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Potential Impact of Biotechnology Research for Multipurpose Tree Species

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EXECUTIVE SUMMARY

Research efforts in biotechnology can make a contribution toward addressing resource management problems in the forestry sectors of the Philippines, Thailand, and Nepal -- the countries included in this study. Part I, however, proposes that the general forestry management approach adopted by a country substantially affects the potential relevance of such technologies.

The basic objective of the study is to assess the potential socio-economic effect of multipurpose tree species (MPTS) biotechnology research. Three research areas were identified from interviews with various researchers and resource administrators: (1) tissue culture for planting material production and enhancement, (2) tissue culture for MPTS genetic improvement, and (3) use of micro-organisms to enhance MPTS performance.

The assessment process is initiated in Part II by classifying biotechnology according to whether it is basic, strategic, or applied. Tissue culture for planting materials and the use of micro-organisms to improve MPTS performance are classified as applied and adaptive because they attempt to resolve specific, actual constraints in forestry projects. Tissue culture for genetic improvement is strategic research because it addresses more general concerns such as the determination of the traits that govern acid soil tolerance in MPTS. While the applied studies are expected to have short-term returns to research investment, the potentials of tissue culture for genetic improvement, being more strategic in nature, are expected to materialize only in the long term.

Part III looks at the problem of deforestation and the trends in the contribution of forestry to the national economy. It is shown that forestry over-exploitation has been associated with a declining forestry contribution for the Philippines and Nepal. Although data is incomplete, there is indication that the commercial forestry sector is smaller than the upland farming sub-sector, at least in terms of population affected. As far as national socio-economic impact is concerned therefore, there is a need to also focus on the upland cultivators and on their demand for forest products -- a demand that is dominated by fuelwood requirements.

Part IV defines the fundamental problem of resource over-exploitation as one caused by population pressure and inappropriate resource management systems. The latter undervalues the sustainable uses of forests in favor of capturing short-term returns. Thus, for the commercial sector, logging is so profitable because cutting fees are excessively low. For upland farmers, short-term gains from excessive use of lands and trees for crops, fuelwood, and fodder are preferred to conservation because they lack secure claims to their land and consequently have no stake in ensuring long-term productivity.

Within this implicit anti-conservation structure of incentives, the "traditional forestry" approach attempts to promote conservation through regulation and enforcement -- with poor results. A "participatory-agroforestry" strategy is one emerging alternative that directly addresses the population pressure problem by awarding cultivation rights to upland farmers and enlisting them as partners in the management of their lands and forests. The potential contribution of a particular biotechnology will clearly vary depending on what is the prevailing strategy.

Part V brings to bear the framework developed above in evaluating the potential impact of the proposed biotechnology for MPTS. Due to limited data and other constraints, no full benefit-cost analysis is possible. However, there is enough basis for identifying and quantifying the key benefits and costs to allow informed judgement on the potentials of each biotechnology.

<u>On tissue culture for enhancement and increased production of planting material</u>. Although introducing this biotechnology will probably provide benefits in terms of better seedling supply compared to the supply <u>without</u> the technology, such benefits are difficult to measure. The assessment therefore focused on whether the cost of the technology can be kept at the level of current propagation methods. Researchers in Nepal suggest that modifying the micropropagation process by eliminating expensive sterile-rooting procedures will allow the technology to be competitive.

Any technology needs to be incorporated with a reforestation program through which its benefits may eventually reach society. Micropropagation will be appropriate if governments pursue large-scale contract reforestation schemes (such as that currently starting in the Philippines). However, the potential effectiveness of such reforestation efforts, in terms of meeting growing fuelwood demand, is less than that of reforestation done through involving significant numbers of farmers (following the "participatory-agroforestry" approach), both in the uplands and in the lowlands.

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The problem, however, is that the micropropagation approach, which is biased toward centralized production of seedlings as well as toward specialization in particular types of plantation trees, will not be very appropriate in a "participatory-agroforestry" reforestation approach. While such biotechnology should not be discounted solely on this basis, the eventual social contribution will tend to be limited.

On tissue culture for genetic improvement of MPTS. Research on tissue culture for genetic improvement, being strategic rather than applied, will have limited near-term potential. Indeed the results from this kind of research effort are expected to come out only after substantial time lags. Thus for any given set of actual current constraints, it will be better to utilize traditional testing and screening of various trees, with biotechnology being used to assist in the selection and micropropagation work.

If the national emphasis for forestry programs is on the small farm sector, there will be even less direct relevance for genetic engineering of MPTS. The reason is that the kinds of contribution that have been envisioned for such research aim at enhancing commercial and marketable products from trees (e.g., increasing yield of resins) or on increasing incremental growth for trees that will be in demand for private plantations. For the small farm sector, however, the interest is primarily fuelwood and fodder, and the production of these from trees do not lend themselves to marginal improvements. For example, if more fuelwood supply is desired by the farmer, it would be better to plant two trees rather than to risk experimenting with one "incrementally improved" tree.

On the use of beneficial micro-organisms for MPTS. These microorganisms include fungi (such as mycorrhiza) and bacteria (such as rhizobium). Beneficial results from the use of mycorrhiza, for example, include increased survival rates of outplantings as well as enhanced growth.

The potential national significance of these biotechnologies revolve around two effects. The first effect is on increasing tree seedling survival rates. For example, in the Philippine reforestation program, if the use of mycorrhiza can reduce seedling mortality by, say, 25% the cost per hectare of forest actually established could be reduced to roughly P3,000-4,000 from P4,000-12,000 (P20 = US$1).

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The second effect is on the reduction of fertilization rates for seedling establishment. Philippine estimates are about P550 per hectare per year for fertilizer for the first two years after planting. If a 50% reduction in fertilization could be achieved, the cost per hectare would be reduced to P225 per hectare for two years. Since the actual cost of mycorrhiza inoculation is less than P1.00 per seedling, the net savings are large.

To maximize the impact of biotechnology, the research focus should be on field applications, emphasizing the collection of existing organisms from various local sites, followed by rapid screening and development of practical inoculants. This type of adaptive research is usually too expensive for standard research budgets because it requires a large scale of activities that will involve large outlays for travel and personnel as well as site trial facilities and operational costs.

With respect to the role of the national resource management strategy, there will be cost-savings, if this technology can be used for replanting schemes under a "traditional forestry" approach. However, even if the approach follows the "participatory-agroforestry" strategy, the technology could also lead to substantial benefits.

The reason is that the technology does not require the centralization of seedling production that is associated with tissue culture for micropropagation. Thus the use of a decentralized distribution system for seedlings will not be significantly affected by an inoculation program. Indeed the use of inoculants might actually represent a more acceptable technology for small farmers relative to fertilizer use. It has been indicated, especially in discussions with Thai researchers, that it will be unrealistic to expect farmers to apply fertilizer to trees, even at the time of establishment. Most subsistence farmers usually avoid monetary outlays, and inorganic fertilizers are expensive. Since inoculants can be incorporated in the planting material itself, there would be no additional fertilizer needs.

The general result of the assessment is that there will be value in research investment in biotechnology, but not all types will lead to significant contributions. Researchers must be aware that the potential usefulness of their individual projects must work through general implementation programs. They therefore have a stake in promoting implementation strategies that can enhance the relevance of their work.

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THE POTENTIAL IMPACT OF BIOTECHNOLOGY RESEARCH ON MULTIPURPOSE TREE SPECIES

I. Introduction

A. The National Resource Management Approach as the Context of Specific Research and Development Efforts

The challenge to developing countries of translating policy objectives into effective programs in forest resource management is both complex and broad. It is certainly complex because the perceived goals of society are potentially conflicting: both promoting sustainable production as well as ensuring equitable access to resources have not always been complementary activities. At the same time, the challenge is exceedingly large: the problems of upland degradation and the over-exploitation of forests (leading to excessive soil erosion and decline in land productivity) have reached critical proportions.

This leads to two important implications in the assessment of the potential contributions of biotechnology as applied to multi-purpose tree species (MPTS). First, research needs to be evaluated in terms of its potential for attaining multiple goals. The goals of upland research and development, being derived from the needs of policy-making and implementation programs, are complex. On the one hand, the concern is promoting productivity; on the other it is addressing poverty. On both counts, equity considerations loom large, either taking the form of intergenerational equity (when the concern is the sustainability of productivity gains) or sectoral equity (when it focuses on income and asset distribution among current users of the resource).

Second, because the needs are so broad, the research approach has to be sufficiently focused to make an impact. Most effective research activities, both by design as well as by limited resources, only address a small portion of the issues and plans that are required by national programs at any given stage of implementation. Therefore a realistic assessment of their potential contribution requires placing the activities in the context of the social perception of the resource management problem as well as the actual management strategies being followed by the country's resource administrators.

B. Assessment Goals for Biotechnology Research on Multipurpose Trees

The basic objective of this assessment is to study the potential socio-economic effects of biotechnology research on multipurpose tree species in Nepal, the Philippines, and Thailand. (Please see Appendix 1 for the assessment terms of reference.)

The MPTS priority species identified by F/FRED include the following:

for the humid and sub-humid tropics --

1. *Acacia auriculiformis*
2. *Acacia mangium*
3. *Leucaena spp.*

for the arid and semi-arid tropics --

1. *Acacia nilotica*
2. *Dalbergia sissoo*
3. *Eucalyptus camaldulensis*.

In addition to the above, three other species were listed for future consideration by the network, and two were included in the tissue culture feasibility study commissioned by the Forestry/Fuelwood Research and Development Project (F/FRED) for future network consideration (Gavinlertvatana et al., 1987). These include:

1. *Alnus nepalensis*
2. *Leucaena diversifolia*
3. *Robinia pseudoacacia*
4. *Melia azedarach*
5. *Azadirachta indica*.

The specific areas of biotechnology research are defined for this study both by previous and current technical evaluation undertaken by the F/FRED Project and by the focus of researchers and resource administrators interviewed in the course of this assessment.

A technical feasibility evaluation of the potential for tissue culture of MPTS has already been done (Gavinlertvatana et al., 1987). Similar evaluations by F/FRED of the potentials of mycorrhizae and Rhizobium spp. and of specific gum and resin producing trees are currently underway.

In addition to the F/FRED evaluation studies, a series of discussions with forestry and biotechnology researchers as well as with government resource administrators and various development project personnel was undertaken in Nepal, the Philippines, and Thailand in early 1988. (Appendix 2 lists the detailed itinerary and interviews for the study.)

From the F/FRED technical studies and from the interviews undertaken, the biotechnology research topics identified as potentially important are: (a) tissue culture of MPTS for increased production of planting materials as well as improved and uniform quality of these materials, (b) tissue culture to enhance specific features of MPTS, and (c) research on mycorrhizae and Rhizobium for improving outplanting survival rates as well as enhancing growth.

The potential socio-economic effects of the above MPTS biotechnology research topics are to be evaluated on two levels. The first is with respect to scope of assessment. A national perspective for each of the three countries is adopted. The second level is with respect to potential effects specific groups of people. The emphasis at this level is on the impact of research and development on small upland farmers and the rural economy of the three countries.

C. Overview of the Study

The various steps in comprehending the potential socio-economic impact of biotechnology research are developed in Parts II to IV. The specific biotechnologies being considered are described in Part II, and a typology of research is utilized to derive a preliminary classification of the technologies. In Part III, the manifestations of the forest management problem are surveyed in terms of increasing forest losses and land degradation and in terms of declining sectoral contributions to national income and growth. The characteristics of the commercial and upland farming sub-sectors, together with the various outputs and resource uses within the forestry sector are described to set the stage for identification of the direction of beneficial effects of technology development.

Part IV presents a framework for understanding the resource management problem in terms of population pressure on limited resources, compounded by inappropriate incentive systems for resource exploitation. Two implicit strategies for management are identified: (a) a "traditional forestry" strategy and (b) an emerging "participatory-agroforestry" strategy. These constitute the policy environment which will modify the potential contributions of various technology development efforts.

Finally, Part V builds on the preceding sections as components for assessing the three types of biotechnologies considered in the study.

II. A Typology for MPTS Biotechnology Research

Bonnen (1986) has provided a classification framework for research activities that is of relevance to the biotechnology and MPTS research themes that we are considering. A distinction is made between basic and applied research, with the former focusing on increasing disciplinary knowledge (e.g., in chemistry) while the latter addresses subject matter (e.g., strengthening institutions) and problem-solving knowledge (e.g., how to improve seed quality).

It is the last category of research, the one that increases problem-solving knowledge, that leads to directly usable results for projects and policy. An important group of such problem-solving research are adaptive studies or those studies that seek to apply a known product or process to specific local conditions. Studies on seedling propagation for MPTS might be viewed as adaptive research efforts.

In addition, Herdt and Riely (1987) have defined a third type of research -- strategic research -- that lies somewhere in the middle of the basic to applied research continuum. Strategic research may be, for example, on the topic of determining the genetic factors that lead to biological nitrogen fixation in plants -- a topic that is neither basic nor applied. Studies on genetic engineering of MPTS are more appropriately classified as strategic rather than applied research activities.

These typologies are useful for assessing potential contributions of research efforts. For example, the closeness of the goal of a given research activity to specific, real-world problems means that tangible benefits are more likely. On the other hand, the strategic studies usually require substantial lags before their results can be related to specific problem areas. Even when such problem areas are associated with the studies, the results to be directly relevant will still have to be adapted to local needs. Thus strategic research is at least two steps removed from measurable contributions to specific problem areas.

A. Proposed MPTS Biotechnology Research

The following topics are based on the interest indicated by forestry researchers and resource administrators in the countries included in the assessment. A brief description of the subject is provided together with an overview of the kinds of benefit or the nature of demand for them. The typology presented above is then applied to have an indicative classification of the proposed research activities. Some related research efforts that may address parallel goals or substitute for biotechnology are also mentioned.

Tissue Culture for Improving Planting Material Supplies

In the interviews undertaken in the three countries, it was suggested that one of the most important contributions that biotechnology can make is toward increasing the supply of planting materials as well as improving quality control in their production. The potential use of seedlings is primarily for (a) reforestation and plantation programs, (b) agroforestry projects, and (c) decentralized planting activities in individual farms.

The kind of tissue culture studies that are of interest are mostly of an applied and adaptive nature, aimed at propagating planting material in substantial and affordable quantities. Two concerns were noted in the discussion: (a) the first was on the need to increase the varieties of planting materials that were being studied (including local varieties) to improve flexibility for various country locations, and (b) the second was on the need for simplification of the tissue culture process to allow inexpensive up-scaling of the procedure.

Relevant research efforts on baseline technologies or alternatives for comparing with the prospects of biotechnology research in the assessment include improving standard seed-production and certification approaches.

Tissue Culture for Genetic Improvement of MPTS

It was suggested that one justification for providing support for genetic improvement of MPTS is that such support will not be forthcoming from private sector interests. This may be especially true for fuelwood and fodder trees where there may be limited potential for private firms to benefit from research results. Although this argument is not as convincing for research on fruit trees (since commercial returns from plantations may be attractive), it was observed that focusing solely on MPTS ignores the perception that small farmers want

fruit trees for their own use, as well as to augment cash income. There was also interest in a third set of trees: those meant primarily for problem soils and extremely degraded sites. The immediate usefulness of the output from this kind of research should be for government replanting projects in problem areas.

To be classified as applied or adaptive research, these kinds of genetic improvement efforts need to be coordinated with the identification of specific traits that will be beneficial. Such traits are not as well understood in forestry as they are for field crops or fruit trees in lowland farming. Without this kind of focus, tissue culture research for genetic manipulation would be more of the strategic and less of the adaptive type of research. The implications for immediate usefulness or contribution would thus be more limited.

Finally, research efforts having goals comparable with the thrust of genetic improvement include (a) site- or adaptation-oriented screening and testing of various trees on a large-scale to determine species that will perform well for particular objectives and (b) farming systems-oriented research that will focus on tree-crop and tree-livestock interactions to develop combinations that improve the usefulness or performance of MPTS.

Use of Microorganisms with MPTS

On-going and prospective research on the use of fungi and bacteria that are beneficial to MPTS performance focus on (a) increasing survival rates of outplantings or on (b) reducing or eliminating fertilizer needs. Specific topics mentioned in this field include problems such as those having to do with culturing the microorganisms and transporting these under varying conditions. Much of the interest, however, is on the applied aspects, especially on the identification of local strains and their testing in action-research types of projects. This applied emphasis has been particularly associated with the need to link up with reforestation and seedling dissemination activities.

One comparable research activity is to assess how providing maintenance and technical support for reforestation might contribute to improving survival rates in replanting projects.

On Technology Delivery as Associated Non-biotechnology Research

A separate set of topics that was not concerned with biotechnology but which was considered complementary or relevant to the utilization of research outputs from biotechnology were also brought out during the discussions. These centered on the role of technology delivery systems and participatory schemes for project implementation.

It was pointed out that there is a need to integrate technology delivery with biotechnology studies. There are several interesting approaches. One that has already been mentioned above is to incorporate research in actual implementation programs to address specific constraints, such as poor seedling survival. Another effort might focus on using workable methods from other network projects and modifying these for local implementation. A third approach might go into direct training and increased funding of extension support for MPTS use in small-farm systems.

This last point is important because most forestry administration agencies do not have the tradition of providing extension or similar support services (which would be the focus in agricultural or cooperatives agencies). The implication of the growing recognition of an important small-scale farming sector in forest land management means that, increasingly, forest land administration will need to be transformed from its traditional role as policeman (whose main job is preventing people from using resources) into an extension-oriented organization.

III. The Forestry Problem and the Potential Sectoral Beneficiaries of Research

A. Over-exploitation of Forest Lands

The single, most graphic, indicator of forest over-exploitation is the rate of forest destruction. The average annual deforestation rate, from 1976 to 1985, exceeded 1.3 million hectares for all Southeast Asia (Table 1).

TABLE 1 Average Annual Deforestation Rates in Southeast Asia (SEA), 1976-80 and 1981-85, in thousand hectares

	1976-80	1981-85
All SEA	1,316	1,308
Thailand	333	252
Philippines	100	90

Source: FAO (1965 and 1983)

In the Philippines and Thailand, deforestation (in hectares per year) is still substantial although it has declined somewhat since the early 1980s. However, in absolute hectarage losses, Thailand is second only to India in Asia. Also, the rate of forest clearing in Thailand of about 0.33 million hectares per year represents 3.6% of its forest lands. Thus in terms of per cent of area being cleared, Thailand is highest in all Asia with the exception of Nepal (where forest clearing is occurring at the rate of 4.3% per year of forest area).

Table 2, which is consolidated from various sources, presents the trends in forest land reduction for the three countries. Thailand, which has the largest land area has its forests declining from more than half of total land area in the sixties to less than a third in this decade.

TABLE 2 Total Land Area and Trends in Forest Cover from the mid-1960's to the mid-1980's, for Thailand, the Philippines and Nepal.

	Thailand million ha	%	Philippines million ha	%	Nepal million ha	%
1960's	27.4 (a)	53	10.1 (d)	34	6.4 (g)	45
1970's	19.8 (b)	39	8.5 (e)	28	4.8 (h)	34
1980's	14.9 (c)	29	7.8 (f)	26	3.8 (i)	27
Total land area	51.3	100	30.0	100	14.1	100

Notes:

(a)-(c) Data from TDRI (1987) for 1961, 1976, and 1985, respectively.

(d)-(f) Computation of forested forest land by Revilla (1984) based on BFD AERIAL photographs using 1969, (e) is for 1976, and (f) is forecast for 1983.

(g)-(i) The data for (g)-(h) are from Wallace (1985) for 1964 and 1975, respectively; (i) is from Upadhyay (1986)

The Philippines, with its insular physiography and large population, had only a little more than one-third of lands forested in the sixties, and this had decreased to only a little more than one-fourth by the mid seventies. In Nepal, the proportion of forest lands has declined form 45 to 34 percent in the seventies to only 27 percent in 1986. With substantially steeper slopes, the environmental degradation represented by this is aggravated.

B. Potential National Gains

The conventional economic significance of forestry lies in its contribution to national production and foreign exchange generation. In the economies of the three countries, the forest sector has historically been important. However, its role has been declining. Thus research that increases productivity and sustainability of the sector has potential significance independently of equity effects.

In the Philippines and Thailand, the forestry sector's role is usually evaluated in terms of the proportion of gross national product (GNP) or gross domestic product (GDP) that it contributes. In the Philippines, the proportion of GNP generated by the forestry sector reached a peak of about 5 percent each year, from 1965 to 1969 (IMF, 1984). Since the early 1970s, this has progressively declined so that, by the early 1980s, the contribution of forestry to Philippine GNP was only a little more than 2 percent per year (IMF, 1984).

Table 3 provides data on the output of traditional Philippine forest products. The decreasing trend explains the decline in the forestry sector's role in the economy.

TABLE 3 Quantity of Philippine Forest Products, in 1975, 1980, and 1985, in 1,000 Cubic Meters.

	1975	1980	1985
Logs	11,156	6,368	3,568
Lumber	2,274	1,529	1,062
Plywood	466	553	350
Veneer	207	660	77

Source: NEDA (1987).

This decline is also seen in Philippine exports. Table 4 shows that in the early seventies logs and lumber consistently contributed close to one-fifth of the total value of exports and ranked within the top three exports. However, by the 1980s the contribution has only been around 5 per cent of total exports, and the rank of logs and lumber export has shifted to the lower half of the top ten list.

TABLE 4 Ranking of exports of forest products in the top ten principal exports, 1970-85 (FOB value in US$000).

	Total Exports	Ten Principal	Other Exports	Logs and Lumber	Plywood
1970	1,142	888	254	249	19
1971	1,189	928	261	16	16
1972	1,168	890	277	174	33
1973	1,837	1,450	386	338	58
1974	2,724	2,145	579	246	
1975	2,294	1,640	653	194	
1976	2,573	1,648	924	203	
1977	3,424	1,877	1,547	230	
1978	3,424	1,877	1,547	230	
1979	4,601	2,463	2,137	342	107
1980	5,787	3,142	2,645	273	
1981	5,720	2,958	2,761	202	110
1982	5,020	1,871	3,148	202	
1983	5,005	1,048	3,956	39	
1984	5,390	772	4,618	34	
1985	4,628	1,124	3,504	129	

Source of Basic Data: Central Bank Statistical Bulletin, 1970-1982. Philippine Statistical Yearbook, 1984-1986.

Note: Plywood exports are not listed in the years when these did not make the top ten list.

For Thailand, Table 5 shows the separate shares of agriculture and forestry in gross domestic product or GDP from 1975 to 1985. As in the Philippines, the contribution of forestry is significant but has been declining -- from 2.4% of GDP in 1975 to 1.4% by 1985. With respect to exports, traditional forest exports, such as teak logs have substantially decreased. Data from the Department of Customs of the Ministry of Finance show that the contribution of teak logs, timber, and other teak products to total exports has gone down since the early 1960s. In 1960, these products contributed 4.1 per cent of total exports. This contribution declined to 1.1 per cent by 1970 and only 0.03 per cent in 1985 (C. Mehl, pers. comm.)

TABLE 5 Share of Agriculture and Forestry Sections to Thailand's Gross Domestic Project, 1975 1980, 1985 in 1972 prices.

Sector	1975		1980		1985	
	Billion Baht	% of GDP	Billion Baht	% of GDP	Billion Baht	% of GDP
Agriculture	53.0	26.0	63.2	21.6	77.8	20.5
Forestry and Related Industries	4.9	2.4	5.5	1.8	5.6	1.4
- Timber, fuelwood, minor forest products	3.3	1.6	3.3	1.1	2.8	0.7
Total GDP	204.1	100	292.9	100	378.8	100

Source: TDRI (1987) from National Accounts Division of NESDB.

While the traditional forestry exports of Thailand have declined in importance, non-traditional forestry exports, such as wood furniture and utensils, have increased (Table 7). As Table 7 indicates, the substantial growth of these new products (especially minor forest products and paper products) has contributed to the continuing growth of export value. This kind of substitution of non-traditional or minor forestry products has also occurred in the Philippines. However, the growth of these products in the Philippines has not been as large as in the case of Thailand

TABLE 6 Export Values of Forestry and Related Industries, Thailand, 1980-85 (in million Baht).

Forestry and related industries						
Total Value	1,928	1,931	2,018	2,130	2,648	3,446
Percent of Total Exports	1.4	1.3	1.3	1.5	1.5	1.5
Timber and wood products	1,420	1,499	1,424	1,484	1,733	2,031
-teak veneer	259	250	283	349	505	474
-household utensils of wood	376	406	407	500	501	543
-articles of wood furniture	234	183	230	215	176	267
-others	551	660	504	420	551	747
Minor forest products	283	244	358	421	634	802
Paper and products	225	188	236	225	281	613

Source: TDRI (1987).

For Nepal, the major national production contribution of forestry is in terms of fuelwood and fodder output. Detailed forestry data are limited (Wallace, 1988). However, Wallace (1988) estimates that in the mid-1960's, when the first forest resource survey was undertaken, fuelwood demand was clearly less than the sustainable supply (where sustainable supply is defined as that arising from new growth). By the mid-1980's, the annual fuelwood demand was in excess of 15 million cubic meters while the sustainable supply was less than 7 million cubic meters (Wallace 1988). This means that, to meet current demand, there is substantial net reduction in the forest stock.

With respect to exports, Table 7 presents the value of Nepal's timber exports in relation to all primary commodity exports form 1982 to 1985. Both the value of timber exports and its share to total exports have been declining. This is in contrast to previous increases from the sixties to the eighties.

TABLE 7 Value of forestry and other Primary Commodity Exports of Nepal 1981-1985.

	1982		1983		1984		1985	
	Million R	% of Row 3		% of Row 3		% of Row 3		% of Row 3
Primary Commodity Exports to India	440.3	70.4	372.8	373.8	500.2	100	722.1	100
Timber	87.2	14.0	28.8	7.4	7.9	1.6	25.7	3.6
Primary Commodity Exports to All Countries	625.0	100	390.0	100	500.2	100	722.1	100

Source: Nepal Statistical Handbook, 1986.

To summarize, the contribution of forestry to national welfare, in terms of national production and foreign exchange generation, is historically significant for the three countries. The problem of sustainability of production from forest lands, however, threatens to limit this contribution.

For both the Philippines and Thailand, logs, lumber, and wood products are the conventional forestry products that are of national importance. These products have been declining in importance. Forest products exports have also decreased in importance for both countries although in Thailand the substantial growth of non-traditional wood products and other forestry-related products has kept the export contribution of forestry and forestry-related sectors quite stable.

In Nepal, the most important national role of forestry is in providing for energy and fodder needs. The capacity of the forest sector to maintain this role is being threatened by the excessive pressure being put on a contracting forest resource base. In the area of exports, the decreased availability of forest products is suggested by the large reduction of the role of timber exports.

C. Potential Sectoral Beneficiaries

The potential sectoral beneficiaries in forestry may be broken down into two sub-sectors -- the commercial forestry and upland farming sectors. The economic activity and output of the commercial sector is fairly specialized and centers on timber harvesting and processing. The activities of the upland farming sub-sector, however, is much less specialized. The main activities include the cultivation of upland corps and the gathering of fuelwood and fodder.

The Formal or Commercial Sector

In the Philippines, the commercial sector is composed mostly of holders of timber license agreements to whom 6.0 million hectares of forest lands were allocated (BFD, 1985). A system of licensing limits the area and duration of concessions. The current limit is 100,000 hectares per concession, and the duration is 50 years, including renewals.

A total of 6.6 million hectares (a little more than one-fifth of the total land area of the Philippines) were under license to the commercial sector for timber harvesting, pulpwood plantations, and other forestry uses. There were 165 concessionaires or license holders in 1985, with an average concession of 40,000 hectares and an annual allowable forest harvest of 59,000 cubic meters.

In terms of employment, the number of workers employed by the commercial logging sector in 1985 was about 21,941 with dependents of 101,336. Including the sawmill and plywood and veneer industry workers, the total commercial forestry employment was 60,914 workers with dependents numbering 280,735 (BFD, 1985). The total population, benefitting from employment in the sector, numbers about 341,649 people. This is in addition to the 165 concessionaires which will include corporate owners and their dependents aside from individual concessionaires and their families.

For Thailand, there were 621 logging concessions in 1985, controlling about 19.6 million hectares or a little less than 40 percent of the total land area (TDRI, 1987). The average concession was 31,557 hectares. Table 8 shows the figures for employment in commercial forestry activities in Thailand for 1982. The total estimated number of employees was 130,568. Assuming four dependents per employee, the total population dependent on the commercial forestry sector in Thailand is in excess of 520,000.

TABLE 8 Employment in Thailand Commercial Forestry Activities, 1982.

No.	Activity	No. of Business Units	Estimated Employees
1	Logging	336 Concessions	6,700
2	Mangrove Clearing and Charcoal Production	309 Concessions 1,280 Ovens	9,270
3	Mechanized Sawmills	464 Mills	23,200
4	Mechanized Products of Forest Products	2,833 Factories	70,825
5	Unmechanized Sawmills	230 Mills	1,380
6	Unmechanized Production of Forest Products	1,103 Factories	3,380
7	Lumber Stores	1,741 Mills	10,446
8	Forest Product Sales	1,789 Individuals	5,367
	Total	5,367	130,568

Source: Forestry Development Under the Fifth Economic and Social Development Plan, NESDB 1983, cited by TDRI (1987).

In Nepal, the commercial forestry sector is made up primarily of government corporations, which include (a) Timber Corporation of Nepal, (b), Fuelwood Corporation, (c), Royal Drug Limited, (d) Forest Products Development Board, (e) Herbs Production and Processing Company Limited, and (f) Nepal Resettlement Company (Manandhar, 1982). Indeed, the state did not control forests in Nepal until the forest nationalization act of 1957 formalized ownership of all forests under the government (Manandhar, 1982). The limited private sector commercial exploitation of forestry in Nepal contrasts with the extent of private sector commercial forestry exploitation in the Philippines and Thailand.

The Informal or Upland Farming Sector

The importance of the informal or upland farming sector is closely linked to the problem of population pressure in forest lands. The existence of substantial population density levels in Nepal has already been mentioned, and the major exploitation of the uplands has been for crop cultivation and fuelwood and fodder harvesting.

For the Philippines and Thailand the extent of the upland population has only been recently recognized. This is not surprising because upland resource exploitation has been traditionally oriented toward commercial forest harvesting in these countries.

Population Pressure and Environmental Degradation

Proper identification of the beneficiaries of research for upland development requires an assessment of the upland population. Indeed the rate of deforestation described above is closely related to the extent of land use conversion that has been going on in the uplands, and this is associated with increasing population density. Forest fires may have accounted for large components of forest hectarage that is lost. However, it is the continuing conversion of forest lands to inappropriate forms of cultivation (together with commercial exploitation) that underlies the serious environmental degradation problem in the uplands.

Soil erosion from Philippine uplands averages from 20 to 40 tons per hectare per year. In degraded lands, as much as 100 tons/ha/yr may be lost (Revilla, 1985). In Thailand, data from the Royal Irrigation Department (reported by TDRI, 1987) show that sedimentation in major river systems is increasing. Consequently, sedimentation in major reservoirs and in the Gulf of Thailand have also increased (TDRI, 1987). In Nepal, the serious erosion problems from the mountain and hill areas affect not only the upland population but also the millions of people downstream in the Gangetic plain (Manandhar, 1982).

In Nepal, there is relatively more concern on population estimates by physiographic zones or land use. It has been reported that the number of persons per hectare of arable land varies from about 15.76 in the Middle Hills to 3.79 in the Terai, and the farm size per family is about 0.4 hectares (World Bank, 1979). Table 9, constructed from data provided by the Water and Energy Commission of Nepal (WEC, 1983), show Hill region density figures that are lower since total land is used as the basis.

Table 10 presents migration flows into the Terai as an indicator of the extent of population pressure on the mountain and hill regions of Nepal. These census data suggest that population pressure is greatest in the Middle hills of Nepal. In addition to the absolute numbers involved, most of the population in these areas are dependent on subsistence level farming so that most arable land is already completely utilized (Applegate and Gilmour, 1987). Most farmers also keep livestock, and the number of large animals (such as cows) has been estimated to range from 3.7 to 9.4 animals per household. Small animals (such as goats) number about 4 per household (Applegate and Gilmour, 1987, and Mahat, 1985).

TABLE 9 1981 Population, Land Area, and Population Density by Zone, Nepal

Region	Land Area (000 ha.)	Population (000 pers.)	Density (pers./ha.)
Hills	9,689.0	8,546.3	11.1
Siwaliks	1,582.0	475.8	0.3
Terai	2,448.4	5,998.4	2.5

Source of basic data : WEC (1983)

TABLE 10 Intercensal (1971-1981) Net-Migration by Regions, Nepal

Geographic Regions	Net Migration Male	Net Migration Female
Mountain--		
Eastern	-89,814	-78,271
Central	- 2,450	- 1,964
Western	-10,307	-10,922
Mid-Western	+ 982	+ 842
Far-Western	- 527	- 42
Hill--		
Eastern	-63,195	-56,181
Central	- 7,933	- 8,889
Western	-21,755	-20,665
Mid-Western	- 4,792	- 2,511
Far-Western	- 9,028	- 8,677
Terai--		
Eastern	+78,821	+69,075
Central	+49,371	+46,703
Western	+35,839	+33,466
Mid-Western	+16,165	+14,717
Far-Western	+28,623	+23,319

Source: Central Bureau of Statistics, 1985.

The Implications of Population Pressure

In the Philippines, official statistics for a long time seriously understated the demographic aspects of the problem, reporting cases of illegal occupancy of the uplands at less than one million persons. With the new government and recent research, this view is changing. Current upland population assessments (C. Cruz et al., 1986) now recognize the major role that population pressure and upland migration play in the problem of over-exploitation.

This presents major resource management problems which are not addressed by traditional forestry administration. The Philippines uses a one-dimensional criterion for classification of uplands. Lands with slopes of 18% or more are classified as forest lands, under the jurisdiction of the Department of Environment and Natural Resources (DENR) and considered part of the public domain. Special exceptions for military reservations and other government uses are made, but on the whole DENR is expected to manage about 60% of Philippines land area.

This would be a large enough challenge if there were no population pressure problem. With 1980 census data, however, it has been shown that more than 14 million people occupy upland areas(C. Cruz et al., 1986). Additional information show that beyond the absolute numbers there are other demographic aspects that complicate the problem. First is that there are more lowland migrants than tribal people in the uplands. The second is that the lowland-upland migration patterns tend to dominate overall migration. These indicate that (a) most upland dwellers have neither formal nor traditional claims on the land and (b) being from the lowlands, most migrants will not have the technology that is adapted to minimizing the environmental effects of sloping land agriculture.

Relative to Nepal and the Philippines, Thailand has more arable land available to its population. Since its total land area is in excess of 51 million hectares while its 1985 population was about 50 million, the national population density is about 100 persons per square kilometer. In contrast to this, the Philippines has about 55 million population but only less than 60 percent of the land area of Thailand. Thus Philippine population density is almost double at 196 persons per square kilometer while its lands are generally less arable.

It is therefore not surprising that the population density problem is not viewed with the same alarm in Thailand as in Nepal and the Philippines. Indeed, there is some tendency among the forestry researchers and administrators that were interviewed in the course of this assessment to view the upland population problem as a problem of <u>hill tribe shifting cultivators.</u> It has been reported that there are about half a million tribal population, practicing various forms of shifting cultivation in the uplands of Northern Thailand (e.g., TDRI, 1987).

It must be emphasized, however, that the upland population pressure problem should already assume priority status for Thailand. There are two important reasons for this. The first is that the absolute numbers of people and upland hectarage affected are already large, even if in proportion to total national land area these are relatively smaller than those for Nepal and the Philippines.

Beyond the 500,000 hill tribe population, there are at least 1,000,313 families involved since these have been reported by various upland settlement and self-help programs as their beneficiaries (Chiripanda, 1985). For the most part, the hill tribe population and these project beneficiaries do not over-lap. Thus the implication is that about 5.5 million people (one million households multiplied by an average household size of six, including the mother and father, plus the hill tribe population) must be a conservative figure for the upland population. This is in the order of 10% of total population in Thailand while the upland population for the Philippines is about 30% of the entire population.

The second reason is that in Thailand, the motivation for upland exploitation by the informal sector may actually be influenced by market forces beyond the levels observed for Nepal and the Philippines where upland farming is primarily subsistence-oriented. Since the sixties, upland crop cultivation grew with increased commercialization of Thai agriculture (Chiripanda, 1985). Table 11 lists hectarage, production, and export for major crops, for 1960 and 1983, and TAble 12 shows the associated growth rates. The expansion of land for the crops listed in the table is very large.

This has been most important in cassava and maize cultivation. For cassava, there was about a twenty-fold increase in hectarage during the period. For maize, cultivation has increased from less than 300,000 hectares in 1960 to nearly 1.7 million hectares in 1983. Also, this rapid increase in both cassava and maize has been almost entirely in upland areas, at the expense of forest lands.

TABLE 11 Growth of Area and Production of Rice and Upland Crops in Thailand, 1960-83.

	Year 1960			Year 1983		
	Area ('000 ha)	Production ('000 tons)	Export ('000 tons)	Area ('000 ha)	Production ('000 tons)	Export (000 tons)
Rice	5,921	7,834	1,203	9,925	18,730	3,534
Cassava	72	1,222	270	1,405	19,985	5,196
Sugar Cane	158	5,382	67	577	21,568	1,526
Rubber	481	171	170	1,623	594	552
Corn	286	544	515	1,688	3,552	2,646

Source: Chiripanda (1985) from data of Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

TABLE 12 Rates of growth in production of major crops, 1960-1983

	1960-83 of growth (5 p.a.)	
	Area	Quantity produced
Rice	2.29	3.60
Cassava	15.11	14.36
Sugar cane	11.32	12.23
Rubber	4.41	5.56
Corn	7.81	8.05

Source: Chiripanda (1985).

D. Beneficiaries in Terms of Producer-Consumer Groups

Aside from identifying potential beneficiaries directly, another approach in assessing welfare implications of a technology change is to look at the effects on production and consumption activities. The impact on producers or consumers may then be evaluated. In the case of forestry, this impact will probably be different between the two sub-sectors since they have very different uses for the resource.

One of the counter-intuitive results that have been shown in agricultural research is that technology changes that increase the supply of a product (and consequently causes a relative fall in its price) will not necessarily lead to welfare improvement for the producers of the product unless they consume all of their output. The larger the proportion that they sell, the greater the relative fall in their product's price (due to the increased technological productivity), and the smaller the decrease in their input costs, the more probable it will be that they will suffer a welfare loss (Herdt, 1988). Now in the case of upland farmers, they do consume a large proportion of their own products so that the effects of technological change are easier to sort out: if technological change leads to more output there will usually be welfare gains for the upland farmers.

The Role of Forest-based Production

Table 13 provides data on the average annual volume of wood removed from forests. The Philippines has historically had a larger harvest from forests although Thailand has more than caught up since the mid seventies. There has not been any absolute decline in production for all three countries. However, growth rates are clearly declining. The production data in Table 14 satisfy the two major uses of timber harvests -- for industrial roundwood production and for fuelwood.

As indicated earlier, the use by upland farmers of forestry resources is much less specialized than by the commercial sector. Timber harvesting is undertaken primarily for domestic construction and production use although small-scale logging is not unknown especially when forests are close to urban or market centers. Most timber production therefore is adequately reflected by the commercial cutting and trade figures (in Table 14). Although national figures tend to focus on timber production because it is commercialized, it appears that fuelwood is the more important product from the forest, as may be seen by comparing Tables 14 and 15.

TABLE 13 Average Annual Total Volume of Forest Removals (million cubic meters).

Year	Philippines	Thailand	Nepal
1955-59	NA	NA	7.3
1960-64	20.9	13.1	7.7
1965-69	29.2	21.9	9.3
1970-74	32.9	32.5	11.5
1975-79	34.6	37.0	12.9
1980-82	35.2	39.2	14.1

Source: FAO, World Forest Products Statistics, 1965 and FAO, Yearbook of Forest Products, various issues.

TABLE 14 Total Volume of Industrial Roundwood Production (million cubic meters)

Year	Indonesia	S. Korea	Philippines	Thailand	India	Nepal
1955-59	5.2	0.4	4.9	1.6	4.7	0.4
1960-64	5.6	0.4	8.7	2.9	6.8	0.5
1965-69	6.9	0.8	11.4	4.4	8.8	0.5
1970-74	20.2	0.9	11.4	5.0	14.2	0.6
1975-79	25.1	1.1	10.3	5.3	17.8	0.6
1980-82	19.0	1.0	8.1	4.4	19.8	0.6

Source: FAO, World Forest Products Statistics, Rome, 1965 FAO, Yearbook of Forest Products, Various issues, for 1961-1965.

TABLE 15 Average annual fuelwood production (million cubic meters)

	Indonesia	S.Korea	Philippines	Thailand	India	Nepal	Total
1955-59	70.0	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]	NA
1960-64	78.6	6.6	11.9	10.3	71.3	7.3	186.0
1965-69	92.1	9.0	17.3	17.5	118.1	8.8	262.8
1970-74	96.6	6.1	21.0	27.5	169.2	10.9	331.3
1975-79	103.3	6.4	24.3	31.7	188.9	12.3	336.9
1980-82	110.5	6.8	27.1	34.7	204.5	13.5	397.1

Source: FAO, World Products Statistics, Rome, 1965, for 1955 to 1960.
FAO, Yearbook for Forest Products, Various issues for 1961-1982.

FAO figures for 1955-1959 refer to recorded removals only while later years include estimates of all removals.

In Nepal, fuelwood is identified as the main source of energy, accounting for more than 87% of total energy consumption (Haque, 1987). However, Applegate and Gilmour (1987) report that various estimates place the fuelwood use at more than 90%. Of the total energy consumed, households account for 94% (Haque, 1987). Rural households almost entirely use fuelwood or other biomass fuels, and even urban households use fuelwood for 83% of their energy needs (Haque, 1987). The annual per capita consumption of fuelwood varies from 632 kg in the Mountain and Hill zones to 386 kg in the Terai and 248 kg in urban areas (Haque, 1987).

Although fuelwood in the form of firewood and charcoal are also the most important energy sources for the Philippines and Thailand, the actual levels of use are much lower (due to the absence of energy requirements of heating).

For example in the Philippines, according to the 1980 Census of Population and Housing (NCSO, 1980), 72% of all households use fuelwood for cooking. There is a substantial rural bias for the household use of fuelwood compared to urban households.

In terms of physical quantities of use in the Philippines, the average household consumption reported for Northern Luzon is 65 kg per week (Dixon and Hyman, 1986). Given an average household size of about 7.5, the annual per capita consumption is about 450 kilograms.

IV. The Forest Resource Management Problem and Emerging Strategies for Sustainable Development and Equity

In this section we focus on the basic problem of resource mismanagement and identify the emerging strategies for sustainable development and equity in Nepal, the Philippines, and Thailand.

A. The Demographic and Environmental Context and the Structure of Incentives for Resource Use

Population pressure and the propensity of upland agriculture toward soil erosion may be viewed as the demographic and environmental context of the forest resource management problem. The difficulty is that, for the most part, government policy and projects can modify the effects of demographic and environmental factors only indirectly. For example, changing population growth rates and migration patterns require long-term government commitment to population planning as well as employment generation.

Therefore, in evolving a strategy for directly addressing the upland problem, the demographic and environmental factors may be considered constant, and the primary thrust for government programs must be in addressing the resource management system that governs the activities of the various users of upland resources.

The problem of resource mis-management is rooted in the undervaluation of natural resources. Traditionally, official or administrative resource pricing underestimates the true value of natural resources -- both in terms of their development contribution as well as the conservation role. This undervaluation of resources leads to fundamental problems of resource management, including the creation of excessive rents, promotion of over-exploitation, and the institutionalization of rent-seeking as the main mode of economic behavior.

As in any other economic activity, the private sector's use of natural resources responds to price signals. For example with respect to upland resources, if the price of getting access to logging concessions is low then more individuals will be interested in exploiting forests than if the price of access were higher.

If there is, however, a general social perception that in fact natural resources are being exploited, then the price signals that the economy is sending to private users are not correct -- at least from the social point of view. Economists have long recognized that price signals will be misleading if an individual's economic activity generates physical effects which leads to costs or losses for others but for which the individual is not held economically accountable. Thus, for example, cutting trees may be fine for individual concessionaires because they are not charged for the effects of excessive soil erosion on hydro-electric plants and irrigation reservoirs.

This recognition that the exploitation of upland natural resource systems generates substantial non-priced effects on other individuals in society is the basic justification for government intervention on their use. The role of government therefore in managing resources on behalf of society should be to defend a social price for the exploitation of resources. Our expectation would be that the prices administered by the government for access to; upland resource exploitation would be substantially greater than the market prices that would otherwise prevail for access to the same resources.

However, any casual survey of the charges, fees, and licenses as the administrative prices for resource exploitation will show that, contrary to our expectations, these are too low to properly reflect social valuations. Indeed, in some instances they are even much lower than what would prevail if the rights to use resources were simply put on the auction table and prices were determined by the market. In the Philippines, for example, the cutting charge for timber is close to becoming a classic example of this undervaluation: the charge is P30 per cubic meter of wood for cutting down forests vs. a market price (depending on the type of wood) beyond one or two thousand pesos per cubic meter.

B. Implications for Over-exploitation, Equity, and Sustainable Production

Thus the rents that are earned by those firms that gain the right to exploit the resource are unusually large. It is well known that the effect of such unearned surpluses is to motivate widespread rent-seeking behavior since these rents, by definition, represent returns above that which is actually required to attract or keep firms in an industry. Over time, the persistence of such rents lead to over-exploitation of the resource as private interests scramble to partake of the windfall.

Indeed, the widely recognized problem of inequity in the social sharing from the benefits of the use of natural resources is also ultimately related to this institutionalization of excessive rents. The reason is that the existence of discretionary resource administration plus the competition to penetrate bureaucratic red tape and fulfill difficult requirements to capture those elusive licenses, concessions, and claims almost ensure that small-time operators or community interests will be squeezed out by the big and influential concerns.

In addition to the unrealistic discretionary pricing in the case of commercial forestry, for upland farming, proper valuation is constrained by the property rights context within which the small upland farmers's decision-making is done. Because he has no secure and permanent claim on the land that he cultivates, the farmers has no stake in ensuring the sustainability of land beyond what limited cropping time frame he perceives to be reasonable. This indicates that while he may respond to conservation motivation whose pay-offs are fairly short-term in nature, he will normally shirk from undertaking aero-forestry investment or land improvements (such as terracing) that are long-term or permanent in nature.

C. Regulation- vs. Participation-Oriented Management Strategies

The necessary changes in management approach follow logically from this analysis. In general, there are really only two basic tools available to effect changes in resource use: through rules or through incentives. Rules refer to formal or informal regulation aimed at structuring the behavior of individuals, with compliance achieved through the use of sanctions or enforcement. Management by incentives, on the other hand, refers to the use of price changes -- both market prices or non-market valuations -- and of institutional or property rights changes to alter the incentive system on which individual decision-making is based. The approach therefore utilizes the willing participation of individual actors within the forest sector.

Both approaches have the objective of re-directing individual actions toward socially beneficial results. While rule-making has, of course, always been the concern of government, natural resource management through participatory interventions has had a much shorter history in public administration.

Indeed the tradition of forestry administration in most countries of the world has generally followed a rule-oriented approach, and our current discussion of the upland resource management problem shows the need for integrating pricing policy or re-structuring of incentive systems with the traditional rule-oriented approach. With the great expanse of the public uplands to be managed and with the many and dispersed users of upland resources, integrating the proper incentives for harnessing local management potential may be the only practical approach to resource management.

From this discussion, two forest lands management strategies that are relevant for Nepal, the Philippines, and Thailand may be defined:

(1) The Traditional Forestry Strategy. -- This is the traditional approach, and notwithstanding current criticisms of this approach from within and without the forestry profession, there are still foresters who sincerely believe that forests can be effectively managed by regulation alone. (Indeed there are still some foresters who believe that the management solution is to simply keep people out of forest lands).

(2) The Participatory-Agroforestry Strategy. -- This refers to the style of management that emphasizes the role of forest communities in the management of upland resources. This approach focuses on the upland farmers' decision-making environment and introduces economic and institutional incentive changes to allow local communities to be partners in the management of their own resources.

While many resource administrators will claim to subscribe to the Participatory-Agroforestry Strategy to upland resource management (even those who may, in fact, privately adhere to a Traditional Forestry Strategy), most will actually promote a transitional approach. The primary characteristic of a transitional approach is that participatory components are just being introduced into the management system so that the regulation-oriented thrust of resource administration remains basically unchanged.

In the Philippines, for example, programs of social forestry stop short of actually granting ownership rights to upland farmers, and the coverage of these programs address less than 5% of uplands that may be suitable for upland agriculture. In Thailand, the Sir Tar Ko (meaning "right to cultivate") or STK program offers some security of tenure, but together with the other settlement programs it covers only about one million households, and the extent of the upland population problem is not validated with systematic assessments.

Even in Nepal, where there is so much talk of community forestry, actual forest users and decision-makers are not identified and linked with existing management units. Most of the initial panchayat forests and panchayat-protected forests actually utilized local participation in the form of project wage labor, and it is only now that they are finally moving into organizing user groups for user management.

V. Assessment of MPTS Biotechnology Research in the Context of Prevailing Management Strategies

A. Cost-Effectiveness Analysis of Tissue Culture for Micropropagation

The need for planting materials to improve the quality and the supply of seedlings for reforestation and planting programs will be substantial. Even at present, many such reforestation programs are on-going, and inadequate supply as well as poor quality of seedlings have been reported. For these programs, especially for those to be undertaken by government agencies, the availability of MPTS planting materials will be important. Tissue culture work will be relevant here.

Even among the F/FRED priority species that are profuse seeders (such as Leucaena leucocephala), tissue culture may still be beneficial because of the quality control aspect (see, for example, FAO, 1987). During discussions in Thailand, it was pointed out that anywhere from 30% to 40% of seeds are of questionable quality, and with conventional production systems, the time frame for seedlings is three years before they are ready for outplanting.

In Thailand, reforestation and plantation activities have been increasing. It was reported that the Forest Industry Organization (FIO) is currently planning to reforest about 100,00 hectares using E. camaldulensis for chipboard and particle board projects, and this will require substantial seedling supply. In addition, private sector plantations have also been established, and these have been using many fast-growing species (Table 16).

TABLE 16 Plantation of Fast Growing Trees by Private Sector in Various Regions of Thailand, 1985.

Tree Species	Total (rai)	Total (%)	Central & East (%)	North (%)	North -east (%)	South (%)
Eucalyptus camaldulensis	85,438.07	100.00	55.88	13.55	30.43	0.14
Casuarina junghuhniana	38,875.89	100.00	78.26	1.83	18.97	0.94
Rhizophora indica	8,569.25	100.00	99.59	-	-	0.41
Anacardium occidentale	4,071.75	100.00	68.73	0.88	5.02	25.37
Acacia auri-culiformis	930.75	100.00	-	96.27	3.73	-
Leucaena leucocephala	1,549.75	100.00	31.68	57.54	10.78	-
Casuarina equisetifolia	1,667.00	100.00	84.35	5.58	2.70	6.87
Artocarpus fraxinifolius	325.00	100.00	-	67.74	-	32.23
Others	9,189.25	100.00	62.18	33.46	4.10	0.36

Source: Planning Division, Royal Forest Department, cited by TDRI (1987)

Incorporated in the government's priorities for replanting is the role of community participation. This is important in the assessment of potential benefits from MPTS research for reforestation since government-implemented reforestation will have limited direct impact aside form whatever temporary or contractual employment might be generated by the government agencies involved.

In the Philippines, the new government is embarking on an ambitious reforestation program that will cover 1.4 million hectares in about a decade, and seedling production of MPTS species has been identified as one of the critical activities in the program. TAble 17 shows the yearly targets in the new plan. More than 2,000 seedlings will be required for each hectare, with a projected budget of about P2,000 per hectare.

As in Thailand, there is also a concern that there should be more community participation, but the current Philippine emphasis is not so much on participation as it is on increasing survival of outplantings through contractual reforestation and maintenance systems and through the involvement of youth and civic organizations.

TABLE 17 Proposed National Reforestation Program for the Philippines, 1988-2000

Year	Target (has.)	Financial Requirements (at 1988 costs) (P'000)	Seedling Requirement
	39,194 (1987)		
1988	50,000	774,813	103,100.000
1989	59,375	920,090	122,431,250
1990	68,750	1,065,367	141,762,500
1991	78,125	1,210,645	161,093,750
1992	87,500*	1,355,922	180,425,000
1993	96,875	1,501,199	199,756,250
1994	106,250	1,646,477	219,087,500
1995	115,625	1,791,754	238,418,750
1996	125,000	1,937,031	257,750,000
1997	134,375	2,082,309	277,081,250
1998	143,750	2,227,586	296,412,500
1999	153,125	2,372,863	315,743,750
2000	162,500	2,518,141	335,075,000
TOTAL	1,420,444 **	2,869,541,695	2,928,955,528

Notes: *Target up to 1992.
**Total by year 2000.

Source: Preliminary data from DENR Planning and Policy Staff.

The need for massive reforestation and planting is most apparent in Nepal. In a study of the trends for Nepal forestry (WEC, 1983), three regions were identified as the most critical for reforestation programs (see TAble 19). These were the Sapt Kosi and Gandak watersheds in the Terai zone and the Gandak watershed in the Hill zone.

In these regions, depletion of forest resources is forecast by the year 2000 at the current rate of wood consumption (of 20 and 30 cubic meters per capita in the Terai and Hill zones, respectively) and population growth. It should be noted that the target reforestation hectarage in Table 18 is a yearly goal to provide the expected wood consumption for the year 2000 (assuming a 16 year rotation).

TABLE 18 Critical Reforestation Regions in Nepal and Yearly Hectarage Targets

Region/ Watershed	Expected Depletion Year	Annual Target	Replanting (hectares)
1. Sapt Kosi (Terai)	1990	19,930	
2. Gandak (Terai)	2000	16,656	
3. Gandak (Hill)	2000	29,300	

Source: WEC (1983)

Current Capabilities

In both Thailand and the Philippines, the facilities are available with at least one laboratory to do the tissue culture work for micropropagation. The constraints are more in the area of scaling up micropropagation and in the operational cost (including travel and monitoring cost) of testing the planting materials in various locations. One or two additional laboratories will be useful to disperse some of the research and the regional implementation links. In Thailand, a regional center such as Khon Kaen should be one prospective laboratory site, especially with the emphasis on the Northeast "re-greening" program. Indicative estimates by researchers suggest that, with a budget in the order of US$100,000, a complete laboratory, including equipment and a small office, may be operated for one or two years.

The situation is different in Nepal. In the Department of Medicinal Plants, tissue culture work that successfully bypasses the need for plant rooting in special sterile media was demonstrated for Eucalyptus camaldulensis and for Dalbergia sissoo (e.g., in Gurung and Rajbhandary, n.d.) This is important because one of the main cost constraints that makes planting material production with micropropagation ten times more expensive than traditional methods is the need for an expensive root-development process. With the non-sterile rooting procedure, scaling up the micropropagation technique is also facilitated. It was reported, for example, that one worker would be able to produce 100 to 200 plants a day with this rooting procedure.

The facilities for testing at least one scaled-up operation will be needed, but this is not expected to be very expensive because of the modification of the micropropagation procedure. Greenhouses and field-testing facilities and operational support will be the main costs involved in undertaking such an activity.

One important constraint identified for Nepal is the scarcity of specialists and middle-level technicians for this kind of work. In Thailand and the Philippines, while specialists may be limited, at least there is less of a constraint on the availability of middle-level scientific personnel. Aside from the staff at the Department of Medicinal Plants in Nepal, there is limited professional capability. This seems to be the case even at the Department of Horticulture where middle-level laboratory workers are in short supply.

Cost Effectiveness Approach for Evaluation

A practical procedure for assessment of the economic feasibility of tissue culture for planting material production is to use a cost-effectiveness appraisal framework. In cost-effectiveness analysis, there is an initial presumption that the benefits associated with the traditional or status quo procedure are more or less equivalent to those associated with the proposed technique. Thus the emphasis of evaluation is to determine whether the new procedure will be more cost-effective.

This approach to appraisal of the potentials of this biotechnology research will also be conservative. The reason is that there is, in fact, a presumption that with micropropagation the use of superior parent will be facilitated and quality of seedling will improve. The problem is that the gains from this type of improvement will be difficult to measure. Since the appraisal does not incorporate this improvement and looks only at the cost side, there is an assurance that overly optimistic assessments will not be done.

The focus will then be on quantifying the expected costs, which seem to be the more predictable and measurable component. As cited by Gurung and Rajbhandary (n.d.), unless the expensive sterile medium rooting procedure can be modified or eliminated, tissue culture for micropropagation will be in the order of ten times the cost of standard propagation techniques. Since benefits will hardly even double, biotechnology will just be relatively too expensive. Therefore the claim by researchers in Nepal that this expensive cost component may be eliminated (at least for some of the MPTS species) indicate the feasibility of the technology. Additional investment, especially for field-testing and scaling up the process, is indicated.

Micropropagation Research in the Context of Current Government Strategy

As was proposed earlier, the standard considerations of benefits and costs of new projects need to be modified in the context of the prevailing strategy that resource administrators adopt. The reason is that beyond the conventional assessment stance to evaluate the potential net benefit based on the difference between reforestation gains without the biotechnology and reforestation gains with the biotechnology, the basic scope of reforestation gains itself will change, depending on the general government strategy to which the reforestation effort will be linked.

With the Traditional Forestry Strategy, reforestation even on a large scale (with the participation of non-government entities under contract) will make some contribution to wood supplies. This benefit will be important. For Nepal due to fuelwood constraints that will become effective within a decade, replanting now, with the normal growing period requirements for trees, will just manage to provide the stock to be harvested by the mid-1990s (as shown above in Table 18). In the Philippines, an incipient fuelwood crisis will be the major problem around the turn of the century (see TAble 19). For Thailand, with its better resource endowment relative to both the Philippines and Nepal, the fuelwood problem may be less constraining.

TABLE 19 Philippine Fuelwood and Pulpwood Demand and Supply Scenarios for 1990, 2000, and 2025

	1990	2000	2025
Demand for Household and Industrial fuelwood/pulpwood (in million m^3)	67.7	111.3	189.1
Supply from:			
(in million m^3)			
Plantations	43.7	55.0	90.9
Natural Forests	4.5	9.5	8.0
Total Supply	47.7	64.5	98.9
Agroforestlands (in million ha.)	1.6	2.6	2.6
Plantations (in million ha.)	1.5	3.5	5.9
Population (in million)	59.8	73.4	118.7

Source: Revilla (1984).

The problem is that the record of reforestation within the Traditional Forestry strategy has not been good, and (even under optimistic assumptions of improved survival and establishment rates) the combined problems of large population growth and decreasing old growth forest stock will mean that the expected shortfall of wood products will not be eliminated by reforestation projects.

Tables 20 and 21, for the Philippines and Thailand, show that the historical rate of reforestation has been small. The minimum reforestation requirement, however, is for more than 1.5 million hectares of government plantations and 1.6 million hectares of agroforestry plantations (from Table 19). The conclusion is that a Traditional Forestry approach (even if it is augmented by agroforestry plantations) will not meet the challenge of providing sustainable supplies.

The implication on the role of biotechnology research on micropropagation is that while it can be a viable component of the reforestation program, the program itself will not be very effective.

TABLE 20 Area Reforested Annually by the Government and Private Sector, Philippines

		Government Sector			Private Sector
Year	TOTAL	Total	BFD	Cooperative[1]	Total
CY 1985	24231	12684	12201	483	11547
1984	38935	16088	15520	568	22847
1983	78538	42239	27155	15084	36299
1982	63262	35201	31202	3999	28061
1981	64541	33296	30707	2589	31245
1980	60516	39881	32956	6925	20635
1979	79397	51858	36305	16553	27539
1978	78425	44686	34343	10343	33739
1977	53263	33365	23677	9688	19898
1976	31733	23228	20977	2251	8505

[1]Reforestation activities by all other government agencies.

Source: BFD, 1985.

TABLE 21 Reforestation by government Agencies and concessionaires 1961-1985, in rai, Thailand

	up to 1980	1981	1982	1983	1984	1985	Total
Afforestation in Forest Villages	1,002,644	94,713	56,281	56,094	56,450	66,330	1,332,422
Watershed Re-forestation	394,625	87,250	48,750	46,925	56,575	63,300	697,425
Reforestation of Degraded Forests	375,706	89,781	30,600	30,100	32,575	48,200	606,962
Concessionaires' Reforestation	361,569	69,400	74,981	96,569	67,244	68,875	738,638
TOTAL	2,134,544	341,144	210,612	229,688	212,844	246,675	3,375,507

Source: RFD, 1985a, p. 29, cited by TDRI, 1987.

The Implications of a Participatory-Agroforestry Strategy

It is important to consider the implications of a shift to Participatory-Agroforestry Strategy. The benefits associated with a reforestation program linked to a Participatory-Agroforestry Strategy will be different from its benefits under a Traditional Forestry Strategy. These differences will be in terms of the following (using the procedure of Anderson and Fishwick, 1984):

(a) Planting rates. -- In the Participatory-Agroforestry Strategy, forestation will be through the efforts of upland farmers themselves. Planting rates will therefore be much greater simply because there are so many more upland farmers than foresters. For example, in the Philippines, the upland population is in excess of 14 million people while foresters to replant fulltime may be increased to about 10,000 so there will be a ratio of about 200 farmers for each forester. Even if these farmers devote only 10 days a year to replanting and maintenance vs. 261 working days for fulltime foresters, there will still be an excess of 7 to 8 farmer replanting days to 1 forester day. Thus the conservative multiplication of reforestation effort will be at least 7-fold. (This is conservative because the estimate presumes a large number of fulltime foresters will be employed and also because the role of lowland farmers in replanting along their residences and dikes is not included).

(b) Cost and returns. -- Since the labor of farmers would not be monetized, in financial terms this would reduce the actual expenditures of government. Of course, in economic analysis this labor would also be costed; however in the long-term the real labor cost associated with fuelwood will decline (in terms of labor for gathering) because the sources will be planted closer to the point of use.

(c) Environmental and production benefits. -- Farm-level planting will have much more direct effects in terms of environmental benefits toward soil conservation as well as long-term farm productivity. Tree growth rates themselves will tend to increase since there will be more free-standing planting patterns.

On the cost side, there will still be the need for research support for seed production, and the role of biotechnology for micropropagation discussed above will remain. However, there will be a major shift away from centralized or even regional/provincial seed production toward greatly decentralized nursery systems. These systems will, by necessity, be very simple in operation so that tissue culture techniques will probably be inappropriate. At the same time, there should be an increase in the number of varieties that farmers will want, and this will further reduce the relevance of tissue culture which in practice is better suited to developing fewer vs. more kinds of trees.

A second major shift in cost patterns for a Participatory-Agroforestry Strategy will be in the increase in extension and support services that will be required by planting programs that will utilize farm-level resources.

To conclude, tissue culture micropropagation for seedling production can be cost-effective, presuming that the difficulty with the rooting process is resolved or by-passed. However, its usefulness is predicated on the governments' persisting with a Traditional Forestry Strategy, and the prospects of this strategy are undermined by its expected inability to meet national as well as farm-level wood needs. A shift to a replanting scheme in the context of a Participatory-Agroforestry Strategy should be made.

Indeed there seems to be every indication that in Nepal at least the top decision-makers, as well as private and international donor agencies, are going to pursue the Participatory-Agroforestry Strategy. The current plan in the Philippines, however, does not seem to fully recognize the need for this approach. There will, of course be some gains even from a Traditional Forestry Strategy, especially if the effort will be as massive as the planned Philippine reforestation program. However, these gains will most likely be limited. If the government moves toward a Participatory-Agroforestry Strategy -- and there is every indication that at least a Transitional Approach will be adopted in Thailand and in the Philippines -- the relevance of biotechnology for planting material production will decline.

B. Indicative Assessment of Tissue Culture for Genetic Improvement

In tissue culture for planting materials, some improvements aside from increased uniformity may be expected. In this section, however, the focus is on genetic improvement itself. Gavinlertvatana et al. (1987) provide a review of the technical feasibility of this type of research. Following the typology in Part II, it may be best to classify this as strategic research in that there are no clear links to specific real-world constraints motivating this research effort. There is just a concern for general improvement -- e.g., changing salinity tolerance traits in MPTs. Indeed the results from this kind of research effort are expected to come out only after substantial time lags.

Thus for any given set of actual current constraints, it will probably be best to look for traditional testing and screening of various trees, with biotechnology being used to assist in the selection and micropropagation work. However, genetic manipulation itself, through protoplast fusion or other techniques, will not be the focus.

Given these considerations on the demand or benefit side, should this form of tissue culture research not be supported at all? There are two reasons why some support might be offered, albeit with correspondingly lower priorities and levels of funding. In the first place, there is really very little tissue culture work for genetic improvement that is being pursued. Most current and planned tissue culture work is on micropropagation for seedling purposes. Thus properly focused tissue culture for genetic improvement could have high initial productivity.

It should be reasonable, at least for Thailand and the Philippines, to develop some local experience in this, even if in the long-term, this effort should be based in international research agencies or specialized institutions. Indeed the facilities and expertise are already available in Thailand and the Philippines, and mostly only operational costs would have to be funded.

The second positive consideration for tissue culture for genetic engineering is that the research could be so designed that it will be fairly inexpensive relative to the other topics being evaluated. The main reason is that such an effort, being highly specialized, could be formed to involve only a small group whose work could then be spread out over several years. Thus no large budgets would be needed.

A related reason is that because there are not field-testing or action-research components, there would be no need for large budgets for travel and personnel operational costs. The latter would be essential in projects that explicitly aim at developing "products" or "packages" that could be used for nationwide impact.

The recommendation that could be made for this topic is that it should be treated as a research activity acceptable for funding but with low priority. When we bring in considerations having to do with the national strategies for addressing the forest land management problem, the above conclusion will not change. Indeed this conclusion is supported since there will be even less direct relevance for genetic engineering of MPTS.

The reason is that the kinds of contribution that have been envisioned for such research focus on enhancing commercial and marketable products from trees (e.g., increasing yield of resins) or on increasing incremental growth for trees that will be in demand for private plantations. In the latter case, large numbers, of such trees would be planted so that rates of return could be quite sensitive to marginal improvements.

In fact, the species currently being considered are primarily eucalyptus which has limited small farm use. For the small farm sector the interest is primarily fuelwood and fodder, and the production of these from trees do not lend themselves to marginal improvements. For example, if more fuelwood supply is desired by the farmer, it would probably be better to plant two trees rather than to experiment with one "incrementally improved" tree. The real question of interest here is whether the farmer will plant the first tree anyway; and if he does not, how can the incentive system be changed so that he will.

C. The Benefits and Costs of Research on the Use of Beneficial Microorganisms for MPTS

As previously described, research on the use of beneficial microorganisms for MPTS have the goals of improving seedling establishment and of enhancing growth of plants with little or no fertilization. The kind of microorganisms relevant in this topic include fungi (such as mycorrhiza) and bacteria (such as rhizobium). Some beneficial results associated with the use of mycorrhiza for example, include: better absorption of moisture and nutrients form the soil, reduction of pathogenic root infections, and improvements in the soil structure around the roots. In turn these effects are usually associated with increased survival rates of outplantings as well as enhanced growth.

There is currently limited actual application in forestry of this technology in the three countries being considered although there is already wide use of these biotechnologies for lowland legumes such as soybeans. It has been reported that while there is hardly any work on this in Thailand for trees, with the knowledge and experience in agriculture, existing facilities and current expertise could easily move into this field. There is even less actual work being done in Nepal, but in the Philippines definite progress has been reported, especially in the field of ectomycorrhiza technology.

The potential national significance of these biotechnologies revolve around two aspects. The first effect is on increasing tree seedling survival rates. According to one estimate for the Philippines, survival rates in government reforestation is only in the order of 15% of plantings. For private plantations, the survival rate is in the order of 40 percent. For Thailand, the comparative rates are 30 and 40 percent. The main reason, of course, for the difference between government and private plantations is in the care and fertilization of young trees. With little probability that public reforestation efforts will receive improved maintenance, there would be a premium on seedling inoculation.

In the Philippines, clear improvements have been reported from several field tests. As an example, for 6 to 18 month pines and eucalyptus inoculated with mycorrhiza, 50% or greater growth in height and width relative to uninoculated trees were reported (de la Cruz, 1987).

Now if the use of microorganism can reduce seedling mortality by a conservative figure, say 25% reforestation costs to effectively cover the sam hectarage targets could be reduced by 25 percent. In the Philippines, the cost of government's new reforestation program is in the order of P2,000 per hectare planted, but with survival rates of 15% to 40% the cost per hectare of actually established forest will be effectively P4,000 to P12,000 (i.e., to establish one hectare, roughly 2 to 6 hectares would need to be planted). With the 25% increase in survival the cost per hectare of forest actually established could be reduced to roughly P3,000 to P4,000 (please refer to Table 18 and Appendix 3 for cost of reforestation estimates). Thus actual per hectare savings could be in the order of P1,000 to P8,000.

The second effect is on the reduction of fertilization rates for seedling establishment. Philippine estimates are about P550 per hectare per year for fertilizer for the first two years of the project. In Appendix 3, it is estimated that there will be about 50 grams of fertilizer per plant and about 2,500 to 3,000 plants per hectare. If a 50% reduction in fertilization could be achieved, the cost per hectare would be reduced to P225 per hectare for two years. Since the actual cost of mycorrhiza inoculation is less than P1.00 per seedling, the net savings in the two examples above would be quite large.

Since there are no comparable examples for the use of rhizobium for trees, illustrative data from soybeans might be helpful. With the use of sterile carriers, the cost would be about P10 per packet of rhizobium, and four packets would normally be used per hectare of soybeans so the cost is P40. This can substitute for about 30 kg of urea, which has a much higher cost of roughly P200 per hectare. In Thailand, the preference seems to be to use non-sterile carriers for rhizobium. While production cost would certainly decline, there would be some losses in effectivity.

Proposed Research Focus and Implications of Government Strategies

It has been suggested that in research projects on microorganisms the focus should be on field applications, emphasizing the collection of existing organisms from various local sites, followed by rapid screening and development of practical inoculants. This type of adaptive research is usually too expensive given the standard research budgets because it requires a large scale of activities that will involve large outlays for travel and personnel as well as site trial facilities and operational cost.

However, if the prevailing approach follows the Traditional Forestry Strategy outlined above, there will clearly be large savings since the hectarage targets run into the tens of thousand s for reforestation. What is interesting is that even if the approach follows the Participatory-AGroforestry Strategy, the technology could also lead to substantial benefits.

The reason is that the technology does not require the kind of centralization of seedling production that may be associated with tissue culture for micropropagation. Thus the use of a decentralized distribution system for seedlings will not be significantly affected by an inoculation program.

Indeed the use of inoculants might actually represent a more acceptable technology for small farmers relative to fertilizer use. It has been indicated, especially in discussions with Thai researchers, that it will be unrealistic to expect farmers to apply fertilizer to trees, even at the time of establishment. Most subsistence farmers usually refrain from any monetary outlays, and inorganic fertilizers are relatively expensive. Since inoculates can be incorporated in the planting material itself, there would be less resistance from farmers. The presumption here, of course, is that the afforestation program will provide seedlings to farmers for free.

Conclusion

The two basic objectives of any forestry-oriented technology development effort should be to contribute toward promoting sustainable production and equity goals in forest lands management. The first objective is served by improvements in technology that can provide increased wold production or greater effective hectarage of afforestation. The second objective is served if those who most need assistance are the ones beneficially affected. The target group may be benefitted through increased availability of the products they gather form forests or through improvements in their own production and consumption activities.

Aside from the commercial forest sector, population growth and migration from the lowlands in the Philippines and Thailard have led to the creation of a large upland farming sector. In Nepal, population growth and the lack of new lands to move into have led to critical congestion in the traditional hill farming sector. Constrained by unproductive marginal lands as well as by their lack of technical know-how and by a government resource adminstration system that provides neither security nor technical support, it is not surprising that this group has been characterized as being among the most disadvantaged of society. Driven by their poverty, they perpetuate a cycle of resource over-exploitation, increasing environmental degradation, and declining productivity.

Examples of the result of biotechnology research, such as the increased availability of robust seedlings through micropropagation techniques can clearly contribute to both the goals of sustainability and equity. However, the increasing complexity and scope of the forestry management problem suggests that there should not be excessive optimism on the potential of biotechnology to crank out products, process, or organisms that will provide acceptable benefits relative to their cost. After all, the presumption is that the financial resources supporting development research is limited os that investment in technical change should be directed to where benefits will probably be substantial.

The general result of our assessment of the three technologies was that research investment in biotechnology must be weighed carefully. It appears that the work on micro-organisms will be more relevant than that on tissue culture for micropropagation and that investment in tissue culture for genetic engineering might best be kept small. In any case, researchers must be aware that the potential usefulness of their individual projects must work through general implementation programs. They therefore have a stake in promoting implementation strategies that can enhance the relevance of their work.

It was with this view that we proceeded to determine the alternative national strategies by which the management problem might be tackled. The conclusion was that the emerging strategy of making the upland farming sector partners in resource management offers a potentially powerful approach for promoting techniques of resource conservation that are closely tied in with equity gains. The need to evaluate the promise of this Participatory-Agroforestry Strategy and its production-equity implications is outside the scope of this assessment. However, a realistic assessment of the potential efficacy of biotechnologies required that their evaluation also consider how they might be integrated for maximizing impact either with the Traditional Forestry Strategy or with the emerging approach.

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APPENDIX 1
TERMS OF REFERENCE

The consultant will carry out an analysis of potential socio-economic effects in Nepal, the Philippines and Thailand of the proposed biotechnologies for multipurpose trees recommended in the technical studies prepared for the Forestry/Fuelwood Research and Development Project. The consultant's activities under this contract well include:

1. Travel to Nepal, the Philippines and Thailand to visit research institutes with tissue culture and other proposed biotechnological capabilities;

2. Field interviews with forestry, agricultural, economic, and social science researchers and forestry and extension officials who can provide information on the potential for the proposed biotechnologies and the potential socio-economic effects of these technologies;

3. An assessment of the economic viability of the provision of recommended biotechnologies to small farmers by research institutes and extension services in these countries;

4. An assessment of socio-economic impact (including a rough estimate of costs and benefits) of the proposed biotechnologies on the rural economy of these countries and

5. Prepare a report with an executive summary on the results of items 1 through 4 above.

APPENDIX 2
ITINERARY OF FIELD VISITS TO REGIONAL F/FRED SITES AND RESOURCE PERSONS IN THAILAND, NEPAL AND THE PHILIPPINES

Thailand

4 January	Arrival in Bangkok	
5 January	1.	Dr. Charles Mehl
	2.	Dr. Amara, Dr. Charit Tingsabadh, and Ms. Kobkul Phutaraporn, Chulalongkorn University Social Research Institute (CUSRI)
6 January	1.	Dr. Somkid Siripatanadilok Dr. Uthaiwan Sangwanit Faculty of Forestry Kasetsart University Bangkok
	2.	Dr. Suree Blumibhamon Deputy Director Regional Community Forestry Training Center c/o Faculty of Forestry Kasetsart University Bangkok
7 January	1.	Dr. Amnuay Kerwanich Faculty of Forestry Kasetsart University (social forestry)
	2.	Dr. Nantakorn Boonkerd Director BNFRC and Chief, Soil Microbiology Rhizobium Bldg., Div. of Soils Dept. of Agriculture Bangkok
8 January	1.	Dr. Suthad Sethboonsarng Dr. Suthaiwan Research Fellows Agriculture and Rural Development Program Thailand Development Research Institute Bangkok
	2.	Napoleon Vergara David Thomas Participatory Forestry Development Through Extension Program c/o UNDP, G.P.O. Box 618 Bangkok

10 January		Arrival in Khon Kaen
11 January	1.	George Lovelace Dr. Yaowalak Apichatvullop and staff Faculty of Humanities and Social Sciences Khon Kaen University Khon Kaen
	2.	Dr. Utai Pisone Director Northeast Regional Office of Agriculture Tha Phra, Khon Kaen
	3.	Mr. Ian Craig Consultant Northeast Rainfed Agricultural Development (NERAD) Project USAID and Ministry of Agriculture and Cooperatives
12 January	1.	Dr. Terry Grandstaff Dr. Somluckrat Grandstaff KKU-Ford Upland Social Forestry Project Khon Kaen University Khon Kaen
	2.	Mr. Mongkol Dandhanin Deputy Director for Research and Planning Research and Development Institute Khon Kaen University Khon Kaen
	3.	Mr. Uthai Thongmee Project Field Director Integrated Development of the Phu-Wiang Watershed Project P.O. Box 13 Phu Wiang, Khon Kaen
	4.	Mr. Pieter Van Ginneken Team Leader/Land Use Planner Integrated Development of the Phu-Wiang Watershed Project P.O. Box 13 Phu Wiang, Khon Kaen

Philippines

25 January

1. Dr. Robert Salazar (Director)
   Ms. Ellen Chiong-Javier (Research Associate)
   De La Salle University Research Center
   Manila

2. Dr. Marina de los Angeles
   Research Fellow
   Philippine Institute for Development Studies
   Manila

3. Mr. Ricardo Umali
   Undersecretary for Planning
   Dept. of Environment and Natural Resources
   Manila

4. Mr. Edwin Payuan
   Chief, Social Forestry Division
   Forest Management Bureau (FMB)
   Dept. of Environment and Natural Resources
   Manila

26 January

1. Dr. Corazon Lamug
   Director for Research
   University of the Philippines at Los Banos
   Laguna

2. Dr. Enrique Pacardo (Executive Director)
   Dr. Antonio Alcantara (Deputy Director)
   Dr. Ma. Concepcion Cruz (Head, Envir. Educ. Div.)
   Institute of Environmental Science and Management (IESAM)
   University of the Philippines at Los Banos
   Laguna

3. Dr. Reynaldo de la Cruz and staff
   Forest Biological Sciences Dept.
   College of Forestry
   University of the Philippines at Los Banos
   Laguna

4. Dr. Mercedes Garcia
   Forest Biological Sciences Dept.
   College of Forestry
   University of the Philippines at Los Banos
   Laguna

5. Dr. William Padolina and staff
Biotech
U.P. Los Banos campus
Laguna

27 January

1. Dr. Roberto Dalmacio
SFI, College of Forestry
-- site visit to Bayog Agroforestry Experimental Project (Mr. Akira Sato, Project Leader)

2. Dr. Romulo del Castillo
Forest Resources Management Dept.
College of Forestry
and Consultant, Ford Foundation, Manila

3. Dr. Sinesio Mariano
Dr. Domingo Ramirez
Dept. of Social Forestry
College of Forestry
University of the Philippines at Los Banos
Laguna

4. Dr. Severo Saplaco (Director)
Asean-US Watershed Project
College of Forestry
University of the Philippines at Los Banos
Laguna

28 January

Arrival in Baguio City, Northern Luzon

1. Mr. Benjamin Tapang and staff
Cordillera Studies Center
U.P. Baguio
Baguio City

2. Mr. Godfrey Cawis (ADF, Officer-in-charge)
Mr. Guillermo Fianza (Asst. District Forester)
Forest Management Bureau
Pacdal, Baguio

3. Mr. Paquito Untalan (Agroforestry Dept. Chairman)
Mr. Inocentes Moldez (Forest Res. Mgt. Chairman)
Mr. Anthony Lopez (Instructor)
Mr. Egidio Costales (Instructor)
Mr. Feliciano Calera (Chairman)
Dr. Herminia Francisco
Benguet State University
La Trinidad, Benguet

29 January — site visit to Forest Management Bureau (FMB) field office in Loakan, Benguet.

Nepal

1 February — Arrival in Kathmandu

Mr. T.M. Vinod Kumar (Regional Program Co-ordinator, District Energy Planning and Management)
Mr. Bhaskar Thapa (Research Associate)
Dr. T.B.S. Mahat (Coordinator, Watershed and Forest Mgt. Programme)
International Centre for Integrated Mountain Development (ICIMOD)
G.P.O. Box 3226
Kathmandu

2 February — Dr. S.B. Rajbhandary
Deputy Director General
Dept. of Medicinal Plants
Thapathali, Kathmandu

Field Visit to Godavari Experiment Station

3 February

1. Dr. Mukunda Ranjitkar
Director
Horticulture Research Centre
Kirtipur, Kathmandu

2. Ms. Neeru Shrestha
Community Forest and Afforestation
Division Naxal, Kathmandu

3. Dr. Deepak Bajracharya
Division Head
Mountain Population and Institutions
International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu

4 February

1. Dr. Ram Prakash Yadav
Deputy Director
International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu

2. Dr. Binayak Bhadra
Centre for Economic Development Administration (CEDA)
Kirtipur, Kathmandu

3. Mr. Kamal Rizal
Mr. Stephen Graham (Energy Planning Advisor and Project Director)
Mr. Kenneth Smith (Forestry Advisor)
Water and Energy Commission Secretariat
Water and Energy Resources Development Project
Singha Durbar
Kathmandu

5 February

1. John Hudson
Team Leader
Nepal-UK Forestry Research Project
c/o British Embassy
P.O. Box 106
Kathmandu

2. Mr. Rauno Laitalainen
Team Leader
Master Plan for Forestry Sector
Ministry of Forests and Soil Conservation
New Baneswor, Kathmandu

3. Mr. George Taylor
Agricultural Development Office
U.S.AID
Rabi Bhawan, Kathmandu

APPENDIX 3
COST ESTIMATES OF ESTABLISHMENT, PROTECTION AND MAINTENANCE PER HECTARE IN GOVERNMENT REFORESTATION PROJECTS IN THE PHILIPPINES, CY 1988

Activities	Goal/ha	Mandays/ha (2x2 m.spacing)	Cost (in P/ha)
A. Nursery Operations			4,607.55
Seed procurement and handling	28.4 lb.		86.25
Nursery site preparation	15.0 sq.m.		52.62
Sowing of seeds			
Gathering and preparation of soils	1.51 cu.m.	1.51	79.46
Potting of seedlings	2,790 sdlgs.	6.88	362.02
Preparation of potbeds and arranging pots	11.5 sq.m.	0.46	791.00
Maintenance of seedlings (8 months)	2,750 sdlgs.	55.0	2,894.10
Cost of plastic bags	2,750 pcs.		330.00
Cost of Fertilizer at 1 gram/seedling	(for 2,750 sdlgs.)		12.10
B. Plantation Establishment			3,091.38
Detailed survey and mapping	1.0 ha.	0.02	3.62
Site preparation:			
a. strip brushing	5,000 sq.m.	16.67	877.18
b. digging of holes and pulverization	2,500 holes	16.67	877.18
Transport of seedlings	2,600 sdlgs.	8.67	456.22
Planting	2,600 sdlgs.	16.67	877.18

			(1st year)	(2nd year)
C. Maintenance and Protection			1,691.32	1,516.10
Plantation Maintenance:				
a. brushing and fertilizer application	2,500 spots	16.67	877.18	877.18
b. replanting	250 spots	0.83	43.67	43.67
c. fertilizer cost	50 grams/hill		550.00	550.00
Firebreak construction (10 m. wide)	150 sq.m.	0.5	26.31	26.31
Footpath construction (1 m. wide)	50 sq.m.	3.33	175.22	
Patrol work (6 months)	1 ha	0.36	18.94	18.94
D. Administration and Supervision (including equipment and capital outlays)		1,606.00		
TOTAL			10,996.25	1,516.10

Source: Preliminary estimates from Department of Environment and Natural Resources (DENR) Planning and Policy Staff.

Multipurpose Tree Species Network Research Series

Papers

no. 1. Feasibility Study on Tissue Culture for Multipurpose Tree Species. Paiboolya Gavinlertvatana, A. Colin Matheson, and Eng Peng Sim. 1987.

no. 2. A Regional Research Plan for Leucaena Psyllid Control. Banpot Napompeth, Kenneth G. MacDicken, Max McFadden, and I.N. Oka. 1987.

Reports

no. 1. Multipurpose Tree Species Networks for the Forestry/Fuelwood Research and Development Project: Recommendations. Kenneth G. MacDicken, Michael R. Dove, James L. Brewbaker, and William F. Hyde. 1986.

no. 2. The Status of Multipurpose Trees in Thailand. Suree Bhumibhamon. 1987.

no. 3. Multipurpose Tree Species Trials Data Compilation, Republic of the Philippines. C. Buford Briscoe, Jocelyn M. Alcazar, and Paciencia A. Votacion. 1988.

no. 4. 1987 Seed Collections of *Acacia auriculiformis* from Natural Populations in Papua New Guinea and Northern Australia. Brian Gunn, Maurice McDonald, and James Moriarty, compilers. 1988.

Manuals

no. 1. IADSS Information and Decision Support System (Version 1.1) User's Manual. Global Research Unit. 1988.

no. 2. Manual for Multipurpose Tree Species Research Cooperators for the F/FRED 1987 Humid and Sub-humid Network Trials. Kirtland M. Barker, ed. 1988.

Videos

no. 1. A Guide for Multipurpose Tree Species Research Cooperators for the F/FRED 1987 Humid and Sub-humid Network Trials. Kovith Yantasath and Celso B. Lantican. 1987.

The Forestry/Fuelwood Research and Development (F/FRED) Project is designed to help scientists address the needs of small-scale farmers in the developing world for fuelwood and other tree products. It provides a network through which scientists exchange research plans, methods, and results on the production and use of trees that meet the household needs of small farmers. These trees, in project terms, are multipurpose tree species (MPTS).

F/FRED is being carried out by the Winrock International Institute for Agricultural Development. Winrock was established in 1985 through the merging of the Agricultural Development Council (ADC), the International Agricultural Development Services (IADS), and the Winrock International Livestock Research and Training Center. Winrock's mission is to improve agriculture for the benefit of people—to help increase the productivity, improve the nutrition, and advance the well-being of men, women, and children throughout the world. Winrock's main areas of emphasis are human resources, renewable resources, food policy, animal agriculture and farming systems, and agricultural research and extension.

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