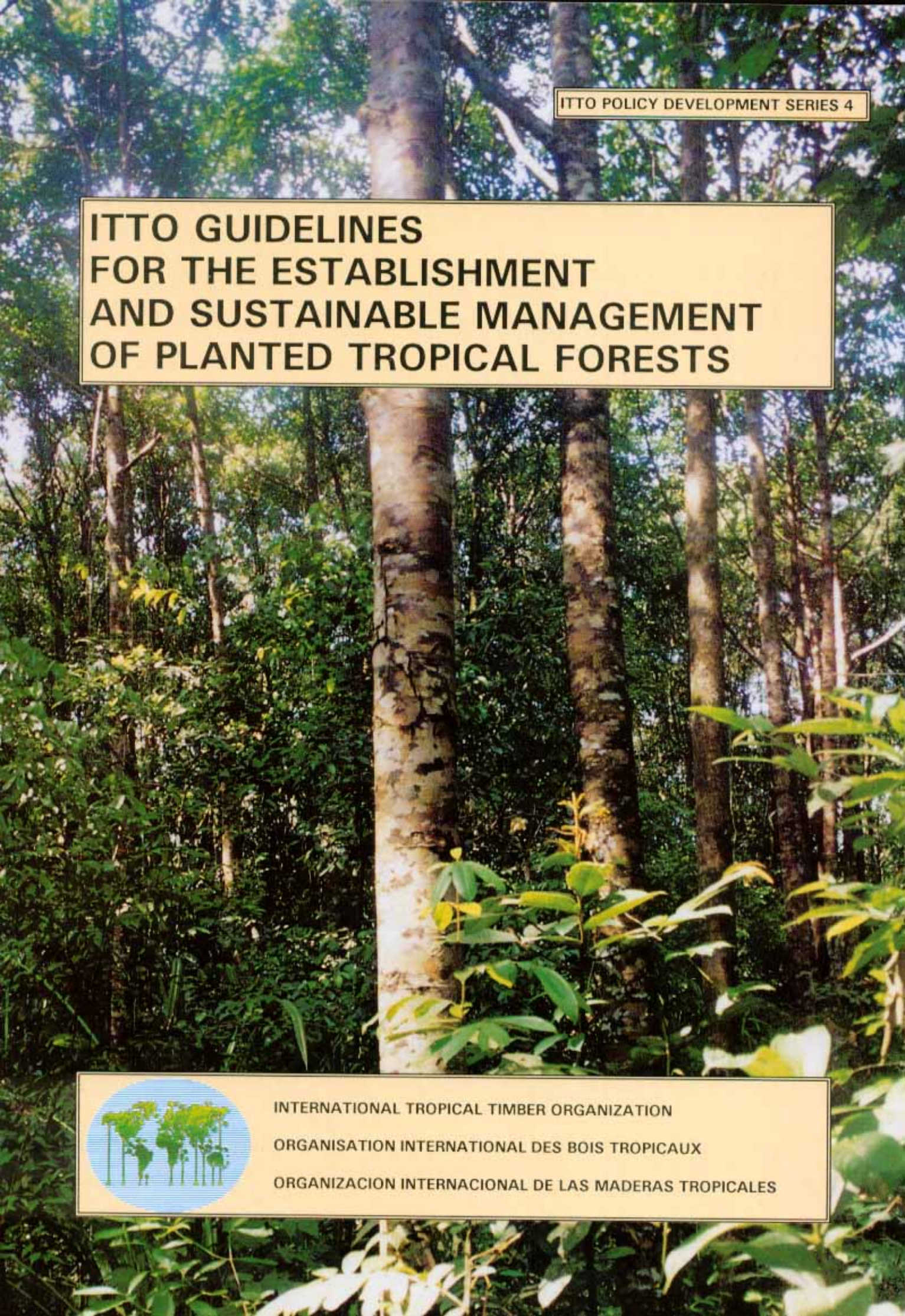

ITTO POLICY DEVELOPMENT SERIES 4

ITTO GUIDELINES FOR THE ESTABLISHMENT AND SUSTAINABLE MANAGEMENT OF PLANTED TROPICAL FORESTS

INTERNATIONAL TROPICAL TIMBER ORGANIZATION

ORGANISATION INTERNATIONAL DES BOIS TROPICAUX

ORGANIZACION INTERNACIONAL DE LAS MADERAS TROPICALES

COVER PHOTO: Engkabang jantong (Shorea Macrophylla) planted 1977 at 5 x 10m spacing to produce high class timber and illipe nuts. A species-rich, diverse understory of invading tree palm and herb species with natural regeneration of Engkabang jantong which will eventually form a self-maintaining and near natural complex multipurpose forest. Engkabang diameter breast height (dbh) at age 15 years (1992) ranges from 25-50 cm; its mean annual increment is more than 12m³/ha/ann. And is still accelerating. Semengoh Forest Reserve, Research Plot 76, Block A1. Sarawak, Malaysia

PHOTOGRAPHED BY: E.F. BRUENIG

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ITTO POLICY DEVELOPMENT 4

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FOREWORD

It is with great pleasure that I hereby introduce this the fourth publication of ITTO Policy Development Series. This publication represents another significant milestone for our young organization as we seek to meet the overall objective of achieving the conservation and management of tropical forests on a sustainable basis. It also represents the continuation of the constructive cooperation between the member countries of ITTO, conservation NGOs and the trade in tropical timber which in 1990 saw the release of the first publication in our Policy Development Series, the ITTO Guidelines for the Sustainable Management of Natural Tropical Forests.

Guidelines for "best practice" for planted tropical forests were first requested by the ITTO Council at its 7th Session in November 1990. Funds were provided to convene an international panel of experts to review a draft set of guidelines which was subsequently prepared by Prof. E.F. Bruenig of the Institute for World Forestry and Ecology at the Federal Research Center for Forestry and Forest Products in Hamburg. The Government of Germany provided financial assistance for the preparation of this initial draft.

The 11 member panel was comprised of representatives from tropical timber producer and consumer countries, environmental NGO's(WWF), UN Agencies (FAO) and the trade in tropical timber (UCBT). They were supported in their deliberations by the ITTO Secretariat and the staff from the Federal Research Center for Forestry and Forest Products in Hamburg where their meeting was held in April 1991. Following this workshop, the report of the panel was reviewed, revised and endorsed at the Tenth Session of ITTC in Quito, Ecuador in June 1991.

The guidelines are not meant to be an encyclopedic silvicultural manual for the establishment and management of planted tropical forests. Rather, they provide a succinct summary of the major issues and principles that need to be addressed in the planning, establishment and management of planted forests in tropical environments. They also aim to introduce readers to the existing more detailed literature on various aspects of the establishment and management of planted forests in the tropics that has been produced by FAO and other agencies. It is hoped that this will help to make this already well documented wealth of both research and management experience more accessible to operational forest managers and planners working in tropical countries.

The report has four major sections which emphasize the various steps in the sustainable establishment and management of planted tropical forests vis, the development of appropriate policy and legislation, feasibility assessment, planted forest establishment and post-establishment management. Each of these sections contains a set of basic principles and recommended actions considered appropriate. The text has been intentionally kept short and concise in order to be readable for a wide audience. Also, because the primary target group is the tropical forest managers and administrators who work in settings where ecological, economic and social circumstances can vary considerably, the recommended actions are proposed in general terms. The framework of these Guidelines should therefore be modified and shaped into more specific guidelines which are compatible with regional and national circumstances.

The dedication and generosity of the experts and consultants who worked to formulate these Guidelines are acknowledged. The Guidelines they produced represent a significant step in the on-going process of developing sustainable management for all tropical forests. They will no doubt need to be modified and expanded as we go along and gain a better understanding of the complexities of managing tropical forest resources. However, the immediate challenge lies in the implementation of these Guidelines on the ground, so that we can gain the experience that will enable improved practices to be developed in the future. This calls for even greater efforts, cooperation and understanding, but the Guidelines themselves are an excellent start to this process. I am therefore sure that this publication will make a major contribution to achieving ITTO's target of producing tropical timber from sustainably managed forests by the year 2000.

Yokohama, Japan
January, 1993

B.C.Y.Freezailah
Executive Director

1. INTRODUCTION

Planted forests are an important element of land use in the tropical world. Planted forests can fulfill many of the productive and protective roles of the natural forest. When they are adequately planned, planted forests can help stabilize and improve the environment. However, conservation of local plant and animal species and ecosystems and ensuring ecological stability at the landscape level require complementary action within integrated land-use and development plans.

Deforestation of all kinds is increasingly becoming a major problem in the world. The world's population is anticipated to double in the next 60 years and social and economic development will increase demand for and consumption of wood products. This demand can only be met by appropriate forest conservation and development, including the establishment and improved silvicultural management of plantations.

Combatting desertification and soil erosion also may require establishment of protective and productive forest plantation. The conservation and preservation of natural forest will certainly become more difficult if complementary plantation forest are not established in an appropriate manner and scale. On the other hand, it would be wrong to assume that planted forests could substitute for natural forests and replace them as source of raw materials and environmental and social benefits. Such assumptions could lead to natural tropical forests being cleared to provide sites for industrial forest plantations which promise to produce much higher volumes of timber per unit area. However, major social conflicts may also arise from industrial plantations displacing existing landholders and disrupting prevailing patterns of land-use. Possible detrimental environmental and ecological effects of large-scale introductions of exotic tree species are also emerging as major concerns and policy issues in some tropical countries and amongst the international community.

Planted tropical forests can achieve extremely high levels of timber production and may therefore offer tropical countries a considerable competitive advantage in the international timber trade. However, despite rapid initial growth, many tropical plantation forests have not fulfilled their early promise and a number of significant problems have arisen.

Some tropical plantations have caused environmental problems through reductions in local biodiversity at both the level of plant and animal species and the landscape level. Poorly designed plantations may even accelerate erosion, water pollution and stream-bed sedimentation. In other cases, plantations have been planted but not adequately maintained. In still other cases, plantation forests have successfully reached maturity only to find that there were no markets for the species that were grown. There is therefore a real need to ensure that the establishment of industrial tropical timber plantations does not lead to the over-production of particular species or classes of forest products similar to the over-production which has occurred with many agricultural plantation crops in the tropics with such devastating economic consequences.

These Guidelines on sustainable management of planted tropical forests have been prepared to help promote sustainability in all aspects of tropical forest management and to help solve existing problems. They have also been prepared to help prevent repeating mistakes made earlier elsewhere. It is hoped that the production of the Guidelines may:

* stimulate policy development and the adoption of comprehensive planning processes;

* help to ensure environmentally and socially acceptable selection of site, species and forest design;

* help to adopt appropriate procedures of establishment and management for all types of planted forests in the tropics;

* help planners to reduce the risk of selecting unsuitable species, provenances or populations (clones);

* stimulate the adoption of appropriate management throughout the whole of the life of the planted forest with particular emphasis on the often neglected post-establishment period;

* focus the attention of forest managers and planners on the importance of pre-establishment and continued market evaluation and the ultimate end use of the forest products they are attempting to grow;

* help to prevent the misallocation of scarce human, land and financial resources.

These Guidelines present a fundamental concepts, expressed as a set of principles and recommended actions. The Guidelines constitute the international reference standard established by ITTO for the development of more specific guidelines, at the national level, for the sustainable establishment and management of planted tropical forests for timber production and other purposes. The development, application, adherence and enforcement of national guidelines based on this standard are matters for national decision by individual timber producing countries.

Tree planting activities encompass diverse agents: state administration and public agencies, large or small industrial and commercial enterprises, regional authorities, communities and individuals. While the guidelines present universally relevant fundamental principles, their specific application depends on the particular condition, of site and case with respect the natural, technological, economic, societal-cultural, and socio-political situation. The eventual role of a planted forest in the general pattern of resource use depends on a mix of social, economic and environmental factors. Decisions on location, site, species, silviculture, management and objectives must therefore comply with local and national political, social, economic and environmental conditions. Of central importance are purpose and functions of the planted forest and the way by which these are achieved.

ITTO attaches high priority to the definition of the essential principles and associated actions which should serve to guide the development of national guidelines in each country so that they may conform to the international reference standard agreed within the Organization. The Organization also gives high priority to assisting member countries, which may need and request assistance, to obtain such outside technical and financial help as they may require to develop their own national guidelines.

The ITTO Guidelines are presented in the form of general principles and recommended actions ranging from general policy considerations to aspects of operational forestry. They are relevant to any deliberate planting of trees in tropical environments. However, they outline principles and actions that should be particularly relevant to the establishment of intensively managed large scale plantation forests for industrial wood production. These general principles are also complemented by Appendix 4 which outlines some more specific issues that need to be considered when planning tree plantings in different circumstances such as in the establishment of agro-silvicultural forests in rural lands.

2. Policy and Legislation

2.1 Forest Policy

Principle 1: The forest sector offers major opportunities for sustainable socio-economic development and the improvement of the quality of life in tropical countries. All countries therefore need to understand both the existing and future demands for all benefits, goods and services from all types and categories of forests. Governments and people must clearly judge and understand the capacity of their forests and forest lands to provide these benefits, goods and services. In particular, studies of both the domestic and export sectors are required to define the country's need for planted forests to complement and supplement their natural forests in all respects, including as a resource base in a long-term wood production strategy.

Natural forests provide optimal comprehensive environmental and habitat protection. First priority should be to maintain and restore natural vegetation cover. Even when natural forest cover is degraded, rehabilitation by natural regeneration rather than replanting is generally the preferred option. Compatible forms of timber harvesting and production management on suitable sites could play a positive role in forest areas where the main management objective is environmental protection.

Recommended Action 1: Undertake comprehensive studies to determine:

* the demand for forest products in both the domestic and export sectors;
* the demand for environmental protection;
* the capacity of the existing forest estate to provide these goods and services;
* the location and extent of the planted forest estate that will be needed to supplement existing forests to meet these production targets and community demands for environmental services in a sustainable manner;
* the dependence and demands of local communities for economic, spiritual and cultural values on the types of forest lands under consideration for reforestation.

Principle 2: Provisions for the establishment and sustainable management of planted forests must be considered in the context of an integrated land-use plan for national economic and social development. Thus, planted forests should normally only be established on lands which are known to be capable of supporting all aspects of their long-term management and utilization without land degradation. The creation of plantations must be balanced with the needs for protection of the site and the environment, the conservation of biological diversity of all types, the needs and aspirations of the present people and the potential demands of future generations.

In particular, any larger-scale plantation scheme must incorporate provisions to meet the needs for site conservation and protection of the environment, customary and statutory land rights and the subsistence needs of local communities.

Principle 3: Strong and continued political commitment at all levels is indispensable for the successful establishment and management of planted forests at the national, management unit and local levels.

Principle 4: Institutional capacities must be established to allow for the development and implementation of the integrated land-use plans necessary for effective forest establishment and management.

Principle 5: Effective community consultation procedures are an essential component of these institutional planning processes.

Recommended Action 2: Formulate and implement a national land-use policy which promotes the sustainable use of all natural resources, including the establishment of a permanent forest estate. Ensure that national land-use policies are in turn an integral part of national socio-economic strategies and plans for the development of industry and employment.

Recommended Action 3: Formulate and implement a national forest policy as an integral part of the national land-use policy to ensure a balanced use of forest resources. Develop national forest policies through systematic consultation with and the consensus of all parties involved or affected, including: national government agencies, provincial and local government, local communities, non-governmental organizations, scientific experts, and the private business sector.

Recommended Action 4: Conduct seminars to discuss policies about land-use, land allocations and the role of planted forests in the national economic and social environment. These seminars should involve all the above-mentioned sectors and interest groups.

2.2 Legislation

Principle 6: The national forest policy must be supported by appropriate legislation which, in turn, should be in harmony with laws concerning related sectors. Sufficient resources must also be allocated on a continuing basis to ensure that legislation and policies are effectively implemented.

Recommended Action 5: Enact laws and regulations at appropriate national and sub-national government levels to support the established forest policy, in harmony with the policies, laws and regulations of related sectors. Achieving such harmonization will often involve repeal or revision of existing laws and regulations, both inside and outside of the forestry sector.

Recommended Action 6: Repeal or revise existing policies and laws that provide incentives for the wasteful use and inappropriate degradation of forested lands. In addition, revise all laws and government policies to both encourage long-term investment in forests and forest-based industries and remove any disincentives to such investments. Provide government assistance to help investors meet wider environmental and socio-economic obligations, both through the provision of financial incentives and the development of appropriate conditions for investment security.

Principle 7: There must be mechanisms for the regular revision of policy and legislation in the light of new social, economic and environmental circumstances and/or the availability of new information.

Recommended Action 7: Provide adequate funds for research, monitoring and continuing community consultation to allow informed updating of policies and practices. In particular, provide for the design and implementation of tariff and tax systems, especially for export forest products. Such systems should allow for sufficient adjustment to changes in the interdependent international and domestic market situations, and consider site disadvantage, such as nature and distances of access.

2.3 National Forest Inventory in Relation to Land Assessment Surveys

Principle 8: A national forest growing stock and land inventory should establish the status of all forests, independent of ownership status. Land tenure, the land development plans of other agencies and customary rights will frequently be a key item in forest land inventory data in many tropical countries. The national forest inventory should provide a clear picture of the legal and ecological status of forests under various forms of land tenure and customary rights. The results of such inventories should be evaluated with the results of broader land-use studies to determine the potential opportunities for and constraints on the development of planted forests. Forest land and growing stock inventories must apply techniques which ensure reliability, continuity, accuracy and sufficiency of data.

Principle 9: There should be flexible provisions for such inventories to be broadened to include information not previously covered, if and when the need and opportunity for the collection of such additional information arises.

2.4 Permanent Forest Estate

Principle 10: Certain categories of land, whether public or private, need to be kept under permanent forest cover to secure their optimal contribution to national development and environmental protection - see Appendix 1.

Principle 11: Land allocation for the establishment of planted forests must consider the interests, legal rights and long-term plans of all sectors concerned with or affected by their development. Particular attention must be given to the interests of the local residents and communities who will experience most closely any changes brought about by particular planted forest proposals. There will therefore be a need for specific planning activities at the national, regional and local levels.

Recommended Action 8: Identify, survey and delineate the various categories of sites, and allocate land to the various forms of forest in consultation with affected communities giving careful consideration to their legal claims on the land. In these evaluations, take into account present and future needs for agricultural and pasture lands, as well as customary use of various forest products and conservation requirements. Define the role of planted forests in achieving or supporting this optimal pattern of forest land allocation needs.

Principle 12: Natural forest should not be cleared for the establishment of planted forests unless this is proved to be essential to justify retaining the land under forest cover.

The feasibility, desirability and necessity of replacing existing natural or secondary forest by planted forest should be expertly assessed in a manner which ensures independence of judgement. This assessment should include the full range of ecological, environmental, economic and social implications and their long-term consequences. The advantages and disadvantages of natural forest regrowth, enriched natural regrowth and planted forests respectively, should always be comprehensively compared before forest allocation and management decisions are taken. These issues should also be subject to wide community consultation and discussion to ensure that forest management decisions meet community needs and are socially acceptable - key pre-requisites for sustainable forest establishment and management.

Principle 13: Notwithstanding the provisions of Principle 12, where natural forest areas have been so severely degraded by past land-use practices that their effective recovery and survival as forests is in doubt, consideration should be given to conversion of suitable sections of these highly degraded areas to more productive planted forests.

In cases where careful assessment has proved that conversion of severely degraded natural or secondary forests to planted forests is justified, fully considering environmental, economic and social factors, such highly degraded areas may be transformed to forests or to suitable forms of agroforestry systems with improved and sustainably high levels of productivity. This would contribute to the overall forest and agricultural productivity and thereby can reduce pressures on remaining natural forests. The overall benefits the community and the nation gains from the forest estate would thereby increase in the long run.

Recommended Action 9: Continuously monitor the condition of the whole forest estate and revise forest management plans in consultation with the community to promote efficient and well balanced use of forest lands.

2.5 Land Ownership

Principle 14: The principles and recommendations outlined in these guidelines for planted forests should be equally applied to publicly and privately-owned lands and to lands controlled by customary rights.

Principle 15: The principles and recommended actions outlined in these guidelines can only be implemented if there is secure and long-term tenure of the land, and acceptance of suggested land-use changes and land allocations by the local communities. In particular, claims based on legal titles or on statutory or customary rights in all types of forest lands must be duly considered,
including claims to ancestral territories and cultural sites. These and other local claims recognized under national law require also consideration in relation to environmental protection, sustainable economic development and compensation for being displaced or otherwise impaired by the establishment of planted forest areas.

Recommended Action 10: Develop comprehensive land allocation plans, legal instruments and investment incentives to protect any permanent forest land tenures. Create and maintain appropriate local institutions to both monitor the implementation of land allocation plans and enforce any legal instruments that may be required. Involve affected people in the development and implementation of such land allocation plans and subject these plans to wide community discussion and review before their approval and implementation.

2.6 National Forest Service

Principle 16: There should be a national agency capable of effective, integrated management of the public forest estate. Such an agency must also be capable of assisting in the establishment and management of all types of forest on communal and private lands, according to the objectives and principles laid down in the national forest policy.

Recommended Action 11: Provide for a national agency to carry out the above functions.

Recommended Action 12: Provide the staff of such an agency with appropriate training and adequate resources to allow them to carry out their duties effectively and efficiently. Where communal or private forest lands are likely to be involved, special emphasis should be placed on developing extension systems and the community communication skills necessary for effective participatory planning.

3. FEASIBILITY ASSESSMENT

3.1 Environmental Considerations

Principle 17: Planting trees will usually induce changes in the local biological and physical environment. These changes can be potentially beneficial or harmful, or both.

Recommended Action 13: Include comprehensive environmental impact assessment procedures in all pre-planting feasibility investigations. Promote the positive impacts of change while simultaneously minimizing any adverse impacts, so as to increase the overall benefits of the proposed planted forest to the community.

Principle 18: In many environmentally important areas such as steep slopes, catchment areas and degraded watersheds, the establishment of a well-managed forest cover offers many environmental, social and economic advantages. Similarly, well-designed and well-managed planted forests can provide appropriate protection and help to stabilize and restore fragile and degraded areas.

Recommended Action 14: Assess the feasibility of establishing planted forest programmes on such lands with particularly important environmental functions, giving recognition to these potential advantages. Such assessments should also recognize that possible environmental restrictions may need to be placed on future harvesting practices, ranging from restrictions on the actual areas eventually harvested, to restrictions on the type of machinery that can be used on particular sensitive sites. In conducting feasibility studies for these areas, determine whether or not the costs of such likely restrictions on utilization are counter-balanced by the direct and indirect benefits afforded by the protective functions and positive environmental effects of the planted forest.

Principle 19: Replacement of natural vegetation by planted forest can simplify existing ecosystems. Although plantations can be designed to contribute to the conservation and enhancement of genetic resources of given target species, their possible negative impacts on ecosystem conservation and overall biodiversity must be carefully assessed. The risks of deterioration of biodiversity should be reduced by appropriate silvicultural management. Important management consideration include the appropriate siting of planted forests and setting aside other land areas primarily for the conservation of regional biodiversity. It should be remembered that planted forests which are designed to provide a diverse habitat, such as mixed, multi-storied forests, are richer in animal and plant species which regulate them whereas uniform, simple monocultural designs create forests which require constant human inputs to maintain viability and productivity.

Recommended Action 15: In evaluating the feasibility of particular proposals to establish planted forests, carefully consider the impact of land-use allocations, the actual siting of the forest land and its detailed compartment design on the local and regional patterns of species distribution and biodiversity and on the local and regional climate (micro-and the mesoclimate).

Principle 20: Potential planting sites can have attributes that have archeological, cultural or spiritual significance at the local, national and global levels that may be adversely affected by forestation activities.

Recommended Action 16: Include the identification, description and evaluation of the significance of such sites in all pre-planting resource inventories. Consider appropriately the resource values to all concerned parties in planning land allocation and establishment of forest plantations.

Principle 21: Natural and planted forests store carbon and exchange a multitude of trace gasses with the atmosphere. They thereby affect micro- and meso-climate and, to a smaller measure, macro-climate. The on-going climate change and warming of the surface water of the tropical oceans will make tropical climate more variable and extreme events more severe. Forest trees and whole forest ecosystems may therefore be expected to suffer increasingly from stress and damage. Precautionary adaptation appears prudent and

should be considered in site selection and crop designing.

Recommended Action 17: Give consideration to these issues in general land-use planning when determining both regional and national planting goals and when specific decisions are taken on forest structure and silvicultural and agroforestry systems for the various types of sites. The objective should be a precautionary adaptation of the forests to expected future environmental conditions such as more violent storms and floods, and more severe droughts. Questions on preservation of suitable germplasm in-situ or elsewhere are relevant in this respect.

3.2 Socio-Economic Considerations

Principle 22: Planting trees can decisively affect social and economic conditions at the national as well as regional and local levels. These effects can be either positive or negative.

Positive effects can range from enhancement of social and economic development through provision of local access to resources; employment generation and the creation of investment opportunities; increased potential for industrial development; the possibility of increasing and stabilizing export earnings; and the subsequent improvement of rural life through better access to enhanced infrastructures, educational opportunities and medical care.

Negative socio-economic impacts can range from disruption of traditional land rights and patterns of land use, reduction of cultural values, inefficient use of investment funds through the development of forest resources not sufficiently targeted to market demands, and possible extra-regional impacts through economic displacement of competing forest enterprises. Local communities experience the most direct beneficial or detrimental impacts. Their views and needs should receive particular attention because their acceptance and cooperation is essential for success.

Recommended Action 18: Include comprehensive social and economic impact assessment procedures in all pre-planting feasibility investigations. Promote the positive impacts of change while simultaneously minimizing any adverse impacts, so as to increase the overall benefits of the proposed planted forest to the community.

Recommended Action 19: Diversify crop types and their site-specific location in the area to meet community demands. Provide for intercropping (taungya, tumpangsari) and mixed cropping (agroforestry) on suitable areas within a plantation scheme to provide ecological and economic benefits that will enhance acceptability to the local community and reduce costs for silvicultural management and protection. Incorporate fuel, fruit or fodder trees in the forest stand for local usage, and allow the supply of timber for domestic use to benefit the community and in return benefit plantation management.

Recommended Action 20: Include detailed market evaluations in all planted forest feasibility studies concerning planted forests of any type, including single-species plantations, mixed forest and agroforestry plantations.

3.3 Institutional Considerations

Principle 23: To succeed at the social, technical and economic levels, and to be environmentally sustainable, planted forest programmes must be supported by strong national and local institutions to ensure integrated planning, community involvement and monitoring of the economic and technical feasibility and performance of all management activities.

The strength of these institutions depends on the strength of the political support they receive. Government institutions must receive adequate financial support, adequate staff, stable employment and attractive career opportunities. The staff should be structured to cover all necessary fields of development, research and extension.

Principle 24: Efficiency must be maintained by adequate in-service and special training. Continuous interchange of information and experiences within and between national institutions and with foreign institutions is necessary to maintain expertise at sufficiently high levels.

Principle 25: Non-governmental organizations (NGOs) can play important roles in forest development programmes as partners of government and local communities in feasibility studies and the planning process, as source of information and often as innovating elements. Their participation should provide information and other resources which constructively contribute to balanced land-use planning.

Recommended Action 21: Implement institutional strengthening and promote participative procedures at all levels, but especially at the local level, to improve efficiency and expertise.

4. PLANTED FOREST ESTABLISHMENT

4.1 Management Plan Preparation

4.1.1 The Importance of Management Planning

Principle 26: Integrated planning at all levels reduces private and public economic and environmental costs. A management plan is therefore an essential component of the establishment and sustainable management of any planted forest, and must complement other relevant plans in related sectors.

Recommended Action 22: Make provision for adequate management planning at all levels of forest management.

Recommended Action 23: Forest management plans should address at least the following topics:

* Areas to be excluded from planting and production management, including steep topography, fragile soils, protective beds along watercourses, areas for the preservation of amenity and areas for nature, species and genotype conservation.

* The layout of the road, fire protection and extraction network.

* Procedures for site preparation; planting; tending; prevention of erosion, compaction and other forms of site degradation; silvicultural treatments; and controlled burning.

* Fire protection and fire management.

* Biological pest management and protection against pests, diseases and climatic calamities.

* Market development and utilization plan.

* Provision of all kinds of forest benefits to the local communities and recognition of customary rights.

Principle 27: Management of planted forests should implement traditional multiple-use principles in order to produce multiple benefits. Management objectives should therefore consider all forest values determined by comprehensive evaluation. Objectives for particular areas will have to be specific to the site and environmental, economic and social circumstances. The objectives must relate appropriately to the goals of the plantation programme and the interests of the local communities. During planning and establishment, these communities should be actively involved in order to motivate them to continued cooperation and eventually increase their income and quality of life. Such involvement could take the form of allowing local people to cultivate agricultural crops between tree plantation for a certain number of years and of continued employment in forest operations.

Recommended Action 22: Prepare or up-date existing "codes of best practice for forest conservation and management" to describe the procedures for planning and monitoring for all planted forest in order to ensure completeness of prescriptions and integration with other forms of land use.

4.1.2 Soil and Site Considerations

Principle 28: In general, the better the soil and site conditions are, the lower the risk will be of land degradation from all forms of land use. This generalization is particularly applicable to intensive cultivation of single-species plantation forests. Unfavorable sites, such as steep slopes, fragile or deficient soils, carry high rates of risk and low rates of productivity and should be reserved for protection and conservation forestry.

Recommended Action 25: Carry out well-designed site mapping in order to carefully determine the suitability

of the site based on adequate site and soil classification and survey procedures. Give particular consideration to both risk and production potential in the site-specific allocations of different forest crops to various types of soil and site. Restrict intensive forestry, especially short-rotation, single-species industrial timber plantations to sites with physically, chemically and biologically favorable soils and flat to gently sloping terrain.

Principle 29: The establishment of a productive forest plantation on degraded land usually requires either a prior phase of a sown or planted pioneer vegetative or a usually expensive artificial amelioration of soil fertility. After afforestation, repeated biological or artificial replenishment of nutrient stock may be necessary in the course of time, to prevent impoverishment of the soil through nutrient losses from leaching, erosion and harvesting. The natural process of restoring soil fertility by secondary forest growth during well-managed fallow periods such as in the various forms of the taungya (agrosilviculture) systems and the traditional systems of shifting swidden cultivation can serve as a model for sustainable silvicultural methods. The degradation of soil and vegetation in short-rotation swidden also demonstrates the consequences of overexploiting the site potential.

Recommended Action 26: Assess the biological soil activity and the nutrient status of soil before afforestation with the objective of designing an adjusted soil amelioration scheme. Regularly monitor the status of the soil and the health of the growing stock.

Principle 30: The activity of soil fauna, flora and microbes is an essential element of soil fertility which requires careful maintenance. The maintenance of adequate conditions of soil biology is a key element of sustainability in the humid tropical forest management.

Recommended Action 27: Minimize soil exposure at the time of initial afforestation and through subsequent forest management activities.

Recommended Action 26: Maintain an effective soil cover to reduce erosion and supply adequate amounts of appropriately mixed organic material to the soil, either by developing and maintaining a diverse, layered forest structure, or by soil-cover crops or by intercropping in single-species uniform industrial plantations.

Principle 31: Together with litter supply and humus formation, the interaction of soil porosity and texture with other physical conditions is a most important factor affecting the effective fertility and biological activity of tropical soils. The use of appropriate technology and careful planning is essential to maintain an appropriate soil environment for sustainable forest management.

Recommended Action 29: Avoid soil erosion and compaction from inappropriate establishment procedures such as the use of excessively heavy machinery or the use of intensive cultivation practices on land not suited to this purpose. Undertake land capability and land suitability appraisals as a key component of planning for the planted forest, to ensure that intensive cultivation and other site preparation practices are restricted to sites capable of supporting these activities without causing land degradation.

Principle 32: Non-crop species of trees and shrubs may have important ecological functions such as fostering the development of symbiotic relationships, improving soil cover and litter diversity and providing habitat for other members of the trophic network. As such, they should not automatically be considered as weeds that have to be immediately eliminated. Rather, their potential benefits should be carefully balanced against the cost of possible competition effects, so that investments in weed control can be focused onto crucial stages of the forest's development. This will help to ensure that funds are used efficiently and tending does not become counter-productive.

Recommended Action 30: Wherever feasible, manage and integrate spontaneous auxiliary vegetation into silvicultural practice rather than automatically eliminating such vegetation. Introduce auxiliary vegetation where ecological stability reasons require such actions.

Recommended Action 31: Control vegetation which is detrimental from an economical and managerial point

of view by low impact methods such as, controlled burning or manual slashing. Minimize the use of chemicals or intensive mechanical disturbance and compaction of the soil, as they may have undesirable effects such as inducing accelerated surface water run-off and erosion or the pollution of adjacent water courses. Avoid the use of chemicals with residual toxic properties and take particular care when their use becomes necessary.

4.1.3 Research Needs

Principle 33: Basic scientific and application-oriented research is the fundamental source of the information needed for sustainable timber production and other forms of forest use. The performance of the forest crop, the impact and effectiveness of forest management operations and the status of soil and site conditions all need to be continuously monitored so that timely corrective measures can be taken in response to any long-term trends of change. Research is also needed to monitor changes in community needs and expectations at the local, regional and national levels together with other aspects of the socio-economic environment in which forest managers must operate.

Recommended Action 32: Where possible and feasible, take advantage of developments of sophisticated methodologies such as systems analysis, ecological modelling, ecosystem level studies and information systems to improve the information base for decision-making in forest management. Ensure that resource economics and the social sciences are an integral part of any research programme associated with planted forests.

4.2. Technical Requirements

4.2.1 Choice of Site, Tree Species and Planting Material

Principle 34: The selection of sites must fully and comprehensively consider natural site conditions, logistic and economic features of the site as well as the social and political environment. In principle, production forests should be as close to the existing markets as other competing land users permit. Once the site is determined, the selection of species and genotype must be carefully matched with the site conditions. Besides considering soil type and average climatic conditions, consideration must also be given to ecological risk factors and extreme events such as excessive rainfall, floods, droughts, cyclonic or convective storms and biotic hazards. These site conditions and risk factors, and competing vegetation should influence the choice of the most suitable type of planting material. In any case, the origin of the seed, plants or cuttings must be identified, certified and labelled. Plantations must only be established with source-identified genetic material.

Recommended Action 33: Select a suitable soil classification and undertake a careful and comprehensive soil and site survey. This is needed to provide the essential basis for the choice of species, species allocation to the site units, and the choice of adapted designs of the structure of the forest crop in order to achieve the highest possible productivity at acceptable low levels of risk. Following these basic decisions, evaluate the range of available planting materials and methods, such as direct seeding, bare rooted seedlings, potted or tubed materials, cuttings of different sizes, provenances and clonal material, and select the most suitable site-specific combination.

Principle 35: Exotic species often have initial superior performance and management advantages as they can grow in the absence of a suite of locally adapted crop predators. However, through the processes of natural selection, domestic tree and shrub species may have developed adaptations to the local edaphic, climatic and biotic conditions which may give them long-term advantages over exotics. Proof of such long-term adaption is usually either lacking or restricted to a few, short-term examples for exotic species in most areas. Forest managers and planners should therefore not assume that the initial growth advantages of exotic species will be able to be maintained without additional management inputs over time.

In the comparative assessment of the potential of native species, it must be considered that when these species are planted in the open and grown in single-species uniform plantations, they often may behave and perform quite differently than in their original habitat. It must also be remembered that practical experience with native species in the past usually has been gained under specific and often unique circumstances of site

and conditions for growth. Such experience therefore can be very misleading. Colloquial experience cannot replace the systematic knowledge gained from well-designed scientific research.

Considerable improvement of growth, yield, produced quality, adaptability to sites, and resistance to pests and diseases are possible through tree breeding. Such improvements are especially important to industrial plantations when economic returns can be demonstrated to outweigh the additional cost of genetically improved material.

Recommended Action 33: Give preference to the use of native tree species wherever feasible and practical both for production of high volumes and for the production of quality timber and high value. In this regard, the ease of obtaining seed and propagating commonly planted exotic timber species such as pines, gmelinas, eucalypts, acacias and teak should be compared with the benefits of the likely long-term adaption to the site by local species.

Recommended Action 35: Carry out research on promising native species in order to establish their real potential as planted forest species for high quality timber production. In particular, research on genetic improvement should be initiated or expanded. This applies also to the genetic improvement of species for agroforestry systems and for environmental improvement.

Recommended Action 36: When exotic species are chosen, care must be taken to reduce risks by:

* allocation to suitable soil/site units;

* Careful screening of provenances, hybrid and clone properties in relation to site requirements, growth performance and product quality;

* Mixing species, provenances or genotypes (clones) both spatially within the same contemporary crop area and temporally with mixed sequences of crops for the site in a rotational silvicultural system.

4.2.2 Roads and Site Protection

Principle 36: The planning, location, design, and construction of roads, bridge structures and other forest management infrastructure should be done so as to minimize erosion and other forms of damage to the site and the wider environment, and allow easy access for all forest operations, including fire management. However, roads constructed to facilitate access and management of planted forests may provide undesirable access to adjacent areas of the natural forests.

Recommended Action 37: Prepare prescriptions for road design, drainage, fire protection and other infrastructure requirements appropriate for local conditions. Provide for prevention of the undesirable use of roads to access natural forest, wildlife or nature protection areas.

Principle 37: Sufficiently broad completely protected buffer strips along stream banks and adjacent riparian areas should be kept under special management to reduce sediment and nutrient inflow into adjacent water courses.

Recommended Action 38: Prevent soil disturbance and maintain an appropriate width of undisturbed vegetation along all water courses and riparian zones to maximize the absorption of overland water flow, nutrients and sediment from disturbed sites in adjacent production forest areas.

Principle 38: Fire can be a serious threat to the productivity, ecological stability and social and environmental quality of planted forests and their growing stock. Fire risks may increase as both living and dead biomass accumulates during the course of planted forest's development. In some areas, fire risk may also increase during the life of a single rotation of the planted forest in response to climate change associated with global warming. Fire risks and fire management requirements will also generally increase with the size of the planted forest estate.

Principle 39: There is a growing body of knowledge about both the significance and behavior of fire in forest ecosystems. This knowledge provides a basis for minimizing fire risks and planning fire management strategies.

Recommended Action 39: Prepare a fire management and fire suppression plan for each planted forest area taking into account the value of the planted forest estate and the degree of risk associated with local conditions. Such fire management plans should at least allow for:

* the establishment and maintenance of cleared fire breaks along boundaries between the forest estate and other areas, and between forest management units within the forest estate;

* the establishment and maintenance of fire resistant species or vegetation types within or between planted forest units;

* a collection and retrieval system for fire weather and fuel data to allow for efficient fire danger and fire behavior prediction;

* a fire detection and warning system;

* a communication strategy for forest users and adjacent residents for periods when restrictions on public access or behavior are required due to either high fire danger or other fire management purposes;

* a hazard reduction burning strategy;

* a prevention and suppression strategy for wildfires including consideration of any societal causal factors;

* a systematic fire reporting system to allow for a better understanding of forest/fire interactions in the future.

4.2.3 Site Preparation

Principle 40: Appropriate site preparation can enhance the early growth and development of planted forests through amelioration and improvement of soil physical conditions and reductions in competition from other vegetation occupying the site during the establishment phase. However, the long-term effects of cultivation, drainage and other intensive forms of site preparation need to be carefully evaluated as they have a significant potential to lead to site decline and unwanted side effects.

Principle 41: Site preparation can also improve access for forest management, fire protection and eventual forest harvesting activities. It can also greatly simplify the re-establishment of subsequent forest crops in future rotations. However, poorly planned or inadequately supervised site preparation can cause serious environmental damage through soil compaction, erosion, loss of top soil nutrients and other forms of land degradation.

Recommended Action 40: Undertake land capability assessments before deciding on site preparation specifications. Restrict mechanical and chemical site preparation techniques to those sites with land suitability classifications capable of supporting these activities without generating accelerated erosion or other unacceptable forms of land degradation.

Recommended Action 41: Ensure that operational staff have access to all required site information and appropriate, well-maintained site preparation equipment, and that they are fully trained in recommended operating procedures. Ensure that all forest planners, managers and operators

are aware of the need for soil conservation and that they are familiar with basic soil conservation principles and practices. Provide facilities for on-going training to continuing improvement understanding in the workforce and field practice.

4.2.4 Approach to Planting

Principle 42: Planting technology is species and site specific, with the choice of technique being significantly influenced by the nature of the soil and the degree of site preparation . For example,in some cases seedling stock may be the best choice, while in others direct sowing or the use of cuttings may be more appropriate.

Recommended Action 42: Select the planting technique most appropriate to the species and local conditions. In the selection of planting technology, take into consideration factors such as soil texture, soil vulnerability and ecological fragility, topography, prevailing average climatic conditions, climatic extremes, species characteristics and the availability of labor and equipment, and the availability of finance and expertise.

4.2.5 Fertilization

Principle 43: Some nutrient supplements are usually necessary during the establishment phase to enhance growth, or in extreme cases, to ensure the survival of planted forests. This is particularly true on seriously degraded lands. Also, nutrient supplements may be necessary later in the life of a plantation, to maintain adequate diameter growth and the passing of the trees from one utilization category to the next. However, the inappropriate use of chemical fertilizers in particular can lead to a range of environmental problems ranging from the accumulation of heavy metals in soil profiles to the eutrophication of adjacent streams and waterbodies. Therefore, in designing any forest fertilization programme, priority should be given toward employing organic and biological fertilization methods. The long-term consequences of any proposed forest fertilization programme must always be carefully weighed against the short-term advantages.

Recommended Action 43: Undertake land capability assessments before deciding on forest fertilization specifications. Restrict applications of chemical and organic fertilizers to sites where they are not likely to be transported to streams, waterways or groundwater as either point or diffuse non-point pollutants.

Recommended Action 44: Synchronize fertilizer applications with seasonal conditions, plant growth patterns and silvicultural operations such as weed control activities that are likely to promote nutrient up-take by the growing stock of the planted forest. This will both increase the cost-effectiveness of forest fertilization programmes and reduce the risk of unwanted nutrient transport away from the application sites.

Recommended Action 45: Design an integrated fertilization schedule that includes the use of biological agents such as plants and soil organisms to fix and store key elements; the use of efficient nutrient-scavenging plants; and the continuous monitoring of physical, chemical and biological soil conditions together with the nutrient status of the crop. Detailed information on integrated fertilization schedules can be obtained from the Tropical Soil Biology and Fertility Programme (see Appendix 6).

4.2.6. Tending and Weed Control

Principle 44: The establishment or failure to establish effective management of competing vegetation is frequently a major determinant of the success or failure of the establishment phase of planted forests in the tropics. However, as discussed is Section 4.1.2, tending prescriptions need to be developed carefully to avoid creating more problems than they solve. Effective weed control should therefore always be developed on the basis of a thorough understanding of the dynamic competition between crop species and other vegetation covers, and a thorough understanding of the short and long-term implications of particular control strategies.

Recommended Action 46: Review principles 30-32 and Recommended Actions 27-31 in Section 4.1.2, to develop appropriate practices for the management of ground vegetation and tending the tree crop. The aim should be to reduce costs and risks and improve ecological stability, environmental protective functions and habitat diversity for the particular site-specific circumstances.

4.2.7 Pest Control and Disease Management

Principle 45: Pest control and disease management practices often become necessary to ensure the survival and effective growth of planted forests. However, many of the chemicals used for these practices can pose significant hazards to the health of both operational personnel and the wider environment through pollutant drift and reductions in local or even regional biodiversity. This in turn can lead to higher risks of new pest and disease outbreaks. Fortunately, the need to use such chemicals can be greatly reduced through the application of ecological principles in integrated pest and disease management strategies.

Recommended Action 47: Carefully match species, provenance and genotype (clone) selections with site conditions and cultural practices to ensure vigorous tree growth capable of resisting the pressures of pest and diseases so that the use of chemical control methods can be reduced as much as possible. Wherever possible employ integrated pest and disease management with emphasis on biological controls. Use the potential of complex structured (layered) multi-species crops to create a diverse ecosystem which is capable to reduce pest and disease problems which are common in monocultural systems.

Recommended Action 48: Develop and apply forest hygiene practices that minimize the spread of fungal or insect pests and diseases.

Recommended Action 49: Design planted forests to enhance biological control through the provision of both floristic and structural diversity. Create obstacles for the spread of pest and disease epidemics by providing an adequate mixture and complexity of both growing stock and appropriate spatial and structural patterns of the whole forest. Recognize however, that maintaining protective strips and reservation areas of natural forest to provide diversity within and between forest stands can also harbour predators and pests.

Recommended Action 50: Develop an understanding of the ecology and life cycle biology of major pest species. Combine this understanding with the principles of biological pest and disease management to avoid inadvertently favoring expansion of pest populations and to allow for more strategic applications of chemical and other control measures. Avoid indiscriminate, blanket applications of chemical control agents.

4.2.7. Staff Development

Principle 46: The success of the establishment of planted forests ultimately depends on having skilled personnel at all levels of planning, management and operational activities. This requires adequate training opportunities and facilities, particularly when staff and labor are recruited locally. Working conditions, in particular safety conditions and pay scales, must be adequate and comply with internationally agreed standards.

Recommended Action 51: Maintain motivation and pride of work by providing appropriate rewards, to personnel at all staff levels from forest laborers to forest managers.

5. POST-ESTABLISHMENT MANAGEMENT

5.1 Operational Planning

5.1.1 Preparation of Work Plans

Principle 47: Sustainable management is concerned with much more than just the establishment phase of the planted forest. It is concerned with management of the whole of the initial rotation and with the maintenance of site productivity for future rotations.

Principle 48: The plantation management plan should form the basis for all action and forecasts for sustainable management. It should cover at least the full initial rotation and provide a systematic framework from which the forest manager can prepare a detailed work plan. This latter document should outline the operations that have to be carried out, the resources required to undertake them and the time scale involved.

5.1.2. Institutional Considerations

Principle 49: Achievement of forest management objectives requires continuity in action. As outlined for public forests in Section 2.6, there should be a national forest agency with the financial and human resources that will enable it to effectively carry out its responsibilities. For the private sector, continuity of tenure must be assured.

Principle 50: Resources should be allocated for basic and applied research programmes aimed at maximizing the efficiency of management operations and improving the productivity of the planted forest enterprise. Forestry research organizations should provide for the continuous feedback of information to forest management agencies.

Principle 51: Efficient and effective implementation of management plans and associated research programmes requires staff with high professional expertise and the ability to work with rural communities.

Recommended Action 52: Establish contract agreements between forest management agencies and forest research organizations for targeted research relevant to planted forest planning and management.

Recommended Action 53: Provide funding for on-going management, research and development activities in all tree planting programmes.

Recommended Action 54: Include high quality training and human resource development programmes as an integral part of all forest management systems.

5.1.3 Social Consideration

Principle 52: The long-term success of planted forests and their management for the sustained production of timber, non-timber products and other services and benefits ultimately depends on their compatibility the regional economy and the economic and land-use policies, as well as the interest of the local and regional communities, and particularly the interests of the local people. In many cases, the effectiveness of forest management can be successfully improved by actively involving the local people and by utilizing with care and discrimination local experience.

Recommended Action 55: As outlined in Section 4.1.3, monitor changes in both community needs and expectations at various levels as well as the social impact of the planted forest on the community.

5.1.4 Economic Considerations

Principle 53: Management of planted forests for timber and other benefits can only be sustained in the long-term if it is economically viable. Thus, monitoring the economic performance of the forest is an essential component of sustainable, research-based management. In the socio-economic context, analysis and evaluation of economic costs and benefits must include valuation of environmental services and local subsistence uses of timber and other products, wildlife and services.

Recommended Action 56: Establish a system for continuous and comprehensive collection of data on all costs and benefits associated with planted forests.

Recommended Action 57: Undertake studies on the short, medium and long-term trends in demand for all forest goods and services in the local, national and international markets, so that forest production can be more closely targeted to meet the diverse and changing market and community demands.

Recommended Action 58: Intensify local, regional, national and international marketing efforts in order to realize the highest possible value returns from the forest products and promote improved utilization of the resources from sustainably managed forests.

5.2 Forest Monitoring, Growth and Yield Prediction

5.2.1 Integrated Resource Inventories

Principle 54: Integrated resource inventories are required to provide information on:

* the health of the trees, the forest ecosystem and the forest environment, any serious risk and damage factors;
* the state and potential development of biodiversity;
* the opportunities for wildlife conservation and management;
* the volume assortment of timber types and sizes, and the quality of the timber growing stock suitably qualified by species and management unit;
* the opportunities for outdoor recreation and the production potential of other non-wood forest products and values.

Principle 55: Forest inventories should obtain information on existing plans affecting land use, land and infrastructural development, land allocation and statutory and customary rights which may affect forest management and forest production. Wherever feasible, this information should be compiled in a Geographic Information System (GIS) to facilitate easy access, retrieval and evaluation of information - see appendix 2. Such access is especially important at the regional land-use level.

Principle 56: Easy access to comprehensive information is necessary for rational planning and forecasting, as well as for early adjustments of production forecasts, marketing strategies and management practices, so that management can remain realistic and relevant to community and market demands in a rapidly changing world.

Recommended Action 59: Carry out continuous integrated forest inventories to determine where appropriate to local conditions:

* the overall health and compatibility of the social and political environment including the impact from encroachment, illicit felling or other kinds of product collection, deliberately lit fires, as well as national disasters;

* the progress in the development of the forest estate;

* the production status of both timber and non-timber products;

* the status of forest wildlife and game species;

* the trends in recreational and other forms of community use;

Recommended Action 60: Establish and regularly monitor a comprehensive network of permanent inventory plots for volume assessment and collection of other necessary information and data.

Recommended Action 61: Prepare and progressively update management information maps and resource inventory summaries to provide a sound basis for on-going community consultation and the regular adjustment of forest management plans.

Recommended Action 62: Where feasible, take advantage of modern geographic information systems technologies to develop efficient and flexible data storage, retrieval, evaluation and forecasting systems.

5.2.2. Timber Production

Principle 57: To achieve a sustained production of timber from each forest management unit, a reliable method for monitoring growing stock condition and increment is required. Similarly, a reliable system controlling timber allocations is also indispensable. Suitable systems of growth and yield prediction by means of simulation should be applied, and where needed be developed, to allow forest managers to respond to changing community and market demands in a manner consistent with the overall objective of sustainable production.

Recommended Action 63: Regularly review Annual Allowable Cut (AAC) estimates in order to take account of deviations from predictions as a result of environmental changes, changes in crop or soil conditions or changes in demand for various forest products. Where appropriate, take advantage of recent developments in system modelling to simulate growth of forest stand and development of the forest enterprise. The objective is to ensure efficient, responsive, yet environmentally, economically and socially sound stand management, yield regulation and harvesting scheduling.

Recommended Action 64: Use AAC estimations to set maximum production limits, but allow forest managers to adapt annual production according to current changes in market opportunities or community demands if necessary.

5.3 Silvicultural Operations

5.3.1 Restoration and Maintenance of Soil Fertility

Principle 58: The restoration and maintenance of soil fertility is just as important for the long-term management of planted forests as it was for their establishment. It is also fundamentally important for the sustainable management of future rotations established by replanting, coppicing or conversion to more complex types of mixed forests.

Recommended Action 65: Review the Principles and Recommended Actions outlined in Section 4.1.2, and apply as appropriate during the post-establishment management phase, with emphasis on artificial or spontaneously developing mixtures of tree species and soil cover crops.

Recommended Action 66: Take particular care to manage the impact of harvesting activities by reviewing the procedures suggested for roads and site protection in Section 4.2.2.

5.3.2 Tending Operations and Weed Control

Principle 59: While the competition effects of weeds and other non-crop forms of vegetation is generally less critical later in the forest rotation than in the establishment phase, tending and weed control may still be necessary to facilitate access for fire control, harvesting and other management activities. However, as discussed in Section 4.2.6, it is important to approach weed control in a considered manner to ensure that such actions are environmentally and ecologically sound and cost effective.

Recommended Action 67: Review Principles 30-32 and Recommended Actions 27-31 in Section 4.1.2 to develop tending practices appropriate for the circumstances of particular planted forests.

5.3.3 Thinning and Pruning

Principle 60: Thinning and pruning planted forests can have a substantial influence on the end use and profitability of their products. The periodicity and intensity of thinning is usually influenced by growing stock conditions, increment responses to stand density, the availability of markets for smaller sized logs and the market incentives for larger sized end-of-rotation logs. Pruning is only usually justified where the accumulated sum of both direct costs and opportunity costs associated with temporary reductions in growth increment after pruning are more than offset by the ultimate increased value of knot free timber.

Recommended Action 68: Carefully evaluate the desirability of incorporating thinning and pruning schedules into the management of planted forests. In making provision for these activities, give particular consideration to the timing of such activities so as to reduce costs and produce maximum advantage. The spacing of trees and the regulation of mixing of tree species and the treatment schedules throughout the life of the forest stand should be designed by calculating backward from the desired features of the target mature crop, applying appropriate stand growth models.

5.3.4 Roading

Principle 61: Good access is essential for all management activities in planted forests. However, inadequately designed, inadequately constructed or inadequately maintained roads can cause problems of access in crucial periods of high demand, increased costs and substantial on-site and off-site environmental damage.

Principle 62: Forest road and track alignments should be carefully planed and preferably located on stable soils, have appropriately compacted surfaces, be well drained and have sufficient exposure to sun-light to ensure rapid drying after rain. Good drainage is crucial and roads should be located accordingly. Effective drainage must be assured by appropriate road construction and maintenance. Drainage specifications should be designed to ensure that structures are capable of handling peak discharges and that they minimize erosion and sedimentation in adjacent streams. Bridges and culverts should be of adequate capacity and be kept clear of obstructions.

Recommended Action 69: Develop an integrated plan to link roading, fire trail and harvesting access requirements in a manner consistent with the protection of the site and the wider environment.

Recommended Action 70: Provide close management supervision of all road construction activities to ensure conformity with approved planning specifications. Regularly monitor the condition of all roads and drainage structures and ensure that maintenance schedules are themselves maintained.

5.4 Forest Protection

5.4.1 Control of Access

Principle 63: Planted forest areas must be protected from activities that are incompatible with environmental protection and sustainable timber production, such as encroachment by cultivators, illegal wood cutters, and illicit litter collectors. Local communities are often most effective in controlling access, provided that they view the planted forest as a benefit to them, and are given the authority and the means for effective access control.

Recommended Action 71: Control public access to roads where these roads lead solely to forest working areas. Reduce pressures for forest encroachment by integrating forest management into wider rural development strategies. For example, consideration could be given to the possibility of managing special buffer zones within and beyond the border of the planted forests, to help provide for the basic needs of the local population living near the forest and prevent illicit uses and encroachments. In the buffer zone, multiple-use should have priority.

5.4.2 Protection from Fire

Principle 64: As discussed previously in Section 4.2.2, fire can be a serious threat to the productivity and environmental quality of any planted forest. Fire risks must therefore be taken seriously and be addressed by active fire management programmes.

Recommended Action 72: Review Principles 38 and 39 and Recommended Action 39 in Section 4.2.2, and adapt appropriately to the post-establishment management phase. Give particular attention to the problem of debris management following thinning or other harvesting operations.

5.4.3 Pest Disease and Fire Management

Principle 65: Pest and disease outbreaks and fire can occur at any stage during the rotation. Managers need to be prepared with well thought out control strategies.

Recommended Action 73: Review the Principles and Recommended Actions outlined in Section 4.2.7 and apply as appropriate to the post-establishment management phase. Give particular attention to cultural practices that maintain vigorous growth and to the problem of debris and slash management following thinning or other forms of forest harvesting. Apply washdown and other simple hygiene practices to all machinery entering the forest from other areas, and prevent oil spills.

Recommended Action 74: Make adequate provision in the annual budget for fire management and by means of a contingency fund for fighting fire outbreaks. A simple standard operating procedure and instruction manual should be prepared which can be easily understood and carried out by lower-level staff to be used in fire management and fire fighting.

5.5 Harvesting and Planning of the Subsequent Rotation

Principle 66: Planted forests are highly artificial and in many cases narrowly focussed on maximizing single-product functions. Natural and semi-natural forests are more widely focussed on multiple use and perform more functions of production and protection.

Recommendation Action 75: Before the final harvest felling is made, the decision should be taken on the design of the following forest generation. Wherever possible and feasible, this second generation should be planned to become more complex and diverse in order to promote ecological stability and diversity of production and of non-productive multiple forest functions.

APPENDIX 1.

CATEGORIES OF FORESTS AND FOREST LANDS

Forests and forest lands can be categorized by both their function and their condition. When evaluating the potential of a site for a planted forest enterprise, both these aspects are important and the following classifications are suggested to aid in the consistent description of forest conditions and management objectives.

1. CATEGORIES OF FORESTS AND FOREST LANDS BY FOREST FUNCTIONS

(a) PROTECTION FORESTS

These are lands where for various reasons, timber harvesting is prohibited. In some cases, low intensity harvesting of non-timber products (extractives, fruits, cane etc.) may be admitted under certain rules and management prescriptions. In other cases, total protection of the forest is necessary to meet management objectives.

Planted Forests include the following forest categories:

- Protection Forests On Fragile Lands

Fragile lands with sensitive soils or steep slopes should be kept under permanent forest cover, or, if barren, be revegetated for protective purposes. These areas include in particular: critically unstable soils; catchment protection areas; slopes steeper than 25^{o}; and land at high altitudes. The main criteria influencing such designations are related to the erosion potential of the soil (function of climate, especially amount and intensity of rainfall, soil erodability, parent material and angle of slope). Other criteria are inherent infertility and unsuitability for harvesting on either topographic or catchment protection grounds, eg. some podzolic soils, some mountain or cloud forests.

- Forests Set Aside For Plant And Animal Species And Ecosystem Preservation

Forests set aside for the purpose of nature conservation should form a network designed to preserve a representative sample of all ecosystem types, areas of high biodiversity, and habitats of endangered species and genotypes as well as wide-ranging and migratory species. These measures should be supplemented by specific management prescriptions on other, possibly adjacent forest areas to promote the conservation of wide-ranging vertebrate species.

- Totally Protected Areas

In both of the above forest land categories, low intensity harvesting of non-timber forest products might be compatible with conservation objectives. However, the management objectives for some conservation reserves such as National Parks, Strict Nature Reserves and Wildlife Sanctuaries may demand total protection. In these forests categories, direct use is usually restricted to purposes such as scientific research and controlled tourism, and in some cases even these may need to be restricted in order to achieve specific conservation objectives.

(b) PRODUCTION FORESTS

These forests are designated for the sustained production of timber and other forest products, often with environmental protection and/or nature conservation as recognized secondary objectives. Such areas should be chosen because of their potential to provide a yield of high-quality timber in perpetuity at low risk. Production forests should be deliberately planned. They should not be just a residual land-use. This category may however, also include areas of degraded land appropriate for reforestation.

(c) CONVERSION FOREST

Land destined, in the national or regional land use plans, to be converted to other uses should be kept under forest until required, and meanwhile cautiously and properly harvested according to the same or similar guidelines as the Permanent Production Forest. The same precaution of regulated harvesting should apply to forest land of which the final use is not yet determined.

2. CATEGORIES OF FOREST AND FOREST LANDS BY FOREST CONDITION

2.1 NATURAL FORESTS

(a) PRIMARY FOREST (syn. pristine, virgin, or old growth forest)

In this category, the forest has never been subject to human disturbance, or has been so little affected by hunting and gathering that its natural structure, functions and dynamics are not significantly altered.

(b) MODIFIED FOREST (part syn. logged-over forest, manipulated forest)

Here, the forest cover has been retained but has been affected by uncontrolled timber exploitations or controlled timber harvesting (creaming, selective logging, selective-silvicultural management and other systems), or by such intensity of harvesting of non-timber products (tapping of latex, collecting of cane, fruits etc. including elimination, reduction or introduction of tree and other useful species) that its structure, functions and dynamics are noticeably altered.

2.2 FORESTS CREATED AS A RESULT OF HUMAN ACTIVITIES

(a) SECONDARY FOREST (syn. pioneer forest)

Forest which has developed by secondary succession on deforested land, such as land abandoned after shifting or settled agriculture, or after pasture.

(b) PLANTED FORESTS

These forests have been established by planting or sowing on

- barren land
- grassland
- land cleared of secondary forest or scrub
- land cleared of primary or modified forest.

APPENDIX 2
NATIONAL FOREST INVENTORY, LAND CAPABILITY SURVEY AND GEOGRAPHIC INFORMATION SYSTEM (GIS)

1. National Inventory

A national forest inventory and survey of the present state of all forested and non-forested land should be carried out to establish its suitability for the following purposes:

- production of timber (quantifying standing timber volume of both presently merchantable and as yet unmarketable species, and regenerative capacity)
- production of non-timber products (both of present and potential value)
- protection, including that of climate
- nature, species and genotype conservation
- the establishment of man-made forests of various kinds
- various agricultural and other land uses.

The most appropriate use should be made of developments in satellite and computer technology.

2. Integrated Land Capability Surveys

Land capability and land suitability assessment is an essential component of land-use planning for the establishment of planted forests and determining priorities for the retention of other areas as part of the permanent forest estate. Comprehensive land evaluation is particularly important where intensive site preparation techniques are planned for forest establishment in tropical environments, as such activities can easily lead to erosion and other forms of land degradation.

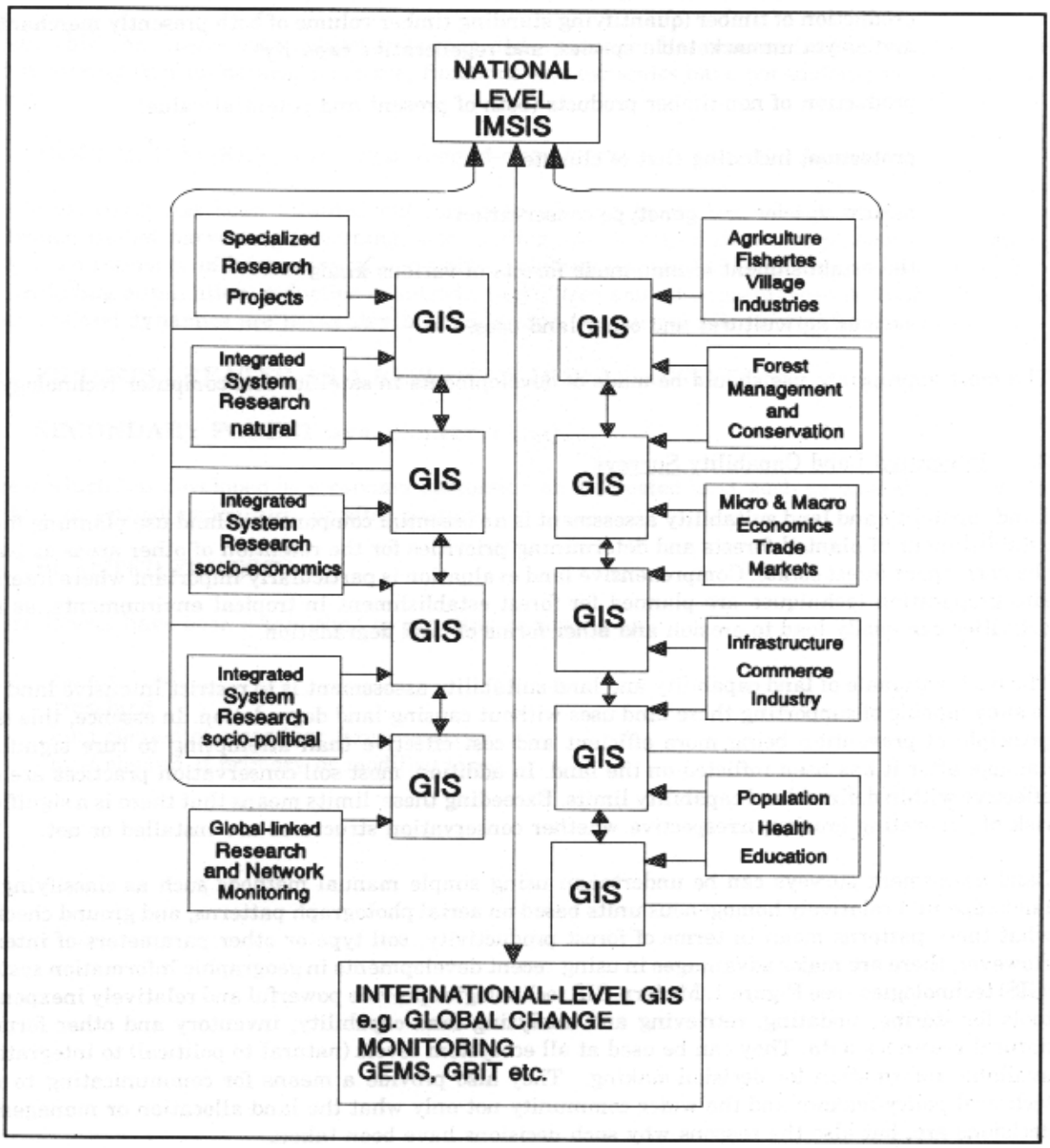
The basic rationale of land capability and land suitability assessment is to restrict intensive land uses to sites capable of supporting these land uses without causing land degradation. In essence, this is the principle of prevention being more efficient and cost effective than attempting to cure significant damage after it has been inflicted on the land. In addition, most soil conservation practices are only effective within defined land capability limits. Exceeding these limits means that there is a significant risk of generating erosion, irrespective whether conservation structures are installed or not.

Land assessment surveys can be undertaken using simple manual methods such as classifying the landscape into relatively homogenous units based on aerial photograph patterns, and ground checking what these patterns mean in terms of forest productivity, soil type or other parameters of interest. However, there are major advantages in using recent developments in geographic information systems (GIS) technologies - see Figure 1. Modern GIS technologies provide powerful and relatively inexpensive tools for storing, updating, retrieving and analyzing land capability, inventory and other forms of natural resources data. They can be used at all ecosystem levels (natural to political) to integrate all available information for decision-making. They also provide a means for communicating to non-technical policy-makers and the wider community not only what the land allocation or management decisions are, but also the reasons why such decisions have been taken.

FIGURE 1

The Structure of a Harmonized and Integrated Geographical Information System Serving Research and the Practice of Sustainable Forest Management, Development and Monitoring

Research aspects of GIS (left) are linked to practice (right) by the Integrated Multi-sectoral Spatial Information System (IMSIS) at the national level. IMSIS supplies land-use and socio-economic information for analysis of potential conflicts and sources of instability in long-term economic development planning.



Adapted from Bruenig et al., 1993

3. Static and Dynamic Inventories

The main purpose of static and dynamic inventory is to assess the potential and possibilities for current timber utilization and long-term timber production and yield. Quantitative information should be gathered on both commercial and presently non-commercial species, including the lower diameter classes, and regeneration, and on the potential for non-timber products. To be meaningful and useful in terms of yield forecasting and environmental assessments, the inventory should include information that can be used for soil and site capability survey and mapping.

During integrated forest inventories, other aspects of the forest soils and sites, such as potential for non-timber forest products, environmental protection, recreation and the potential of soils and sites for non-forestry uses, should be qualitatively assessed at little extra cost. Cooperation with other institutions and facilitation of the evaluation of survey data by researchers and practitioners from other disciplines can help to improve the utility of forest inventories and surveys and strengthen the position of the forest services in land-use planning. The history of management of a forest and the history of deforested sites with potential for afforestation and the causal factors responsible for land degradation should be recorded if known.

APPENDIX 3.

ROADS AND HARVESTING

The following considerations are important on grounds of efficiency and to keep damage to the soil, forest stand and the environment to a minimum.

I. ROADS AND TRACKS

(a) Limit the dimensions of roads, ramps and harvesting tracks to the level that is absolutely technically necessary.

(b) Siting of all types of roads should consider topography, rock formation and soil properties in order to reduce erosion hazard and maintenance costs and avoid roads and tracks that have steep gradients.

(c) Drainage should remove water from the surface of roads and tracks rapidly and prevent water flowing either parallel to the road or tracking over long distances on sloping ground. Effective drainage can be achieved by such means as regular turn-out drains, culverts or cross-drains and ditches.

(d) Harvesting tracks within compartments should be planned before planting but maybe constructed later to reduce the period of soil exposure.

(e) Stream crossings should be preferably permanent and designed to minimize soil and stream bed disturbance in the course of plantation establishment and subsequent operations of protection, tending and harvesting.

(f) Establishment of protective strips of natural vegetation of sufficient width along water courses and ponds, the width depending on the slope of the adjoining land and the width of the watercourse.

(g) The need to restrain the size and weight of any machinery, logging vehicles, to keep soil disturbance and compaction at acceptable low levels. Light cable systems for thinning and final harvest often prove preferable.

(h) Employment of skilled forest labor for all harvesting operations and provision of suitable training for them.

(i) Definition of weather and road conditions under which skidding and hauling is to be restricted or altogether discontinued.

II. HARVESTING

(a) The early selection and marking of elite final-crop trees to facilitate tending and thinning operations.

(b) The marking of trees for removal to avoid mistakes by the fellers.

(c) The design of programmes including maps for tending, thinning and final harvest for the purpose of coordinating efficient road and track construction maintenance with silvicultural and harvesting operations.

(d) The designation and mapping of protection strips and other protected areas which have to be left undisturbed by harvesting and any other forest operation.

APPENDIX 4
PRINCIPAL CRITERIA AND GUIDELINES FOR DESIGNING MAN-MADE FORESTS

The guidelines in this report are presented as general principles that are relevant to any deliberate planting of trees in tropical environments. However, they outline principles and actions that are particularly relevant to the establishment of intensively managed, large-scale plantation projects for industrial wood production. In this appendix, these general principles are complemented with some more specific considerations for some planted forests in particular circumstances vis, afforestation on barren and degraded land; single-species plantations; multi-species mixed forest plantings; and agro-silvicultural planted forests

(1) Afforestation on barren and degraded land

Afforestation of degraded land has the primary purposes of:

- reestablishing soil fertility by producing soil organic matter and restoring soil biological activity and soil surface cover
- using a pioneer forest to produce microclimatic conditions which are favorable to the successive transformation into more divers forest ecosystems
- initiating the first steps towards effective soil protection to promote rainfall infiltration and reduce and soil erosion.

The design of such pioneer forests for the rehabilitation of barren and degraded land should consider the following guidelines:

1. Identify the factors which have caused degradation as they may still be active.
2. Explore the forces behind these factors which are mostly socio-economic in nature.
3. If possible, remove these factors directly and observe the natural spontaneous responses on the site of successional revegetation. This may be sufficient for low cost rehabilitation of the site.
4. If planting becomes unavoidable, make sure the area is protected against the degrading forces and that the planted species are suitable for both the natural site conditions (soil, biota, climate) and the ultimate management objectives for the site.
5. Remember that the crop extracts whatever nutrients the degraded soil still contains. Litter collecting and wood harvesting may therefore leave the soil even more impoverished than it was before. Such harvesting will not be sustainable unless it is matched by nutrient inputs from managers or users.
6. Remember that a uniform canopy taller than about 15 m often increases the size and hence the kinetic energy of water-drops that reach the forest floor during rainfall events. Also, remember that in most tropical environments, such forests often only retain a small proportion of the rainfall by interception. Afforestation alone may therefore actually increase soil erosion unless forest managers take active steps to establish and maintain an effective understory and protective cover for the soil surface.
7. Plan the transformation into more diverse mixed forest at the time you choose the pioneer species, because incompatibilities may make transformation difficult and costly.

(2) Single Species Plantations

Pure plantation monocultures have been a common form of large-scale plantation development in many tropical areas. They can produce high levels of output on a sustainable basis provided they continue to receive high levels of management inputs. However, they are also exposed to a high level of risk, not the least being that economic circumstance may change reducing the chances of maintaining essential management inputs. The following guidelines have been suggested as a means of reducing risks and promoting the achievement of the desired functionality of such forests:

1. Select species carefully with respect to suitability for the site, preferring native species wherever possible. Aim to produce a forest that can produce a versatile range of timber and other products.

2. Divert the maximum fraction of available solar energy to crop trees which produce the highest net value by giving them preferential growing space.

3. Allocate all surplus energy and remaining growing space, which are not needed for the major value-creating commercial crop, to ecologically beneficial auxiliary vegetation. This vegetation may possibly already form the next crop which may be established by underplanting.

4. Design the stand canopy in such manner that the aerodynamic roughness, diffusion resistance and growing requirements of the trees in the various "niches" are mutually adjusted and suit the site conditions. In these designs, consider the variability and possible changes in climate, and the effects of pollutants.

5. Space the crop to obtain good working conditions, stable trees and rapid growth toward the desired final products. Try to reach production goals as fast and safely as possible.

6. Promote the vigour of stem diameter and crown growth during the juvenile stage to produce commercially attractive dimensions early with healthy, stable and sturdy trees.

7. From planting to harvest, consistently regulate the spacing (density and pattern) of the plantation toward set goals. Aim to keep rates of biomass and energy turnover at the maximum compatible with production targets in order to achieve adequate elastic stability of the whole ecosystem.

8. Aim to produce the highest possible floral (trees, shrubs, herbs) diversity, biological activity and organizational complexity that is compatible with the single-species uniform crop regime and its economic and technical production targets.

9. Avoid narrow optimization towards a unique narrowly defined target (e. g. maximum volume, biomass, energy or money yields). Apply the principle of broad optimization to promote survival and elasticity of the crop, high buffering capacity of stand and soil, and high technical and economic adaptability and flexibility for the crop in a continually changing natural and economic environment.

10. Evaluate the use of new information technologies and simulation models to increase management flexibility in high investment enterprises.

11. Utilize and amplify the natural dynamic properties of the ecosystems to direct the system toward a broadly conceived production target of a versatile and technically superior tree at low cost and risk. This is commonly a fast-grown tree with a big defect-free bole.

12. Remember that failures to achieve management objectives are largely caused by the instability created by ecologically inadequate crop structures coinciding with rare ("unexpected", "unpredictable") events. In most planted forests, such events often determine the fate of the crop more than silvicultural planning and treatment. With the predicted changes in global climate and other factors, they may do this even more so in the future.

13. Remember that forest ecosystems are far more dynamic and that their development much less deterministic than it is commonly believed. Forest production systems are closely linked and interact with the technical, economic and socio-political systems of their environment, and these socio-political systems are perhaps even more uncertain and unpredictable than natural ecosystems. In these

circumstances, forest managers should favor those designs for long-term plantations which are most likely to be the least wrong, and not optimize narrowly to maximize certain functions.

(3) Multi-species mixed forest

The guidelines 1 - 13 for plantations apply in principle also to mixed multi-species forest crops. In addition:

1. Consider phenological (leafing, leaf fall, fruiting), physio-ecological (water and nutrient consumption) and architectural (crown shape and size, rooting spread and depth) compatibility of tree species.

2. Consider the possibility of creating a combination of a mixed and successional forest by establishing the following generation by under-planting the present crop with another, suitable species or species mix, such as:

   - mixture of species in the main canopy, a mixed or single-species understorey

   - single-species main canopy over single or multiple species understorey

3. Consider the possibility of enhancing growth and health by symbiotic interrelationships such as by introducing nitrogen-fixing or other effective nutrient-scavenging tree species in the stand.

   In principle, single-species, uniform forest plantation which are repeated in succession as monocultural plantations typically present a number of problems because of the accelerating need for intensive human inputs to maintain growth and viability by fertilizing, soil working and control of seeds, pests and diseases. They will certainly provide fewer potential uses by local communities, fewer environmental services, and by definition are less valuable in terms of the maintenance of biodiversity. The more diverse habitats of mixed and successional forests by contrast pose less problems and offer more social and environmental benefits. Given the long lag time in producing timber and the difficulty of predicting future market and social demands, multi-species plantations offer greater potential economic stability by providing a greater variety of future options for marketable products and non-marketable services.

(4) Agro-silvicultural forest

While the previous criteria and guidelines in principle also apply to agro-silvicultural forest crop types, the range of agroforestry systems is very much wider. Such different types are included as fallow vegetation, single-tree growing on pasture, hedge-rows, border line tree rows, village gardens, road-side trees and so on. Broad generalizations are not possible to cover such extremely wide range of fundamentally different structural and functional agroforestry crop and management types.

APPENDIX 5.

INDICATIVE SCHEME OF PREREQUISITES FOR SUSTAINABLE MANAGEMENT AT VARIOUS LEVELS, INCLUDING GUIDELINES

	National Level	Management Unit	Local Level
Land use policy and legislation	e.g. * establishing a permanent forest base	e.g. * demarking forest boundaries and buffer zones	e.g. * adjustment & coordination of natural, technical economic & social aspects
Forest policy including forest use planning	e.g. * national land capability survey and forest land inventory * assuring a balanced use of natural and planted forests * assuring conditions for implementation	e.g. * designating categories of forest land * forest inventory, soil and site surveying and mapping * regionally integrated forestry and agricultural development	e.g. * detailed soil, site & vegetation survey & mapping * planning of work processes
Forest planning & management	e.g. * providing guidelines for planning and monitoring management units	e.g. * adaptation of national guidelines * choice of silvicultural system * providing operational guidelines	e.g. * adaptation of operational guidelines * preparation of working & management plans * coordination of forest management & trade & industry in the area
Operation		e.g. * stand treatment design of roads and other infra-structures	e.g. * rules to define operator responsibilities * work planning

The table shows actions and outputs at different levels which in combination constitute the prerequisite for sustainable management. Some of the outputs are the consequence of other higher ranking outputs, others are complementary to each other.

APPENDIX 6

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