirachta indica* (neem) against insects and fungi. Farmers use technologies such as fallowing, mulching, organic manure, or plant nitrogen-fixing species to enrich the soil. An old technique for stimulating seedling survival and growth rate in the nursery and field is inoculation of nursery soils or planting holes with soil from the natural forest, which is now known to bring in mycorrhiza.

Farmers with small landholdings usually have few trees on their farm and selectively fell to remove less vigorous, diseased, or dying trees. They retain few dominant trees so that crops, pastures, and lower canopy plants receive adequate light. Pruning, coppicing, and pollarding are common practices, in most cases for the supply of fuelwood and fodder.[13] For example, pollarding of *Grevillia* sp. is common in Kenya and the coppicing of *Eucalyptus* spp. has been practiced for many years wherever they are planted. Pruning can stimulate and activate tree growth, encourage straight stems, and/or allow light to reach the undergrowth. At ground level, manual weeding using a hand hoe, bushknife, slasher, and other hand tools is the most common method for controlling weeds. It requires little skill and capital and can be used on any terrain. Protection through the use of artificial and live fencing with thorny shrubs or unpalatable plants is widely employed in the field to prevent damage from browsing, breaking, and/or trampling by animals. Farmers sometimes stake young seedlings to protect them from strong winds.

The type of technology industry or farmers adopt will depend on the desired end product, technological skill, and economy of scale. Industry will generally have access to all three, but farmers rarely have adequate access to any of them. Indigenous technologies tend to be simple and sustainable, designed to maximize production from a small number of plants. However, small farmers can adopt some technologies used by industry, either directly or with some modifications, to increase the quality and quantity of their product. The similarities in the underlying principles of industry and indigenous technologies permit merging certain aspects that are easy to adopt and use to obtain produce of maximum quality and quantity. Comparing contemporary technologies

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[12] Watering is done in a few places where irrigation systems exist, *e.g.* poplar in north India, or by drip irrigation in Israel.

[13] Coppicing involves cutting the tree to its stump and allowing it to sprout, while pollarding involves cutting branches just above the main stem, and pruning is simply cutting some of the side or top branches.

with indigenous technologies is important to ascertain which aspects of the contemporary technologies small farmers can adopt. A brief discussion of possibilities follows:

- **Species**. Where a market exists for a particular species and end product and farmers have either land lying fallow or land that is no longer highly productive for agricultural crops, they can establish single species, exotic or indigenous, that are well adapted. The correct silvicultural techniques and management will be critical for the end product to be competitive. In many instances wood products from particular species are so valuable and in such demand that farmers with high quality sites may profitably plant trees along with their traditional agriculture crops to provide additional income for specific purposes (weddings, burials, and so on).

- **Planting stock**. To improve seedling quality, and thereby the end product, farmers need to use modern nursery technologies, including seed grading and preparation, the latest containers, organic potting mixtures, and all the other innovations of modern nursery technology.

- **Spacing, geometry, age structure and thinning**. Good silvicultural techniques are important whether areas planted are small or large. Even with the use of improved material, if the establishment, spacing, and thinning are unsatisfactory, the crop will suffer. Industrial plantations usually use linear planting because it makes both planting and harvesting easy, but on small farms this is not an important factor. However, competition, which will be influenced by spacing, thinning, and age groups in an area, is important, but species specific.

- **Protection**. For the size of areas planted, spending money on artificial fences will hardly be justified, though protecting individual plants may be possible. Small-scale landholders are usually able to provide personal protection to trees on their farms, a luxury seldom available to the industrial planter.

4.3 The Quality of Planting Stock and Tree Improvement

The success of any tree planting project is determined by its ability to supply high yields of good quality products at low cost. Good quality seedlings and appropriate silvicultural practices are essential.[14] High costs can be incurred and time wasted by planting poor quality seedlings simply for the sake of meeting tree planting targets. Poorly developed seedlings are less likely to withstand hostile weather and edaphic conditions in the field, compete with weeds, or resist pests and diseases, and even when they survive, they will have slower growth rates and produce poor quality products, especially straight poles or veneer quality wood. It is therefore critical that farmers are provided with good quality seedlings or improved seeds and assisted in adopting the best possible techniques for raising and tending trees on the farm.

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[14] The quality of seedlings is determined by two major factors: the genetic makeup of the parent stock and the physical growth conditions. The latter is influenced by nursery and field management practices. The genetic composition can be improved through progeny selection and genetic breeding and improvement, while the physical quality can be improved through careful seed handling and use of best nursery practices.

Generally, the quality of tree planting stock farmers have used in the past has ranged from fair to poor, whether supplied by the government, purchased locally, or raised themselves. Farmers tend to collect seeds from trees that are convenient to collect from or trees with plenty of fruit, regardless of their phenotypic characteristics. This compromises the genetic vigor of the planting stock and results in both low productivity and poor quality products. The genetic and physical quality of plants need to be improved. With the exception of a few agroforestry species like leucaena, most tree improvement research has focused on selecting and breeding trees for industrial plantations. The primary objective has been to produce fast-growing trees with large, straight boles and high quality wood to supply pulp factories and sawmills. Researchers have made little effort to enhance the quality and yield of indigenous fruit and fodder trees grown on smallholder farms.

Although genetic improvement has not directly addressed farmers' needs, improvements made in nursery technology during the past two decades are important to farmers if adapted to their needs. Because farmers use a large number of species, improvement should concentrate on the four most extensively planted botanical families. Therefore, to improve the quality of planting stock, and ultimately the yield and quality of tree products in participatory forestry programs, good seed harvesting and nursery practices need to be adapted to benefit local farmers, as do modern technologies to improve trees.

4.3.1 Tree Quality Control and Maintenance

To ensure good planting stock and proper seed collection, handling, and storage, proper nursery practices, careful outplanting, and good postplanting tree management are essential. The following sections highlight some of the more important aspects of modern technology.

SEED TECHNOLOGY. Seeds should always be collected from mother trees that are healthy and vigorous, with the desired characteristics, and where possible not isolated. Seed harvesting is seasonal and planning is a year long task, because seed trees need to be inspected regularly to determine both the onset and extent of flowering. Developing fruits need frequent examination to judge seed maturation and detect pests so as to predict likely seed yields accurately. Some species are harvested from the crown, others from the ground, entailing significant organizational and cost differences. Seed processing is a highly specialized task as there are many different types of fruits. Some species have fruits difficult to open, so fruits rather than seeds are processed, stored, and sown; however, in most cases seeds are extracted for processing. Although both large and small seeds can produce good plants in nurseries, it is best to have seeds of similar size in individual beds, so seed grading will be needed to ensure uniform growth after germination. Often treatments are needed before seeds can be stored and a good planter must keep a store of seed ready for the following season.

NURSERY PRACTICES. Sowing good quality seeds does not, in itself, guarantee good seedlings, proper and careful management practices in the nursery are essential.[15] Forest tree nursery practices have improved significantly in recent years, with innovations such as overhead irrigation, mist or fogging conditions, shade cloth giving fixed light percentages, improved organic potting media for containers, root-trainers emerging as the best type of container, machines for precision sowing of seeds either in containers or on beds, mechanical undercutting and lifting for bare root plants, and cloning technologies. An efficient nursery operation must review new technologies and install those it considers the best to ensure high quality plants, relating investment not only to the cost of installation, but, more important to the value of the improved plantation.

POSTPLANTING TREE MANAGEMENT TECHNIQUES. After planting a quality seedling on the farm, the silvicultural practices employed determine the quality of the tree products at harvest. Farmers have wide experience in plant culture and adapt best practices. They must take care when pruning or pollarding not to cause excessive damage. Thinning is straightforward: only trees most likely to gain in size and value are retained.

4.3.2 Clonal Planting Stock

Throughout the earlier part of this paper, most references to planting stock have implied seedling plants. There is another type of vegetatively propagated planting stock known as clonal plants, which is increasingly being used in forestry operations. This is an adaptation of traditional horticultural techniques used for certain agricultural crops, and particularly ornamental species, for generations. It involves cutting stems into sections and setting these in a suitable rooting medium, which causes root formation and development of a new plant. Excellent examples are seen in the well-documented propagation of unrelated species such as cassava and bougainvillea. Most trees are difficult to propagate in this manner. Only some members of the Salicaceae such as willow and poplar form roots readily. In the mid-1970s forest researchers found that stem sections bearing leaves could develop roots provided they were set under conditions of continuous high humidity to prevent desiccation. As researchers delved deeper into the subject they found that most tree species will form roots on stem cuttings of juvenile physiological character. Luckily, many species of forest trees can rejuvenate, so using modern techniques, material from mature trees is rejuvenated and stem cuttings used to multiply individuals.

Industrial planters have recognized the benefits of this technology, and although it is still not widely used, where it has been implemented, the method increases productivity significantly. The basic principles have a simple logic. Forest or plantation trees are screened to select the best-looking individuals (outstanding phenotypes). The level of selection can vary, and is usually more intensive than 1 in 10,000. These trees will be spatially widely scattered, and centralizing them is necessary before the process of multiplication can begin. This is accomplished by using another traditional horticultural propagation technology: grafting. Regrowth from the grafted parts will

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[15] Good seedlings are sturdy plants of superior genetic composition with a well-balanced shoot-root system, a strong undamaged stem, a well-established fibrous root system (with uncoiled taproot and many side roots), and no symptoms of mineral deficiency.

have rejuvenated to some extent and provide a limited amount of material to set cuttings. Once these have been established they provide more cuttings, and the process continues until a "cutting orchard" can be established to provide enough material for the planting program.

Research has shown that plants raised by cloning are generally more uniform than those from seedling stock, and also that if planting stock is raised from selected phenotypes, the resultant planting stock is at least as good, but usually better, than seedling plantations established from seeds collected from the same crop. This is a technology that can be quickly adapted to improve planting stock for farmers. Leakey and others (1990) developed a system of low cost propagators that enables small-scale planters to implement the technology, providing they have the base material to propagate. McDicken and Bhumibhamon (1989) describe a methodology of how forest breeders, referred to as barefoot breeders, can work with farmers to promote tree improvement.

A more sophisticated method of propagation, tissue culture, has been developed in horticulture and used to mass multiply material from a very limited source. For forest trees this technology is in its early stages, and is being used for industrial species in some countries such as China (eucalyptus), New Zealand (radiata pine), Thailand (teak), and Nepal (sisoo), (White 1986). In this technique, cells or buds from actively growing shoot tips of the desired parent plant are removed and cultured in an appropriate medium under aseptic conditions for mass production of vegetative plantlets or clones. The plantlets, initially shoots without roots, are subdivided after some weeks of active growth and placed in a new medium to produce plantlets with both shoots and roots. Where this technology is available for the required species, it should be used in planting programs, but more frequently it is a research tool. In the Bank-sponsored China National Afforestation Project, tissue culture is used for initial multiplication of eucalyptus clones and the resulting plants are multiplied further in the nursery using leafy cutting technologies.

4.3.3 Technologies for Tree Improvement

Tree improvement basically refers to the process of enhancing the genetic vitality of trees to ensure higher productivity, better quality, and improved resistance to harsh growth conditions, pests, and diseases. Tree improvement programs include selecting superior parent materials with the desired traits followed by breeding to develop improved strains.[16] Most agricultural crops have undergone intensive genetic improvement programs, and farmers now have the ability to choose precise varieties for specific sites and climatic conditions knowing they will yield a product of predictable quantity.

Forest research is a long way from this type of precision, and probably only poplar and radiata pine fall into this knowledge league, although a number of other species have attained some acceptable levels of domestication. Part of the problem lies in the number of species for which knowledge is needed (see Annex 1) and the limited number of people and funds available for the work. Improvement studies lead to the domestication of species, but they take time and

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[16] Some tree improvement technologies have provided promising results, such as increased biomass production and the development of genetically improved strains of fast-growing species. For example, provenance trials of *Eucalyptus camaldulensis* in Nigeria, Congo, and Brazil have demonstrated significant increases in yield (Spears 1989).

are expensive. One of the reasons this work seems slow for forest species is that it is being carried out on too many species. Therefore, high on the list of immediate requirements is a system of classifying the species currently being favored and then determining whether certain groups can be given higher priority than others.

In Annex 2, the species favored in different countries are identified by their botanical families, which may prove to be a suitable stratification unit. This work will require the help of experienced taxonomists before the concept can be put to test. However, as mentioned earlier, data included in these lists suggest that studies on Leguminosae species should have high priority in any region. It is possible, though not necessarily always the case, that success with any individual species in the family may be directly transferable to other species in that family, or at least indicative of short-cuts in the domestication process. By the same logic, work in the regions should next give priority to species of the Meliaceae, Moraceae, and Myrtaceae. Thus, when Bank projects include research on species, particularly genetic research, species of these four families should be given preference. Furthermore, all Bank projects should try to cross-reference information on species from these four families. While this approach will provide only a limited advantage, it has the benefit of being scientifically oriented and should form a sound foundation of knowledge as investment in domestication continues. It is currently the best means of improving the quality of farm planting stock.

The process of genetic domestication is well documented. First, the natural distribution of a species is determined. Next, areas within the distribution with particular site features are identified (for example, species occurring at different altitudes or on different aspects of a mountain range). Areas defined in this way are known as provenances. The importance of provenance was first brought home to foresters in the 1960s when an international provenance trial of *Eucalyptus camaldulensis* sponsored by the FAO planted seeds obtained from identified provenances on a range of sites. Provenance trials normally give usable results at half the expected rotation age for the species, but for accurate predictions the trials must continue to the rotation age and be repeated. One of the major problems that has emerged from innumerable provenance trials is that once a suited provenance has been determined, obtaining adequate quantities of seeds for a plantation program is often difficult (and sometimes impossible).

Concurrently with provenance identification, but in the case of exotic species some time later, outstanding individuals are selected. These are known as candidate plus trees (CPTs) to distinguish them from plus trees (PTs), which are trees of proven genetic potential, that is, tested in progeny and clonal trials and proved as outstanding genotypes. With regard to indigenous and multipurpose trees, knowledge of the best provenances to use is frequently available, and in some cases CPTs have been selected, but rarely will material from PTs. From a practical viewpoint, a planter needs to be supplied with an adequate quantity of seeds from CPTs of the selected provenances. Should this prove difficult, it may be expedient to raise clonal planting stock from CPTs, or as an interim measure, to convert the best of the limited number of seedlings available from either the general provenance collection (or better still CPTs in that provenance) into clonal plants to supply farmers with improved planting stock. These are practical suggestions for improved stock and must not be confused with ongoing research programs to genetically improve the species in question.

Seeds collected from CPTs are used in research programs for progeny tests, and because only one parent is known, these are called half-sib progeny tests (1PGT). These will give some indication of the genetic quality of the CPT, but experience over the years indicates that these trials have only a limited value. The only reliable progeny trials are those conducted with seeds from controlled pollination so that both parents are known: these are full-sib progeny trials (2PGT). The sophistication needed for controlled pollination work varies with species. With some such as pines it is relatively easy, but eucalyptus presents problems. The grafting technique mentioned earlier is used to encourage early production of flowers and ensures that flowers are formed on accessible branches. Lopping and pruning of the branches helps to maintain accessibility of the flowers. Progeny trials are combined with clonal trials to establish the genetic validity of CPTs and the best are elevated to PTs. Records indicate that only about 10 percent of CPTs become PTs. Controlled pollination techniques can be used to create interspecific hybrids, and the most recent work with eucalyptus, some acacias, and the southern American and Caribbean pine hybrids has yielded highly significant productivity gains that can be captured by cloning. These technologies will have to be harnessed to bring these gains into the farmer's field. Once such planting material becomes available, farmers will probably become more enthusiastic about growing trees.

4.4 Location and Patterns of Trees on Farms

The location of trees on farms and the patterns in which they are grown with agricultural crops and/or pastures (agroforestry systems) vary considerably. They include pure tree stands (farm woodlots), rotational agrosilviculture or sequential cropping (growing crops and trees one after the other), spatial mixed agrosilviculture or intercropping (growing crops and trees at the same time), and sylvipastoral systems (growing of trees in animal pastures). The choice of system depends on a number of factors such as security of tenure, size of land, and compatibility of trees with crops.

4.4.1 Farm Woodlots

Farm woodlots are small plantations or groups of trees that farmers retain or plant to provide farm wood products (such as fuelwood, poles, or timber) and nonwood products, as well as shelter or windbreaks or watershed protection. Farm woodlots have been widely established in a number of developing countries such as India, Kenya, Malaysia, Peru, the Philippines, and Thailand. By planting woodlots, farmers have been able to meet their domestic needs for building materials and fuelwood. In some areas, farmers have been able to market some of their products, which has improved their standard of living. The size of farm woodlots depends on how much land the farmer can afford to devote to pure forestry and the availability of markets for wood and nonwood products.

4.4.2 Rotational Agrosilvicultural Systems

Rotational Agrosilvicultural Systems are ones in which farmers grow crops and trees on the same piece of farmland in rotation. An example of rotational agrosilviculture is the taungya system, or what is sometimes referred to as establishment intercropping. This system originated in Myanmar and has been practiced in other countries under different names, for example, *shamba* in Kenya and *tumpangsari* in Indonesia (Stoney and Bratamihardja 1990), as a means of reforestation or establishing government forest plantations. Basically, it is a system where shifting cultivators or landless farmers are allowed to cultivate annual crops under trees planted on government land for a limited period of time in return for protecting and tending the trees. Crop production continues until the tree canopy closes; the farmer is then allocated another plot. Another example of rotational cropping is the improved tree fallow system in which trees, usually nitrogen-fixing trees, are planted in fallow land primarily for improving the soil; these are used in Sudan *Acacia senegal* in the fallow for up to 16 years, Ecuador *Inga edulis* up to 8 years and Indonesia, planting *Acacia mearnsii* (Evans 1992).

4.4.3 Mixed Agrosilvicultural/Intercropping Systems

In many developing countries, trees are commonly planted or retained on farms and intercropped in different patterns, including home gardens, trees scattered over crops, or planted as hedges, along boundaries, and recently in alleys. The home garden farming system has been and remains a widespread agroforestry system in the tropics. It is a fairly complex multistory system in which crops are grown with trees of mixed canopy levels, for example, a lower layer of short annual crops (yams); a second layer of tall crops (cassava); a third layer of young trees, shrubs, and bananas; and a fourth layer of tall trees, including fruit and timber species. Home gardens have been practiced in most humid tropical countries in south east Asia, Africa, and Central America. Some home gardens have been described in great detail, for example, the Chagga home gardens in Tanzania (Maghembe, Fernandes, and O'Ktingoti 1984) and the Kandyan home garden in Sri Lanka (Perera and Rajapakse 1989). It is an intensive land use system appropriate in areas where land is scarce, and its complexity and diversity can lead to greater agro-ecological stability and long-term benefits to farmers.

Another common form of intercropping is trees on cropland. Many tropical crops, including coffee, cocoa, tea, and bananas, grow best under shade. Several tree species such as *Albizia* spp., *Grevillia* spp., *Cordia* spp., *Erythrina* spp., *Ficus* spp., and some fruit trees are planted to provide shade. Farmers also plant trees to stabilize the soil and limit erosion, to conserve moisture in the soil through shading, and to add organic matter through litter and nutrients through nitrogen fixation. Trees are spaced sufficiently far apart and intensively managed through thinning and pruning and do not interfere with crop production. In Uganda, coffee and bananas are traditionally grown under *Ficus natalensis*. In the tropical savanna areas, trees are commonly scattered in fields with annual crops like maize, sorghum, millet, beans, and peanuts (Warner 1993). In Kenya farmers commonly grow *Grevillia robusta* and *Markhamia platycalyx* with maize and beans (Kerkhof 1990), while in Thailand they grow *Acacia mangium* with sorghum and *Eucalyptus camaldulensis* with cassava (Evans 1992).

Alley farming is currently promoted in Africa by the International Institute of Tropical Agriculture and in Indonesia, especially Java, by the U.S. Agency for International Development. Agricultural crops are grown between rows or alleys of nitrogen-fixing tree species like leucaena, erythrina, gliricidia, prosopis and calliandra, at four to six meters apart. The rows are intensively managed by constant pruning, coppicing, or pollarding to minimize their competitive effect on the crops, and pruned material is applied to the farm as mulch or used for fodder and firewood. This practice has been widely adopted in Kenya and Nigeria, where maize and beans are grown in alleys of leucaena and other legumes (Warner 1993). This practice is too fastidious for rural farmers, who rarely stick to the precision of planting trees in lines at regular intervals. Planting of trees on terraces is an old and common practice in a number of countries. For example, in the Philippines, farmers have adopted the Sloping Agriculture Land Technology, in which they grow different types of crops separately in between rows of leguminous trees and shrubs planted along contours, four to five meters apart, to form vegetative barriers that control soil erosion while helping to restore fertility (Laquithon 1989). Farmers have traditionally used boundary planting to demarcate their plots. Some serve as shelterbelts, while others supplement fuelwood. In Uganda farmers *plant Markhamia platycalyx* along borders for firewood and never with crops in the field because it affects crop yields, although it is a good tree for fuelwood (Tamale 1990).

4.4.4 Silvipastoral Systems

Four main types of tree-livestock systems have developed in different countries, namely, forest grazing, trees over pastures, live fences, and fodderbank systems. Forest grazing is a system of controlled grazing and browsing of livestock under tree plantations or fruit tree farms (orchards). For example, farmers graze cattle in *Araucaria cunninghamii* plantations in Australia and in *Populus deltoides* plantations in South Africa (Payne 1985). Growing or retaining trees over pastures is another old practice that provides shade for animals and also helps to conserve soil moisture and add organic matter. Live fences using thorny or unpalatable trees has been widely used in the tropics. In Uganda, farmers plant *Lantana camara* and *Euphorbia* spp. very close together and regularly pollard or prune them to maintain vigorous regrowth of lower branches to keep the fence intact. *Hippophae rhamnoides* is grown in China and *Jatropha curcas* in Honduras. Establishment of intensive fodder tree gardens (fodderbanks) is becoming more widely adopted, especially in areas where grazing land is scarce. The Sweden International Development Agency project in Tamil Nadu, India, promoted this practice. In some countries like Burkina Faso, Kenya, and Sudan, farmers plant strips of fodder trees, such as *Sesbania sesban*, leuceana, gliricidia and calliandra, to provide food for animals, especially in the dry season (Kerkhof 1990).

4.5 Factors Affecting Farmers' Choice of Forest Technology

A farmer's choice of technology is determined not only by social factors, but also by its costs and benefits. Costs include tools and equipment, land, labor, level of technical skills needed, and ergonomic factors related to the technology (including amount of stress, strain, and risks involved). Benefits relate to the technology's relevance to the farmer's perceived needs, skills, market opportunities, and ease with which it can be adapted to change. Basic criteria on which farmers base their choice of technology include the following:

- **Simplicity**. New technology should be easy for farmers to understand and implement. Technical skills required are a critical factor.

- **Productivity and profitability**. The technology should increase yields and quality of tree products in the shortest time possible without incurring excessive additional investment costs.
- **Availability of inputs**. Inputs required should be readily available.
- **Relevance**. The technology should be relevant to farmers and contribute to better living standards.
- **Sustainability**. Increases in productivity and quality should be stable and sustainable with no significant impacts on other parts of the farming system or on the environment (Ortiz and others 1991).
- **Market orientation**. The technology should promote tree products with good market prospects.

4.6 Linking Modern Technology to Farmers' Needs and Knowledge

The significance of directly linking research on forest technology to farmers' needs is frequently overlooked. There has been little interaction between farmers and forestry researchers in defining needs and problems and setting an agenda for afforestation and tree improvement. This has resulted in the development of technologies irrelevant to farms and extension agents are often ignorant of relevant technologies. To develop appropriate technologies and adapt those already generated, the following requirements need to be recognized:

- Research must focus on farmers' needs and problems;
- Agro-ecological and socioeconomic aspects of the farming system must be understood;
- Scientists must understand the technologies farmers already use;
- Feedback on transferred technologies should be provided to researchers (Eponou 1993).

Scientific research on farm tree planting should start from the farmers' own knowledge, acknowledging their objectives and seeking appropriate solutions to their problems, wherever possible using locally available resources. Only by understanding farmers' problems can research help improve their standard of living.

Effective technology transfer has been limited in many countries because of inappropriate selection of technologies resulting from poor communication and a lack of coordination between researchers, extension agents, and farmers. Interaction between farmers and local technicians and between local technicians and on-station researchers is often poor, and extension agents should provide the relevant linkage. If appropriate technologies are to be developed or modern technologies adopted, this communication gap must be bridged. Continuous feedback and refinement of technologies as new information becomes available are necessary. Social communication strategies, including social action learning, listening, and extension, are needed to stimulate dialogue and mutual understanding between scientists and farmers. This requires technicians to identify and learn the technical jargon in local languages to be able to translate technical subject matter to farmers into a simple and relevant format. Many local languages have rich vocabularies capable of accommodating different scientific idioms.

Another strategy is training farmers to assist informed adoption of new technologies to complement what they already know. Such training should not be too formal, as has often happened when selected groups of farmers are taken to research stations where they sit in classrooms to learn new techniques. Training should be both at the stations and in villages or on selected farmers' farms. Caution is also needed so that past mistakes, where the "progressive farmer" concept benefited only the well-off members of local communities, are not repeated. Forestry researchers and extension agents require regular refresher courses so that they are able to provide farmers with relevant technical advice.

Study of various indigenous, ongoing forest management systems and practices to integrate these with relevant new technologies will ensure that technologies developed are appropriate for farmers. Without this, scientific research has often developed technologies that have not met farmers' needs and expectations. Developing an appropriate technology is impossible without a clear idea of what farmers already know and what they want. Analysis of indigenous systems should aim at:

- Ascertaining farmers' knowledge and skills;
- Contributing to the revitalization or adaptation of local technologies;
- Sensitizing researchers and extension agents about indigenous farmer skills;
- Helping farmers appreciate the value of their own skills for adapting modern technologies.

In summary, efforts to link modern technology to farmers' needs and knowledge require foresters and farmers to learn together in an interactive manner.

5. DISCUSSION AND CONCLUSIONS

The Bank faces a number of challenges in transforming its sectoral work in forestry and agriculture so as to achieve its primary goals of alleviating poverty, improving living standards for local people, and ensuring environmental sustainability. These will require institutional and policy reforms to allow the identification and promotion of appropriate technical interventions, the integration of forestry into the broader concept of rural development, and the promotion of more local control over and management of forest resources.

Farm forestry represents an important opportunity for stimulating participatory forestry management and decentralized economic activities in rural areas. Where broadly based rural development is the objective, farm forestry helps meet the needs of the rural poor. Forest tree planting would allow people to be more self-sufficient in wood products and target parts of the forest product market to provide a reliable source of income. The use of appropriate species and best quality planting stock integrated in farms in appropriate locations and patterns will effectively provide tree products for market and meet the subsistence needs of local people. High value timber species could be selectively raised on farms to reduce or replace households' dependence on the natural forest. However, project planners must recognize the technical and socioeconomic limitations of such approaches. To build upon the successes achieved so far and design new strategies that are relevant and profitable, farmers must use the best quality stock of the species they prefer, planted on locations of their choice using appropriate patterns of intercropping. Participatory forestry in community forests requires financial, and especially political, commitment.

Forestry in one form or another is an important component of rural development. Local communities must be recognized as key players in tree planting, giving rise to the need to promote appropriate forestry technologies. Farmers will develop new attitudes toward and skills in planting trees through exchanged knowledge and experiences once they realize what the benefits are and accept the basic idea of integrating trees into farming systems. Tree planting will be widely adopted when appropriate technologies are promoted and community initiatives supported. Farmers do not need any technical advice on the practice of tree planting, only advice on how to obtain the trees they want and the best quality trees. Foresters must learn the needs and skills of their farming colleagues. Technical interventions should not necessarily supersede already existing technology, but adapt, complement, and improve it.

The critical importance of involving local communities and farmers in tree planting has been taken seriously only in recent years. To develop and promote appropriate, acceptable, and affordable tree planting technologies requires a re-orientation of forestry research and extension. Hitherto, forestry research has concentrated on plantation silviculture, forest biology, and wood technology. Scientific data and information in these fields already exist in the archives of research stations, but are only partially utilized. The challenge now is to translate this information into usable practice for local farmers.[17] An important step forward will be prioritizing research investments to focus on species in the four most widely planted botanical families.

6. RECOMMENDATIONS

6.1 Technical

Local consultants should be engaged for the diagnostic (baseline) surveys needed during the design and formulation of participatory forestry projects to ascertain farmers' perceptions, needs, and species' preferences; determine site compatibility; and assess market prospects. Cultural beliefs and practices related to trees must be identified and local technologies determined. Bank staff may need more time than currently available for such work. Where possible, they should stay with local communities to assess local situations effectively. Developing project designs suited to local needs, including species selected by the communities involved requires appropriate analysis of survey results.

Once project designers identify appropriate species, a suitable specialist should describe in detail the best seed technology and nursery practices to ensure that only the very best plants are provided to farmers in forestry projects. Demonstration plots of both native and exotic species,

[17] This is not to suggest, however, that more research is not required, but rather that it should emphasize areas that have been neglected in the past and ensure that already existing information is put to use.

using appropriate agroforestry practices aligned with traditional techniques, should be established. Simple technologies such as cloning must be promoted in the projects and used where possible to raise better quality and uniform planting stock, but they must be low cost and easily implemented. On-farm research should have project financing to help researchers learn both from and with farmers, adjusting research in terms of complexity, precision, and needs.

Project consultants must make newly developed technologies available to farmers, as quickly, economically, and efficiently as possible. Problems of disseminating information caused by inadequate infrastructures will have to be addressed. Government forestry and agricultural research institutes need to develop more flexibility in identifying farmers' needs and channeling information to a wide set of farmers. Because extension officers tend to be old-fashioned in deciding what farmers need to learn or what they can participate in, changes are needed in their training. As government and agricultural organizations remain the major distributors of information from research, efforts must be made to overcome these institutional problems. By contrast, where private companies are involved they deal directly with farmers, usually efficiently bringing commercial research and extension into projects and making results from research accessible. Private companies and nongovernmental organizations involved in developmental work will be important links in disseminating technologies, and must be included to ensure that the infrastructure can reach the largest possible number of farmers.

Technology transfer must concentrate on techniques that farmers are able to perform and not those that require high levels of skills or are expensive. Complex techniques are best left to professionals and only the improved material from them sold to farmers. Less complex practices, such as selecting mother trees and grafting, will be carried out by farmers who are well organized to participate in seedling supply. Project time and resources will be needed to produce good quality planting stock, both of which may be limiting for the farmer.

The market potential of species recommended for planting must be reviewed to ensure adequate economic returns for farmers and wherever possible species should be selected to satisfy established markets. Production of nonwood products should be encouraged in jointly managed forests to provide intermediate income until the trees are ready for harvesting.

6.2 Research

Support should be given to research for improvement through domestication of species from the four priority families: Leguminosae, Meliaceae, Moraceae, and Myrtaceae. There are some region-specific families, such as the dipterocarps in Asia, vochysias in Central America, and combretacias in Africa that will need support.

6.3 Institutional

Success must be measured in terms of people's capacity to continue tree planting and management for long-term benefits and not the number of trees planted at the end of a project. The emphasis should be on "process" rather than "product" in setting criteria for determining the success of forestry projects in order to address issues of local empowerment, equity, social welfare, and sustainability.

Participatory projects must have continuous interaction between foresters and farmers, and regular monitoring is essential to maintain rapport between farmer and forester. Forest extension agents must be innovative, and versatile and must ensure that extension services are user-driven and not simply transferred technical fixes. Recruiters of extension agents need to look for these special qualities. Projects need to consolidate agriculture and forestry extension services and avoid sending mixed, often confusing, messages to farmers.

ANNEX 1

TREE SPECIES COMMONLY GROWN IN DIFFERENT REGIONS

The tree species farmers planted vary considerably from country to country and within specific agro-ecological zones. This annes provides a general overview of the tree species commonly grown on farms in different countries in Africa, Asia, and Latin America. The primary objective is to identify families, genera, or species on which to concentrate future research work for tree improvement and domestication, because tree breeding is expensive and requires intensive work by multi-disciplinary research teams.[18]

Africa

The tree species farmers planted vary, but overall they prefer fruit trees and other species that produce marketable products like timber, poles, and fodder.

In Uganda farmers have traditionally planted and/or retained different types of trees, *Antiaris toxicaria, Butyrospermum parkii, Canarium schweinfurthii, Milicia excelsa,* on their farms for various purposes. The commonly planted species include *Acacia mearnsii, Albizia coriaria, Entanda abyssinica, Entandrophragma angolense, Erythrina abyssinica, Ficus natalensis* (for bark cloth and provision of shade), *Maesopsis eminii, Markhamia lutea, M. platycalyx, Ricinus communis,* and fruit trees including *Mangifera indica, Artocarpus heterophyllus, Persea americana, Psidium guajava, Citrus* spp., *Tamarindus indica.* Well-known exotic species, such as *Eucalyptus* spp., *Cupressus lusitanica, Pinus* spp., *Leuceana leucocephala, Sesbania sesban* and *Gliricidia sepium* (Oduol and Aluma 1990; Tamale 1990; Warner 1993) are widely planted.

In Rwanda many farmers have planted *Eucalyptus* spp. and *Grevillea robusta* for poles and timber because they are fast-growing, bringing returns quickly. Farmers have also planted and/or maintained a variety of other tree species on their farms, including *Cedrela serrulata, Maesopsis eminii, Markhamia lutea, Erythrina abyssinica, Prosopis* spp., *Ficus* spp., *Ricinus communis, Albizia* spp., *Cassia spectabilis,* and *Leucaena leucocephala* and fruit trees including *Mangifera indica, Artocarpus heterophyllus, Persea americana, Psidium guajava, Citrus* spp. (Balusubramanian and Egli 1989).

The species commonly grown in Burundi are by and large similar to those grown in Rwanda. In addition, the following are grown: *Ficus ingens, Aruninaria alpina, Solanum aculeastrum, Dracaena afromontana, Iboza riparia, Vernonia amygdalina,* and *Acacia mearnsii.*

In western Kenya, especially in the tobacco growing areas, most farmers plant *Eucalyptus* spp. and *Cupressus lusitanica* for fuelwood because they are fast growing (Kerkhof 1990). A

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[18] Noted that the species outline is based on a desk literature review. Field data collection will be necessary in the future to compile a precise list of species farmers prefer by country and by agro-ecological region. The sequence in which the species are listed does not show their order of prevalence or importance and the choice of countries depended on availability of literature.

study carried out in Embu on the slopes of Mount Kenya identified the following as some of the species most planted by farmers: *Commiphora* spp., *Melia volkensii, Tamarindus indica, Balanites aegyptiaca, Cordia abyssinica, Croton megalocarpus, Terminalia prunioides, Grevillea robusta, Cassia siamea, C. spectabilis,* and *Melia azedarach* (Shepherd 1990). In Siaya, farmers identified the following species they felt grew well with crops: *Croton* spp., *Leuceana leucocephala, Sesbania sesban, Calliandra calothyrsus,* and *Samanea saman*. In the dry zones, the species commonly planted or protected include *Faidherbia albida, Acacia senegal, A. tortilis, Butyrospermum parkii, Parkia biglobosa, Phoenix dactylifera, Detarium senegalense,* and *Parinari* spp. (Maydell 1987).

In Tanzania the commonly grown trees include *Cassia siamea, Albizia lebbek, Melia azedarach, Delonix regia, Acacia nilotica, Eucalyptus* spp., *Grevillea robusta, Parkinsonia aculeata,* and fruit trees including *Mangifera indica, Persea americana, Psidium guajava, Citrus* spp., *Tamarindus indica* (Warner 1993).

In Malawi fruit trees, particularly *Mangifera indica*, are the most commonly planted trees. Others species grown for timber, poles, and fuelwood include *Eucalyptus* spp., *Cassia siamea, Gmelina arborea, Toona ciliata,* and *Melia azedarach,* and trees commonly retained on farms include *Faidherbia albida, Acacia polyacantha, Albizia* spp., *Combretum ternifolium, Erythrina tomentosa, Markhamia obtusifolia, Parinari curatifolia, Pericopsis angolense, Pterocarpus angolense,* and *Ziziphus mauritania* (Warner 1993).

In Zambia most farmers plant fruit trees, including *Mangifera indica, Carica papaya, Psidium guajava, Citrus* spp. Other species commonly grown or retained on farms include *Faidherbia albida, Pterocarpus angolensis,* and *Leuceana leucocephala* (Kerkhof 1990).

In Zimbabwe most farmers also planted fruit trees, including *Mangifera indica, Carica papaya, Citrus sinensis, Ficus capensis,* and *Persea americana*. Other trees planted include *Eucalyptus* spp.

In Nigeria major forest plantation species include *Gmelina arborea, Tectona grandis, Nauclea diderrichii, Terminalia ivorensis, Azadirachta indica,* and *Pinus caribaea,* and to a lesser extent *Cassia siamea* and *Eucalyptus* spp. Trees on farms and home gardens include *Cedrela odorata, Antiaris africana, Terminalia catapa, T. superba, Vernonia amygdalina, Moringa oleifera, Ficus capensis, Pterocarpus* spp., *Cola acuminata, Albizia ferruginea, A. zygia, Canarium schweinfurthii,* and *Milicia excelsa*. In the drier parts of the country, farmers commonly grow the following trees: *Faidherbia albida, Acacia nilotica, A. senegal, A. tortilis, A. seyal, Prosopis juliflora, P. africana, Parkia biglobosa,* and *Vitellaria paradoxum*. Farmers have also traditionally retained various fruit trees on their farms, including *Chrysophyllum albidum, Cola acuminata, Dacryodes edulis, Irvingia gabonensis, Pentaclethra macrophylla, Treculia africana,* and *Elaeis guineensis* (Lowe 1987; Okafor and Fernandes 1987).

In Niger, Mali, and other Sahelian countries, commonly planted or retained species include *Faidherbia albida, Acacia nilotica, A. senegal, A. raddiana, Adansonia digitata, Parkia clappertoniana, Tamarindus indica, Balanites aegyptiaca, Borassus aethiopium, Ziziphus* *mauritiana, Prosopis juliflora, P. africana, P. chilensis, Khaya senegalensis, Salvadora purica, Xeminia americana*, and *Azadirachta indica* (anonymous 1983; Kerkhof 1990).

Asia

Several tree species are grown in Asia for different purposes. Like in Africa, the trees farmers planted vary from country to country. However, certain species, such as *Tectona grandis, Albizia* spp., and fruit trees such as *Artocarpus heterophyllus, Mangifera indica,* and *Cocos nucifera,* are more universally planted (Mehl 1991).

In India the tree and shrub species farmers commonly plant include *Tectona grandis, Melia azedarach, E. tereticornis, Populus deltoides, P. euphratica, Dalbergia sissoo, Albizia procera, Acacia lebbek, Azadirachta indica, Ailanthus altissima, A. excelsa, Hardwaickia binata, Salix tetrasperma, Casuarina equisetifolia, Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora, S. sesban, Paraserianthes falcataria, Moringa oleifera, Paulownia tomentosa,* and *Dendrocalamus strictus* (male bamboo) in humid areas and *Acacia nilotica, A. catechu, A. leucophloea, A. auriculiformis, Cassia siamea, Faidherbia albida, Hardwickia binata*, and *Prosopis juliflora* in dry areas (Banerjee, pers. comm.; Hegde 1988; Pathak 1991).

In Bangladesh the predominantly grown species include *Phoenix dactylifera, P. sylevestris* (wild date palm), *Aegle marmelos, Syzygium cuminii, Albizzia* spp., *Bambusa arundinacea, Borassus flabellifer, B. aethiopium, Litchi chinensis, Acacia nilotica, A. catechu, Ziziphus jujuba, Artocarpus heterophyllum, Mangifera indica, Cocos nucifera* and *Psidium guajava* (Abedin and others 1988; Mehl 1991).

In Indonesia some of the common trees managed as part of tree gardens include *Toona sinensis, Durio zibethinus, Pterospermum javanicum, Leuceana leucocephala, Gliricidium sepium* and *Cinnamomum burmani* (Michon and Bompart 1986). Other common species include *Paraserianthes falcataria, Swietenia macrophylla, Tectona grandis, Maesopsis eminiii, Schima noronhae, Albizia procera, Parkia speciosa, Achras zapota, Dendrocalamus* spp., and *Gigantocloa apus*. Fruit trees include *Artocarpus heterophyllum, Mangifera indica, Cocos nucifera,* and *Persea americana* (Mehl 1991).

In Nepal some of the commonly planted species include *Dalbergia sisoo, D. latifolia, Eucalyptus camaldulensis, Prunus cerasoides, Castinopsis indica, Betula alnoides, Alnus nepalensis, Schima wallinchii, Shorea robusta, Erythrina arborescens, Ficus glaberrima, F. lacor, F. semicordata, Arundineria* spp., *Dendrocalamus strictus, D. hamiltonii, Litsea monopetala, Myrica naji, Thysanolaena agrostis, Cassia siamea, Acacia catechu, A. auriculoformis*, and *Leucaena leucocephala* (Gilmour and Fisher 1991; Sapkota 1988).

In the Philippines fruit tree species include *Cocos nucifera, Psidium guajava, Artocarpus heterophyllum, Persea americana, Mangifera indica, Citrus microcarpa,* and *C. nobilis*, and common nonfruit trees include *Leuceana leucocephala, Gliricidia sepium, Shorea polysperma, Chrysophyllum cainito, Sandoricum koetjape, Dipterocarpus grandiforus, Alnus maritima, Vitex perviflora, Syzygium cuminii*, and *Paraserianthes falcataria* (Mehl 1991).

In Sri Lanka species commonly grown include *Artocarpus heterophyllus, Mangifera indica, Cocos nucifera, Psidium guajava, Persea americana, Gliricidia sepium, Tamarindus indica, Exacum trinerva, Careya arborea, Madhuca longifolia, Pongamia pinata, Persea gratissima, Syzgium faranica, Croton laccifer, Pterocarpus marsupium*, and *Thespecia populnea* (Mehl 1991).

In Thailand common species include *Shorea obtusea, S. siamensis, Dipterocarpus tuberculata, D. alatus, D. obtusifolia, Tamarindus indica, Melia azedarach, Gmelina arborea, Tectona grandis, Cassia siamea, Xylia xylocarpa, Ceiba petandra, Auricularia polytricha, Azadirachta indica, Pterocarpus macrocarpus, Irvingia malayana, Cotylelobium melanoxylon,* and *Leucaena leucocephala*, and fruit trees include *Mangifera indica, Artocarpus heterophyllus,* and *Cocos nucifera* (Bhumibhamon 1988; Mehl 1991; Pragtong 1986).

Latin America

In Latin America, tree growing by smallholder farmers on their farms has been limited, although farm tree planting is growing rapidly. Most of the existing tree planting programs have focused on establishing industrial plantations, mainly growing eucalyptus and pines. In some countries a few exotic and indigenous species have been planted in farms.

In Costa Rica agroforestry systems include trees such as *Cordia alliodora, Bactris gasipaes, Tectona grandis, Swietenia humilis, Macadamia entegrifolia,* and *Cedrela odorata* as shade trees; *Erythrina poeppigiana* and *Gliricidia sepium* in alley farming; *Alnus acuminata* over pastures; *Erythrina berteroana, E. glauca, Spondias purpurea, Ficus pertusa,* and *Croton glabellus* as live fences; and fruit trees including *Artocarpus incisa, A. integrifolia, Cocos nucifera*, and *Psidium guajava*. Other species, commonly grown as forest blocks or woodlots include *Eucalyptus deglupta* (Budowski, 1987; Combe and Budowski, 1979).

In Mexico, species grown on farms include *Magnolia yoroconte, Cedrela odorata, Inga* spp., *Prosopis* spp., *Leuceana esculanta, Pithecolobium,* spp., *Manilkara zapota* (for producing latex used to make chewing gum), *Psuedobombax ellipticum* (for veneer), *Brosimum alicastrum, Burseria simaruba*, and *Metopium brownei* (Richards 1993).

In Peru the species commonly grown with crops include *Cedrelinga catenaeformis, Cedrela odorata, Caryocar glabrum, Schlizolobium amazonian, Clarisia racemosa, Vitex pseudolea,* and *Inga* spp., and fruit trees such as *Persea americana, Mangifera indica, Psidium guajava, Cocos nucifera, Elaeis guineensis* and *Citrus* spp (Reategui 1979).

In Ecuador the most common species include *Eucalyptus globulus, Cupressus* spp., *Acacia manacantha, Cedrela montana, Alnus jorullensis, Syzygium jambos,* and *Prosopis juliflora,* and fruit trees such as *Psidium guajava, Artocarpus alfalfis, Inga edulis, Persea americana,* and *Citrus* spp. (Lojan 1979).

Tree Species Commonly Grown on Plantations

Plantation forestry continues to play a significant role in the promotion of tree planting in many countries. The species used on plantations vary but the most common genera are *Eucalyptus, Pinus,* and *Tectona,* which in 1980 accounted for about 85 percent of all plantations in the tropics (Evans 1992). The most commonly grown species in plantations are listed in Table A1.

Table A1: Species Commonly Grown on Tropical Plantations

Genus/Group	Species (in order of relative importance)	Percentage
Eucalyptus	*E. grandis, camaldulensis, globulus, saligna, tereticornis, robusta, citriodora, urophylla, deglupta*, and others	37.5
Pinus	*P. patula, caribaea, eliottii, merkusii, kesiya, oocarpa*	33.7
Other conifers	*Araucaria cunninghamii, A. angustifolia, Cupressus lusitanica*	3.0
Tectona	*T. grandis* (teak)	14.2
Other hardwoods	*Acacia, Gmelina, Leuceana, Grevillea, Melia, Terminalia, Albizia, Prosopis, Casuarina, Cordia*	11.6
		100.0

Source: Evans (1992, pp. 36).

ANNEX 2

LIST OF FAMILIES, GENERA, AND SPECIES OF COMMONLY GROWN TREES

Africa

FAMILY	GENUS	SPECIES
Leguminosae	*Acacia*	*mearsii*
Leguminosae	*Acacia*	*nilotica*
Leguminosae	*Acacia*	*polycantha*
Leguminosae	*Acacia*	*raddiana*
Leguminosae	*Acacia*	*senegal*
Leguminosae	*Acacia*	*seyal*
Leguminosae	*Acacia*	*tortilis*
Leguminosae	*Albizia*	*coriaria*
Leguminosae	*Albizia*	*ferruginea*
Leguminosae	*Albizia*	*lebbek*
Leguminosae	*Albizia*	*zygia*
Leguminosae	*Calliandra*	*calothyrsus*
Leguminosae	*Cassia*	*siamea*
Leguminosae	*Cassia*	*spectabilis*
Leguminosae	*Delonix*	*regia*
Leguminosae	*Detarium*	*senegalense*
Leguminosae	*Entanda*	*abyssinica*
Leguminosae	*Erythrina*	*abyssinica*
Leguminosae	*Erythrina*	*tomentosa*
Leguminosae	*Faidherbia*	*albida*
Leguminosae	*Gliricidia*	*sepium*
Leguminosae	*Leuceana*	*leucocephala*
Leguminosae	*Parkia*	*biglobosa*
Leguminosae	*Parkia*	*clappertoniana*
Leguminosae	*Parkinsonia*	*aculeata*
Leguminosae	*Pentaclethra*	*macrophylla*
Leguminosae	*Pericopsis*	*angolense*

FAMILY	GENUS	SPECIES
Leguminosae	*Prosopis*	*africana*
Leguminosae	*Prosopis*	*juliflora*
Leguminosae	*Samanea*	*saman*
Leguminosae	*Sesbania*	*sesban*
Leguminosae	*Tamarindus*	*indica*
Moraceae	*Antiaris*	*africana*
Moraceae	*Antiaris*	*toxicaria*
Moraceae	*Artocarpus*	*heterophyllus*
Moraceae	*Artocarpus*	*integrafolia*
Moraceae	*Ficus*	*capensis*
Moraceae	*Ficus*	*ingens*
Moraceae	*Ficus*	*natalensis*
Moraceae	*Milicia*	*excelsa*
Moraceae	*Treculia*	*africana*
Meliaceae	*Azadirachta*	*indica*
Meliaceae	*Cedrela*	*odorata*
Meliaceae	*Cedrela*	*serrulata*
Meliaceae	*Entandrophragma*	*angolense*
Meliaceae	*Khaya*	*senegalensis*
Meliaceae	*Melia*	*azedarach*
Meliaceae	*Melia*	*volkensii*
Meliaceae	*Toona*	*ciliata*
Combretaceae	*Combretum*	*ternifolium*
Combretaceae	*Terminalia*	*catapa*
Combretaceae	*Terminalia*	*ivorensis*
Combretaceae	*Terminalia*	*prunioides*
Combretaceae	*Terminalia*	*superba*
Palmaceae	*Borassus*	*ethiopium*
Palmaceae	*Cocos*	*nucifera*
Palmaceae	*Elaeis*	*guineensis*
Palmaceae	*Phoenix*	*dactylifera*

FAMILY	**GENUS**	**SPECIES**
Bignoniaceae	*Markhamia*	*lutea*
Bignoniaceae	*Markhamia*	*obtusifolia*
Bignoniaceae	*Markhamia*	*platycalyx*
Burseraceae	*Canarium*	*schweinfurthii*
Burseraceae	*Commiphora*	*Commiphora sp.*
Burseraceae	*Dacryodes*	*edulis*
Boraginaceae	*Cordia*	*abysisinica*
Boraginaceae	*Cordia*	*alliodora*
Myrtaceae	*Eucalyptus*	*Eucalyptus sp.*
Myrtaceae	*Psidium*	*guajava*
Sapotaceae	*Butyrospermum*	*parkii*
Sapotaceae	*Chrysophyllum*	*albidum*
Sapotaceae	*Vitellaria*	*paradoxum*
Rhamnaceae	*Maesopsis*	*eminii*
Rhamnaceae	*Ziziphus*	*mauritania*
Anacardiaceae	*Mangifera*	*indica*
Asteraceae	*Vernonia*	*amygdalina*
Balanitaceae	*Balanites*	*aegyptiaca*
Caracaceae	*Carica*	*papaya*
Casuarinaceae	*Casuarina*	*equistifolia*
Chrysobalanaceae	*Parinari*	*curatifolia*
Cupressaceae	*Cupressus*	*lusitanica*
Euphobiaceae	*Croton*	*megalocarpus*
Graminae	*Arundinaria*	*alpina*
Ixononthaceae	*Irvingia*	*gabonensis*
Lauraceae	*Persea*	*americana*
Liliaceae	*Dracaena*	*afromontana*
Moringaceae	*Moringa*	*oleifera*
Olacaceae	*Xeminia*	*americana*
Proteaceae	*Grevillea*	*robusta*
Pterocarpaceae	*Pterocarpus*	*angolense*

FAMILY	GENUS	SPECIES
Rubiaceae	*Nauclea*	*diderrichii*
Rutaceae	*Citrus*	*Citrus sp.*
Solanaceae	*Solanum*	*aculeastrum*
Sterculiaceae	*Cola*	*acuminata*
Verbenaceae	*Gmelina*	*arborea*

Asia

FAMILY	GENUS	SPECIES
Leguminosae	*Acacia*	*auriculiformis*
Leguminosae	*Acacia*	*catechu*
Leguminosae	*Acacia*	*leucopholea*
Leguminosae	*Acacia*	*nilotica*
Leguminosae	*Albizia*	*lebbek*
Leguminosae	*Albizia*	*procera*
Leguminosae	*Calliandra*	*calothyrsus*
Leguminosae	*Cassia*	*siamea*
Leguminosae	*Dalbergia*	*latifolia,*
Leguminosae	*Dalbergia*	*sissoo*
Leguminosae	*Erythrina*	*arborescens*
Leguminosae	*Faidherbia*	*albida*
Leguminosae	*Gliricidia*	*sepium*
Leguminosae	*Hardwickia*	*binata*
Leguminosae	*Leuceana*	*diversifolia*
Leguminosae	*Leuceana*	*leucocephala*
Leguminosae	*Paraserianthes*	*falcataria*
Leguminosae	*Parkia*	*speciosa*
Leguminosae	*Pentaclethra*	*macrophylla*
Leguminosae	*Pongamia*	*pinata*
Leguminosae	*Prosopis*	*cineraria,*
Leguminosae	*Prosopis*	*juliflora*
Leguminosae	*Sesbania*	*grandiflora*
Leguminosae	*Sesbania*	*sesban*
Leguminosae	*Tamarindus*	*indica*
Leguminosae	*Xylia*	*xylocarpa*
Dipterocarpaceae	*Dipterocarpus*	*alatus*
Dipterocarpaceae	*Dipterocarpus*	*grandiforus*
Dipterocarpaceae	*Dipterocarpus*	*obtusifolia*
Dipterocarpaceae	*Dipterocarpus*	*tuberculata*

FAMILY	GENUS	SPECIES
Dipterocarpaceae	*Shorea*	*obtusea*
Dipterocarpaceae	*Shorea*	*polysperma*
Dipterocarpaceac	*Shorea*	*robusta*
Dipterocarpaceac	*Shorea*	*siamensis*
Myrtaceae	*Eucalyptus*	*cameldulensis*
Myrtaceac	*Eucalyptus*	*saligna*
Myrtaceac	*Eucalyptus*	*tereticornis*
Myrtaceac	*Psidium*	*guajava*
Myrtaceac	*Syzygium*	*cuminii*
Myrtaceac	*Syzygium*	*jaranica*
Gramineac	*Bambusa*	*arundinacea*
Gramineae	*Dendrocalamus*	*hamiltonii*
Gramineac	*Dendrocalamus*	*strictus*
Gramineac	*Gigantochloa*	*apus*
Gramineac	*Thysanolaena*	*agrostis*
Meliaceae	*Azadirachta*	*indica*
Meliaceac	*Melia*	*azedarach*
Meliaceac	*Sandoricum*	*koetjape*
Meliaceac	*Swietenia*	*macrophylla*
Meliaceae	*Toona*	*sinensis*
Moraceae	*Artocarpus*	*altilis*
Moraceac	*Artocarpus*	*heterophyllus*
Moraceac	*Ficus*	*glaberrima*
Moraceac	*Ficus*	*lacor*
Moraceac	*Ficus*	*semicordata*
Lauraceac	*Cinnamomum*	*burmani*
Lauraceac	*Litsea*	*monopetala*
Lauraceae	*Persea*	*americana*
Lauraceae	*Persea*	*gratissima*
Palmaceac	*Borassus*	*aethiopium*
Palmaceae	*Borassus*	*flabellifer*

FAMILY	GENUS	SPECIES
Palmaceae	*Cocos*	*nucifera*
Palmaceae	*Phoenix*	*dactylifera*
Rutaceae	*Aegle*	*marmelos*
Rutaceae	*Citrus*	*microcarpa*
Rutaceae	*Citrus*	*nobilis*
Salicaceae	*Populus*	*deltoides*
Salicaceae	*Populus*	*euphratica*
Salicaceae	*Salix*	*tetrasperma*
Sapotaceae	*Achras*	*zapota*
Sapotaceae	*Chrysophyllum*	*cainito*
Sapotaceae	*Madhuca*	*longifolia*
Verbenaceae	*Gmelina*	*arborea*
Verbenaceae	*Tectona*	*grandis*
Verbenaceae	*Vitex*	*perviflora*
Pterocarpaceae	*Pterocarpus*	*macrocarpus*
Pterocarpaceae	*Pterocarpus*	*marsupium*
Rhamnaceae	*Maesopsis*	*eminii*
Rhamnaceae	*Ziziphus*	*jujuba*
Simaroubaceae	*Ailanthus*	*altissima*
Simaroubaceae	*Ailanthus*	*exclesa*
Theacceae	*Schima*	*noronhae*
Theacceae	*Schima*	*wallinchii*
Anacardiaceae	*Mangifera*	*indica*
Auriculariaceae	*Auricularia*	*polytricha,*
Bambusaceae	*Arundineria*	*wightiana*
Barringtoniaceae	*Careya*	*arborea*
Betulaceae	*Betula*	*alnoides*
Bombacaceae	*Ceiba*	*pentandra*
Casuarinaceae	*Casuarina*	*equistifolia*
Cupressaceae	*Cupressus*	*lusitanica*
Euphobiaceae	*Croton*	*laccifer*

FAMILY	GENUS	SPECIES
Gentianaceae	*Canscora*	*trinerva*
Icacinaceae	*Castinopsis*	*indica*
Ioxononthaceae	*Irvingia*	*malayana*
Malvaceae	*Thespesia*	*populnea*
Moringaceae	*Moringa*	*oleifera*
Myricaceae	*Myrica*	*naji*
Rosaceae	*Prunus*	*cerasoides*
Sapindaceae	*Litchi*	*chinensis*
Scrophulariaceae	*Paulownia*	*tomentosa*
Sterculiaceae	*Pterospermum*	*javanicum*

Latin America

FAMILY	GENUS	SPECIES
Leguminosae	*Acacia*	*manacantha*
Leguminosae	*Albizia*	*guachapele*
Leguminosae	*Dipteryx*	*panamensis*
Leguminosae	*Enterolobium*	*cyclocarpum*
Leguminosae	*Erythrina*	*berteroana*
Leguminosae	*Erythrina*	*glauca*
Leguminosae	*Erythrina*	*poeppigiana*
Leguminosae	*Faidherbia*	*albida*
Leguminosae	*Gliricidia*	*sepium*
Leguminosae	*Hymenaea*	*courbaril*
Leguminosae	*Inga*	*edulis*
Leguminosae	*Leuceana*	*esculanta*
Leguminosae	*Pithecellobium*	*saman*
Leguminosae	*Prosopis*	*juliflora*
Leguminosae	*Schizolobium*	*parahybum*
Leguminosae	*Schlizolobium*	*amazonian*
Leguminosae	*Sesbania*	*sesban*
Leguminosae	*Stryphondendron*	*excelsum*
Leguminosae	*Tamarindus*	*indica*
Meliaceae	*Azadirachta*	*indica*
Meliaceae	*Carapa*	*gulanensis*
Meliaceae	*Cedrela*	*montana*
Meliaceae	*Cedrela*	*odorata*
Meliaceae	*Cedrela*	*tonduzii*
Meliaceae	*Swietenia*	*humilis*
Moraceae	*Artocarpus*	*alfalfis*
Moraceae	*Artocarpus*	*heterophyllus*
Moraceae	*Artocarpus*	*incisa*
Moraceae	*Artocarpus*	*integrifolia*

FAMILY	GENUS	SPECIES
Moraceae	*Brosimum*	*alicastrum*
Moraceae	*Ficus*	*pertusa*
Anacardiaceae	*Astronium*	*graveolens*
Anacardiaceae	*Mangifera*	*indica*
Anacardiaceae	*Metopium*	*brownei*
Anacardiaceae	*Spondias*	*purpurea*
Palmaceae	*Bactris*	*gasipaes*
Palmaceae	*Cocos*	*nucifera*
Palmaceae	*Elaeis*	*guineensis*
Palmaceae	*Phoenix*	*dactylifera*
Myrtaceae	*Eucalyptus*	*deglupta*
Myrtaceae	*Psidium*	*guajava*
Myrtaceae	*Syzygium*	*jambos*
Rutaceae	*Citrus*	*microcarpa*
Rutaceae	*Citrus*	*nobilis*
Rutaceae	*Zanthoxylum*	*mayanum*
Betulaceae	*Alnus*	*acuminata*
Betulaceae	*Alnus*	*jorullensis*
Bignoniaceae	*Jacaranda*	*copaia*
Bignoniaceae	*Tabebuia*	*rosea*
Combretaceae	*Terminalia*	*amazonia*
Combretaceae	*Terminalia*	*oblonga*
Euphobiaceae	*Croton*	*glabellus*
Euphorbiaceae	*Hyeronima*	*alchorneiodes*
Verbenaceae	*Tectona*	*grandis*
Verbenaceae	*Vitex*	*psuedolea*
Vochysiaceae	*Vochysia*	*guatemalensis*
Vochysiaceae	*Vochysia*	*ferruginea*
Apocynaceae	*Aspidosperma*	*megalocarpon*
Bombacaccae	*Bombacopsis*	*quinatum*
Boraginaccae	*Cordia*	*alliodora*

FAMILY	GENUS	SPECIES
Burseraceae	*Bursera*	*simaruba*
Caryocaraceae	*Caryocar*	*glabrum*
Faboideae	*Platymiscium*	*pleiostachum*
Guttiferae	*Calophyllum*	*brasiliense*
Lauraceae	*Persea*	*americana*
Magnoliaceae	*Magnolia*	*yoroconte*
Myristicaceae	*Virola*	*koschnyi*
Proteaceae	*Macadamia*	*entegrifolia*
Sapotaceae	*Manilkara*	*zapota*
Simaroubaceae	*Simaruouba*	*amara*
Tiliaceae	*Goethalsia*	*meiantha*

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