BIOLOGICAL AND SOCIOLOGICAL BASIS FOR A RATIONAL USE OF FOREST RESOURCES FOR ENERGY AND ORGANICS

PROCEEDINGS OF AN INTERNATIONAL WORKSHOP

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BIOLOGICAL AND SOCIOLOGICAL BASIS FOR A RATIONAL USE OF FOREST RESOURCES FOR ENERGY AND ORGANICS

An International Workshop

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of Canada, Mexico, and the United States

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Abstract.--Recommendations, conclusions, proposed actions, and technical papers from different parts of the world are compiled from a Man and the Biosphere Workshop on the rational use of forests for energy and organics. The three primary issues addressed were: socio-economic relationships, the energy input/output relations of forests, and the environmental consequences of using forests and trees for fuel.

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FOREWORD

The objective of the Man and the Biosphere Program (MAB) is to evelop the basis within the natural and social sciences for the ational use and conservation of the biosphere--that portion of the earth's crust and lower atmosphere which contains life--and for the improvement of the relationship between man and the environment. MAB is an integrated, interdisciplinary, and problem-focused approach to the management problems arising from the interactions between human activities and natural systems.

In achieving its objectives, MAB provides for the coordination of diffuse national and international research, conservation, and training activities.

It is in the MAB context that this international workshop was organized by the MAB Committees of Canada, Mexico, and the United States to examine world-wide the use of forest biomass for energy applications. Wood is vitally important as a fuel source in developing countries and is given increasingly serious consideration as an energy source in developed countries as fossil fuels become more costly and scarce. The use of wood for energy purposes has many socio-economic and environmental implications, and raises important technical questions concerning the growth, management, harvest, and regeneration of energy trees. The purpose of the workshop was to consider all of these issues in an overall integrated framework and to: (1) clarify the impacts and conflicts resulting from the use of forest biomass for energy applications; (2) identify gaps in knowledge; (3) make recommendations about needed research, training and information transfer programs; (4) suggest priority needs; and (5) reinforce international cooperation in the management and use of forest biomass resources.

The workshop was held at Michigan State University from May 6 through 11, 1979, and was attended by participants from developing and developed nations with wide representation from all parts of the globe. Funding was provided by the U.S. Agency for International Development, the U.S. Department of Energy, the U.S. Department of Agriculture (Forest Service), UNESCO-Paris, Canadian National Commission for UNESCO, Michigan State University, and U.S. MAB.

Special thanks go to all the participants and to Professor G. J. Afolabi Ojo of the Department of Geography, University of Ife, Ile-Ife, Nigeria; Dr. J. D. Ovington, Director of the Australian National Parks and Wildlife Service, Canberra City, Australia; and Dr. Patricia Roberts-Pichette of the Canada International Development Agency, Hull, Quebec, Canada, who served as chairpersons during the workshop.

The workshop was organized by a diverse group which included Dr. Stephen G. Boyce, U.S. Department of Agriculture, Forest Service, Asheville, North Carolina (U.S. MAB 1); Dr. Russell M. Burns, U.S. MAB, Washington, D.C.; Josephine K. Doherty, National Science Foundation, Washington, D.C.; Dr. Peter F. Ffolliott, University of Arizona, Tucson, Arizona (Chairman, U.S. MAB 2); Dr. A. Gomez-Pompa, Chairman, Mexico-MAB, Jalapa, Veracruz, Mexico; Dr. Irwin Hornstein, U.S. Agency for International Development, Washington, D.C.; Dr. Frank B. Golley, University of Georgia, Athens, Georgia (Chairman, U.S. MAB 1); Anne Fege, U.S. Department of Energy, Washington, D.C.; Dr. Stanley Krugman, U.S. Department of Agriculture, Forest Service, Washington, D.C. (U.S. MAB 8); Dr. Peter Murphy, Michigan State University, East Lansing, Michigan (U.S. MAB 1); Dr. Walter Parham, Office of Technology Assessment, U.S. Congress, Washington, D.C. (U.S. MAB 1); Dr. Patricia Roberts-Pichette, Canada International Development Agency, Hull, Quebec, Canada (Canada MAB); Oscar J. Olson, Jr., Executive Director, U.S. MAB, Washington, D.C.; Phylis N. Rubin, U.S. MAB, Washington, D.C.; Dr. David B. Thorud, U.S. Department of Agriculture, Forest Service, Washington, D.C. (U.S. MAB 3); Dr. Harold E. Wahlgren, U.S. Department of Agriculture, Forest Service, Washington, D.C.; Dr. Richard C. Steele, The Institute of Terrestrial Ecology, Cambridge, England; Joan Yantko, University of Georgia, Athens, Georgia; and Glenda McMahon, U.S. Department of Agriculture, Forest Service, Asheville, North Carolina, who typed much of the proceedings and made invaluable contributions in organizing, printing, and distributing the report.

DONALD R. KING
Chairman, U.S. MAB

DAVID B. THORUD
Chairman, Workshop

May 11, 1979

CONTENTS

INTRODUCTION

One concern of the Organizing Committee was to suggest a set of actions common to all countries. Five actions are presented in the summary.

Another concern was to present conclusions and recommendations which must be considered in carrying out the suggested actions. These conclusions and recommendations are presented in the three working group reports.

The Organizing Committee wanted to report differences that were found to be associated with social, economic, and biological situations. This was accomplished by maintaining the organization and wording of the group reports with a minimum of editing. The group reports were not adjusted to eliminate overlapping ideas, or to bring about full agreement. Furthermore, from the last plenary session comments that reflected different opinions were recorded and published.

Invited papers were prepared by the authors to meet minimum standards set by the editor. This permitted prompt reproduction for the workshop and for the proceedings. These papers were the primary sources of information for the workshop.

Volunteer papers were accepted at the workshop. The Organizing Committee chose to include these papers essentially as submitted, so publication of the proceedings would not be delayed.

Finally, the Organizing Committee included statements describing how MAB provides the mechanism for coordinating national and international research, conservation, and training activities; how the workshop was planned and conducted; and a list of the participants.

THE ORGANIZING COMMITTEE

SUMMARY

It became apparent, soon after the workshop convened, that the most important issue was the combustion of wood for heat. It was recognized that forests and trees are sources of organics, such as organic acids, aromatics, drying oils, lubricants, synthetic fibers, cosmetics, dyes, animal feed, and solvents. These chemicals and all other forms of forest benefits including water, habitats for endemic plants and animals, paper, lumber, a sink for carbon, shelterbelts, and landscape amenities, are important. However, the immediate worldwide concern for assessing all possible sources of energy, especially combustible materials, resulted in the members of the workshop directing their attention toward the use of forests and trees, defined in the broadest sense, for fuel.

Forest benefits other than fuel were not ignored. One working group considered the environmental consequences of using dense plantations of trees with 3- to 10-year harvest, short harvest periods in natural stands, genetics, fertilizer, and other cultivation practices to exploit forests primarily for generating steam. This group considered utilizing forests for fuel and the consequences of using forests for fuel. An important concern was the necessity to include biological processes in economic analyses. Another working group examined the physical input and output considerations for directing "naturally" regenerated forests, plantations, and agro-forests toward producing primarily fuelwood. A third working group examined the socio-economic consequences of and constraints for the use of land and forests for fuelwood. The latter issue is most important because the rational use of the world's biological resources must take into consideration different social, cultural, and economic systems.

The working groups described how the whole problem of energy development requires investigation by teams of social scientists, foresters, engineers, biologists, and other technologists. Because of the many variables involved, it is important to provide interdisciplinary training for people to effectively assess different situations and evolve tactics for effectively and efficiently implementing projects.

The situations in different parts of the world were reviewed in a number of informative papers that circulated to all participants before and during the workshops. In three working groups ideas, concepts, data, and proposals were interrelated to produce specific recommendations. These recommendations are described in three group reports. Not all recommendations apply to all social, cultural, economic, and biological situations. Thus, five specific actions are suggested for the purpose of aiding decisionmakers in assessing and implementing the recommendations; in developing international and interdisciplinary cooperative efforts by countries, international development agencies, development banks and components of the MAB organization; and for countries to develop institutional arrangements to help groups use their cultural, economic, and biological resources to more effectively assess the use of wood for fuels.

Suggested Action 1

Each country, under its particular social and economic conditions, should assess its biological potential for using woody materials for energy.

The assessment in each country should include an inventory of the biological resources in forests, trees, and shrublands; the trends in current use of these resources for whatever purpose; the productive potential of the lands now in forests, trees, and shrubs, and the identification of lands for afforestation and reforestation. Evaluations of proposed actions for the increased use of woody materials for fuel should incorporate into the analytic process the findings and recommendations presented in this report. The social and economic elements of evaluation are as important as the biological resources.

Suggested Action 2

Each country should develop an effective way to monitor changes in the biological productivity of forests, trees, and shrublands in relation to their use for energy and organics.

It is important that the biological productivity of the land not be lost, for it is on this base that the social, economic, and political structures are built. The issue papers, the findings, and the recommendations of this report provide checklists, precautions, and considerations that must be incorporated into a monitoring system. It is particularly important that baseline information be obtained of the parameters for biological productivity as a standard for decisions by governments and regional institutions.

Suggested Action 3

Institutional arrangements should be made for international exchanges of information and technology, and for the use of forest, tree, and shrubland resources for energy in relation to social, cultural, political, and economic relationships.

Scientific and technological information is available world-wide through many channels of communication. The implementation of this information in relation to differences in political systems, resource perspectives, and cultural heritage, requires modification, sorting, and recombination of the knowledge to fit specific relationships. Examples of how this is done are not effectively transmitted by conventional channels of communication. Demonstrations and small scale operations are almost always essential before full scale implementations.

Suggested Action 4

MAB should encourage and coordinate studies of social, economic, and biological opportunities in small communities to more effectively use woody materials for fuel.

Various agencies are to be encouraged to collaborate in applying knowledge from different disciplines to more effectively use biological resources, primarily the energy component, to achieve social, cultural, and economic ends. Interdisciplinary training must be provided if effective teams of social scientists, biologists, foresters, engineers, and other technologists are formed.

Countries are to be encouraged to identify one or more communities which would be used for studies, demonstrations, and small scale operations. Findings, results, and achievements are to be made available to all countries. The use of ecosystems that include people and the use of interdisciplinary techniques are expected to result in the more effective use of natural resources to achieve human goals.

Suggested Action 5

Increasing human demands on the forests and shrublands should be given priority in assessments of wood for energy; in monitoring changes in the productivity of lands; and in programs to expand, modify, and transform forests and shrublands to other uses.

The purpose for this statement is to emphasize the necessity for including in all analyses changes in the size of human populations and changes in the kinds and amounts of natural resources consumed.

The findings and recommendations for the three issues provide the social and economic considerations, the model for examining the input and output relations for human communities, and the consequences that must be considered.

REPORT OF WORKING GROUP 1

THE SOCIO-ECONOMIC CONSEQUENCES AND CONSTRAINTS TO THE USE OF LAND AND FORESTS FOR ENERGY AND ORGANICS

RECOMMENDATIONS[1/]

1. Every effort should be made to economize on the use of fossil fuels. Saving fossil fuels has two implications:

   a. It would ensure that fossil fuels last longer

   b. It would allow more time for phasing in the use of renewable energy sources.

2. All countries should increase their wood supply for environmental and economic reasons. Planting of more trees must start now. There is a time span between planting and utilization. Unused land should be planted with trees. The productivity of stands should be improved. In addition to wood, high priority should be given to other non-fossil fuels from biomass sources.

3. Forest management for energy and other uses must be perceived as an integral part of a total socio-economic, biological, and physical system. Human needs and values must receive full consideration as forest management practices are developed. In this connection the people who live in the areas where it is proposed to make interventions must be an integral part of the process of developing the forest management practices for the area. Whenever possible, however, wood should be used as a source of energy, provided that the forest ecosystem is not degraded ecologically or socially. Each country should ensure that its forest biomass data base is sufficient in relation to the development of its forest energy resource.

4. Land use planning for a particular area must take into consideration the balance between the needs of a given population for food and energy to evolve economically and socially viable land use systems.

   Increased efforts should be made to locate forests closer to the source of consumption to ensure that their products will be as competitively priced as possible and that optimum energy results will be obtained.

5. The technology for the more efficient conversion of wood into energy and organics, including convenience of use, should be developed. The goal is to make wood more acceptable as a fuel.

6. The consequences of current rates of population growth must be considered in all long-term planning for natural resources.

7. Peoples' changing behavior in relation to their use of fuels will require scholarly investigation by teams of social scientists, ecologists, foresters, and technologists. It is necessary to make a multidisciplinary analysis of a proposed energy-forestry activity in order to maximize long lasting social benefits. Sociological

1/ Submitted by the Chairman, Professor G. J. Afolabi Ojo.

and socio-psychological studies are required to identify obstacles to implementing forest energy projects which would be economically, socially, and environmentally sound.

The results of such studies should be used for appropriate communication and training for users of forest products and forest resource decisionmakers. It is important that this research be centrally coordinated for all ecosystems or regions. The methodology used must be consistent. Comparative research on the several ecosystems or regions should be integrated in ways that reveal socio-economic constraints, as well as ecological constraints on this use.

8. Traditional cultures should provide the basis for the development of forest energy resources, which should be improved upon with available appropriate technology. Cultural diversity should be retained and encouraged, since it equates with diversity of resource use and management.

9. Initiate demonstration projects where research from different disciplines can be put into practice in developing the use of wood for energy and organics. Local populations must be consulted in connection with determining the use of land for different purposes, including reforestation and the management of existing forests.

10. There must be major transfers of capital from the developed nations to the developing nations where large scale forest management is required and these should be in the form of outright grants. The only restrictions on these grants should be that the leaders will energetically pursue the needed steps toward the establishment of national or, preferably, regional self-reliance with respect to energy and other resource needs.

11. MAB should:

    a. foster increased international exchange of information among those involved with an increased use of forests as an energy source;

    b. encourage the submission of proposals to deal with increasing the use of wood for energy and to appropriate agencies for funding;

    c. finance studies for more effective production of charcoal (the results of such studies should be disseminated); and

    d. organize a workshop to deal with organics from wood.

12. Governments should reevaluate their national energy policies to include the encouragement of the development of forest energy sources at local, regional, and national levels.

13. Appropriate incentives should be provided to promote the development of the use of forests for energy.

14. Pilot agro-forestry projects should be developed, which would experiment with using the same plot of land for forestry and food crops. These pilot efforts should include experimentation with varieties of crops which would grow effectively with trees on the same site.

15. Increased use should be made of village woodlots to provide energy for rural areas.

CONCLUSIONS THAT SUPPORT THE RECOMMENDATIONS

1. Energy continues, and will continue, to play a strategic role in the world's economic development. There is, therefore, justification for the current world-wide concern to broaden the world's energy base in order to make available as many alternative sources of energy as possible. The use of the land and forests for energy and organics is likely to gather momentum in the future in view of the particular attention being given to forests as a dependable renewable source which can be utilized by existing technology with low capital input and with present manpower and material resources. Furthermore, the use of forests for energy and organics could become more ecologically acceptable than many other energy sources, mainly because of the limited associated population problems. However, such use is fraught with many socio-economic consequences and constraints, which deserve urgent attention and action if optimum results are to be obtained.

2. In general, energy exploitation and utilization are issues of global concern, in spite of the obvious differences among nations in terms of their varying socio-economic development. The use of forest resources for the production of energy and organics could play a significant part in the alleviation of recent and current energy crises. A world-wide approach to the planning and development of forest energy stocks will not only promote multinational cooperation, but will also yield some definite benefits, including an adjustment in the present pattern of world trade, transfer of technology and management skills, and decreasing dependence on the use of fossil fuel for certain uses.

3. Even though global approaches to the exploitation and utilization of forest energy resources are feasible, it is obvious that different areas of the world could develop particular and distinct, though possibly complementary, approaches which become necessary in view of the peculiarities of the socio-economic circumstances of each of these areas. Clearly, the approaches adopted by the developing and developed countries of the world are bound to be different, in degree if not in kind, because of the varying levels of their industrial needs and technological development. For example, the approaches of the developed countries are determined, to a considerable extent, by the fact that the most usual and current source of energy is fossil fuels, although hydroelectric and other conventional sources may be important locally. Similarly, the approaches of most of the developing countries seem to be emerging within the framework of the fact that fuelwood constitutes the bulk of their energy sources, especially for cooking and heating purposes. In summary, there is considerable variation in the magnitude and scales of approaches from local, regional, and national, to global levels, as well as within each of these levels.

4. It is noteworthy that although the goal of development can be said to be universal, the emphasis and priorities vary from country to country. In all countries of the world, especially in the developed, people expect and also endeavor to maintain, and preferably improve their standard of living. However, some developing countries emphasize such concepts as the well being of all, or self-reliance, or people's participation as part of their strategy for development. These varying degrees of viewpoints on development goals put different shades of emphasis on the socio-economic determinants of the use of any resource whatsoever and could lead to differing paths of development, even though the overall goal of any strategy adopted will still be geared towards human welfare and development.

5. There is a noticeable difference between the degree of socio-economic significance of forest energy resources in the developed and developing countries. In the former, energy from wood is unlikely, in the immediate future, to sustain the existing level of economic development and can at best be a supplementary source of energy. The developed countries will undoubtedly continue to use wood for many purposes, especially for industrial uses, but this will probably be a small proportion of the total energy use. There are, however, bright prospects for using low quality wood and wood waste for fuel. On the other hand, fuelwood remains the primary, if not the total, souce of energy for cooking and heating in most of the developing countries, in some cases more than 90% of the total energy needs. In general, changes affecting forest energy resources are bound to have more far-reaching effects in the socio-economic milieu of the developing countries than in that of the developed. The differences portrayed by developed and developing countries in terms of the relative importance of fuelwood are similar to those between urban and rural areas of many countries of the world. Fuelwood, for instance, is not as important to the energy requirements of people in the urban areas as it is in the

rural areas. The socio-economic consequences and constraints of the use of land and forests for energy are also less dramatic in the urban than rural areas.

6. The uneven distribution of energy sources, both renewable and nonrenewable, coupled with the varying levels of technological development, among developed and developing countries, could further widen the economic gap between these two parts of the world. Such a situation could also exacerbate the existing political-economic instability between the haves and have-nots of the world and reinforce the geographical tyranny that allows a small proportion of humanity to live in the midst of material opulence and which at the same time condemns the much larger portion of the world's inhabitants to a life of material deprivation. Similarly, the differentials of overall economic opportunities between urban and rural dwellers could engender spatial disparities and imbalance of resource allocation, distribution, and availability. The confrontation which thrives on this type of polarization continues to permeate the political environment in which development of resources, including the use of forest energy sources, takes place.

7. The socio-economic circumstances of development in general, and that of the use of forest development for energy in particular, are being constantly affected by demographic changes in the different parts of the world. As the population increases, pressure on land and other resources, including forests, increases. As a result, land and forests which were available for use at a particular time in the past might become inadequate later, simply because of rising population. It is well known that the population in many developing countries has been increasing in recent decades out of proportion to other resources, such as food and energy. Furthermore, the skills of the population are being upgraded through increasing educational input in the last few decades. This has resulted in increased income for workers who normally tend to give up using primary sources of energy, such as fuelwood, in order to utilize secondary or tertiary sources such as electricity or gas. There is a strong correlation between income and the type of energy sources being utilized.

8. Traditional cultural practices, which the vast majority of the people continue to cherish, include the land tenure systems and the structuring of society in accordance with an existing order of value systems. Both of these situations are changing rapidly up to the point of disappearance of traditionally approved societal arrangements. This, of course, means that the socio-economic possibilities which they provided for the extraction and utilization of forest energy resources have been vanishing gradually. In many parts of the developing world, traditional land tenure systems have been modified or are being modified to provide the basis for modern large scale agriculture operated on a cooperative basis. Similarly, children who used to fetch firewood, almost without exception, have become less attached to the farms as they have to attend schools, and later migrate to the cities.

9. In the process of the socio-economic transition of some countries of the developing world, various forms of technology have been transferred from the developed world. With particular reference to forest resources for fuel, power tools have become readily available in many countries. This equipment has given an unusual power advantage to the users, with a tendency to degrade the environment. In short, the inhabitants of the developing countries are gradually but constantly attaining a higher standard of living. The consumption of goods with which standards of living are often equated, depends on abundant supplies of energy and can lead to abuse of the environment.

10. The socio-economic consequences and constraints of the use of forests for energy and organics are too many to permit detailed listing. They are probably best viewed as determinants of human attitudes to the use of forests for energy and organics. As has been shown above, such attitudes will derive from a host of factors which affect the perception and actual experiences of the people and those of the nation. There are, for instance, developed countries which seem to be determined to import fossil fuels, at this present stage, rather than explore the possibilities of forest energy, assuming, of course, that they do not have their own or adequate sources of fossil fuels. Similarly, there are developing countries which have not developed their forest energy resources because they are developing conventional energy resources, more or less, in line with what has been the practice in the developed countries, some of which have fossil fuel resources. There are many factors in the decision often taken to develop conventional energy sources rather than the renewable ones. However, such factors derive mainly from the socio-economic constraints on the use of resources which operate in a systems relationship with other bio-physical constraints.

11. The use of forest resources for energy and organics has obvious advantages. These include a dependable supply of energy based on the renewability of forest resources, an even spread of developmental activities through the afforestation of marginal lands, and the generation of employment opportunities particularly in rural areas which are invariably closer to forests. On balance, the world economy stands to gain from the use of land and forests for energy and organics.

REPORT OF WORKING GROUP 2

THE ESSENTIAL ENERGY INPUT/OUTPUT RELATIONS WHEN FORESTS ARE USED FOR ENERGY AND ORGANICS

RECOMMENDATIONS[1/]

1. Baseline information should be obtained for the parameters given in the conceptual model of interrelationships (see conclusions) for national, regional, local, and individual ecosystems.

2. All information should be collected and stored in a consistent manner to facilitate its exchange.

3. Funds should be provided by national and international organizations to promote the collection and exchange of information, the training of personnel and the exchange of specialists.

4. High priority must be given to the development and implementation of pilot research and demonstration projects designed to meet community needs in:

    a. treeless areas--possibly by the development of village and/or family plantations;

    b. agricultural areas for the development of agro-forestry systems to provide food, fiber, and energy; and

    c. slash and burn areas for the development of forest systems which besides providing energy help to maintain the capacity of the land to produce organic matter.

5. In developed countries, especially those with a limited forest resource, develop land use programs in which forest use for energy is included as one of the accepted uses.

6. A workshop should be held in five years' time to review the progress made in implementing the recommendations of this workshop.

CONCLUSIONS THAT SUPPORT THE RECOMMENDATIONS

Forest systems produce organic matter as a result of photosynthesis and the energy contained in the organic matter is the energy capital available for use by people. The rate of solar energy conversion by forests varies greatly according to the forest, but there are physiological constraints on the maximum amount of energy that can be captured per unit area of land and, hence, is available for human use.

To convert wood energy for human use also requires an energy input as human effort or the use of various other fuels. This energy is dissipated. In any energy balance calculations, this amount must be discounted from the total energy to determine the energy gain.

Some forest systems require energy only at the time of harvest and during its transportation to the processing plant. Other systems require a continuous energy input by people from the beginning to the end of the forest rotation. Additional energy is required in harvesting, transporting, and processing of the crop. Information is needed of the relative efficiency of the necessary energy investment to obtain a given energy gain.

1/ Submitted by the Chairman, Professor J. D. Ovington.

Sufficient information and technical skills are available now to assess and initiate forest programs in many parts of the world to supplement existing energy supplies. These programs can be further developed for industrial needs by a systematic expansion of the existing data base. The energy flow chart model and tables presented later can be used to identify data base needs and establish research and development priorities.

The ranges of forests and management systems are so diverse that in order to establish principles, three distinct kinds of forests are considered.

Kinds of Forests Considered

Natural Regenerating Forests

A natural regenerating forest usually has a mix of native tree species and ages over a large area and a capability of maintaining itself, or a successional stage, without human intervention.

Natural regenerating forests have several advantages in terms of energy production: (1) humans need invest no energy in the establishment of the stand, since the forest regenerates itself; (2) energy is not needed to maintain the stand in an acceptable growing condition; and (3) its net energy production can be quite high, particularly for young stands.

The disadvantages of managing multispecies forests are well known: (1) little information is available about overall growth rates; (2) management is relatively complex and techniques are only partially developed; (3) harvesting is frequently difficult; and (4) reproduction of shade-intolerant trees can present a problem.

The major energy investment from human sources is at the end of the rotation being required for harvesting, transporting, and processing the crop.

Plantation (Manmade) Forests

Plantation forests usually consist of an age sequence (depending on the forest rotation) of evenaged blocks of a single tree species planted at a uniform spacing.

As a source of energy, plantations seem to be an attractive proposition mainly because: (1) management can be prescribed relatively precisely and carried out by unskilled workers; (2) growth over the rotations can be forecasted relatively accurately and the rotation length adjusted to give maximum or optimum production to meet specified energy needs; (3) net primary production is relatively large (in Japan, for example, about twice as large for natural regeneration stands); (4) management and utilization can be mechanized; and (5) plantation forestry is founded on a long history of research.

Doubts about the suitability of plantation forests as a source of energy arise from concern that: (1) they may present a greater risk of pest, disease, and fire damage and loss of soil fertility; (2) aesthetic, wildlife, and recreation values may be diminished; (3) there is a heavy investment of financial resources and energy in establishment and maintenance; and (4) once planted, options for alternative land uses are curtailed.

A major investment of energy from human sources is required throughout the rotation.

Agro-Forests

The growing of a tree resource in conjunction with agricultural crops is defined as agro-forestry. An array of different systems exists. The common main element in most such systems is that they are man-made and close to local energy needs. A system common in the tropics is slash-burn agriculture, where the forest is only present for a short period of time. The main objective is to grow agricultural crops and the energy in the trees is not fully utilized, but the burning of unharvested tree material returns plant nutrients to the soil.

In many other agro-forestry systems throughout the world, fuelwood constitutes an important energy resource. Trees may be planted for other purposes, e.g., as windbreaks, to provide shade for an agricultural crop and to produce fence posts and high-value lumber. Alternatively, or additionally, the function of the wood resource can be to meet a local energy need. Establishment energy inputs become the main "cost", harvesting is by hand, and transportation energy needs are small.

The advantages of agro-forestry are: (1) that the tree species are either self-regenerating or readily available for planting; (2) maintenance costs are minimal; (3) the energy output is profitable at the village, and even the farmer, level; (4) no major capital investment is needed; and (5) transport costs are minimal.

The disadvantages are: (1) that tree planting in conjunction with agriculture in many cases reduces the yield and quality of both crops; and (2) soil fertility may be reduced in slash-burn situations.

Forest Dynamics

The forest is a solar energy converter and energy store. It is imperative that the capability for further energy trapping and storage not be impaired in managing and harvesting this resource. An important objective of any system of forest management should be to preserve the energy converting potential at the optimum level.

There are a series of energy inputs as well as outputs in any forest resource system, which need to be identified and quantified. The relationship of these energy inputs and outputs can be expressed in several different ways. For the purposes of this report, the major energy inputs and outputs that should be identified are listed in table 1. These components can be quantified and used as a managerial tool, as suggested in table 2. The interrelationships of these same components, and where they occur in the system, are illustrated in figure 1.

Table 1.--The energy components of a forest resource system.

Capital	Removal
Trees - above ground	Trees
- below ground	Understory plants
Other living organisms	Secondary producers
- plants	
- animals	Change in capital
Dead organic matter	Trees
	Other living organisms
Solar input	Dead organic matter
Trees - above ground	
- below ground	Management costs
Understory plants	Establishment
	Maintenance
Biological drain	Harvesting
Decomposition	Transportation
Conversion to secondary producers	Provision of forest infrastructure
	Forest administration

Table 2.--A summary balance sheet for decisionmakers of the energy components of different forest resource systems[1/]

	Regenerating natural forests		Plantation forests		Agro-forests	
	Temperate	Tropical	Temperate	Tropical	Temperate	Tropical
Solar input (NPP)						
Management costs Establishment						
Maintenance						
Harvest						
Transport						
Processing						
Capital change						
Removal						

1/ To develop this balance sheet, a common energy unit for all energy components must be used. Calories per square meter per year (Cal/m^2/yr) is one constant unit applicable to all aspects of forest energy production and use. Conversion factors and appropriate equations can be developed to convert currently available data, such as manhours per m^3, or cost per day to this constant unit.

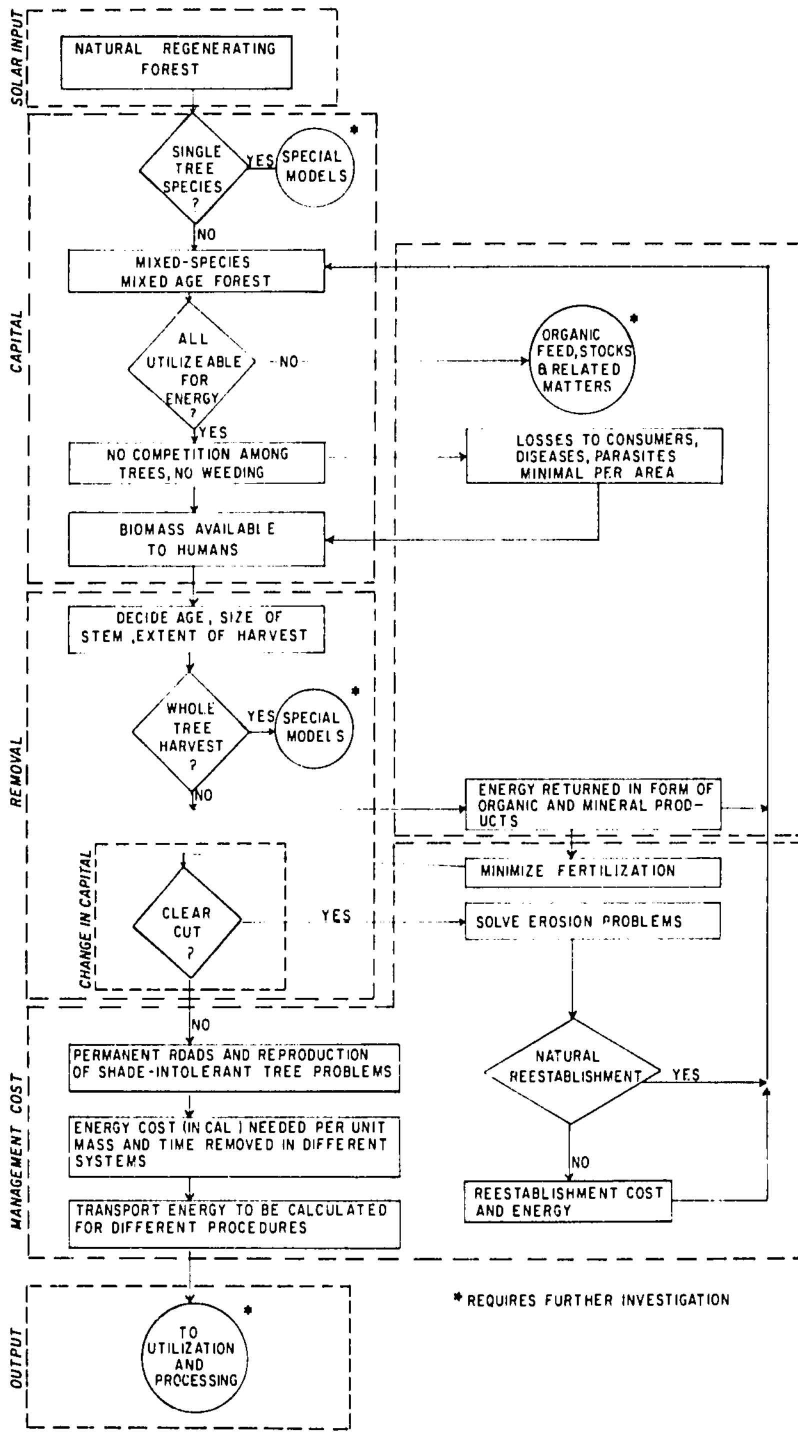

Figure 1.--A model of the interrelationship of the energy components of a forest resource system.

Research

To supplement the supply of energy for human use, major emphasis should be given to applying existing knowledge and technology to the utilization of forest resources and of waste material at processing plants. In the longer term, research will improve the basis of forest management for energy. The following suggestions are indicative of the kinds of research that are needed: (1) more reliable data are needed of existing forest resources, current and future demands, and likely surpluses; (2) further information is needed on the capture of energy by photosynthesis, and the factors which influence net productivity including genetic variation and consumers, parasites, and diseases, especially in the tropics; (3) the greater use of native tree species in plantation forests should be explored; (4) the productivities of mixed species and monocultures should be compared under plantation and natural regenerating conditions; (5) information on the amount of energy to harvest and transport forest products is needed; and (6) further information is needed on the conversion of forest products to supply useful forms of energy and the amount of energy required for such conversion.

Public Awareness

In order to have forestry for energy production included in overall land use planning, the public and decisionmakers need to be made aware of the potential and constraints of this resource as an alternative energy supply.

Training

Additional training for forest officers and technicians is required for the complementary management of forests as an energy source.

International Cooperation

International cooperation is needed on bilateral and multilateral bases to enable: (1) the development of a data base; (2) the sharing of expertise and the provision of specialist teams to work in developing countries; (3) the exchange of biological materials having potential for energy use; (4) complementary integration of forestry activities between timber exporting and importing countries; and (5) training needs to be met.

Nations cannot assume that decisions and policies made regarding energy or other forest resources within a country will not affect the decisions and lives of other nations. A global energy policy framework is needed within which individual nations can decide their own policies. International organizations of all sorts should encourage responsible policies and assist communication regarding the international consequences of national energy decisions.

REPORT OF WORKING GROUP 3

THE ENVIRONMENTAL CONSEQUENCES OF INTENSIVE FORESTRY AND THE REMOVAL OF WHOLE TREES FROM FORESTS

RECOMMENDATIONS[1/]

1. Information on the physical limits of the forest resource and the long-term effects that various uses can be expected to have must be made available to decisionmakers, politicians, and the publics they represent. This may be possible through articles, briefing papers, workshops, or symposia, and should be undertaken jointly with agencies and organizations also dependent on the maintenance of biological productivity.

2. A dynamic model with economic and ecological feedback should be developed for one or more plantations or forests under intensive management for energy.

3. People in developed countries must realize that there is very little potential in tropical regions for production of biomass for energy and organics for export. The production in tropical countries is needed for local consumption.

4. Governments in developing countries should recognize that biomass is an important source of energy, pulp, and other organics. These important uses for wood will increase in the future. Further, governments should recognize the environmental consequences of intensive use of biomass.

5. Governments should carry out ecological land classification surveys to ensure the best utilization of various land types. Governments should increase research on tropical forests to assure long-term productivity of wood for lumber and fuel and the maintenance of plant and animal genetic resources.

6. There is a need for single or mixed species plantations on degraded land, a need to develop suitable species for plantations, and a need to continue research on agroforestry into more efficient production of food, fodder, and fuel.

7. There is a need to increase research for the utilization of other forms of biomass for energy. For example, increase the efficiency of methods for production of charcoal and biogas, and inform people through extension services.

8. Local people must be involved in planning and establishing plantations so these people participate more directly in the processes and benefits of plantations.

9. Continue research efforts in those ecosystems subject to periodic fires (some deciduous forests and Mediterranean ecosystems) to improve knowledge of when to harvest biomass to avoid loss through wildfires.

10. Encourage governments of developing countries to weigh carefully the short-term benefits of excessive forest exploitation for immediate economic gain against the long-term benefits of forest maintenance for future generations.

1/ Submitted by the Chairman, Dr. Patricia Roberts-Pichette.

There are two very desirable consequences with respect to the use of land and forest in all countries:

(1) The capability of land to produce a variety of goods and services must be maintained.

(2) The species and genetic diversity of forest ecosystems must be maintained.

Given the validity of these two desires, it was agreed that certain lands and forests could be used for specific ends, within the bounds of their productive capacity. Opportunities for providing energy or energy supplements from forest resources should not be overlooked, since it is recognized that the diversification of energy sources is advisable.

The attractiveness of wood biomass is its renewability, but the renewability will only be realized if the basis for it is maintained. If any country were to approach this opportunity by using the forest to manage the economy for energy (or other products), then productivity may be lost and considerable damage done. On the other hand, if the forest is managed properly to contribute to the economy, it can make a substantial contribution to the energy needs.

Forestry in developed countries can provide energy by making fuller use of unmarketable forest and mill residues. Such use can often serve a dual role by disposing of material that either presents environmental problems or inhibits forest regeneration. Thinning stands of unmarketable and defective trees can also contribute wood for energy--at the same time it improves the remaining stand's quality and growth for traditional commercial uses. Though the energy contribution may be small, the impact on the forest may be large if the opportunity is not approached with care.

In the developing countries the environmental consequences of wood utilization and the problems of ecosystem maintenance are fundamentally the same as those in developed countries. However, the economic framework in which this utilization occurs is different from that in developed countries and, thus, recommendations and solutions must be made within the context of local problems.

The issue of primary importance in many developing countries is that the rural population is highly dependent on surrounding forests for fuel, food, and fiber. The problem is not whether those populations should use biomass for fuel, but rather how best to keep existing forests and people from being destroyed by irrational use. The question is how to rationally use the forest resources over time, keeping in mind that extreme energy needs of the present dictate that such forests and shrublands will be used for fuel and other benefits.

There is evidence that exploitation of forests for energy and organics in many ecosystems leads to environmental disturbance of the forests and modifies regeneration, the soil, water balance, wildlife, etc. These consequences must be considered in some detail. Therefore, to provide a framework and a concrete basis for thought and discussion, the potential sources of wood biomass for energy are identified as natural forest, short rotation plantations, and mill residues. The problems and opportunities associated with each of these sources are identified and discussed as outlined in table 1.

Exploitation of Natural Forests

The environmental consequences of total harvesting of forests for energy resource are essentially the same as those resulting from total forest removal for lumber production and pulp and paper production. What follows is a brief discussion of some of the most adverse environmental impacts, which might be expected where forests are intensively harvested for fuel, and where management is lacking. The consequences may be less adverse, if the intensity of harvesting is less severe, provided adequate precautions are taken.

Removal of timber, fuel, and logging residues removes nutrients from the site, withdraws food from the soil microorganisms upon which the nutrient cycle depends, and reduces the productivity of the soil. Nutrient availability and microorganismal activity are inextricably linked. Gathering of large amounts of fuelwood for cooking and heating may result in a loss of nutrient capital and therefore loss of productive capacity. Other consequences may be soil compaction, loss of porosity, increase in erosion, reduction or complete suppression of regeneration, and adverse consequences for persons living in or near the areas that have been harvested.

Removal of forest residues may result in a much harsher microclimate near the ground than with the residues present. Removing residues may increase solar radiation, increase re-radiation, result in extreme temperatures, result in a dry soil surface, reduce the growth and survival of seedlings,

Table 1.--Sources of energy--problems and opportunities.

Source	Problems	Opportunities
Natural forests provide fuelwood and logging residues	Reduced soil fertility Habitat destruction Regeneration problems	Improvement of forest management Esthetics--recreation Reduction of animal disease and damage
Short rotation plantations for energy	Reduced soil fertility Reduced water quality Unstable systems Competition with agriculture	Genetic engineering Use of marginal lands Reduction of pressure on "natural" forests
Mill residues		Supplement to mill energy requirements

and reduce the accumulation of biomass.

Forest residues are compartments of energy stocks, and as such, they are used as habitat by a variety of organisms peculiarly equipped to "plug in" to these energy sources. When such residues are removed, the result is to erase the rich texture of organic life that was feeding itself and holding energy in the overall system.

Removal of forest cover results in the destruction of habitat for wildlife species. Some species may migrate and adapt successfully in different habitats. Others may not survive in new or less protective environments. Damage is greater where forests are clearcut. Even where selective cutting is practiced, species are adversely affected. Survival of wildlife species in plantations for energy will depend on the tree species selected and the management strategy implemented.

Selective, as well as clearcut, harvesting for timber products often leaves heavy forest residues that may preclude regeneration, and make forest management for high quality timber generally more difficult. Planting procedures are facilitated by removal of forest residues, particularly where scarification is a recommended operation. Removing unmerchantable, small, and defective trees may improve the quality of the regeneration, provided that suitable seed sources are available or planting is undertaken. Removal of thinnings becomes more attractive when they represent an economic gain in themselves, as well as an assurance of higher quality future timber. No forest management practice will reduce damage done to a site by inappropriate harvesting methods, road building, timber removal, or other activity which results in wholesale loss of site quality. This is particularly true for the nutrient cycle-energy flow system, which operates through the medium of the soil and accompanying litter layers.

Forests are prime recreational areas, particularly near urban centers. Removal of forest residues is likely to improve public acceptance of cut areas, since regeneration is obvious sooner and use of forests for recreational purposes is established more quickly after cutting operations. Clearcut areas may be marginally more acceptable by the public if residues are removed than otherwise.

Large amounts of slash left after logging operations in certain cases may become fuel for wildfires. This poses two problems: (1) the potential for wildfires, and (2) negative environmental effects caused by the fire. Removal and use of the slash for energy can have desirable consequences.

If a legacy of degraded soils is not to be left to future generations, it is essential that more be learned about the effects of biomass removal on forests and soils. This requires:

(1) collection of data and storage in a central data bank;

(2) development of models to identify information gaps; and

(3) research to describe relationships and fill information gaps.

Short Rotation Plantations for Energy

In developing countries, plantations maintained for continued fuelwood production over the long term are probably desirable for the production of fuelwood. In some areas pollarding and coppicing are likely to be practiced to increase potential fuel supply.

Many of the effects that have already been discussed in the section on problems of exploitation of natural forests are applicable to short rotation plantations (10- to 20-year periods) but with greater intensity, since juvenile trees have a higher nutrient concentration, whole trees may be removed, and harvesting occurs more frequently. Under such conditions, intensive fertilizer and organic matter supplements may be needed to keep biomass productivity of the plantation at an acceptable level.

The problems can be ameliorated where necessary by accepting an optimizing rather than maximizing strategy, so that less demanding, and possibly more efficient (better adaptive), species can be used.

If plantations are treated with chemical fertilizers, sewage sludge, pesticides or herbicides, there is some possibility that the groundwater may become contaminated. Application of the proper amount of such substances and at the correct time helps to minimize this problem.

Mini- (2 to 10 years) and short (10 to 12 years) rotation plantations for the maximization of biomass production closely approximate agricultural systems. These systems are considered unstable because they need a high energy input, over and above that of solar radiation. The maintenance of these plantations requires:

(1) intensive cultivation and/or the use of herbicides;

(2) the use of fertilizers; and

(3) disease and insect control, possibly through the application of fungicides and pesticides.

Short rotation plantations may compete for rich agricultural land. This is likely when food production is directly competitive with energy production. For developing countries, food production is likely to remain the first priority with fuelwood production a close second.

There may be ways of using genetic engineering for the development of species and varities capable of increasing the present 1% photosynthetic capability of trees. This achievement would increase the productivity of plantations for energy and reduce some adverse consequences.

Short rotation plantations may be established on lands marginally economic for agriculture. Such plantations on communally-owned lands may provide some fuelwood, or other benefits without adverse consequences.

Peatlands are treated in the northern boreal forests and used for grazing and hay production. Peat is often burned for fuel. Opportunities for establishing short rotation plantations on peatlands are being explored in the Scandinavian countries. Treatments include the use of fertilizer and drainage. Conflicts are expected for the use of peatlands for plantation sites and for their use in the hydrologic cycle. The use of fertilizer on peatlands could increase eutrophication in streams and lakes. Also, peatlands are important floral and faunal refuges.

Short rotation tree crops for fuel provide a quickly recurring harvest of biomass devoid of esthetic and organic benefits associated with naturally regenerating forest. By satisfying the urgent need for fuelwood, plantations may provide a safety valve against the pressures to exploit "natural" forests by an energy-short society. The carefully husbanded natural forests can continue to serve society in many ways: some providing fuel, timber, recreation, water, and other benefits; some set aside as yardsticks for managed forests and for research into natural system mechanics and evolution; and some, on being released from continued pressure, may illustrate development without human intervention.

Mill Residues

Bark, sawdust, edgings, slabs, other wood materials, and spent-liquor--separated from the final product as mill residues--no longer present a problem of disposal. Most of these residues are used for fuel. Many wood industry plants are providing some energy needs with mill residues--an action with desirable consequences. However, other uses for mill residue (including spent-liquors) include fabrication of composite wood products and extraction of various organic feedstocks. Decisions on the various options will normally be made on economic grounds. However, the environmental consequences of alternative actions should be included in the analyses along with economic considerations.

A Dynamic Model for Ecological and Economic Interations

One of the more important gaps in knowledge is the lack of a dynamic model that successfully incorporates ecological and economic negative feedback. The development of such a model should be attempted as a collaborative effort between ecologists and economists using data from intensively managed forest ecosystems such as envisioned for supplying energy. Attention in the model would be given to the way energy flows in relation to the accumulation of biomass. Economic values should be assigned to the practices that perpetuate the ecosystem flows of energy and materials and guarantee the continued production of biomass. Current econometric models typically assign values to the cost of actions and to marketable biomass, but it is the dynamics of the biological system that maintain production of the marketable biomass.

Application of a model based on natural systems and their feedback control mechanisms can contribute to the development of national policy through expressing, in economic terms, the long-term value to society of ecosystem dynamics that maintain the production of desirable benefits. For example, there is little potential in tropical regions for exporting forest biomass for energy on a sustained yield basis. The biological system cannot withstand mass exploitation. What little potential exists is needed for local consumption. In some areas, political and economic factors have led to destructive exploitation of marketable biomass, due in part to a lack of understanding of the necessity to maintain the biological capability of the area for continued production. A dynamic model for ecological and economic interactions may provide the basis for a more rational use of tropical forest for energy and other benefits.

COMMENTS ON THE WORKING GROUP REPORTS

In order that the record contain a representation of participant opinion, recorded here is a summary of comments made at the concluding plenary session.

While it is logical to recommend that more trees be planted, it may, in practice, be difficult to identify significant areas of unused land amenable to the growth of trees.

"Human needs and values" must dictate the way in which we develop our forest resource, rather than merely receiving "full considerations as forest management practices are developed."

Considerable information already exists regarding the production of charcoal. Also, there are negative ecological aspects to charcoal production.

Although it is true that rates of forest production are subject to physiological constraints, potentials to increase the efficiency of energy capture by forest systems should be acknowledged.

While the costs of maintaining agro-forests may be low in a relative sense, often inputs of energy are necessary.

The statement that "the objective of any system of forest management should be to preserve the energy converting potential at the optimum level" may give the false impression that other considerations, such as the maintenance of genetic diversity, are of less importance.

The phrase, "land capability survey", should be defined to include soils, plant and animal communities, accessibility, erodibility, wildfire and storm frequency, and a variety of other features that would affect land use.

"Consciousness-raising" meetings for decisionmakers on the theme of this workshop were recommended for consideration by MAB and each country.

KEYNOTE ADDRESS

FOREST BIOMASS FOR ENERGY

Bernd von Droste[1/]

Abstract.--The launching of a network of demonstration sites for high energy-yield forestry under the umbrella of the MAB Programme is recommended. This would demonstrate application of existing knowledge, serve the study of ecological and social effects of forest energy plantations, and provide for training of scientific and technical personnel from developing countries for which forest biomass continues to be a key fuel resource.

As of today, Unesco's Man and the Biosphere Programme comprises more than 600 operational field projects in about 60 countries, involving the coordinated interdisciplinary research efforts of several thousands of scientists all over the world. About 160 biosphere reserves provide for permanent conservation, research, and monitoring as well as training facilities in about 40 countries. Furthermore, a number of training courses are supported under the MAB Programme annually to enhance man's knowledge in the field of ecological theory and its application to natural resource management.

I mention this as an indication of the rapid expansion which MAB has experienced during the last years. However, this forces us today to concentrate our limited resources on a few priority areas. There is no doubt that among the priority areas are tropical forest and arid land ecosystems.

It is exactly within these two bioclimatic regions of the world that the most pressing problems of rational use of forest resources as a main source of energy have to be solved. Therefore, this International MAB Workshop emphasizes one of MAB's important operations, one focusing on interdisciplinary research into the environmental and socio-economic effects of increasing use of forest resources for energy and for feedstocks. At least half of all the timber cut in the world still serves its original role for human beings -- as fuel for cooking and, particularly in colder mountain and boreal regions, for home heating. Nine-tenths of the people in most poor countries today depend on firewood as their chief source of fuel. All too often the growth in human populations outdistances the growth of new trees--not surprising, however, when the average user burns as much as a ton of firewood a year. The results are soaring wood prices, a growing drain on income and physical energies in order to satisfy basic fuel needs, a costly diversion of animal manures from food production uses to cooking, and an ecologically disastrous spread of treeless landscapes.

Man's well-being and survival depend ultimately on the renewable biological resources of our planet providing him with indispensable sources of food, fibre and energy. No doubt, one of the most precious, indispensable natural heritages of mankind is the world's still large forest resource covering one-third of the terrestrial surface. Most of the major regions of the world, except for Asia and the Pacific, have at least one-fourth of their land covered by forests; in North America, South America, and the U.S.S.R., the total is more than one-third. One of the most important values for human population of this immense resource is its great potential for producing energy and feedstocks on a sustained basis and pollution-free. Indeed, world forests constitute not only the terrestrial ecosystems that contain the greatest reserve of energy per unit area of land, but also the largest plant biomass pool because of their wide distribution from the boreal through to the temperate, Mediterranean, and semi-arid zones, and in the subtropical and tropical bioclimatic regions of the world.

Findings of the International Biological Programme have confirmed the high net productivity of natural forest ecosystems. However, even higher net productivity rates have been stated, such as for artificial monoculture with pine, gmelina, eucalyptus, or other tree species.

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and the so-called B.T.U. bushes, and sugar cane.

What is the actual energy content of world forest biomass? This appears to be a purely academic question. But if the energy value of wood is taken to be 7500 British thermal units per pound, the annual net primary production of the forests is roughly 1200 quads or five times the world's use of 230 quads of energy in 1975. Yet this enormous potential for satisfying increasing demands for energy and organic feedstocks is not fully available to man for a variety of reasons.

1. First of all, this potential cannot be fully used due to the lack of adequate technologies and gaps in our knowledge with regard to the understanding of the photosynthetic process, species characteristics, and proper management for maximal primary net production.

2. Secondly, the environmental effects of such predominant forest use can be disastrous; for example, such use may jeopardize protective forest functions. Therefore, environmental considerations impose a number of restrictions on forest use of this kind.

3. Thirdly, for economic and social reasons, other uses of forest land for food, fibre and lumber, may be even more important, particularly when alternate energy sources are available at reasonable cost for local populations.

The problems of energy use of forest biomass are not new to mankind. Going back through forest history, the use of forest biomass for energy indeed appears to be a concern of long standing. In fact, during the "Wood Age" in Europe and North America, until the end of the 18th century, almost all energy needs were satisfied by outright combustion of wooden plant material. This led very often to wholesale destruction of forests, particularly in the neighbourhood of human settlements and of the iron, salt, and glass industries. In order to remedy this situation, new forest management concepts (such as short rotation forestry, using coppice) were introduced in Germany as early as the 13th century.

Coal and oil became increasingly important as energy sources from the 19th century onwards, and, in many parts of the world, alleviated disastrous pressure on forests as the sole fuel source. However, even in industrialized countries where these alternate energy sources became available at cheaper costs, the pendulum swung back to man's major reliance on wood as fuel in times of crisis, particularly by force of a war economy. Is there any chance that this will happen again?

Certainly, today's energy crisis is less one of energy supply than one of economics, and the pendulum is not likely to swing back to wood as a major energy source in industrialized societies in the future. In some industrialized countries such as New Zealand, Brazil and Finland, for example, with plenty of land use potential for forestry but without domestic fossil fuel, energy forest industries may become quite important. Given the economic disparity between industrialized and developing countries, access to fossil fuel is increasingly becoming a privilege for affluent societies. These societies will probably continue to rely on fossil fuels for another 30 to 40 years -- at increasing price levels -- while destitute peoples in many regions of the Third World will continue to experience the Wood Age, long gone, for example, in Europe, North America, and Japan.

A global view of today's major energy supply sources conceals this dramatic difference between the Third World and industrialized societies, mainly because there is a tremendous difference in the rate and scale of energy use. The per capita energy consumption in India, for example, amounts to only about 1/1000 of the per capita energy consumption in the U.S., and more important, wood provides about 60% of the total energy consumed in India and probably less than 5% in the U.S. It is therefore not astonishing that for the world as a whole, wood is usually considered the fourth most important source of energy after oil, coal, and natural gas. Wood provided only 6% of the estimated total energy consumption in 1977, although this figure may be less today. Nevertheless, it is well-founded to say that for the greater part of mankind, wood is the energy source which satisfies the basic needs of cooking and heating. An estimated total of two billion people in the Third World still use wood as a prime source of energy, particularly in the rural zones where wood is readily available.

Keeping in mind the gravity of the shortage of fuelwood in many developing regions of the world, it is not much comfort to look at the enormous forest biomass found elsewhere, as fuelwood transportation costs are rather prohibitive in order to reconcile regional disparities. Therefore, the majority of developing countries will continue to rely on increasing production and the use of wooden plant material as fuel, partly because of this and other economic constraints.

The degree to which developing countries depend on wood as a major source of fuel can also be seen by the fact that in rural areas nearly 95% of households depend on wood as a primary source of energy. This almost total dependency on wooden plant material for satisfying energy as well as other needs very often constitutes a major obstacle to conservation and rational management and use of forests in the Third World. For example, in semi-arid regions, particularly in the Sahel zone, from Senegal to Ethiopia, the ecological consequences of firewood consumption contribute to the process of desertification. Furthermore, by way of another example, a manual labourer in Niamey must now spend nearly one-quarter of his income for fuel. This highlights the relevance of what has been stated elsewhere in that the world's energy crisis is a poor man's crisis. It very often implies an environmental crisis as well. For example, virtually all the trees within 70 km of Ouagadougou have been consumed as fuel by the city's inhabitants, and this circle of land stripped bare for firewood is continually expanding. Analogously alarming situations of environmental degradation are found throughout the developing world.

The logical response to the fuelwood and associated environmental crisis is obviously the planting of more trees, proper forest management and conservation -- and, of course, substitution of wood by other energy sources. These are crucial tasks as, with the growth of human population, the forests are still being cut down faster than they grow, particularly in the Third World, partly to make room for new farm lands and partly for use as fuel.

Such a desperate struggle for survival in developing countries at the expense of forest lands and forest ecosystem stability calls for major efforts in the scientific field to develop new concepts of forestry and technology, with the promise of higher energy yield for human use per unit area. It also calls for substitution of wood energy by other energy sources until new stands of high-energy yield can be established. From a scientific point of view, it appears to be important to :

(i) Identify, disseminate and apply existing knowledge in the management and use of forest stands for sustained maximal energy yield, with due consideration to environmental effects such as prevention of (a) soil erosion in the tropics and (b) desertification in semi-arid zones. The most important social impacts must be taken into account as well, such as increasing distances to secure domestic fuel. For example, in some of the most remote villages of the world, deep in the once heavily forested Himalayan foothills of Nepal journeying out to gather firewood is now an entire day's task. Just one generation ago, the same expedition required no more than an hour or two. In terms of both labour and money, half of the world's population finds the price of firewood too high to pay.

(ii) Embark on new studies in order to increase energy outputs from forest lands. At present, forestry as a solar energy-based industry works with rather low efficiency. Commonly used tree species use less than 1% of the incoming radiation, whereas the maximal efficiency of photosynthesis is several times higher. Therefore, a major challenge for today's genetic research is to identify and breed species and varieties which convert solar energy more effectively. Plants with much higher conversion efficiency than tree species at present in use are already known. For example, sugar cane and sorghum have reached conversion efficiencies approaching 3%. Other promising plants such as latex-producing species, including Havea brasiliensis, are of special interest, as well as Euphorbia lathyris, which is particularly suited for cultivation on otherwise infertile arid lands.

(iii) Develop new silvicultural and forest management systems, with a view to maximal net primary production; this deserves special attention. The most promising options appear to be short rotation forestry, total tree-use systems, growing of coppice stands, and, in some cases, replacement of tree species by so-called B.T.U. bushes and other crops such as sugar cane. Before the implementation of such new schemes, their environmental effects and social impacts must be assessed carefully and locally. This should warrant sustained growth, ecological stability, and help resolve the problems of very often conflicting demands for food, fibre, timber, and fuel from forest lands through socially acceptable resource allocation. The development of combined production systems (food, fibre, fuel) merits special attention.

(iv) Promote technological research for more effective use of plant biomass than direct burning ; this also deserves special attention. It involves application of complex technologies. Cellulose and lignin must be separated and then processed further, or the wood must be converted to carbon monoxide and hydrogen and, thence, to methanol or methane. Plant materials lend themselves to anaerobic fermentation resulting in methane and CO_2, with the latter being easily removed. One potentiality that merits further study is the hydrogenation of wood which is known to yield combustible liquids. Yet another effort lies in a more rational utilization of wood residues by forest industries for generating heat and electricity. New technologies have also to be developed to reduce air pollution by combustion of woodfuel.

(v) Accept new forest management practice and technologies on the part of local, particularly rural populations in developing countries. This is indispensable for bridging the large gap between theoretical insight and actual practice. In fact, social and socio-cultural studies are a key element, along with environmental education, for ensuring application of existing knowledge and implementation of rational forest management and use.

There is no need to stress the great role that the MAB Programme could play in coordinating some of the above-mentioned interdisciplinary research, particularly as regards the establishment of a number of demonstration projects for high energy-yield forestry, study of its ecological effects and social impacts, and training of technical and scientific personnel, in addition to the general role of disseminating and transferring existing knowledge and the exchange of information and researchers between field project sites. The execution of such a programme, however, based on a network of demonstration sites, requires considerable financial and manpower inputs from countries, increased bilateral and multilateral assistance, and effective cooperation with a great number of governmental and nongovernmental organizations at the national, regional, and global levels.

I am confident that this Workshop will help promote such cooperation, identify the main directions of further coordinated action, contribute to the dissemination and transfer of existing knowledge, and ultimately lead to a network of field demonstration projects under the umbrella of the MAB Programme.

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ISSUE 1
SYNTHESIS PAPER

THE SOCIO-ECONOMIC CONSEQUENCES OF AND CONSTRAINTS TO THE USE OF LAND AND FORESTS FOR ENERGY AND ORGANICS

G. J. Afolabi Ojo[1/]

Abstract.--The focus of using forests as alternative sources of energy must be on human development. People's participation in developing policy is essential for the implementation of effective programs.

GENERAL

The following points were considered by Professor Ojo to be common to most of the background papers.

World-wide, there is an awareness and consciousness of the need to diversify the energy base for all countries.

Wood is one of the sources of fuel that is not fully exploited in all countries.

When possible, we should use wood, a renewable material, as a source of heat in order to conserve fossil fuels.

An important part of forestry, especially in developing countries, is the use of woody materials for fuel. In many countries wood is now the principal source of energy.

The amount of fuelwood available in many countries is unknown because of inadequate resource information.

Energy policies, which include fuelwood, can affect land use, the economy as a whole, and in particular, unemployment, in large numbers of countries.

Specific Points

Professor Ojo identified specific points that should be considered in the workshop.

So long as fossil fuels are available in large quantities, it is unlikely that industrialized nations such as Canada, the U.S.A., and oil-rich nations like Mexico, will show other than marginal interest in "natural" forests as sources of energy and organics. It is in the third-world nations, which lack fossil fuel and possess a forest resource, that forest-derived energy will be of major significance in the next several decades. For these nations, every litre of petroleum and every kilogram of coal that can be replaced by in-country production of wood-based energy will be most significant.

Canada, the United States, and Mexico either possess within their national territories or otherwise have access to fossil fuel and nuclear fuel in quantities sufficient to meet their energy needs for 40 or more years.

Many countries, which have limited access to fossil fuels, have inadequate data on land areas in agriculture and forestry, on fuelwood consumption, and on population distribution in relation to opportunities to use fuelwood.

Several authors referred to the difficulty of establishing national policies on energy and fuel. For example, in India there should not be an immediate and major change in land use policy, since such a change may create enormous difficulties in the social system. In Nigeria, a change in land policy was chosen, since such a change in land policy was found to be a prerequisite to the modernization of land use systems. In Nepal, a new forest plan gave ownership of the village forests to the village governments. In order to protect the forests, the villages were then prohibited from grazing the forests. The development of policies without involving the people can negate the intent of the policies.

Suggestions

Professor Ojo made the following suggestions to participants in the workshop.

For rational planning, more reliable data are required on existing forest resources in many countries. We need to know more about the potential annual cut of wood for fuelwood, the present stage of utilization of fuelwood, and the current and projected demands for fuel-

1/ Professor of Geography, University of Ife, Ile-Ife, Nigeria. These comments were abstracted from a tape recording of Professor Ojo's comments at the first plenary session.

wood and lumber. We need to know where there are likely surpluses and deficits by different economic regions. This resource information must be related to socio-economic aspects of the local situations.

The objectives of forest management for production purposes have to be clearly understood with due emphasis on ultimate utilization of all raw materials, and on specific climates for industries and markets.

Some of the authors suggested ways to obtain additional supplies of fuelwood. We should examine the possibilities for increased utilization of logging wastes, the increased cultivation of trees on farm lands, and the possibility of raising trees in energy plantations.

In India the concept of social forestry includes the production of fuelwood in combination with various activities in farm forestry, extension forestry, shelterbelts, reforestation of marginal and degraded forests, and recreation forestry.

Because of the time lag, often 10 and more years, between planting and availability for fuelwood, there is a strong argument in favor of every country increasing its forest area to the largest extent possible.

The focus of a strategy to use wood for fuel must be on human development. The development of a nation should not be limited to a "sectional" activity; rather, it should be seen as a multi-sectional core of a broader development process and integrated with rural development. People's participation in decisionmaking is essential in order to select the appropriate programs and projects, to outline the methods of implementation, to determine the procedure for monitoring and evaluation, and most of all, in setting criteria for sharing the benefits.

ISSUE 2
SYNTHESIS PAPER

SOME CONSIDERATIONS OF FOREST USE AND ENERGY FLOW

J. Derrick Ovington[1/]

Abstract.--Consideration is given to the effects of politics, resource perspectives, and environmental factors on forest productivity. Various aspects of energy balance sheets are discussed and their relevance to energy forests as an answer to the energy crisis is examined. Whilst energy forests may help to alleviate the effects of energy shortages it is suggested that they are not the long term answer.

INTRODUCTION

The biosphere is coming under mounting pressure from having to support not only a greater number of people but people with more demanding and polluting life styles. Over exploitation in some locations has brought about a serious reduction in the capacity of land to produce organic matter following the clearing of vegetation and the subsequent loss of soil.

Consequently, even though the ultimate capacity of the biosphere to meet human needs is not fully committed, there is some urgency to develop and implement national programs of forest resource use and management based on sound ecological principles. Not to do so could have far reaching consequences for human welfare and future generations. Already many countries are experiencing rapid and massive forest destruction. By the mid 1970s the remaining forest resources per person ranged for areas of closed forest from 0.2 (Asia) to 4.2 (Oceania) hectares and for standing wood volume of 15 (Asia) to 329 (USSR) cubic metres (Eckholm 1979).

Over the centuries the human race has developed an enormous technological ability to manipulate organisms and the environment. Misdirected, this technology could lead to widespread devastation but properly applied it provides the means whereby better use can be made of the earth's resources. An understanding of the pattern of energy flow in different forest types can form the basis for developing a world strategy for forest use. In the long term the protection of forest ecosystems and amenities may depend upon the successful application of this technology in managing forests and utilising forest products.

POLITICS

Politics as an expression of social, cultural and economic considerations is probably the most important factor affecting forest production policies and the flow of energy and nutrients through native forests. In many lands the remaining reserves of native forest are threatened by forest clearance, especially for agriculture; by replacement with commercial forests planted with a restricted number of species of fast growing trees; and by destructive harvesting for short term economic gain irrespective of the long term consequences. In some countries issues of forest use have had a divisive influence between different community groups. For example, in Australia the logging of native eucalypt forests for the production of woodchips for export to Japan has led to confrontations between foresters and some conservationists.

In a world society based on national independance, the exercise of forest utilisation constraints for the long term protection of global resources poses practical and administrative difficulties. The motivation for national actions in utilising natural resources are complex and a potential for tragedy exists where the sum total of national policies does not result in wise global management. The establishment of sound co-operative programs of economic and resource use policies, in sympathy with sustained organic production, between developing and developed countries may assist in the husbanding of the forest resources of developing countries.

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Currently wasteful exploitation of forests is occurring in some tropical countries to meet the timber needs of more affluent nations. The harvesting procedures which are highly selective for tree species, size and quality give small yields yet cause a dramatic loss of organic capital which is only slowly restored. More rational use of these forests requires the forest product industries to utilise a much wider range of species and size classes. This in turn raises the spectre of such intensive harvesting as to create local deforestation followed by soil denudation. Tosi and Voertman (1964) have pointed out the need to develop high productivity land use systems appropriate to the tropics based on an efficient economic utilisation of the diversity of massive, fast growing, perennial plant species and the kinds of vegetational types which these environments are efficient at producing.

An understanding properly explained of forest production dynamics can provide a basis for politicians and decision makers to reconcile apparent conflicts in forest conservation and use and lead to a better planning for the long term management of forest resources.

RESOURCE PERSPECTIVES

More intensive use of forests as a source of energy and organic materials for people cannot be considered in isolation and needs to be tempered in the light of broader perspectives. There can be little justification for ignoring the local and global environmental significance of forests and the importance of other benefits derived from them.

Locally forests are often a dominant feature of the landscape and complex interrelationships exist between forest production and that of the surrounding areas. Any changes in forest management practices must take account of these relationships.

On a wider scale forests are seen as one of the prime guardians of the global environment. Prudence demands that, in manipulating the remaining forests for harvesting energy or organic materials, care is needed lest their capacity for planetary environmental control is not thoughtlessly squandered to place the future at risk.

For example, important changes have taken place in the earth's atmosphere following the industrial revolution. As fossil fuels are burnt to power industry, vast amounts of carbon dioxide are released into the atmosphere. This discharge of carbon dioxide is seen by some as likely to alter the mean world temperature, rainfall and cloudiness so as to shift the main centres of biological productivity on the earth's surface. The world's forests are believed to ameliorate these trends by their contribution to planetary photosynthesis and by their capacity, not shared by most agricultural crops, for the massive long term storage of carbon with the build up of the forest biomass.

The role of forests as a source of energy and organic material must also be placed in perspective against other less quantifiable, but nevertheless important uses. The recreational opportunities provided in forests can help to ease the burden of urban living for many people. Forest biomes are possibly the oldest and most complex of all terrestrial biomes and are seen as an important part of the world natural heritage. Their biological diversity and functional complexity are the result of a long and irreplaceable evolutionary sequence. The wildlife and wildplaces forests contain are worthy of protection not only in their own right but also because the long term survival of the human race may depend on the genetic wealth contained in forests and the knowledge to be gained from studies of the workings of natural forest ecosystems.

Traditionally foresters have recognised the multiple use values of forests. Sanit Aksornkoae in his paper considers the energy relationships for the mangrove forest ecosystems of Thailand and describes the use of mangroves for the production of firewood, charcoal, timber, tannin and wood tar. He also points out their significance to fish production since they are the nurseries and provide shelter for more commercially important fishes, crabs, prawns and molluscs. Furthermore they are important in the development of alluvial plains and protect the land from marine erosion. Aksornkoae emphasises the complexity of these ciritical communities at the interface between marine and terrestrial environments and with a continual migration of animals into and out of the mangrove habitats. He recognises the need for a better understanding of their dynamics in order to develop management systems to permit use without destroying the mangrove ecosystems. What the balance should be, as between the yield of protein as fish or cellulose as wood, remains in doubt but is the key question to be answered.

The general public has now come to appreciate that forest values are not confined to timber or cellulose production. Any strategy leading to more intensive materialistic use of forests cannot afford to discard the groundswell of public acceptance of other forest values. People are seeking greater involvement in decision making with respect to natural resource use. In many instances they have shown a willingness to sacrifice material gain for other less tangible benefits.

Another facet of this broader public approach to resource management is the greater recognition that is being given to the rights of indigenous people with life styles closely attuned to relatively natural forests. Too often in the past the interests of these people have been ignored in promoting more intensive forest use in tropical areas. Destructive harvesting may provide them with short term economic gains, these advantages may be far outweighed by long term loss of livelihood and indigenous culture. No people can afford to lose its traditional resources and the natural processes by which they are restored.

FOREST DYNAMICS

Forests make a major contribution to energy use (Arnold and Jongma 1978). Approximately one sixth of the world's annual fuel supplies are wood fuel and about half of all trees cut down are used for cooking and heating purposes (Hall 1972). In countries such as Nepal and Papua New Guinea where excessive deforestation has occurred, the village women and children daily have to walk long distances in search of fuelwood. Whilst forest utilisation in such situations is very intensive, the energy cost of the daily search is high and very wasteful of human resources. Agro-forestry in which land use systems are being developed to provide closer intergration between agricultural and forest production seems to offer hope for the future. In some Indian states and China it has reached an advanced stage and farmers include trees as one of their crops.

Despite the major research effort mounted over the last few decades, our knowledge of the functioning of forest ecosystems unfortunately is very incomplete. For a few forests, not necessarily representative of the world's forests, we have fairly detailed figures of energy capture as above ground plant net production and of the major pathways of organic turnover. But for many forests, and especially commercial forests, our knowledge of productivity is limited to estimates of millable timber.

Lieth (1975) in producing world maps of global productivity patterns has stressed the importance of environmental factors and of differences between ecosystem types. Tentative estimates of the earth's primary production indicate that forests and woodlands produce about 45 per cent of the annual production of organic matter and the carbon contained in their biomass (estimated as 400-700 x 10^9 tonnes) is not much less than carbon present as carbon dioxide in the atmosphere 700 x 10^9 tonnes (Anon. 1978).

If balance sheets of energy and organic flow for different forest types are to be prepared to provide guidelines for more rational use of forest resources or to assess the potential of forests as a source of photobiological fuels, several very different organic and energy pathways need to be quantified. In addition to the natural flows of energy into (mainly captured by photosynthesis) and out of (mainly by respiration and decomposition) forest ecosystems and the resultant changes in the amounts of energy contained in the forest biomass (Ovington 1962), it is necessary to determine energy removal in the variety of products harvested, the energy required to sustain and harvest the forest and possibly that used to transport and process forest products.

The world's annual use of energy is only about a tenth of the annual photosynthetic storage so there appears to be considerable potential to harvest plant organic matter for energy supply. Because of the relatively large annual net production of organic matter in fast growing stands, consideration is being given in some countries to energy forests as a means of capturing solar energy for human use. The advantages of using such an energy source are that it is based on a renewable resource, is less ecologically offensive than some other sources of energy and is well within the capacity of known technology. In order to achieve high levels of efficiency such schemes may have to be based on forest monoculture over large areas, mechanical sylviculture and more rapid rotations than formerly.

Considerable doubt exists about the validity of such schemes. Inevitably large areas of land are needed and must be set aside against the needs of other rural and urban uses. Intensive forestry can be demanding of labour, capital, water and fertilisers. The cost of transporting forest produce to processing plants is expensive. Environmental problems arise with the heavy and widespread use of fertilisers and severe effluent disposal problems result from wood hydrolysis processes and in obtaining petrochemical substitutes and gaseous fuels from trees. Monocultures and intensively used forests may prove costly to protect against the ravages of fire, pests or disease organisms and have adverse soil effects.

Because of rising oil prices and changing economic factors comparisons of the cost of producing energy from organic derived materials have limited application.

Synthetic fuel available for use in internal combustion engines can be produced from cellulose and other plant material via processes such as enzyme hydrolosis of starch and fermentation of organic material to methane and pyrolysis of wood to produce pyrolytic oil. It appears a significant part of the world's liquid fuel might be provided from cellulose by growing trees and other plants specifically for conversion to liquid fuel.

Various relevant studies have been done in Australia. As a practical concept, studies have been done to examine the consequences of meeting half of Australia's liquid fuel requirements in the year 2000 by producing "energy crops" and converting them to alcohol for use as fuel. In the case of eucalypts the cost would be $1.60 per gallon requiring 13 million hectares of land, the comparative figures are 80 ¢ per gallon and 4.5 million hectares for cassava (pers. comm. D. Macrae). Alcohol contains only about 62% as much energy as petrol which costs 42 ¢ per gallon without tax. The availability of land and other resources to grow these energy crops and the social and environmental consequences present serious practical problems.

Energy forestry could be more profitable if the annual yield per hectare could be increased without a disproportionate rise in costs. The main possibilities of improving energy yield appear to be improved management practices including the introduction of trees bred for high photosynthetic efficiency and better utilisation of all kinds of forest organic matter.

Various claims have been made by some researchers based on the study of open grown trees that there is a large potential to increase organic production. These claims seem too optimistic. In considering forest production it is essential to think in terms of photosynthesis of the forest as a unit on an area basis.

Studies of production in forest age sequences suggest that the greatest levels of organic production tend to occur relatively early, usually just after the forest canopy closes when there is the maximum amount of leaf. It appears that where soil nutrients and water are not limiting forest production can equal that of other high producing plant communities provided that the tree species used have a high photosynthetic efficiency, the forest rotation is relatively short and the initial stocking is high to make full use of the site when the trees are young. Economic production can also be increased by using species which divert a greater proportion of the photosynthate into harvestable wood material. It has also been thought that coppice woodlands are capable of high levels of net production because less photosynthate goes into root production and stem growth from the coppice shoots is rapid after harvesting.

However, the scope to increase organic production by forest stands is limited since the photosynthetic process is relatively inefficient in capturing incident solar energy. There are also problems of maintaining forest production over several rotations. In South Australia there is evidence of a fall off in production in second rotation stands although the reasons for this are not fully understood. Whilst energy forests are probably not the answer to the energy crisis they do provide some opportunity to lessen its impact.

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ISSUE 3
SYNTHESIS PAPER

THE ENVIRONMENTAL CONSEQUENCES OF INTENSIVE FORESTRY AND THE REMOVAL OF WHOLE TREES FROM FORESTS

Stephen G. Boyce[1/]

Abstract.--Intensive forestry and the removal of whole trees for energy pose dangers of soil erosion, nutrient and organic matter depletion, and a reduction in scenic and recreation values. Each consequence is an holistic problem. An effective solution is to schedule rates of biomass removal and sizes of areas harvested to bring the forest to a state of organization that biologically provides the most desirable combinations of benefits and the least number of consequences.

The harvest of forests for energy, organics, and timber, particularly whole-tree harvesting, disturbs the water, air, and soil. Our knowledge about environmental consequences comes primarily from the removal of timber from large areas and the clearing of land for agriculture. As pointed out by Dr. Kartawinata, extractions by people living on or near forests cause little disturbance. Extraction from large contiguous areas is most destructive.

Frequent harvesting, intensive and repeated cultural treatments such as cultivation and irrigation pose dangers of soil erosion, compaction, and nutrient and organic matter depletion. These nutrient problems are discussed by Drs. Carlisle and Methven. Any or all of these factors may induce detrimental microbiological changes. These intensive forms of forestry are being used in many parts of the world, especially in the tropics, as described by Drs. Jordan and Niles.

Dr. Kartawinata makes the important point that in situ conservation is the most effective way to prevent the loss of productivity and the loss of genetic materials in the tropical forest. Specifically, he encourages solutions to the problems caused by shifting cultivation and poor logging operations. Both of these actions have transformed productive forests into unproductive grasslands, which total many millions of hectares. This paper describes the environmental consequences of the various ways the tropical forests are now being used. Plant and animal communities are dislocated, soils are degraded, and genetic diversity of native species is reduced. There is also a risk of actually losing some species by inappropriate use of the forest.

Dr. Kartawinata summarizes the concerns expressed by many people at the Eighth World Forestry Congress. These concerns include the lack of an ecological basis for the presently used cutting methods, the indiscriminate use of selection and clearcutting methods for regeneration, and the lack of knowledge about species composition, growth, and yield of the second crop. It is already known that certain practices must be implemented, such as minimizing the width of extraction paths, refraining from making unnecessary tractor paths, avoiding excessive wet-weather yarding, and the use of winching techniques to avoid the use of tractors on small hills.

Dr. Jordan makes the important point that while rates of wood production in the tropics are roughly equal to that in the temperate zone on a yearly basis, environmental costs are higher. The high environmental costs result from nutrient losses, soil erosion, and increased numbers of parasitic species. Dr. Niles describes the need for resource evaluation and for long-time studies of environmental changes.

Over time, it is likely that people will become more and more dependent on using woody material for energy and organics. This increased use of woody materials depends on improved technological developments for the culture of woody plants. One of the important challenges is to find ways to direct the flows of diffuse solar energy through natural and artificial ecosystems in such a way that we preserve biological diversity and productivity of the earth. In the words of Rene Dubos (1976):

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"The earth is to be seen neither as an ecosystem to be preserved unchanged nor as a quarry to be exploited for selfish and short-range economic reasons, but as a garden to be cultivated for the development of its own potentialities...."

At this workshop, our primary challenge is to identify opportunities for human intervention to create new kinds of productive ecosystems, maintain some old ecosystems, and provide for the biological components to undergo modification beneficial to mankind and other forms of life. The important question is how? In our research, what do we search for? To what goals are managerial actions to be directed? How is the technological knowledge to be harmonized with sociological attitudes and human behavior?

We cannot define the specifics for every kind of ecosystem. We can offer some principles.

Solar energy is the origin of most forces that do work in ecosystems. Upon arrival at the earth's surface, this solar energy is diffuse and, unless trapped and delayed, the energy rather quickly returns to the universe. Mankind uses ecosystems to trap and store small amounts of solar energy in beneficial forms. But ecosystems provide man with many benefits other than energy and organics. It is the total combination of benefits that concerns us if we are to rationally use forests for energy and organics. Our chore is to direct the flows of diffuse solar energy to provide biologically possible and desirable combinations of benefits without adverse consequences.

The flow, the storage, and the harvest of solar energy in ecosystems is directed by bringing the ecosystems in question to a certain state of organization. For example, if fuel is to be harvested annually from energy plantations which are restricted to a single species, the forest must be organized to maintain, in every age class, an area equal to the annual harvest. This is one state of organization. This is the most costly state in both environmental consequences and in fossil energy investments. The fossil energy investments include the energy required for chemicals, fertilizers, cultivation, genetic improvements, and plantation establishment. The environmental consequences include a reduced livelihood, if not elimination of, most endemic species, soil erosion, increased water runoff, organic matter depletion, soil compaction, and the possibility of reduced future production for marginal landscapes.

A large number of other states of forest organization offer opportunities to limit environmental costs, reduce investments in fossil energy, and improve the desirable combinations of multiple benefits. These states of organization are holistic, because they maintain a variety of forest types in a wide range of age classes and they regulate the size of stands in relation to habitat requirements for endemic species and for the least destructive extraction methods. The dispersion of forest types in combination with other land uses and the regulation of age and area classes of stands can create, over time, an enormous variety of habitats. If the areas of the stands are kept relatively small, less than about 30 hectares, and regeneration after harvest is rapid, many adverse consequences of extraction can be contained (Boyce 1978; Boyce and Cost 1978).

Artificial stands, even intensively cultured single species for short rotations, can be interspersed among natural stands. The use of superimposed rotation periods provides the opportunity for the same piece of land to be used for an intensively cultured plantation, then a natural forest for 80 to 200 years, then food crops for several years, and eventually back to an intensively cultured forest plantation. An enormous number of combinations, forest types, age and area classes, and alternate land uses is possible. The important constraint is not to dissipate by extraction and adverse consequences more energy than can be trapped from the sun.

Professor Margaris proposes an interesting way to manage the Mediterranean type ecosystems. The desired benefits are to reduce wildfires in shrublands and forests, preserve the natural habitats, harvest fuel from the shrublands and some timber from the forests, use the trees and shrubs for animal food, and produce aromatics for export. The simple system is to use a single rotation period for the brushlands, and another single rotation period for the forests. Harvesting the brushlands at 10-year intervals could reduce the wildfire problem and provide some of the other benefits.

The holistic approach would schedule the rates of harvest and the size of areas harvested to bring the brushlands to a state of organization that biologically provides the most desirable combination of benefits and the least number of adverse consequences. For this case, artificial plantations and large cultural investments with fossil energy are not required. Research is required to determine the size of harvested areas, which determines the area of each stand, to determine age class of stands required for each benefit and to determine the oldest stands required to provide a livelihood for endemic species.

Professor Margaris' proposal must represent one of any number of possibilities for forests and shrublands in many parts of the world. It is relatively easy to identify the environmental consequences of intensive forestry and to propose alternative actions. The more difficult and primary challenge is the one I mentioned earlier: "...to identify opportunities for human intervention...." This requires actions harmonized with sociological attitudes and human behavior. Dr. Jordan made the point that forest wardens in Central America have great difficulty telling the campesinos they cannot clear the forest reserves to feed their families. Can we not find a way to use the attitudes and the behavior of the campesino to bring forests and the cropland to a desired state of organization? Can we not cooperate with the campesino and, over time, influence his social attitudes and behavior to reduce the undesirable consequences of using the forest?

The environmental consequences do not stand alone. Each consequence is an holistic problem involving social, biological, and physical elements. Concern with any one of these elements alone only creates more problems, which lead to more problems, which lead to more problems. Soon the enormous number of constraints, tied to each problem, reaches unmanageable proportions. In the workshops that follow, I encourage you to search for holistic solutions that harmonize the various elements of the problem. Instead of trying to make a forest produce so much of this, this, and that, influence the social behavior of people to bring the forest to a desired state of organization.

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SOME SOCIAL AND ECONOMIC CONSEQUENCES AND CONSTRAINTS TO THE USE OF FORESTS FOR ENERGY AND ORGANICS IN GREAT BRITAIN*

R C Steele†

Abstract. The huge imbalance between wood production and consumption in Britain means that there are no immediate prospects for the major use of forests for fuel and organics. Such uses may become necessary in the future so the resulting socio-economic advantages and constraints are noted.

INTRODUCTION

Photosynthesis is the only known way of supplying and storing carbon compounds for energy and chemicals on a renewable basis. A recent review (Hall, 1979), on which this Introduction is based, notes that biological solar energy conversion via the process of photosynthesis produces every year stored energy in the form of biomass which is about ten times the world's annual use of energy. The amount of proven fossil fuel reserves is about equal to the present standing biomass (mostly trees) on the earth's surface while the total fossil fuel resources are possibly only about ten times this amount. This massive capture of solar energy by plants and conversion into a stored product occurs with a low overall efficiency of about 0.1% on a world-wide basis but locally and with certain crops the conversion efficiency can be much higher than this.

About one-sixth of the world's annual fuel supplies are wood fuel and about half of all the trees cut down are used for heating and cooking. In the non-OPEC Developing countries, which contain about 40% of the world's population, non-commercial fuel may comprise up to 90% of the total energy use. About half the world's population relies mainly on wood for cooking, which itself accounts for about four-fifths of the total household energy use. Supply statistics of non-commercial energy are under-estimated and the real use is certainly substantially higher than the figures usually quoted.

Photosynthesis provides man with charcoal, oil and gas, fuelwood, food, fibre and chemicals. The scale of production and the extent to which these products have been used has varied geographically and with time and will continue to vary. The abundant fossil fuel supplies available to the developed countries has resulted in the products of present-day photosynthesis being now used mainly for food, timber and fibre. However, there is world-wide anxiety about the future availability of fossil fuels and the cost of these fuels so more and more attention is being given to photosynthesis as a means of supplying energy for a variety of purposes. Clearly, with today's increased populations and standards of living, it is not possible only to re-employ the old technology. We must in addition develop new methods of using present-day photosynthetic systems more variedly and more efficiently.

Solar energy is very attractive as a source of energy for the future but it does have disadvantages. It is diffuse and intermittent on a daily and seasonal basis so collection and storage costs can be high. However, this meeting is concerned with forests as sources of energy and organics and trees are biological systems which are adept at capturing diffuse solar radiation,

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*/ Overview paper for "Biological and Sociological Basis for a Rational Use of Forest Resources for Energy and Organics". Man and the Biosphere programme, May 6-11, 1979, Kellogg Centre, Michigan State University, East Lansing, Michigan, USA.

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concentrating this energy and storing it for future use.

The social and economic consequences of the use of forests for energy and organics will vary between countries and even within countries and no brief overview paper can provide more than a glimpse of the problems and possibilities. The position in Great Britain, described here, may not be exactly parallel elsewhere but our understanding of the situation may be useful in developing and clarifying more generally applicable ideas.

Table 1. Land-Use - International Comparisons (From Forestry Commission 1979)

Country	Total area (million ha)	Percentage of total area		
		Forestry	Agriculture	Urban and Other
Great Britain	22.8	9	77	14
United Kingdom	24.1	9	78	13
Belgium	3.0	20	50	30
Denmark	4.2	12	69	19
France	54.9	25	67	8
West Germany	24.3	30	55	15
Ireland	6.9	4	70	26
Italy	29.4	27	59	14
Luxembourg	0.3	32	48(est)	20
Netherlands	3.4	10	76	14
EEC Countries	150.5	22	66	12
Norway	30.8	29	3	68
Sweden	41.1	64	8	28
Finland	30.5	74	10	16
USA	919.0	33	19	48
Canada	922.0	35	7	58
USSR	2140.0	43	28	29
Japan	36.8	67	15	18
World	13100.0	29	not available	not available

Source: GB and UK - Government statistics
Other countries - ECE/FAO European Timber Trends and Prospects, 1976 Table 2/5
OECD Study of Trends in Supply and Demand of Major Agricultural Commodities, 1976

Note: 1 Information for each country is based on the latest available published information
2 Forestry areas include unproductive woodland
3 Other land includes mountains, tundra, desert etc

FORESTS IN GREAT BRITAIN

Britain has a land area of 22.8 million hectares and a population of some 55 million. There is thus 0.4 hectares (or one acre) of land per head of population. The forest area amounts to about 2 million hectares or 9% of the land area. This forest area produces only 8% of Britain's current consumption of wood and wood products; therefore some 92% is imported at a very substantial cost to the economy. These stark figures hold the key to the problems encountered in the use of Britain's forests for energy and organics.

Table 1 shows land-use in Great Britain in comparison with some other countries. Thus on a European and a world basis, Britain has a low percentage of forest land and a high percentage of land used for agriculture. There is little slack in the system and any substantial increase in forest production can only follow an increase in the area under forest.

The area of productive forest in Great Britain is equally divided between the Forestry Commission (the State Forestry Service) and private ownership as Table 2 shows.

Table 2. Area of forest in Great Britain (000s ha) (Forestry Commission 1979)

Forest Type	Forestry Commission	Private	Total
Conifer high forest	806	506	1312
Broadleaved high forest	49	319	368
Coppice and coppice-with-standards	1	26	27
Total productive forest	856	851	1707
Unproductive forest	7	283	290
Total forest land	863	1134	1997

Conifer high forest amounts to about 75% of the total area of productive forest and about 65% of the total forest area. Most of these conifer forests have been created by planting. At the middle of the last century, Britain's forests covered only about 3% of the land area. Since then the area has increased, at first slowly but in the past few decades quite rapidly. This increase in area has been achieved mainly by planting upland grassland and moorland often of marginal agricultural value. The main species used have been Norway spruce (*Picea excelsa*), Sitka spruce (*P sitchensis*) and Lodgepole pine (*Pinus contorta*). None of these species are native to Britain and two of them are not native to Europe, but they have been successfully established and are productive under conditions in which Britain's native timber tree species do not thrive. It is worth noting that the very low area of forest land in Britain is not due to unsuitable conditions. Indeed, conditions for growing a variety of conifers in Britain are superior to those found in most other European countries.

The recent increase in Britain's forests has resulted in an uneven age-class distribution for conifer crops. Indeed, 70% of Britain's confier forests has been established since 1950. The hardwoods show the opposite trend with a preponderance of the older age classes. There has been a decline in hardwood planting since 1919 and therefore the younger age classes are inadequately represented.

Current annual consumption of wood and wood products in Britain is equivalent to 44 million m^3 of roundwood (Forestry Commission 1979). Of this consumption about 92% is imported. It is predicted that by the turn of the century demand in Britain will be between 55 and 60 million m^3 of roundwood annually. By the year 2000, wood production from the present forest area will meet about

15% of this demand. The forest area will continue to grow but at what rate and to what extent remains to be seen. The most optimistic forecasts for planting and production however show that there will continue to be a very large difference between consumption and home production. This imbalance, but at a reduced level, is true for the whole European Community.

FORESTS FOR ENERGY IN GREAT BRITAIN

Very little wood is used for fuel in UK and, in the foreseeable future fuelwood is likely to remain as a by-product of other forest production. For example, wood would need to be delivered to the combustion plant at only one-third of 1977 pulpwood prices (Forestry Commission 1977) to compete with fossil fuels. Britain's supplies of natural gas and oil are estimated to last for 20 years and 50 years respectively at current levels of consumption and technology. The preferred fuel thereafter is likely to be coal of which there are estimated to be reserves for 300 years at current rates of consumption.

The immediate outlook in Britain for chemical fuel from wood, ie, methanol and ethanol, is similarly not promising nor is the use of wood as a source of chemicals. However, low quality wood or species that are currently not considered utilisable appear suitable for chemical production so the position may well change in the future.

The general advantages and problems of using forest biomass for energy are summarised in Table 3.

Table 3. Forests for energy (Modified from Hall 1979)

ADVANTAGES	PROBLEMS
1 Capture and store solar energy	1 Requires large areas of land
2 Renewable	2 Competes with other land-uses and especially agriculture
3 Can be utilised by existing technology with low capital input	3 Initial source of energy bulky and may require concentration for economic transportation
4 Can be developed with present manpower and material resources	4 Supplies often far from centres of consumption
5 Ecologically (and therefore socially?) acceptable	5 Maintenance of fertility in intensively used forests on short rotations
6 Have important secondary roles, eg, wildlife conservation; amenity	6 For plantations, initial time lag between planting and harvesting
7 Soil and water conservation	
8 Limited pollution problems	
9 Help in maintaining world balance of CO_2 and O_2 (?)	

More specifically, Britain has a very small area of forest, both comparatively and absolutely. Increase of the forest area is taking place and will continue but this increase will have to be at the expense of marginal agricultural land. However, it is estimated (Centre for Agricultural Strategy, 1976) that the productive area of Britain's forests could be doubled with only a 1% - 2% loss in agricultural production. Even with such an increase in forest area the predicted supply of wood is likely only to meet about 75% of the forecast consumption. Britain is now, and seems likely to continue to be, a country very short of wood but currently at least with adequate supplies of fossil fuels, especially coal. The immediate outlook for the production of fuel and organics from forests in Britain is therefore unpromising. However, recent events have shown how quickly the energy outlook can change so it may be useful to list the socio-economic factors that will have to be considered if Britain's forests were to be used for fuel and organics. These factors fall under two broad headings.

Socio-economic factors affecting the production of biomass in Britain

1 There are few, if any, "natural" forests in Britain. Semi-natural forests and woodlands have an important role in wildlife conservation, landscape and amenity use. They are therefore unlikely to contribute in any substantial measure to the production of fuel or organics.

2 Any future use of trees for fuel and organics will be plantation-based. These plantations will be mainly in the uplands on poorer agricultural soils currently used for extensive rather than intensive production. Biomass production for fuel would be far greater on the more fertile lowland soils used for intensive agriculture but these are in general not available for establishing plantations at present. However, the large agricultural surpluses of some types of food in the European Community could result in some good quality land becoming available for forestry.

3 Some means will have to be found to harmonise the land needs of agriculture and forestry. Currently the position is competitive but will have to be made complementary.

4 A substantial injection of capital will be needed to create fuel plantations.

5 Public pressures are such that fuel plantations will have to be designed and managed with other requirements such as wildlife, landscape, amenity and recreation in mind. Exclusive and very intensive use for fuel may not prove socially tolerable.

6 Non-native species will predominate in fuel plantations. These are likely to be conifers in the uplands but genera such as *Nothafagus* and *Populus* may have their value under better growing conditions. The effects of these species on wildlife and landscape must be considered.

7 In creating and managing fuel plantations more information is needed on matters such as:

(a) The basic dynamics of ecological systems and the effects on them of physical and biological factors, eg, droughts and pests.

(b) Alternative management systems and their effects on biological production and fuel utilisation.

(c) The energy balance of plantations: By this is meant the relationship between the energy produced by forests and the energy in the form of fossil fuels put into creating these forests. This balance should clearly have an important influence on the management regime adopted.

8 Forest land is fairly evenly divided between the State and private sectors in Britain. Any substantial production of fuel and organics from forests must therefore involve the private sector. Because of the long production cycle this means that private owners must have confidence in the future for fuel production which may only be achieved if the State provides long term financial incentives and safeguards.

Socio-economic factors affecting the conversion of biomass into usable sources of energy

1 Environmentally acceptable methods of harvesting and converting tree biomass into fuel and organics will have to be devised.

2 Wood is a bulky product and needs to have its bulk/energy ratio reduced. This may have to be done as near as possible to the source of the wood to save transportation costs. This may create environmental problems.

3 The major sources of wood are likely to be in areas fairly remote from human

habitation. Therefore the infrastructure of such comparatively undeveloped regions will have to be improved to support production, conversion and transport.

4 Many technical problems still remain to be solved in obtaining competitively-priced fuel and/or organics from wood.

CONCLUSION

Although present indications are that Britain and many countries will not give a high priority to the use of forests for fuel and organics this could change when the fossil fuel, and particularly the oil, supply position becomes more acute as it must in the next few decades. Forests as a source of energy may then become much more attractive propositions. Trees, however, take some time to grow and, except for those countries which are fortunate enough to have large areas of forest land surplus to current demands, there will be a considerable time lag between wanting to use forests for fuel and organics and actually using them for this purpose in a planned and methodical way. Therefore, there is a strong argument in favour of every country increasing its forest area to the largest extent possible. Wood is a renewable, versatile and readily-convertible raw material which can be grown under a great variety of conditions. It seems prudent to ensure that there is plenty of it available for future use whatever form this use may take.

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THE SOCIO-ECONOMIC CONSEQUENCES AND CONSTRAINTS TO USE OF LAND AND FOREST FOR ENERGY AND ORGANICS IN INDIA*

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Abstract. The energy crisis is a burning topic of whole world. Wood is the principal source of energy in India for the masses which should be made available to them at reasonable price. "Social Forestry" is the possible answer through which it will be feasible to utilize the unconventional land resources to meet the needs of energy.

India has a good potential for economic growth and much depends on appropriate development strategy and proper direction in the energy sector. The country can become economically viable and self-reliant to a considerable extent if its large man-power and abundant land resources alongwith known technology of development are successfully utilised. The problem is to harness them in a collective national effort so that the latent productivity is realized.

Wood is the principal source of energy in India and used as fuel by the rural people and also by many of the urban poor. Availability of fuelwood for cooking within the purchase capacity, and not the soaring oil prices, is the real energy crisis in India. However, there is evidence of better planning and execution to inspire confidence that rate of development will be accelerated to the extent needed.

Annual domestic energy consumption in rural as well as urban areas of India is about 0.35 tonnes of coal equivalent per person. For a population of about 550 million, the total energy consumption in India is about 190 million tonnes of coal equivalent annually. Consumption of different fuels according to the survey conducted by the National Council of Applied Economic Research is given in table 1.

Table 1. Consumption of different fuels.

Fuels	Consumption: Coal replacement units (Million tonnes)	Consumption: Percentage
Non-commercial		
Firewood	81.7	59.29
Dung cake	18.4	13.35
Vegetable waste	24.7	17.93
Commercial		
Electricity	0.2	0.15
Kerosene	10.7	7.76
Soft coke	2.1	1.52
Total :	137.8	100.00

Firewood, vegetable waste and dung cakes are, thus, the most important fuels used in rural areas,

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besides small quantities of soft coke, kerosene oil and electricity.

About 30 percent of this requirement is met by cowdung cakes and agricultural waste and fuel-wood is the most important source meeting about 60 percent of the energy requirement. The quantity of cowdung cakes burnt annually correspond to the equivalent production of as many as eight fertiliser factories of the capacity of the plant at Sindri which produces 75,000 tonnes of Ammonium sulphate. This colossal waste can be prevented if alternative source of energy is developed. Naturally occurring resources such as coal and mineral oil are limited and a desirable approach would be to rely more on renewable products like fuelwood to conserve fossil fuels for specific uses to avoid conflict of interests.

Fuelwood presents various difficulties in estimation. However, of the total consumption of 203 million cubic metres of fuelwood in India only 13 million cubic metres is from the recorded sources and the balance being from unaunthenticated sources. Based on the trend of population rise, the requirement of fuelwood in India has been projected as 256 million and 300 million cubic metres by 1980 and 1990 respectively by the National Commission on Agriculture, thus pointing to a deficit of 100 million cubic metre of fuelwood in the year 1990.

In view of unexpected rise in prices of the substitute fuels, fuelwood will have to be increasingly depended upon to supply energy for domestic consumption particularly among the rural population. Additional supplies of fuelwood can be obtained through :

(i) utilisation of logging waste

(ii) raising of energy plantation

(iii) tree cultivation on farm lands

Much would, however, depend if the latter two can be successfully implemented, but the solution is not so simple.

The present land use practices in the country and distribution of forests is a relevent point to consider to reckon with the problems of energy plantations. In the table below the situation has been explained.

LAND AREA	(Million ha)
Agriculture (cultivated land)	152.6
Forests	75.0
Other uncultivated land	42.3
Land under Non-Agricultural uses	16.2
Barren and unculturable land	42.7
Total :	328.8

During the past centuries and the early decades of the current one, the forests owned by the States, Table 2, and the private individuals came under the pressure of extensive agro-economic movement and suffered widespread trespass and disintegration as a result of which , except in the remote and inaccessible parts of the country, original form and structure of the forests have been modified by the successive events of human history. Demarcation of forest areas was followed by certain legal injunctions on reckless clearings and constitution of Reserve Forests. Nevertheless, extensive marginal forests were left out adjacent to the village sites, and for many of the social needs, these forests used to be the chief source.

As time passed, agriculture advanced at the expense of forests and the residual vegetation began to degenerate due to intense exploitation. Even when reduced to scrubs, these forests provided the major requirement of fuel and other commodities to the millions in the countryside.

The forests as they survive today have also a very uneven and unbalanced distribution territorially and this was essentially influenced by the extensity and direction

Table 2. Statewise forest area vis-a-vis geographical area (1973-74)

States/Union territories	Area in thousand ha Geographical	Forest	% of forest area to geographical area	Per capita forest area (ha)
States				
Andhra Pradesh	27,682	6,480	23.41	0.14
Assam	7,852	2,855	36.36	0.23
Bihar	17,388	2,932	16.86	0.05
Gujarat	19,598	1,697	8.66	0.06
Haryana	4,422	152	9.66	0.01
Himachal Pradesh	5,567	2,167	38.93	0.61
Jammu & Kashmir	22,224	2,072	9.32	0.43
Karnataka	19,177	3,608	18.82	0.12
Kerala	3,887	1,127	28.99	0.05
Madhya Pradesh	44,284	16,835	38.01	0.38
Maharashtra	30,776	6,613	21.49	0.12
Manipur	2,236	602	26.92	0.53
Meghalaya	2,249	699	31.08	0.66
Nagaland	1,653	288	17.42	0.54
Orissa	15,578	6,793	43.61	0.30
Punjab	5,036	213	4.23	0.01
Rajasthan	34,221	3,589	10.49	0.13
Sikkim	730	265	36.30	0.73
Tamil Nadu	13,007	2,234	17.17	0.05
Tripura	1,048	605	57.73	0.37
Uttar Pradesh	29,441	5,013	17.03	0.05
West Bengal	8,785	1,183	13.47	0.03
Union territories				
Andamans & Nicobar Islands	829	746	89.99	6.16
Arunachal Pradesh	8,358	5,154	61.67	10.52
Dadra and Nagar Haveli	49	20	40.82	0.26
Delhi	149	4	2.68	Negligible
Goa, Daman and Diu	381	131	34.38	0.14
Mizoram	2,109	887	42.06	-
Others	63	-	-	-
All India	328,779	74,964	22.80	0.13

of human settlement and agricultural expansion. Large areas in the Indo-Gangetic Plain, in the coastal strips and other fertile systems are either devoid of forests or carry only sparsely distributed trees and degraded vegetation. Economic significance of forestry operations vary widely from region to region depending on the utility and value of different species, and the situations in which they occur and also on the pattern of livelihood of the people.

Considering the spectrum of alternative economic environment in which villages are situated and link of the people with forest, the following categories can be broadly identified.

(i) Villages mainly dependant on forests and marginally on agriculture e.g., in the Himalayas and similar productive zones,

(ii) Villages totally dependant on agriculture as in the fertile river valley system,

(iii) Villages marginally dependant on agriculture or pastoral economy as in the dry and semi-arid areas of Rajasthan, Gujarat etc.

Thus it will be obvious that there are contrasting situations; thickly populated areas of the river basins where forests have been dispensed with for production of food and at the opposite extreme, there are regions of extensive biological capital where human communities have a low population density. Among these there are many intermediate situations. For any adjustment or change in land use, nature and dimension of socio-economic problems should be clearly understood before setting out any forestry project for social welfare.

The Fuel Policy Committee has recommended that "the energy policy of the country should be designed on the premise that coal would be the primary source of energy in the country for the next few decades". This committee has, also, observed in the same report that "the prime coking coal reserves (of India) are expected to be exhausted in about 40 years". Under the circumstances policy of energy production and its use have to be evolved very carefully. Forests being irregularly distributed, it is necessary to identify the critical areas, and for any rational planning, more reliable information about the existing forest resources, the potential annual cut, stage of utilisation, current and projected demands for fuelwood and timber and the likely surplus and deficit in each economic region. Assuming an average yield of 5 cubic metre of wood per hectare per annum specially from plantations of fast growing tree species, 20 million hectares of fuelwood plantations will be needed to meet the shortage by 1990. An immediate question arises as from where to get the area to accommodate such an extensive reserve of fuelwood to meet the energy requirement without creating a new crisis of land utilisation, development and distribution.

It has been mentioned earlier that the bulk of the forest resources are confined to the uplands in the hill ranges of the Himalayas, the Vindhyas, the Satpuras, Western Ghats and other important mountain systems, and also in the adjoining plains. Most of these areas are earmarked either for production of industrial raw material or protection of highly sensitive watersheds.

The National Commission on Agriculture has identified about 30 million hectares of hardwood forests and about 1 million hectares of conifer forests available for conversion to highly productive plantations which would guarantee supply to various industrial units. In the northern Himalayan zone the forests start in the foot hills, sometimes as pure crops and often as stands constituting a complex broad-leaved association of several species. Higher up, pines dominate gradually yielding place to fir and spruce. From the utilitarian point of view, the number of important species are spruce (<u>Picea smithiana</u>), fir (<u>Abies pindrow</u>), deodar (<u>Cedrus deodara</u>) and pines (<u>Pinus roxburghii</u> and <u>Pinus griffithii</u>) among the conifers and walnut (<u>Juglans regia</u>), birch (<u>Betula alnoides</u> and <u>Betula cylindrostachya</u>) ash (<u>Fraxinus excelsior</u>), elm (<u>Ulmus wallichiana</u>), maples (Acer spp) alders (Alnus spp.) poplars (Populus spp.), hornbeam (<u>Carpinus viminea</u>), sal (<u>Shorea robusta</u>) among the broadleaved.

Down south in the peninsular area, teak is the most important species and also rosewood (<u>Dalbergia latifolia</u>). In the wet evergreen forests Dipterocarps constitute the most important crop. The species that have made a mark in the field of veneer industry are <u>Tectona grandis</u>, <u>Michelia champaca</u>, <u>Schima wallichii</u>, Dipterocarps species and Terminalias. Future industrial possibilities depend on the large scale plantations of these species and there is no alternative site except what has remained within the boundary of the old reserves situated in these regions. In fact, there is hardly any option and it is difficult to manipulate management practices to cater, in addition, the requirement of millions of rural population without upsetting the principal functions of such forest areas. Total industrial raw material requirement by 1990 is given below :

Sawn wood	17.0	million cubic metre
Panel product	1.4	"
Pulp and paper	12.7	"
Fuelwood	300.0	"

The objectives of management of forests for production purposes have to be clearly understood with due emphasis on ultimate utilisation of raw material and, therefore, on specific requirements of industries concerned and the markets to be sustained. In the past, management was primarily linked with limited local demand and in the absence of industrial growth, large users did not exist. Forestry has moved away from this situation and investment opportunities in the potentially productive areas have come to be recognised and the rationale is binding on the foresters to intensify efforts to stimulate higher production on as many sites as possible. Necessity is to change-over to industrial species especially for production of pulp and panel products and only when sufficiently large areas are converted into commercial crops, only then the anticipated demand be met and economic growth sustained.

Table 3 would give an idea of the maximum increment attained by some of the species in the plantation crops.

Table 3. Maximum increment attained by a few species in plantation crops.

Locality	Species	Age	MAI (m^3/ha)
Western Himalayas	*Pinus roxburghii*	38	12.25
Eastern Himalayas	*Alnus nepalensis*	15	16.34
Eastern Himalayas	*Cryptomeria japonica*	32	42.92
Western Ghats (Nilgiri)	*Eucalyptus globulus*	10	50.00
Eastern Ghats	*Eucalyptus grandis*	10	40.00

Growth data of some of the plantation of different species and natural high forests are given in Table 4.

There can be only marginal scope for interference to these functions of the productive forests. Doubtless, surplus material is available from the unutilised wastes from these areas for energy but it is not possible to transport the material to distant places where there is acute shortage, due to prohibitive cost. Further, there are forests closely situated to industrial complex and large populations. But it is risky to open the areas for energy production. Inevitable consequences might be the pressure of unknown demands on the productive forests leading to scarcity of the raw material for industrial production. This calls for caution, and to relieve the burden on such forests, opportunities must be created for growing trees on new sites and in that respect, "Social Forestry" as conceived in India (which includes production of fuel and small timber) has extensive scope. The scope of social forestry includes the following :

A. Farm Forestry

(a) Raising rows of trees on the bunds or boundaries of fields and the individual trees in private agricultural lands;

(b) Windbreaks.

B. Extension Forestry

(a) Mixed forestry, comprising raising of grass and leaf fodder, fruit trees and fuelwood trees on suitable waste lands, Panchayat lands and village commons;

(b) Shelterbelts;

(c) Raising of plantations of different quick-growing species on lands on sides of roads, canal-banks and railway lines.

C. Reforestation in degraded forests.

D. Recreation forestry.

Though in the great Himalayan region and other mountain systems much of the forest is concentrated but at the same time much of the land has been cleared for agriculture, orchard development and pasture. In the upper Gangetic basin for instance, out of 2 million hectares, 0.3 million is under agriculture about 1.2 million under forests and 0.65 million hectares under waste lands. Much of the waste land in this difficult terrain may be brought under forestry. But it may not be desirable to bring it under any short rotation fuelwood crops. Slope, land characteristics and climate in this region are such that erosion hazard is very high and harvesting of any short rotation crop periodically may increase erosion potential. Any short sighted policy can upset all calculations thus, rendering any forestry practice completely ineffective. Introduction of plantation forestry in the watersheds of the Ganges and similar catchment areas elsewhere is a serious technical problem beset with a number of difficulties posed by the terrain and the climate. While suggesting short rotation forest crops for meeting the demands of local population one has to be alert against any sort of gross decision and it would be necessary to evolve a correct land use practice to suit every aspect of management pertaining to production in the overall context of watershed stability.

It is worthwhile to look at the other extreme of the situation where the climate is not favourable. Aridity prevails in the northwestern part of the country and the arid region is surrounded by a semi-arid belt with rainfall 250 cm or less in the former and 250-500 cm in the latter. In the core is the desert where there is little permanent vegetation but there is lush ephemeral growth of herbs and grasses following rains. Bushes and trees

Table 4. Growth data of some species under plantations and natural high forests.

Locality	Species	Age	Standing stem timber (m^3/ha)	Average yield of timber from natural high forests (m^3/ha)*
West Bengal	*Tectona grandis*	30	90.20	67.95
	Tectona grandis	25	77.85	52.75
	Terminalia myriocarpa	30	84.36	21.00
	Terminalia myriocarpa	30	72.70	100.30
	Michelia champaca	36	114.30	100.30
	Michelia champaca	27	170.14	19.50
	Gmelina arborea	26	150.00	102.50

*/ Age 100 years and above.

subsist to some extent in the milder areas within the arid tracts and more frequently in the adjacent semi-arid portions.

The district of Kutch in Gujarat and the area around, have the same history of how forests have suffered widespread destruction and disintegration. The residual forests are either of grasses or thorny scrubs and small trees of *Acacia* Spp., *Prosopis* spp., *Salvadora* spp., and *Tamarix* spp., etc. It is one of the critical areas where the problems are extremely complex. Saline and alkaline soils also cover a large area in this tract. If one takes a look at the rural scene, economy of the region is dominated by two major uses of land - agriculture and pasture. Time and again this region has been overtaken by calamities following periodical drought and the economy has warped. Destruction of forests by reckless clearance for agriculture and excessive use for pastoral purposes have brought extensive ruination.

Studies were conducted by Indian Space Research Organisation, Ahemadabad in which 222 villages were surveyed to find out the losses on account of droughts which are frequent in this tract. Agriculture production was extremely low and famine followed. Table 6, clearly shows how animal husbandry suffered from periodical droughts and how water famine led to large reduction in animal population. Unfortunately, same activities i.e. agriculture and grazing, Table 5, are still considered as props of economic growth and development despite the fact that both these professions have been fatal liabilities in the past.

Table 5. Land utilization.

Village	Land Utilization (ha)			
	Cultivated	Grazing	Waste land	Forest
Narayan-sarovar	3807.00	980.00	30338.00	-
Baranda	3092.00	223.00	32912.00	2360.00
Siyot	7146.00	332.00	18992.00	113.00
Dayapar	11369.00	1185.00	39961.00	5637.00
Naliya	7776.00	2742.00	2389.00	243.00

Table 6. Animal population.

Village	Animal Population									
	Cow		Bullocks		Buffaloes		Goats		Sheep	
	Past	Present	Past	Present	Past	Present	Past	Present	Past	Present
Narayan-sarovar	4236	1951	760	263	725	165	8107	3980	1157	1172
Baranda	5180	1231	83	116	4160	272	3600	6310	560	885
Siyot	6800	1935	280	272	4060	693	3200	5730	1615	275
Dayapar	23566	2989	982	567	2819	846	13250	7724	2600	1400
Naliya	2870	607	918	331	1058	268	3400	3102	800	956

Fundamentally at issue, is the propriety of the present land management practices and whether with certain inputs in technique of cultivation and water conservation was the only logical course. The continuous disturbance of the environment and physical alteration of land surface create a situation where one cannot speculate economics of such land use particularly when the climate is grossly erratic. At the same time social and political options do not permit a drastic change from the current pattern and these are the main constraints to a high quality land use programme.

Of late, plantations of forestry species are being raised in the denuded lands and as well as on the canal banks and roadsides. Some projects in this regions amply demonstrated the gains of plantations of forestry species and gradually it has been realized that entire socio-economic development of this dry region depends upon proper management of land by large scale plantation. One hectare of plantation can give at the end of ten years 60 tonnes of fuelwood or 20 tonnes of charcoal. Cost of fuel per million BTU has been worked out as follows:

Coal	Rs. 9.80
Oil	Rs. 17.50
Fuel plantations.	Rs. 11.15

Cost of fuel plantation may be quite competitive compared to the other types of fuel. Another important fact which should not bypass is that nearly 60-70 percent of the cost of establishment of plantation which is about Rs. 2500/- per hectare is the labour component. In addition fuel plantation will provide 10 tonnes of fodder from foliage and pods per hectare.

Many species are capable of growing inspite of the inhospitable site conditions and most of these can meet chronic fuel shortage in addition to providing fodder, small timber and other forest products. In the past the choice was restricted to Prosopis and sometimes to Acacias but now a large number of species have been successfully established, e.g., Azadirachta indica, Acacia nilotica, Pongamia pinnata, Albizia lebbek, Cassia siamea, Parkinsonia aculeata, and even eucalypts. Several other species are also of considerable importance such as Ceratonia siliqua, Albizia amara, Bursera penicillata, Acacia auriculiformis, Acacia tortilis and Hardwickia pinnata.

In Haryana and Punjab literally the entire land surface has been brought under agriculture through a network of irrigation canals and only the roadsides and canal banks are available for growing tree crops. Demands are acute and potentials are great. Prospective areas for development of energy forests are extensive marginal tracts of Rajasthan, Gujarat, Maharashtra and Madhya Pradesh. Feasibility of a programme would, however, be limited by various institutional and market constraints and overall compulsions of national energy policy. Agriculture should be suitably combined with forestry and strip planting should be undertaken in all these areas. Grazing lands should be similarly treated, and windbreaks and shelterbelts raised at suitable intervals. However, before embarking upon this movement on an extensive scale, it is necessary to consider in respect of its scope, objectives, impact on farm output including fodder, rural employment, role in ecological balance and the mode of its implementation.

Per capita forest area in some of the deficit states is given below :

State	Area in ha
Punjab	0.01
Haryana	0.01
Rajasthan	0.13
Gujarat	0.06

Preparatory work on fuel forests has already started and the State Sub-committee of Gujarat on Fuel Policy for the Power Panel has made interesting observations which are relevant to the regions situated at a distance from the mine heads. Potential import of any development of fuel forests and the demand placed on the rail system for movement of coal from eastern sector to Western India has been analysed. For all the thermal power stations in Gujarat, requirement of coal would be approximately 10,000 tonnes of coal. At present the price of coal at mines is Rs. 50/- per tonne but for Gujarat Electricity Board coal is available at Rs. 130/- per tonne. Because of the high cost, use of coal, oil, lignite, it has been felt that fuel plantation i.e. utilising solar energy for biosynthesis is very attractive, and therefore, this source should be considered seriously. Various studies in India and elsewhere have indicated that an area of 1 km^2 can support a power station of 1 MW. The technology for generation of power by this method is well established.

This system of power generation provides certain significant advantages in terms of economics, air pollution, and improvement of landscape. Capital investment required for fuel per MW of power generation has been indicated as follows:

Fuel	Capital Cost/MW (Rs.in millions)
(a) By fuel plantations near thermal power station (including cost of land)	0.45
(b) By coal (Mining and transportation to power stations in Gujarat).	0.71 to 0.93

Gujarat has a land area of 196,000 sq. km out of which 1,000 sq. km of land would be available to generate and maintain 1,000 MW power. This should not pose a problem.

As stated earlier, the existing forests in India are not equitably distributed. In the Indo-Gangetic basin, a tract where agriculture has been intensively developed, the forest area is not more than 14% including that in the higher catchments. In Uttar Pradesh, the Himalayan tract inhabited by a sparse population has 80% of the forest area while in the Gangetic plain where there is high density of population, only about 2% of the land is under forests. Similarly, in West Bengal the mountaneous tract of Darjeeling has about 45% area under forests, whereas in the thickly populated Gangetic basin of the State, the area of the forest has been reduced to bare 0.35%. Same is the case in peninsular India and the fertile coastal belts. These regions present a number of problems with regard to energy requirement of the local population. The uneven territorial distribution of forest resources makes it necessary to transport fuelwood over long distances and adds to the cost of this source of energy. The rural community obviously has not got the capacity to pay for it, and perforce, is compelled to burn cowdung and agricultural residues. This is an enormous social cost, and as such the practice depletes the soil fertility and productivity of the agricultural lands.

The problem of energy crisis can be solved by creating Village woodlands and giving incentive to farm forestry. Woodlots can be created on all possible land which cannot be profitably cultivated for food grains. Vast areas are lying barren and unused in the form of revenue wastelands, marginal village lands, impoverished and abandoned cultivation. Indian peasant is endowed with small fragmentary holdings and the question of owning farm woodlands as in other countries, where farmers have large holdings does not arise in India. Such community woodlands can be created for each village or a group of villages collectively through cooperative societies.

Cultivated area per capita is about 0.30 hectare and based on this, the number of plots in the country is 550 million. Assuming a periphery of 100 metre per such plot, the total length of inter marginal ridges comes to about 55 million km which can support 5,500 million trees at a spacing of 10 m, equivalent to 5 million hectare of forest plantation. There can be an alternative estimate based on 5 trees per hectare of farm land which would increase land under tree growth by about 7.6 million hectare. From all considerations, every farmer should be self supporting so far fuel and fodder needs are concerned.

Range of opportunity of social forestry has to be considered in relation to large expanse of agricultural area in the country and a situation that would not permit large scale release of land for cultivation of trees. Nevertheless, tree lands have to be created by planting singly, in groups, in strips or small blocks without interfering with agricultural production. Thus alone, the energy resources can be built up and other necessities taken care of. About 13% of land area (43.0 million) is, however under potentially productive wastelands, a substantial part of which can be reclaimed through raising of fuel plantations. Railways in India cover a length of 57,790 km and the road system extends over 12,00,000 km. The national highways traverse over 2900 km. Total length of canals, distributories and minor extends over 1,50,000 km. It is estimated that the area available for tree growth along roads, railways and canals is about 9,02,000 hectare which is quite a significant area. Plantations over 50,000 row km and 33,000 row km have already been raised in Punjab and Haryana.

Such expansion of social forestry would be a bold step forward, but there are some indications that even a sustained programme of this size would be inadequate to meet minimum social needs and avert fuelwood crisis in some regions. For example, a study made in Madhya Pradesh in 1977 of present and projected fuelwood requirements indicates that 26 of the 45 districts of the State are already in a deficit position, and if the present fuelwood use and population trends continue, 39 districts would be in deficit by the end of the century. The Forest Department estimates that in order to meet the projected deficit and avert a serious energy crisis, a total area of 19,630 sq. km has to be brought under fuelwood plantations under social forestry programme by the year 2000, at the rate of 854 sq. km per year. The annual cost is estimated to be Rs.128 million and employment would be generated for about 60,000 people. Creation of employment opportunities for the large rural labour force is one of the main planks of such a programme.

In any developmental strategy for fuelwood reserves, the needs of the local population and creation of employment opportunities should be assigned the highest priority. For instance, programme of large scale industrial plantations in a grossly fuelwood deficit area will not only fail to receive the willing cooperation of the people in distress but would also not fulfil the desired social objectives. The strategy should be dependant on local needs for goods and services, availability and economic priority to be adopted for social uplift. Urbanisation, industrial progress, modernisation of agriculture, population growth and higher expectation in life are all likely to direct the course of development.

The need for greater efforts for raising plantation and rehabilitating the marginal and unproductive lands began to be felt particularly after the Second World War. A reinterpretation of the goal and status of forestry in the framework of land utilisation was considered necessary to replace the autonomous role of agriculture based on the production of food grain alone. Agricultural economy turned a corner and in the prosperity that followed, forestry suffered a setback as forestry activities were not sufficiently attractive to stimulate interest and secure collaborative effort of the farmers.

There are two major aspects for consideration for this state of affairs. Firstly, forestry and its extension projects were usually based on the techno-scientific consideration and there was a tendency (even now the same situation persists) to arrive at a technical solution in disregard of societal value and human behaviour which often caused total collapse of forestry projects. In many situations, forestry projects in the predominantly agriculture area have failed as the complexities of socio-forest relationship, conflicts and behaviour were not realised. It was totally forgotten that problems and decisions particularly in a treeless tract is basically human. So efforts under afforestation schemes and projects could not be made into a movement on a national scale. Secondly, in any development project, economic criteria influence various decisions but objectives of social forestry cannot always permit evaluation based on the current concept of economic analysis. In designing a project the needs of the society and its economic base must be kept in mind. The project must reflect the current social altitudes and it should be continuously and periodically examined to eliminate impediments and make room for newer developments.

It is difficult to say precisely what proportion of the village waste lands and other areas will be available for social forestry. It would not however, be advisable to get into the controversy of landuse survey and conflicts among various users. A basis for compromise has to be evolved in order to provide a foot-hold for projects for energy plantations. There should not be a major change in the immediate land use policy as such a proposition may create suspicion. Effects of growing trees on the agricultural land outputs are difficult to assess but there is evidence that if carefully manipulated the two enterprises would not lead to any loss of farm output. Given the magnitude of three sectors to be affected - energy policy, land use and employment, and fuelwood plantation should prove to be a credible programme for rural development. The programme on "Social Forestry" involves an ecological exercise which can lead to extensive social gains because the plantations not only provide timber, fodder and fruits but more importantly, an easier excess to firewood and timber for domestic use. These are tasks that otherwise sap the energy of the poor rural women and children dependent on their own pickings to keep the kitchen hearth going and their animals fed. It is beginning to be realised how attention to little ordinary details can transform the lives of many.

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THE SOCIO-ECONOMIC CONSEQUENCES AND CONSTRAINTS TO THE USE OF LAND AND FORESTS FOR ENERGY AND ORGANICS

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This paper describes the deterioration of the ecological environment for the production of food, fuel, and housing in relation to the inefficient use of labor. Labor, like time, is lost if unused. The most important challenge for the use of land and forests for energy and organics is to find a way to mobilize and use labor for productive purposes in a nonexploitative manner.

INTRODUCTION

The maintenance of ecological balance between man and nature, that is to say proper use and management of the natural resources such as land, water, forest, and mineral, must be seen not only as a means but as a desirable objective of development. The judicious use of these resources has to be made in order to meet the basic human needs, mainly food, habitat, clothing, and fuel for cooking as well as for heating purposes, depending upon location and climate. The way these resources are used to meet the above basic human needs depends on the amount, and the pattern of distribution of the resources as well as the indigenous technologies and the social values of the people in that society. For exsmple, an abundant resource is likelier to be mismanaged than the scarce one. Of all the factors, the distribution pattern of the resources has significant influence on the use of resources. It is commonly observed that in a sharply unequal society where a privileged minority controls a greater proportion of the national productive resources and the disadvantaged majority is left with little, the abuses of the resources are likely to occur more, as the rich care less about the proper use, while the poor overexploit the resources to eke out a meager living, due to their economic compulsion. This phenomenon is apparently observed in Nepal where the people, particularly in the hills, are found to be cultivating on steep slopes which are unfit for cultivation.

The first part of this paper deals with the pattern of land distribution in Nepal, the population pressure on land, and the existing farming systems and their interdependence with other sectors and socio-economic activities and their effect on the ecological environment. The second part of the paper deals with an alternative strategy of development which would bring the rural poor to participate in the development process and bring about better ecological balance, since I feel that deterioration of the ecological environment is more due to poverty, social inequality, and unemployment in the developing countries.

LAND AND ITS PATTERN OF DISTRIBUTION IN NEPAL

Nepal, with an area of 140,000 square kilometers and a population of about 12.5 million, is a mountainous, land-locked country. Its altitude varies from 500 feet above sea level in the southern plain to 29,141 feet in the Northern Himalayas. Based on altitude, the country is divided into three geographical regions: high mountains, mid-hills, and Tarai and Inner Tarai.

As far as the land-use pattern is concerned, approximately 16 percent of the total area is under cultivation; 15 percent is under perpetual snow; nearly 34 percent is under forest; 19 percent is wasteland, but partly reclaimable; 13 percent is permanent pasture land; and the remaining 3 percent is in water bodies, built-on areas, and roads.

Agriculture is the predominant sector in Nepalese economy. It provides the major source of livelihood to 94 percent of the population and accounts for about two-thirds of the gross national product and 80 percent of export earnings.

The cultivated land in the country amounts to 2.3 million hectares, of which about 38 percent lies in the hilly and mountainous region, where about 62 percent of the population resides.

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The remaining 62 percent of cultivated land falls in the Tarai belt where approximately 38 percent of the population resides.

With regard to land distribution, about 75 percent of the households have holdings as small or less than one hectare, which account for about 25 percent of the total cultivated area. Conversely, as much as 39 percent of cultivated area is owned by a mere 8 percent of households with holdings in excess of 3 hectares.

Per capita landholding has declined from 0.21 hectare in 1961 to 0.17 hectare in 1971 due to increase in population. In terms of geographical distribution, the per capita cultivated land is 0.08 hectare in the mountains, 0.10 hectare in the hills, and 0.3 hectare in the Tarai. The difference in per capita cultivated landholding between the regions is so glaring that this amply demonstrates the regional disparity. Life in the hills would have been extremely difficult had other resources such as forest, pasture, and wasteland not been accessible to the people in the hills. They depend heavily on these privately unaccounted resources (government owned) to provide fodder and grazing land for their animals, supply fuel for cooking, and wood for home and barn construction.

Recently with the enforcement of a new forest plan, the village panchayat (government) officially took over the ownership of the village forest and prohibited the villagers from grazing their animals in order to protect the forest. The villagers immediately felt the pinch of it. One elderly lady reacted strongly with anger and tears in her eyes regarding the implication of this. She said: "We are poor people in the village, we don't have much of our own land. We have been rearing a few cattle and buffaloes and used the adjoining land for fodder and grazing. Now we are prohibited to do so. How can we keep these animals alive, and without them we will be completely ruined." This indicates their dependency on the forest, pasture, and wasteland.

It is well and good to formulate policies or laws from a national point of view with respect to the conservation of forest and other resources, but their socio-economic implications may be far reaching and even could be more adverse to the weaker section of the society than others. The socio-economic implications of the resource conservation measures must be analyzed before adopting these measures. Are there other alternatives? How could the adverse effect of such measures be minimized? These are some important issues which should be the focus of a workshop like this.

POPULATION PRESSURE

One of the most important factors which is causing a serious imbalance in our ecological system is the pressure of increasing population on limited usable land. The population in Nepal is increasing at an annual rate of 2.2 percent. Despite substantial investment in agriculture over the decade (1967-1977). The agricultural production has only registered a meager rise of 1.7 percent per year, which is below the population growth rate and thus resulted in a decline in food grain export from 500,000 metric tons to 100,000 metric tons during the same period.

In the period between 1950 and 1971, the increase in economically active population was 653,000 persons. During the same period, however, there had been an increase of 659,000 people in agricultural sectors, which indicates that agriculture had absorbed not only all the additional economically active population, but also given shelter to the people from other sectors (table 1).

This increase in population has caused two things; first, migration of people from hills to plain. "In the decade from 1964 to 1974, 77,000 hectares of Tarai forest land were officially distributed by the government to (hill) settlers. But more than three times that amount was cleared illegally by migrants from the hills or perhaps even more significantly from India" (Eckholm 1976). Second, forced cultivation on the steeper slopes generally is unfit for continuous farming. The valuable fertile topsoil is washed away by surface runoff and productivity of land is decreasing gradually every year.

A study recently conducted in Nepal indicates that: "Despite the efforts for diversification of the economy, agriculture still needs to provide employment to a vast majority of population. If the present trend in the sectoral growth of the economy continues, there will not be substantial change in the sectoral distribution of population. There will be nearly 11.39 million people in agriculture out of the total labor force of 12.6 million in the year 2000, assuming 2.3 percent annual population growth rate. If no new land is brought under agriculture, the present land will have to provide employment to nearly double of the present agricultural labor force in the same area and the per capita cultivated land will come down to 0.086 hectare at the national level comparable to the present situation in the mountain region" (Agric. Proj. Serv. Cent. 1978).

A recent survey conducted by the National Planning Commission revealed that in the hilly regions of Nepal, farming provides gainful

Table 1.--Economically active population in various sectors, 1950-1971 1/

Year	Total		Agriculture		Industry		Services	
	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
1950	4,199	100.0	3,920	93.30	89	2.12	190	4.53
1960	4,385	100.0	4,140	94.43	90	2.05	155	3.52
1971	4,852	100.0	4,579	94.37	106	2.19	107	3.44

1/ The 1950 and 1960 data are from 1950-1985 Labor Force Projections of ILO, and 1971 information is from Population Census 1971, Central Bureau of Statistics, Nepal.

employment for only 55 days in a year, as compared to 180 days in the plain region of Nepal. Thus, by the year 2000, to provide gainful employment to nearly double of the present agricultural labor force for a full year will be a Herculean task. What alternatives do we have then? Could substantial population be moved out of agriculture into another sector? The last 25 years of developmental efforts do not seem to provide any positive indication for such transformation.

FARMING SYSTEM

Since agriculture completely dominates the economy of Nepal and its development affects almost everyone in the country, the prevailing farming system and its interdependence with other sectors greatly influences the ecological system.

Farming in Nepal is not a single enterprise system, but a mixed enterprise in which a farmer grows both food and cash crops and also tends a few domestic animals and poultry. Most farm families are engaged in diversified production in order to reduce risk, as well as to meet household subsistence needs.

A conceptual model of a hill farming system might look as a series of components: forest land, grazing land, farm land, fruit trees, livestock, and the family members of the household. Figure 1 indicates the flow of goods and interaction between sectors.

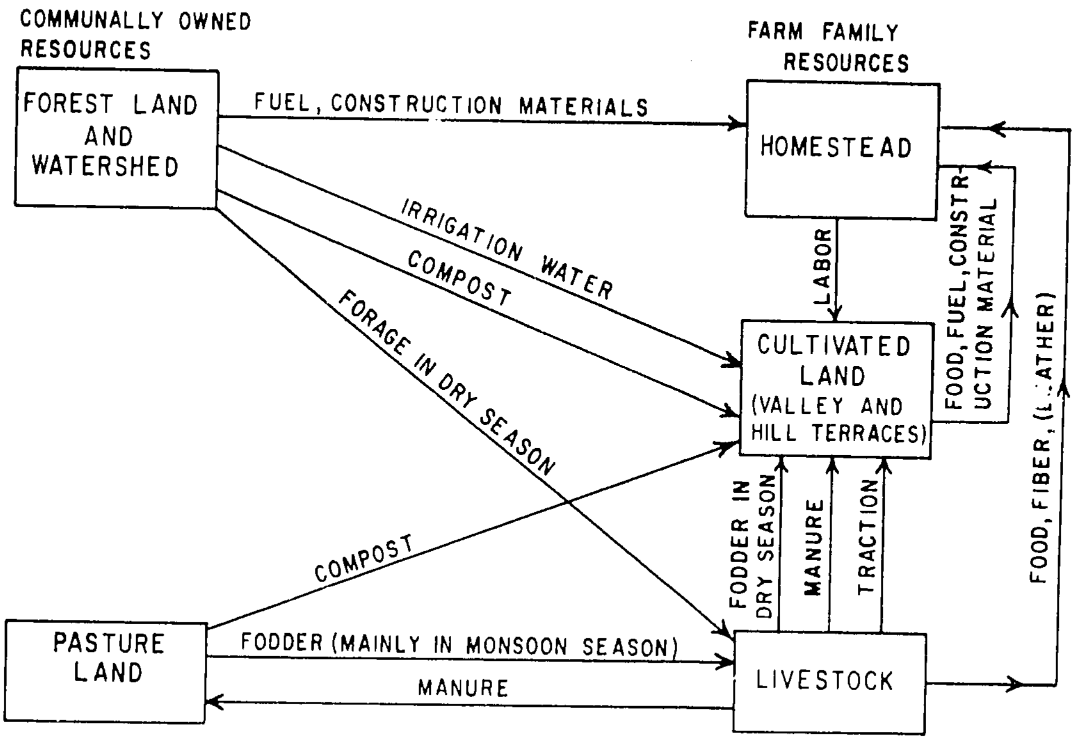
Forest land provides feed for livestock, fuel and building material for homestead, compost for the farm land, and raw material for cottage industry. It also helps to prevent soil erosion. Grazing land provides feed for cattle, compost for the farm land, recreation ground for children, and prevents soil erosion. Farm land provides food for the family, feed for livestock, and also generates some cash incomes to meet other family needs. Livestock provides food, wool, and fuel to the homestead, compost to the farm land, draft animal power for agricultural operations, and generates additional employment and income to the household members. However, it can cause serious ecological imbalances, due to overuse of pasture and forest land. The model of a hill farming system described above is a self-contained system which is now breaking down because of the population pressure (fig. 1).

In the hill region of the country, the population pressure has forced land cultivation onto steeper slopes generally unfit for continuous farming. The forest is being cut down faster than it can regenerate. The pasture land is being overgrazed, due to more livestock and continuous grazing. All these processes have resulted in rapid soil erosion. Most villagers find themselves becoming encircled by denuded, unproductive hillsides, due to excessive deforestation and overgrazing, and they have to travel farther and farther from their homes in order to gather fodder and firewood. Destructive landslides are occurring with increasing frequency throughout the hill region. The naulas (creeks, drinking water source) dry up sooner due to receding vegetation. These are some of the consequences of the improper management of natural resources.

STRATEGY FOR DEVELOPMENT

The problem of resource utilization and conservation could be solved by merely planting a few more trees and erecting a few structures to control landslides, or prohibiting cultivation on steeper slopes. These solutions are like treating the symptoms rather than the diseases. The crux of the problem lies with the development process itself. So, it is important to give a fresh look at it and seek an alternative strategy for development in order to treat the diseases rather than the symptoms. The strategy for development, so far, focused largely on economic growth with the belief that an increase in gross national product will percolate down to the poorest,

Figure 1.--A conceptual model of a small farm system in the hills of Nepal[1/]



and thereby eliminate the chronic problems of poverty, inequality, and unemployment in the country. But after over a quarter of a century's experience and experiment with it, it was realized that a rising growth rate has been no guarantee against poverty. The living condition of the vast majority of people did not improve; rather, for a significant percentage, it has worsened. Thus, the majority of people have been bypassed in the process of development.

Therefore, alternative national strategies should be seen in the context of a process of socio-economic change that involves the transformation of agrarian society to reach a common set of development goals which gives priority to the reduction of poverty, unemployment, and inequality, aims at the satisfaction of basic minimum human needs, and stresses self-reliance and maintenance of ecological balance, and the participation of all the people--especially those who are at the lowest rung of the socio-economic ladder.

The focus of alternative strategy is on human development. Since the majority of human population of developing countries live in rural areas, so the concentration of development activities has to be in the rural areas. The strategy, therefore, may be called rural development. The rural development should not be limited to a "sectoral" activity; rather, it should be seen as the multi-sectoral core of a broader development process. So it may be called "integrated rural development." The integration, however, should be understood more in terms of objectives rather than sectoral. The objectives of rural development as identified above can be looked on as a unified package to be achieved through the programs of rural development, rather than achieving them independently. One is to examine how each program in rural development helps to achieve those objectives in totality. The essence of this strategy of development is in minimizing the trade-off or contradictions within and among the objectives.

The sectoral integration is essential to take advantage of both backward and forward linkages and the complementary effect of different programs in those sectors, but those sectoral programs or projects are always formulated, as well as evaluated, in the light of an integrated set of objectives whose overall purpose is to increase the quality of life of all persons, but specifically to those who are below the subsistence level. The problems of resource utilization and conservation cannot be solved independently, as they are interrelated with other sectors of the economy. Therefore, a multi-sectoral approach becomes relevant.

PEOPLE'S PARTICIPATION

The resource utilization and conservation is an important aspect of rural development programs, of which people's participation is the pivotal. People's participation in decisionmaking is essential in order to select the appropriate programs or projects, to outline the methods of implementation, to determine the procedure of monitoring and evaluation, and most important of all, in setting criteria for sharing the benefits. Thus, people's participation in decisionmaking cuts across the whole development cycle.

Presently there is virtually no participation of rural poor in any kind of decisionmaking process at the village, district, and national levels of government. Their participation is normally secured through some organizations. But the experience of organizations in community development programs in Nepal and elsewhere indicate that these organizations were created on the false assumption that village societies were homogenous social and economic entities. Organizations were formed according to age, sex, and occupation, such as youth clubs, women's organizations, and peasants' associations. The result was that the youth clubs were largely dominated by the elite youths, the women's organizations were largely dominated by the educated, upper-income-class women, and the farmers' associations were dominated by landlords and big farmers. Thus, these organizations and programs associated with these--including cooperative societies--largely served the interests of elite groups on the presumption that these programs equally benefited all members of the society, irrespective of their social and economic status. But in reality, the socially and economically disadvantaged groups did neither participate nor benefit from these organizations or their programs. The lesson, therefore, appears to be that these groups or organizations must be strictly homogenous in socio-economic condition.

The normal practice of people's participation in implementation of community projects such as tree plantation or road construction, etc., has been in the form of contribution of free labor, voluntary or otherwise. It is the poor whose sole asset is labor and who are asked to contribute their only asset without compensation. The rich, on the other hand, are not even required to make sacrifice proportionately, and yet often it is they who benefit more from the community projects. Hence, this practice of people's participation through free labor is both inequitable to and exploitative of the poor. An equitable participation of rural people is essential in all kinds of community programs, and particularly in the utilization and conservation of natural resources which should be a matter of concern to all.

LABOR UTILIZATION

In a subsistence economy, a farmer possessing a small amount of physical resources which is inadequate to meet the subsistence requirement of the family, is compelled to cultivate on marginal land with steep slopes, overgraze the pasture land, and overexploit the forest resources which bring about adverse effects on the ecosystem. Merely prohibiting them from doing so is not the solution. The real solution has to be found in seeking alternative sources of income-generating activities to meet their basic needs before such prohibition is enforced. It may require a redistribution of productive assets, which is mostly land in the developing countries, in favor of landless tenants and small/marginal farmers. The other alternative solution may be in creating more employment opportunities for this majority of population who are either underemployed on their farms, or seasonally unemployed when there is not much work to be done on the farms. Labor is like time; if unused, it is lost and cannot be preserved. How could this vast surplus labor--the only resource the rural poor have--be mobilized and utilized for productive purposes in an equitable and nonexploitative manner? This is the most important issue that this workshop can focus on in order to alleviate poverty, inequality, and unemployment, which in turn would bring a positive impact on resource utilization and conservation.

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SOME SOCIAL AND ECONOMIC CONSEQUENCES AND CONSTRAINTS TO THE USE OF FORESTS FOR ENERGY AND ORGANICS IN CANADA, THE UNITED STATES OF AMERICA AND LOS ESTADOS UNIDOS DE MEXICO

Charles F. Bennett1/

When the objectives of this workshop were conceived Mexico was a relatively minor producer of petroleum and was showing signs of becoming increasingly dependent upon foreign energy sources for the fossil fuel it requires. In a brief span of time that picture has changed and new petroleum discoveries suggest that Mexico's petroleum reserves may be as much as 200 billion barrels putting Mexico in the same class of petroleum-rich nations as the current world leader, Saudi Arabia.

It is important that we keep in mind that the world has not yet come close to exhausting its traditional fossil fuel resources. In addition, there are vast and still untapped reserves of oil shale and tar sands. And one must not overlook nuclear fuel.

So long as fossil fuels are available in large quantities it is unlikely that industrialized nations such as Canada and the United States of America and oil-rich nations like Mexico will show other than marginal interest in "natural" forests as sources of energy and organics. It is in the Third World nations that lack fossil fuel resources but which possess a forest resource that forest-derived energy and organics are at present and for the next several decades of more than academic interest. In those nations every litre of petroleum and every kilogram of coal that can be replaced by in-country production of energy is a consumation devoutly to be wished.

The three nations I have been asked to examine - Canada, the United States of America and Los Estadoes Unidos de Mexico - can take a comparatively relaxed approach to questions respecting the use of "natural" forest for energy and organics.

Ultimately, of course, the coal and oil will become so scarce that they will no longer be able to provide other than a marginal contribution to the energy needs of these three nations. Just when that time will occur is open to speculative discussion. For my part I do not see the time as arriving before the passage of at least four decades and that could be greatly extended if, mirabile dictu, the three nations led by the USA should adopt measures that resulted in a major lessening of the present wasteful consumption of fossil fuel. Another factor influencing the total time remaining for the fossil fuel age is the price people will be willing or able to pay for such fuel. The size of the fossil fuel resource at any given moment is partly a function of the price the product will bring in the marketplace. This factor will also play an essential role in the economics of tar sand, oil shale and nuclear fuel exploitation in the years ahead.

Because I do not perceive any pressing need for near term development of a new or modified policy for the management of "natural" forests for energy and organics in Canada, the USA and Mexico my approach to "The socio-economic consequences and constraints to the use of land and forests for energy and organics" will of necessity take on some of the attributes of "futurism."

In the Introduction provided each author contributing to this workshop the following appears: "natural forests are the most important of all accumulations of contemporary energy and organics." The allusion to "natural" forests suggests that our efforts be directed chiefly to stands of trees that are wild, that is to say, trees not cultivated under plantation management conditions. This I intend to do although I also intend to comment upon other forests as well.

THE UNITED STATES OF AMERICA

A large portion of the timber volume as "natural" forest lands in the United States is under the control of governmental agencies. In terms of area alone, the private sector controls most of the forest lands but if the amount of standing timber - including annual

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volume added - be the measure, then government managed forests are in the forefront - especially with regard to softwoods.

The largest government agency engaged in forest management is the United States Forest Service. This agency engages in a multitude of activities of which determination of the annual allowable timber cut or harvest within the National Forests is one of its chief responsibilities. This figure is determined by evaluating many factors such as the growth rate and age of individual timber stands and these evaluations are modified by the constraints imposed by the Multiple-Use Sustained Yield Act of 1960.

With respect to the question of allowable cut, if one were to listen only to the response of some members of the lumber industry it would appear that the figure set is almost always too low and thus subjects the forests to the wasteful attack of disease and pests.

However, if one listened only to some conservation groups it would appear that every year the Forest Service permits far too much cutting and that the Service has "sold out" to lumber firms.

The point I am attempting to make here is that even with such a traditionally sanctioned use of the forest, viz, timber harvest, emotions wax very hot and cause great difficulties for the Forest Service. Now, if one considers the possibility that such forests might also become the object of harvest for fuel and raw materials (organics) one can quite reasonably suggest that such efforts would be met with massive and probably effective resistence on the part of those constituencies wishing to limit economic use of National forests.

The multiple-use concept is something of a semantic maze and appears capable of being given virtually any meaning the user desires. In practice the multiple use concept has come to include: timber cutting; grazing of livestock; watershed protection and dam construction; recreational use including such activities as hunting, fishing, camping, hiking, skiing and nature study. Each of these named uses (plus others not included here) has its public constituency and these seldom if ever are in agreement as to what balances should be struck with regard to multiple-use of the National Forests. Government management of these forests, therefor, often assumes the aspects of a balancing act that attempts to satisfy to some degree the demands made by each of the constituencies congruent with maintaining the long-term ecological health of the forests.

An important source of conflict between the several constituencies is that some if indeed not most of the recreational elements perceive the National Forests as being virtually "natural," that is, pristine forests and seek by whatever means available to maintain this pristine wilderness quality. Of course these forests are cultural artifacts to greater or lesser degrees depending upon where a given stand of timber is located and thus the degree to which humans have deliberately or inadvertently modified the "natural" forest ecosystems existing prior to human manipulations. Management, after all, means manipulation. But there is a widespread public perception of these forest that they represent something very close to pristine nature and as such must be protected from all but the most limited of economic exploitation. I believe that this perception, so widely held, would presently prevent other than the most limited use of such forests for energy and organics. This limited use would extend, I believe, only to the extent that wood presently wasted as a part of mill operations would be converted to energy or organics. The public perception of National Forests being harvested on a scale large enough to meet any appreciable part of this nation's demands for BTUs would be, I believe, an apocalyptic vision and one so pervasive as to rule out for many decades any possibility of such use being made of "natural" forests in the public domain.

If public lands in the United States are ever to become sources of energy and organics it will be through replanting of trees on areas that have previously suffered grave ecological damage resulting from mis-use of the land. Such projects could conceivably be made acceptable to even the most vehement of the nature conservation groups. However, here the question most likely of major concern will be the economics of such efforts. At present it can only be suggested that careful experimentation ought to be encouraged but that it is unlikely that such lands under such management would supply more than a soupcon to our national energy needs.

Private Forests. Privately-owned forests vary greatly in terms of their degrees of "naturalness." On one end of the scale are the plantations of the southeast with their even-aged stands of a single softwood species and in which plant and animal diversity are minimal. At the opposite end of the scale are forests that differ not at all from the "natural" forest under management by one or another governmental agency. I do not see the need to separate, for this discussion, the plantations from the "natural" forests.

If there is to be a significant contribution made by forests to energy and organics in the near future it will most likely come first from the privately owned forest lands. The chief reason is that the private owner enjoys a relatively high degree of freedom (by no means complete).

I do not believe that any given forest region can be made to yield timber and energy/organics on anything like an equal basis. If the object of the harvest is lumber then there will be some byproduct that can be (and often is) converted to energy but this usually represents a modest aspect of the economics of the operation. If forests are to be grown chiefly for energy production it is almost certain that harvest cycles will be altered over those presently prevailing (probably on a much shorter rotation) and will possibly involve different tree species as well as more rapidly growing clones of species already the object of private forest management.

I further envision the necessity of Government subsidies for research into forest management for energy/organics and such research should include not only aspects directly related to forest management but also associated aspects such as the public reactions to such use of trees. That some energy can be produced economically from lumber mill "waste" products is well known. The point I wish to make here is that it is a great leap from the modest specialty "energy" item that is a byproduct of lumber mill operations to concentrating, for a profit, upon wood as an energy source so long as fossil fuel and nuclear fuel availability are at relatively high levels.

CANADA

The forest industry of Canada is one of the largest in the world. Most of the cut is softwood (approximately 95%) and about two-thirds of the annual harvest is exported.

Although the National Government of Canada has a very active Forest Department most of the government - managed forests in that nation are under Provincial control with each Province having its own laws governing use of the forested lands. The two largest Provincial producers of lumber are British Columbia (the largest) and Quebec. The private sector figures rather unimportantly having about 240,000 square kilometers of forest land out of a total of nearly 2,000,000 square kilometers of forested land in the nation.

It can be expected that there would be strong negative public response if the forests were to be exploited to any major scale for energy since it is highly possible that this would mean the export of forest "energy" products to the United States. I cannot envision any important interest in wood-derived energy in a nation (Canada) that possesses major petroleum and coal reserves not to mention the Athabasca tar sands as well as a great hydroelectric potential in the west and northwest.

Should Quebec become a separate nation it is conceivable that wood-derived energy could become an attractive possibility in that Province. One cannot begin to hazard a guess what the response of the Quebecoise would be to such forest use. At present most of the cut is for pulpwood and more than half is exported to the United States. Quebec Province does not have fossil fuel resources nor a large hydroelectric potential. However, even if the Province should split away from Canada the greater likilhood is for an accommodation with Canada to obtain fossil fuel and the construction of nuclear power plants rather than turning to a wood-based energy system.

An important ecological constraint upon the use of wood for energy production is the fact that Canada occupies a relatively high latitudinal position which reduces the amount of solar energy available for plant growth (as compared, for example, with the southeastern United States and Mexico). In the southeastern US conifers attain a BHD of approximately 30 cm in 20 years but it may require 75 or more years in parts of Canada for softwoods to attain the same growth.

MEXICO

Although a recent map of the vegetation of Mexico (Los Estados Unidos de Mexico) suggests that most of the nation is forest-covered just the opposite, unfortunately, is the case. Part of the paucity of trees is due to natural ecological conditions - limited precipitation chiefly - but a centuries-long history of destructive forest use and abuse accounts for much of the present lack.

Mexico's "natural" forests are extremely varied and include pines, firs and other softwood species as well as mangrove species, oak woodlands, several types of mesquite and broadleaf tropical hardwood forests.

The Mexican National government controls by law the forest lands of the nation. This derives from Article 27 of the 1917 National Constitution. In effect, the Article asserts that all natural resources of the nation are to be used in the best national interests and that private ownership of land does not permit an owner to evade the provisions of the article. The National forest legislation of Mexico is elaborate and detailed but has long suffered from an incomplete compliance on the part of the nation's citizens. Administration of the law has often been made extremely difficult because of political conflicts within government agencies, by a chronic lack of funds and by an inadequate public educational program with respect to forest conservation.

Although there are informed and effective conservationists in Mexico there is as yet little of the national "environmentalist" behaviour one sees exhibited in the United States of America and Canada. There is, unfortunately, a widespread unwillingness on the part of many rural persons to comply with laws governing the allowable harvest from the forest: unlike the US and Canada, an important part of this harvest is for firewood. Although reliable quantitative data are seldom available for other than very local and short-term situations firewood (lena) and charcoal are important economic/ecologic elements of rural life in many parts of the nation. Thus, it can be said that the use of forest for "energy" in Mexico is an old and established practice.

The pressure on the wood resource of Mexico and particularly the softwood resource for lumber is very great and exceeds the capacity of the forest to meet. There is a clandestine market for wood and wood products (almost always softwoods) in parts of the nation - a phenomenon that eloquently attests to the fact that the resource supply falls short of demand. Even if per capita demand were to remain constant the absolute demand would rise rapidly in the future in response to an average annual population increase of 3.5%.

Given the limited data available it is not possible to determine, quantitatively, the amount of wood being burned for heat or the amount of hardwood being converted to charcoal before being used for heat and/or cooking. However, given the fact that Mexico is a natural gas and petroleum rich nation one might suggest that the government of that nation should engage in a major effort to make fossil fuel competetive in price with wood and charcoal and thus reduce the explitive pressures to which much of the forest cover of Mexico is presently subject. The worst possible thing that could happen to the softwood and the hardwood resources of Mexico would be to further increase their use of fuel.

Some of the hectarage of the already badly damaged land (which constitutes an appreciable share of the land surface of the nation) could be planted back to trees. It would be most desirable if the nation were to experiment with this soon even though it is presently oil rich. However, this is not to suggest that even the most successful replanting and sustained yield harvest could ever produce other than a modest fraction of the energy needs of that nation. The population stands today at an estimated 64 million and, unless growth is checked, will attain 100 million by the year 2000. Given the realties of the ecological resources of Mexico it is folly to suggest that forest will be able to provide other than a marginal portion of the energy requirements of the soon-to-arrive year 2000.

The chief hardwood forest resources of Mexico are oaks, mangroves and tropical broadleaf forests. Although no published estimate of the wood volume of the oak resource exists it is known to be modest and usually locally over-exploited. Much of the oak resource long ago disappeared for charcoal, lumber, fuel and as a victim of land clearing. The mangrove resource also is unknown as to volume but it too has been destructively exploited. The important role of this forest association in the ecology of certain shrimp and fish species is leading to greater effective protection. It is possible that mangrove forest ought not be cut at all except under very limited circumstances. The tropical broadleaf hardwood forests are located in the south and chiefly on the Caribbean drainage. The total area of such forest has diminished greatly in the past century and especially in the last few decades - forest laws to the contrary nothwithstanding. The reasons for this are chiefly demographic and economic. The pressure for more cleared land in this land-hungry nation is very great and the tropical forest is generally perceived as an obstacle to be overcome and not as a resource to be managed. The slow rate of regeneration of such forest coupled with the fact that relatively few species have other than a local market potential contribute to this attitude. Small quantities of wood (relative to the total forest volume) are converted to charcoal and some forest plants are harvested in a more or less casual fashion. That these forests may contain plants of great medical or other value has long been suggested but these suggestions have seldom resulted in other than a minor level of harvest activity. In short, the tropical forest in Mexico is popularly perceived not as a resource to be managed but as something to be permanently cleared.

When there is no longer an abundance of petroleum and natural gas in Mexico THEN there may be an opportunity for the development of energy plantations. I use the term "plantations" deliberately because at that future time the "natural" forest resources of the nation will be much less than they are at present. If trees are then to produce an important fraction of the energy the nation requires it will be done not in "natural" forests but on energy plantations whose locations will depend upon social, economic and ecological factors not easily identified at present.

SUMMARY AND CONCLUSIONS

The principal conclusions of this brief overview are:

1. Canada, the United States and Mexico either possess within their national territories or otherwise have access to fossil fuel and nuclear fuel in quantities sufficient to meet the energy needs of these nations for 40 or more years into the future.

2. Given the proposition just stated it is further concluded that there will be no significant movement away from the utilization of fossil and nuclear fuels during the time they are generally available.

3. Until these nations are faced with the more or less immediate possibility of a major energy shortage engendered by an absolute world lack of fossil and nuclear fuels the environmentalist/Conservationist constituencies of Canada and the United States (but to a much lesser degree in Mexico) will effectively resist any efforts to manage public forests for the production of wood-derived energy and organics on other than the most modest scale this being largely limited to more efficient use of by-products of traditional forest utilization.

4. Energy "plantations" will be most easily established on forest lands held by the private sector of all three nations but such establishment must await research on the ecology (S.L.) and economics of such endeavors.

5. The ultimate constraint will be imposed by the levels of primary productivity, that is, carbon fixation, with respect to woody vegetation. This in turn is a function of the total amount of solar energy received at a given site and the photosynthetic efficiency of the woody vegetation species growing there. Thus, at present, I do not envision that wood will supply other than a modest fraction of the energy needs of these three nations even if all visible social constraints were removed.

6. The day will arrive when our energy grids will be fed chiefly from solar energy being received at or near the earth. However, that day lies far off into the future in so far as the currently industrialized nations and the fossil fuel or hydroelectric-rich or nuclear fuel rich Third World nations are concerned.

7. Short of a major revolution in the quantities of energy one cannot envision wood production as supplying other than a modest fraction of the total use.

8. Given the amount and condition of Mexican forests and the human demographic realities of that nation it is unlikely that trees will ever be other than a minor source of energy.

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BURNING ISSUES AND BIOMASS 1.

CARBON DIOXIDE AND FUELS: FOREST AND FOSSIL[1/2/]

Jerry S. Olson[3/]

Abstract. Growth of human populations and energy and forest consumption are forcing rising rates of CO_2 production and net accumulation of CO_2 in the global atmosphere. Other reviews confirm that significant climatic changes are likely to follow from the probable continued increase of CO_2. Climatic change could be great enough to shift locations of major ecosystem/land use regions that are illustrated on a preliminary new digitized biosphere map. The socio-economic uncertainties and non-trivial risks from continued rapid depletion of large but finite reserves of petroleum, gas, coal and shale kerogen add to other reasons for anticipating times when renewable biomass production will help serve highest-priority needs for carbon feedstocks and at least supplementary or emergency energy sources. However, to help (even modestly) to draw down the atmosphere's excess CO_2 by recycling it to biomass and humus storage would demand a widely shared understanding, policy and action: i.e., to reverse the recent tendency for decreasing forest area, mean biomass per unit area and rotation periods.

Combined research and assessment are needed for three hypotheses. 1) Social and economic factors will draw down biomass stocks without displacing a large fraction of expanding fossil fuel use (and excess CO_2). 2) Reasons for limited roles of biomass include low energy efficiency (considering cost of harvest and delivery) and very uneven biomass carbon geographic distribution as mapped. 3) risks of degrading ecosystem capacity for fixing solar energy and carbon are commonly related to low reserves of nutrients and moisture-holding capacity in humus. The author relates these issues to a goal of creating energy/carbon growing stocks that temporarily absorb excess CO_2, rebuild humus and broaden humanity's future options for coping with long-range energy needs and the real risks of significant climatic change from CO_2.

1/ An overview paper for Workshop Proceedings on "Biological and Sociological Basis for a Rational Use of Forest Resources for Energy and Organics", Man and the Biosphere Program, May 6-11, 1979, Kellogg Center, Michigan State University, East Lansing, Michigan.

2/ Research supported jointly by the National Science Foundation's Ecosystem Studies Program under Interagency Agreement No. DEB77-26722 and the U.S. Department of Energy, Division of Environmental Research, Carbon Dioxide Effects Research and Assessment Program, under Contract W-7405-eng-26 with Union Carbide Corporation.

3/ Senior Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA. ESD Publication No. .

FORESTS USES IN GLOBAL AND REGIONAL (US.) PERSPECTIVES.

Helmut Lieth[1/]

Abstract. The paper presents a collection of tables, maps, and figures for the discussion of materials and energy from the biosphere with special references to the CO_2 flux from atmosphere to deep ocean via the biosphere. Emphasis in data collection is placed on forest vegetation.

INTRODUCTION

The utilization of the world's forest resources has been accelerated in the last 25 years to the extent that recent statistical assessments indicate that utilization of forest resources outweigh regrowth.

The reason for such calculations was the assumption that forests may serve as temporary sinks for CO_2 from the atmosphere and therefore reduce some of the CO_2 generated from burning fossil fuel. Depending on the available statistics used the results were quite different. The discussion about the reduction or increase of standing biomass in the world's forests is therefore still continuing.

The problem of CO_2 exchange between atmosphere and biosphere products is, however, far more complex than assessing forest productivity or net biomass increment of wood in timber. The use of biomass for either industrial products or simply as energy source is of great importance for the decision whether the equivalent of CO_2 residing in the biomass harvested enters the atmosphere within a short period or ever. The discussion about CO_2 increase of the atmosphere becomes therefore immediately relevant to the topic of this meeting, materials and energy from forests.

The calculation of the CO_2 amounts exchanged through the biosphere should easily be accessible through statistical handbooks from forestry, agriculture, and commerce. Our first attempts to use these became unfortunately the most frustrating experience. It was therefore necessary to resort to several other logical methods to prove or disprove statistical data.

A research group at the University of Osnabrück received recently a grant to reassess again the carbon flux through the biosphere with the best achievable accuracy. The group started its work only one month ago and overall results cannot be presented. But what we can do here is to present our research methods and goals, offer a few glimpses of our initial work with data from the US, and otherwise listen to the suggestions offered at this meeting for our future work.

The data used in this presentation are largely based on our own previous publications e.g. in Lieth and Whittaker (1975) and Lieth (1978) and publications by Windhorst as summerized by Windhorst (1978).

The model of CO_2 flux through the biosphere Fig. 1 shows the CO_2 flux model used by our group to test the various sources and sinks of carbon on its way from the atmosphere through the biosphere into the deep ocean. A model like this allows the utilization of research methods from biology, geography, and forestry. Sources and sinks are marked specifically. One can easily see that variables like "wood", "fire", or "industrial lumber" are the topics for the discussion here and we will undertake it in the next two years to put the most accurate numbers to these boxes stratified by geographical region, vegetation types, major drainage systems, climatic types, great soil groups as well as political units, economic categories a.s.o.

The numbers we have entered in the next few graphs, maps or tables are mostly those collected in previous works. We make the attempt to present the relevant data in any available form side by side for the world and for the United States. No attempt will be made

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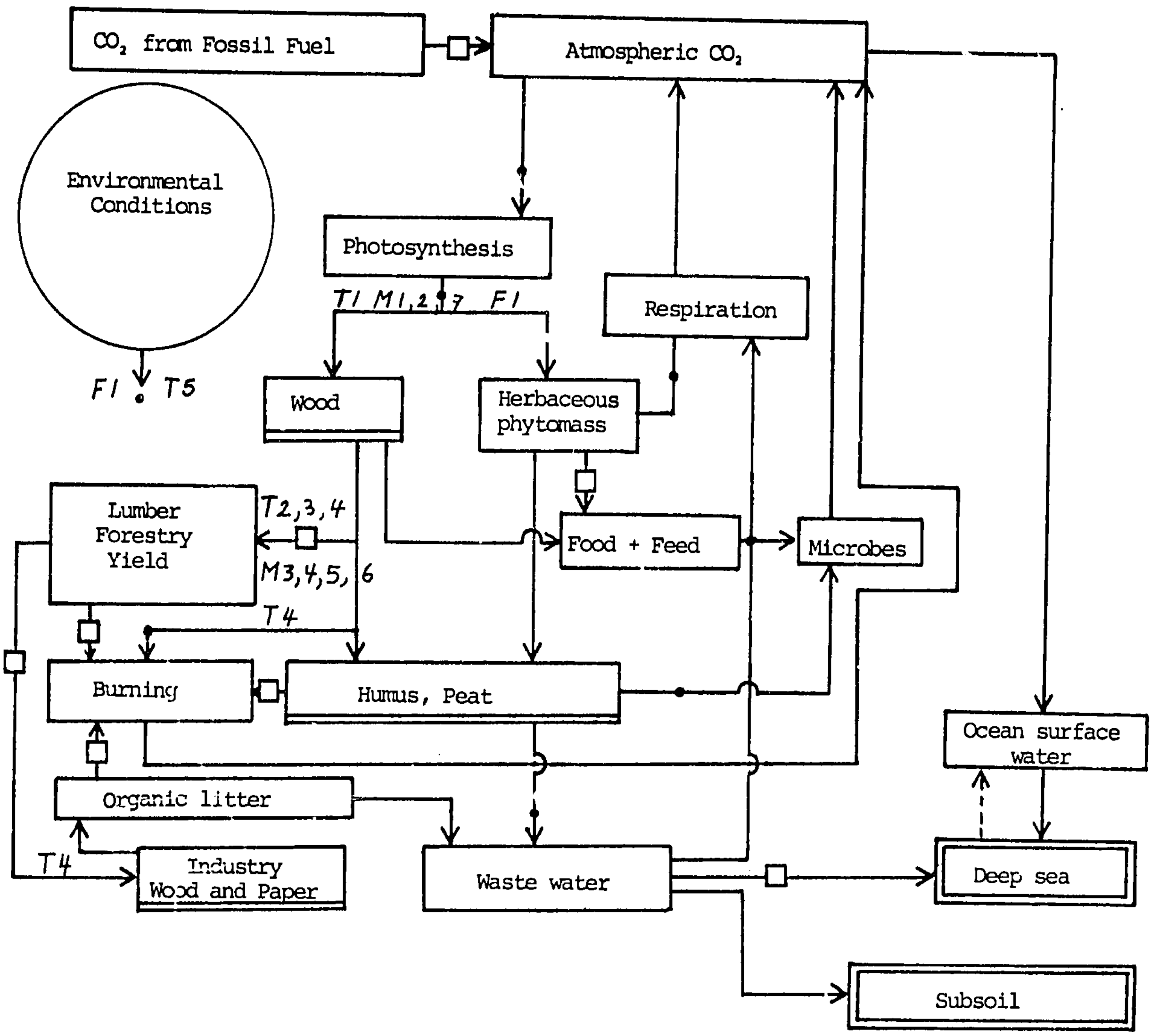
Fig 1: CO_2 Flux through the biosphere



indicating temporary [ ] and permanent [ ] sinks relevant to the transfer of CO_2 from atmosphere to the deep ocean.
The indices T 1 ... X, M_1 ... X, and F_1 ... X refer to tables, maps and figures respectively in which relevant information is given in the following pages.

to compare these data sets with each other. The demonstration in this form should simply indicate that we want to analyse each geographical or political unit of the world in the same way as we did previously or just started for the U.S. In some areas of the world we may do even better than for the U.S. with the same method, in other areas we will have to use different methods to come to values one can safely utilize in reasonably accurate world models.

DATA FOR THE DISCUSSION

The following graphs, tables, and maps are included:

Fig. 1: A - Correlation between length of vegetation period and net primary productivity in the Eastern U.S.,

B - extrapolated for the world and compared with other global productivity models.
A from Reader 1973 in Lieth 1975, B from Lieth 1975.

Tab. 1: Net primary productivity estimates for the world.

Tab. 2: Forest area estimated for the world by different scientific groups (from Windhorst 1978).

Tab. 3: Forest area in the U.S. by state for the years indicated (from US Forest Service statistics).

Tab. 4: Amount of wood utilized for different purposes for selected countries (from Windhorst 1978).

Tab. 5: Correlation between environmental parameters and net primary productivity.

Map 1: Net primary productivity pattern of the world.

Map 2: Net primary productivity pattern of the U.S. calculated from evapotranspiration data by Sharp (1975).

Map 3: % forest cover of the world by country (from Windhorst 1978).

Map 4: Forest cover of the U.S. by state, sequence of States follows listing in table 3.

Map 5: Forest utilization of the world by country in dry metric tons/ha.

Map 6: Change of hardwood timber volume in the U.S. between the years indicated.

Map 7: Annual Energy Fixation of the land vegetation; from Lieth (1977).

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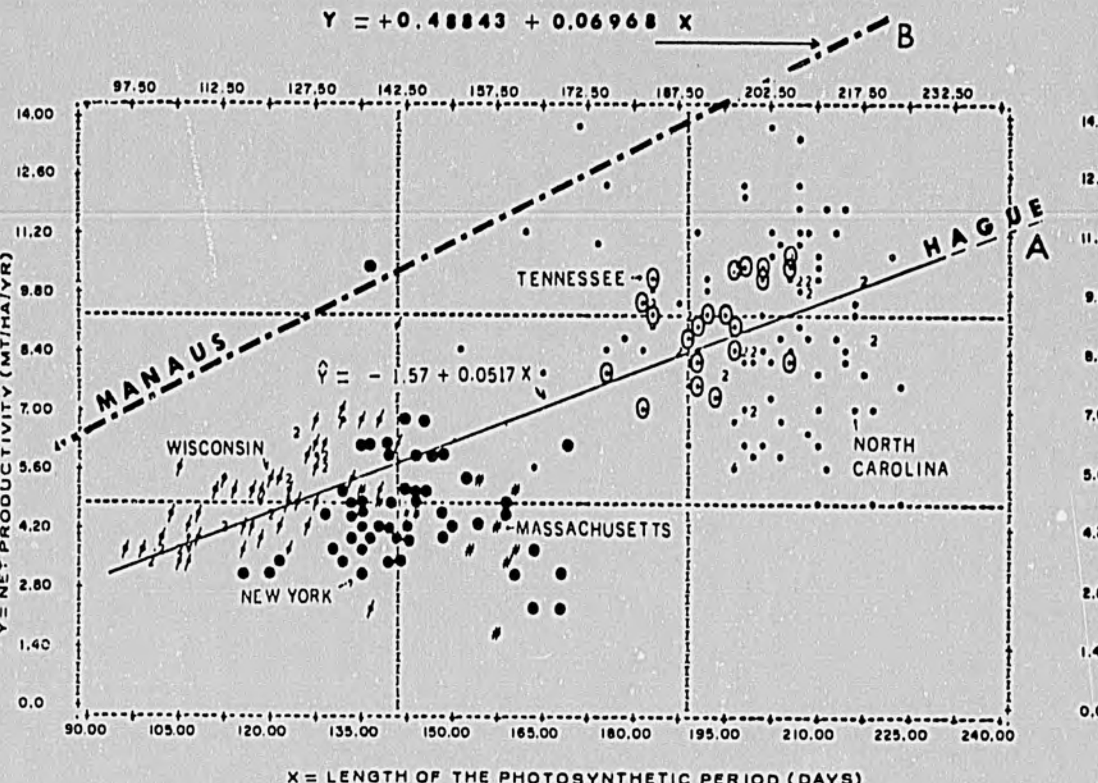
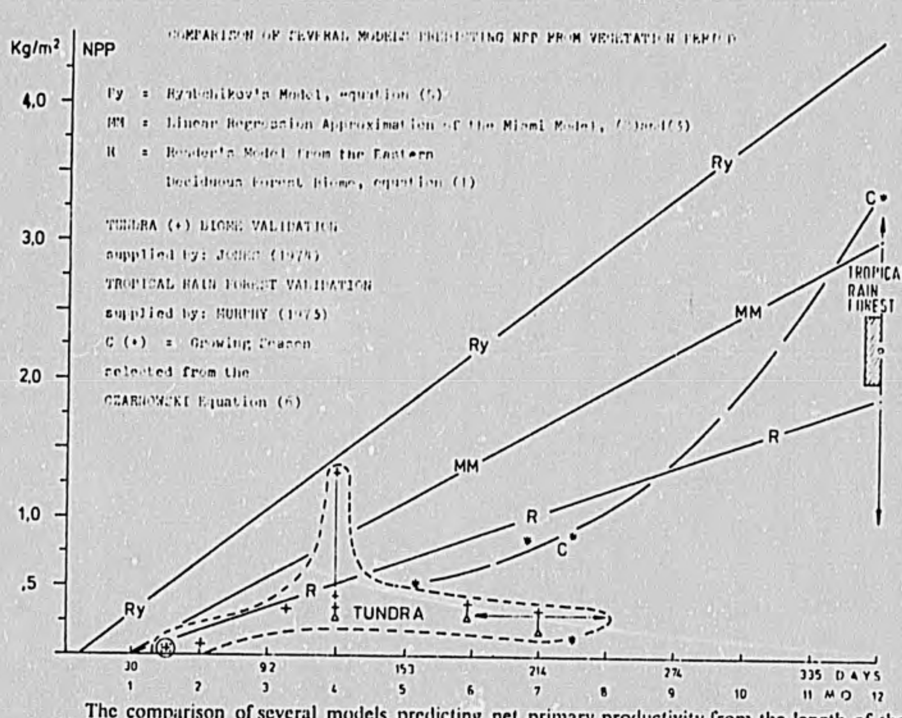


FIGURE 2A — *Correlations of net primary productivity and length of vegetation period. Abscissa — length of vegetation period; ordinate — net primary productivity.*



The comparison of several models predicting net primary productivity from the length of the vegetation period. Abscissa: vegetation period in days or months; ordinate: net primary productivity in kg/m² per year.

Fig. 2B - Productivity and Vegetation period; Global correlation; from Lieth 1975

Table 1: Net primary productivity, energy fixation and standing biomass estimates for various physiognomic vegetation units.

vegetation unit	area size	productivity levels: range	productivity levels: approx. mean	productivity levels: total for area	average combustion value for biomass	energy fix.	energy fix.	standing biomass: range	standing biomass: mean	standing biomass: total	author[1]
	10^6 km^2	g/m^2/yr	g/m^2/yr	10^9 t/yr	kcal/g	10^6 cal/m^2	10^{18} cal	kg/m^2	kg/m^2	10^9t	
1	2	3	4	5	6	7	8	9	10	11	12
Tropical rain forest	17.0	1 000–3 500	2 000	34.0	4.1	8.2	139.4				1
	17.0	1 000–3 500	2 200	37.4				6– 80	45	765	2
	12.8		2 500	32.0							3
Raingreen forest	7.5	600–3 500	1 500	11.3	4.2	6.3	47.2				1
Tropical seasonal forest	7.5	1 000–2 500	1 600	12.0				6– 60	35	260	2
Tropical rain-green forest	8.7		1 500	130.1							3
Tropical micro-phyllous forest	4.3	1 000		42.9							3
Tropical montane forest	2.7	1 500		40.7							3
Warm temperate mixed forest	5.0	600–2 500	1 000	5.0	4.7	4.7	23.5				1
Temperate forest evergreen	5.0	600–2 500	1 300	6.5				6–200	35	175	2
Summergreen forest	7.0	400–2 500	1 000	7.0	4.6	4.6	32.2				1
Temperate forest deciduous	7.0	600–2 500	1 200	8.4				6– 60	30	210	2

1	2	3	4	5	6	7	8	9	10	11	12
Summergreen forest	5.8		1 300	74.8							3
Broad-leaved and mixed evergreen forest	2.9		1 800	51.7							3
Mid-latitude coniferous forest	1.5		1 800	24.9							3
Mixed coniferous and summer-green forest	3.3		1 500 1 400 1 100	39.8							3
Sclerophyllous forest	0.9		1 300	12.3							3
Chaparral	1.5	250–1 500	800	1.2	4.9	3.9	5.9				1
Boreal forest	12.0	200–1 500	500	6.0	4.8	2.4	28.8				1
	12.0	400–2 000	800	9.6				6–40	20	240	2
	17.2		500–700–900–1300	122.6							1
Forest TOTAL	50.0		1 290	64.5							1
Sub-boreal aspen/birch forest	0.4		900	3.2							3
Woodland	7.0	200–1 000	600	4.2	4.6	2.8	19.6				1
Woodland and scrubland	8.5	250–1 200	700	6.0				2–20	6	50	2
TOTAL Sclerophyllous scrub	1.7		700	11.7							3

Table 1 continued

1	2	3	4	5	6	7	8	9	10	11	12
TOTAL Treed grassland	19.7			204.4							3
Mid-latitude "forest-steppe"	1.4	1 250		17.9							3
Savanna	15.0	200-2 000	900	13.5				0.2-15	4	60	2
Tropical Savanna	17.8	1 500-1 000 500		181.9							3
Sub-Tropical Savanna	0.5		1 000	4.6							3
Tropical Grassland	15.0	200-2 000	700	10.5	4.0	2.8					1
Temperate grassland	9.0	100-1 500	500	4.5	4.0	2.0	18.0				1
	9.0	200-1 500	600	5.4				0.2- 5	1.6	14	2
TOTAL grassland	24.0		600	15.0							1
TOTAL grassland	7.2		1 000-700	62.0							3
Tundra	8.0	100-400	140	1.1	4.5	0.6	4.8				1
Tundra and alpine	8.0	10-400	140	1.1				0.1- 3	0.6	5	2
Dwarf and open Scrub	26.0		90	2.4							1
TOTAL tundra and alpine	13.1	75 175 325	21,3								3
		..	..								
Dry desert	8.5	0- 10			4.5		0.1				1
Ice desert	15.5	0- 1									1

Table 1 continued

1	2	3	4	5	6	7	8	9	10	11	12
Desert and semi-desert scrub	18.0	10– 250	90	1,6				0.1–4	0.7	13	2
Desert (EXTREME)	24.0		1				0.1				1
Rock, sand, ice	24.0	0– 10	3	0.07				0 –0.2	0.2	0.5	2
TOTAL desert and semi-desert	26.0	500 150 50 3	28.1								3
Cultivated land	14.0	100–4 000	650	9.1	4.1	2.7	37.8				1
	14.0	100–4 000	650	9.1				0.4–12	1	14	2
Swamp and marsh	2.0	800–4 000	2000	4.0	4.2	8.4	16.8				1
	2.0	800–6 000	3000	6.0				3 –50	15	30	1
Lake and stream	2.0	100–1 500	500	1.0	4.5	2.3	4.6				1
	2.0	100–1 500	400	0.8				0 –0.1	0.02	0.05	2
FRESHWATER	4.0		1250	5.0			21.4				1
TOTAL Continental	149.0		669	100.2			426.1				1
	149.0		782	117.5					12.2	1 837	2
TOTAL land	128.2			1.190.8							3
Open Ocean	332.0	2– 400	782	41.5	4.9	0.6	199.2				1
	332.0	2– 400	125	41.5				0–0.005	0.003	1.0	2
Upwelling zones	0.4	400– 600	500	0.2	4.9	2,5	1.0				1
	0.4	400–1 000	500	0.2				0.005 –0.1			2

Table 1 continued

1	2	3	4	5	6	7	8	9	10	11	12
Continental shelf	26.6	200- 600	350	9.3	4.5	1.6	42.6				1
	26.6	200- 600	360	9.6				0.001- 0.04	0.001		2
Algalbeds and reefs	0.6	500-4.000	2 500	1.6				0,04-4	2	1.2	2
Estuaries (excluding marsh)	1.4	200-4 000	1 500	2.1				0,01-4	1	1.4	2
Reefs and estuaries	2.0	500-4.000	2 000	4.0	4.5	9.0	18.0				1
TOTAL Oceanic	361		155	55.0			260.8				1
TOTAL Marine	361		155	55.0					0.01	3.9	2
TOTAL Earth	510		303	155.2			686.9				1
Full TOTAL	510		366	172.5					3.6	1.841,0	2

1 1 Lieth 1972,

2 Whittaker und Likens 1975,

3 Eyre 1978,

Lieth and Blum (1979 in press)

Table 1 continued

Table 2: Forest area estimates by different scientific groups.

1. <u>Foresters</u>

Author	area	production rate	total production	remarks
	10^6 km^2	t/ha.yr	10^9 t	
Weck 1961	24,77	1,79	4,43	yield potential for forest promissing sustaining yield
Brüning 1971	39,5	10,7	44,01	above ground biomass only
Brüning 1974	41,5	10,4	42,8	net annual production above ground biomass

2. <u>Geographers</u>

Author	area	production rate	total production	remarks
	10^6 km^2	t/ha.yr	10^9 t	
Windhorst 1974, 1976	23,93	1,87	46,73	criteria as stated by Weck 1961
Eyre 1978	60,50		86,3 (65,4)	 (above ground portion)

3. <u>Biologists</u>

Author	area	production rate	total production
	10^6 km^2	t/ha.yr	10^9 t
Whittaker and Wordwell 1971	50,0	14,6	73,0
Bazilevich et al 1971	52,9	16,6	87,7
Lieth 1972, 1975	50,0	12,9	64,5
Whittaker and Likens 1973	48,5	14,4	69,7
Olson 1975	48,0	16,3	78,2

1 CONNECTICUT
2 MAINE
3 MASSCHUSETTS
4 NEW HAMPSHIRE
5 RHODE ISLAND
6 VERMONT
7 DELAWARE
8 MARYLAND
9 NEW JERSEY
10 NEW YORK
11 PENNSYLVANIA
12 WEST VIRGINIA
13 MICHIGAN
14 MINNESOTA
15 NORTH DAKOTA
16 SOUTH DAKOTA
17 WISCONSIN
18 ILLINOIS
19 INDIANA
20 IOWA
21 KANSAS
22 KENTUCKY
23 MISSOURI
24 NEBRASKA
25 OHIO
26 NORTH CAROLINA
27 SOUTH CAROLINA
28 VIRGINIA
29 FLORIDA
30 GIORGIA
31 ALABAMA
32 MISSISSIPPI
33 TENNESSEE
34 ARKANSAS
35 LOUISIANA
36 OKLAHOMA
37 TEXAS
38 OREGON
39 WASHINGTON
40 CALIFORNIA
41 IDAHO
42 MONTANA
43 WYOMING
44 ARIZONA
45 COLORADO
46 NEVADA
47 NEW MEXICO
48 UTAH

Tab. 3: Forest area in the US by state for different years between 1952 and 1977

1952		1962		1970		1977	
DATUM	VALUE	DATUM	VALUE	DATUM	VALUE	DATUM	VALUE
1	19730.00	1	18937.00	1	18232.00	1	18608.00
2	166094.00	2	167794.00	2	168943.00	2	177486.00
3	32590.00	3	30406.00	3	28463.00	3	29523.00
4	45186.00	4	49376.00	4	48068.00	4	50135.00
5	4300.00	5	4290.00	5	4290.00	5	4042.00
6	38459.00	6	42109.00	6	43640.00	6	45117.00
7	3290.00	7	3910.00	7	3900.00	7	3918.00
8	28547.00	8	28457.00	8	26736.00	8	26532.00
9	20500.00	9	22620.00	9	19785.00	9	19284.00
10	119522.00	10	134172.00	10	144890.00	10	173777.00
11	145740.00	11	162790.00	11	174780.00	11	178320.00
12	102760.00	12	113890.00	12	114397.00	12	116686.00
13	191210.00	13	191210.00	13	108000.00	13	192704.00
14	173687.00	14	620.00	14	168750.00	14	183353.00
15	4510.00	15	4240.00	15	4060.00	15	4218.00
16	3150.00	16	2200.00	16	2230.00	16	3347.00
17	153486.00	17	146933.00	17	145368.00	17	149077.00
18	38300.00	18	37614.00	18	36800.00	18	38104.00
19	40150.00	19	39300.00	19	38400.00	19	39429.00
20	25950.00	20	20000.00	20	17000.00	20	15613.00
21	12080.00	21	11940.00	21	11870.00	21	13444.00
22	114973.00	22	116513.00	22	118260.00	22	121608.00
23	143000.00	23	135000.00	23	125000.00	23	128760.00
24	10504.00	24	10343.00	24	9330.00	24	10291.00
25	54500.00	25	60410.00	25	64220.00	25	65041.00
26	195824.00	26	199894.00	26	201929.00	26	200433.00
27	118838.00	27	121704.00	27	124107.00	27	122484.00
28	154965.00	28	57521.00	28	158594.00	28	164174.00
29	181354.00	29	168300.00	29	162316.00	29	170397.00
30	239691.00	30	262980.00	30	251028.00	30	252560.00
31	207560.00	31	217422.00	31	217422.00	31	213611.00
32	164400.00	32	179760.00	32	168919.00	32	169124.00
33	123010.00	33	136430.00	33	128198.00	33	131605.00
34	192651.00	34	215001.00	34	182067.00	34	182815.00
35	160380.00	35	165120.00	35	153423.00	35	145581.00
36	50441.00	36	47111.00	36	48174.00	36	85133.00
37	131715.00	37	127813.00	37	129243.00	37	232793.00
38	256880.00	38	256230.00	38	253190.00	38	300230.00
39	191880.00	39	188600.00	39	184010.00	39	231810.00
40	171270.00	40	171980.00	40	170810.00	40	401520.00
41	155399.00	41	157251.00	41	151924.00	41	217266.00
42	167532.00	42	168299.00	42	159834.00	42	225593.00
43	47380.00	43	47206.00	43	46498.00	43	100283.00
44	36206.00	44	36927.00	44	36899.00	44	184939.00
45	122849.00	45	123535.00	45	115837.00	45	222710.00
46	1420.00	46	1417.00	46	1286.00	46	76833.00
47	56256.00	47	57464.00	47	57364.00	47	180598.00
48	38819.00	48	38715.00	48	38246.00	48	155574.00

Table 4: Amount of wood utilized for different purposes for selected countries (from Windhorst 1978).

A: Gain and Utilization of Lumber

The ten most important countries for the production of firewood and wood for industrial purposes in 1973 for selected countries (acc. to YFP 1973, Rome 1975)

Country	Firewood and Charcoal	
	amount (1000 cbm)	% of total gain of lumber
Brasil	140 000	85,5
China	136 160	74,4
India	106 000	90,0
Indonesia	104 000	77,4
USSR	85 400	22,3
Nigeria	56 800	95,1
Tansania	31 500	96,4
Ethiopia	23 000	95,0
Phillippine Islands	21 120	60,5
Colombia	20 000	80,2
World	1 146 308	46,5
	Lumber used for Industrial Purposes	
USA	342 247	96,2
USSR	297 600	77,7
Canada	120 785	97,3
Sweden	54 872	94,8
China	46 955	25,6
Japan	43 114	96,7
Finland	35 560	82,8
Germany	28 740	93,7
France	28 078	82,8
Brasilia	23 800	14,5
World	1 351 207	53,5

B: <u>Wood Products</u>

The development of cellulose and paper production from 1962 to 1973 (in 1000 t) by region (acc. to YFP 1973, Rome 1975)

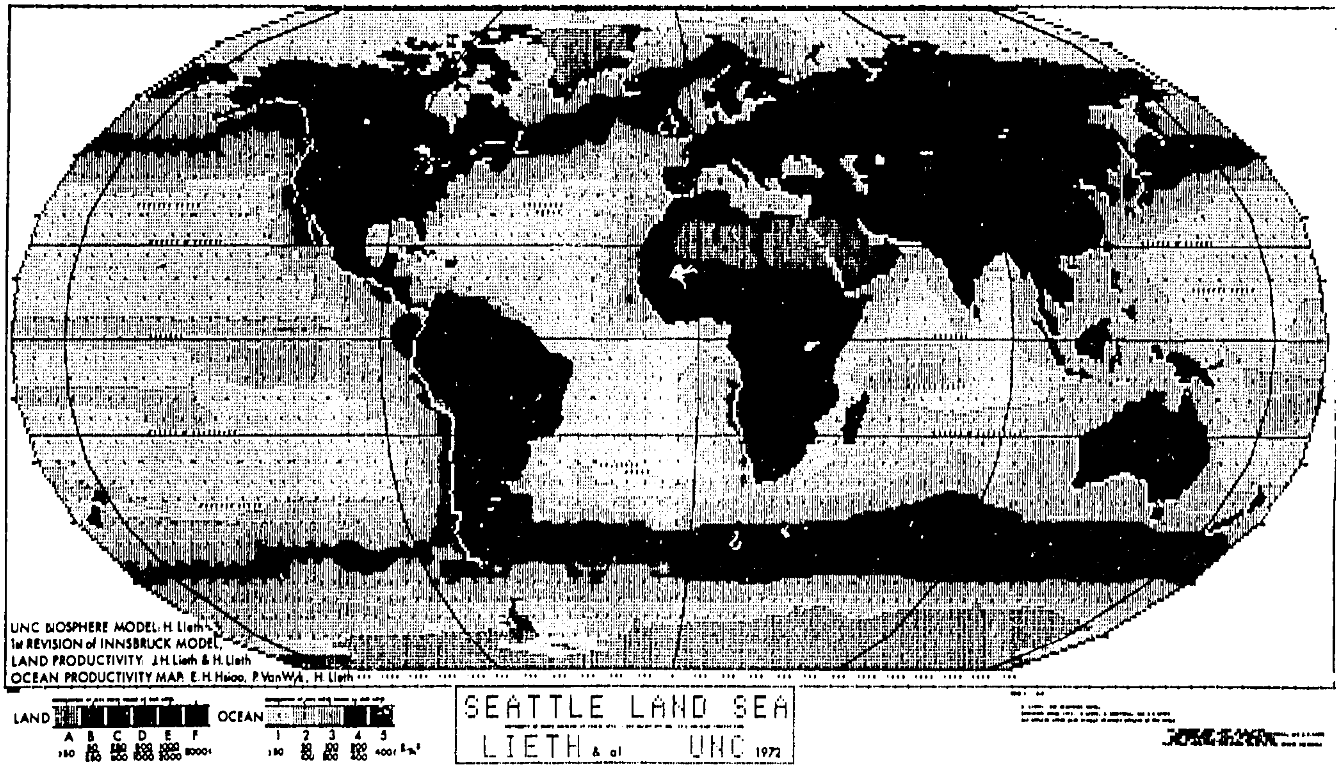
	Cellulose		Paper and Cardboard		Newspaper	
Region	1962	1973	1962	1973	1962	1973
Africa	413	1 353	400	1 178	35	128
N America	36 505	62 171	40 875	66 215	7 978	11 268
S Ameria	575	1 643	1 375	3 364	129	230
Asia	5 116	12 188	9 398	23 369	1 354	3 070
Europe	18 386	30 623	24 291	44 454	4 293	5 685
USSR	3 717	6 967	3 668	7 425	541	1 212
Australia Oceania	637	1 399	754	1 605	207	412
World	65 384	116 334	80 763	147 611	14 537	22 006

C: The development of sheet wood production from 1962 to 1973 (in 1000 cbm) by region (acc. to YFP 1973, Rom 1975)

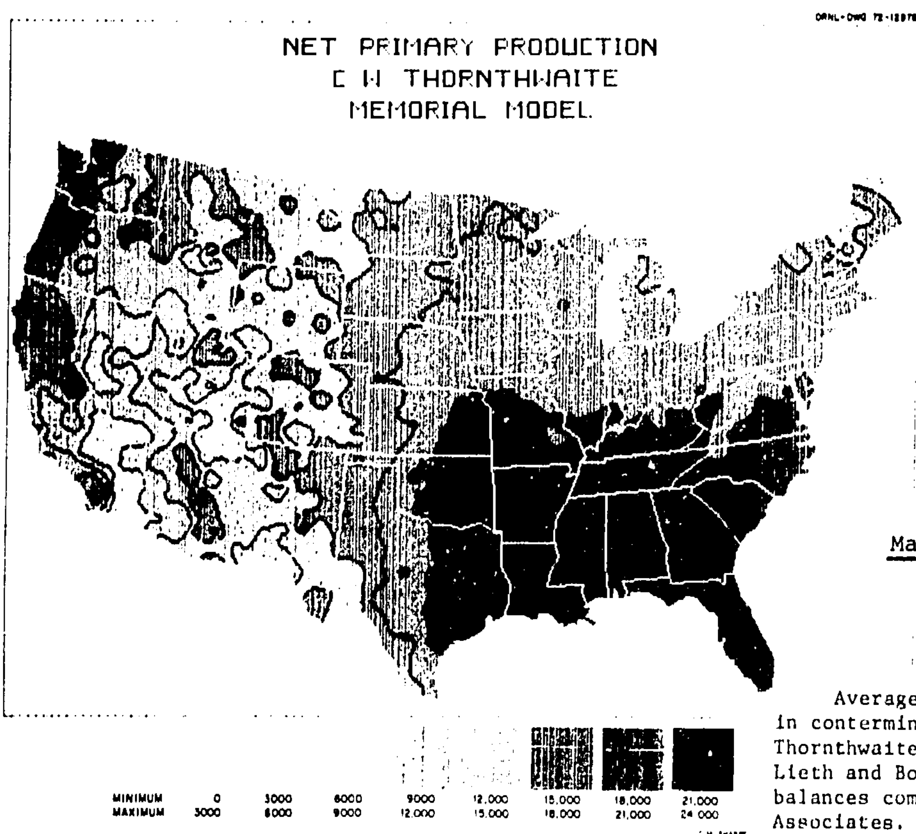
Region	1962	1973
Africa	333	1 091
N America	17 134	37 062
S America	639	2 193
Asia	3 169	16 922
Europe	10 713	30 334
USSR	2 619	7 708
Australia Oceania	369	837
World	34 976	96 146

Table 5: Correlation between environmental parameters and net primary productivity.

EQ			Terr. Glob. NPP
1	$P = -1.57 + 0.0517\ S$	=	$73.5 \times 10^9 t$
2	$P = \frac{3000}{1 + e^{1.315 - 0.119T}}$	=	$121.7 \times 10^9 t$ (2 and 3 bracketed together)
3	$P = 3000\ (1 - e^{-0.000664N})$		
4	$P = 3000\ (1 - e^{-0.0009695(E-20)})$	=	$118 \times 10^9 t$
5	$P = \frac{W\ .\ Tv}{36\ R}$	=	$180 \times 10^9 t$
MAP			
1	Terr. Port. of Seattle map	=	$97 \times 10^9 t$
	Tabular assess. Rodin et al.	=	$172 \times 10^9 t$
TAB			
1	Tabular assess.	=	$120 \times 10^9 t$

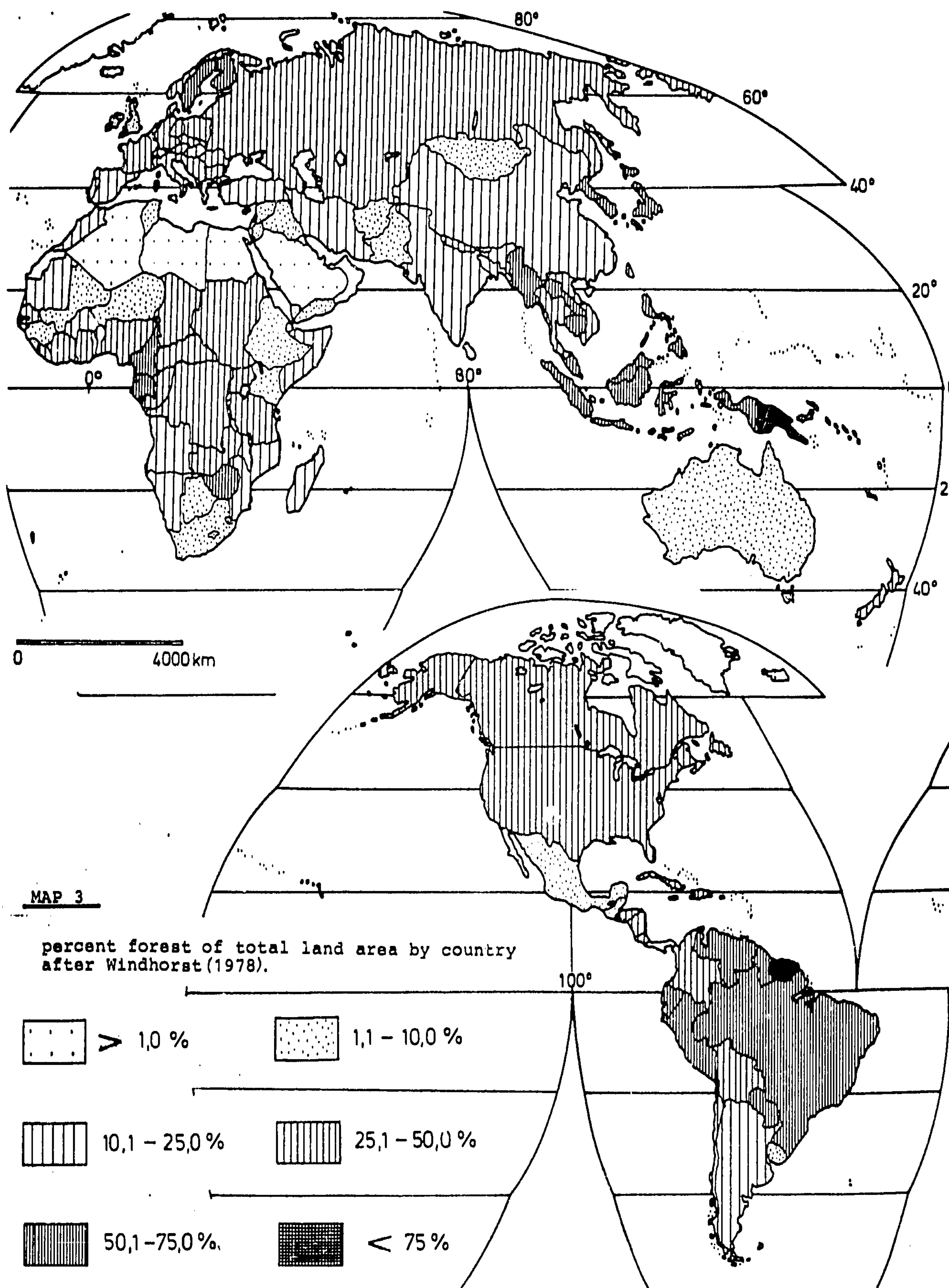


<u>Map 1</u> primary productivity pattern of the world



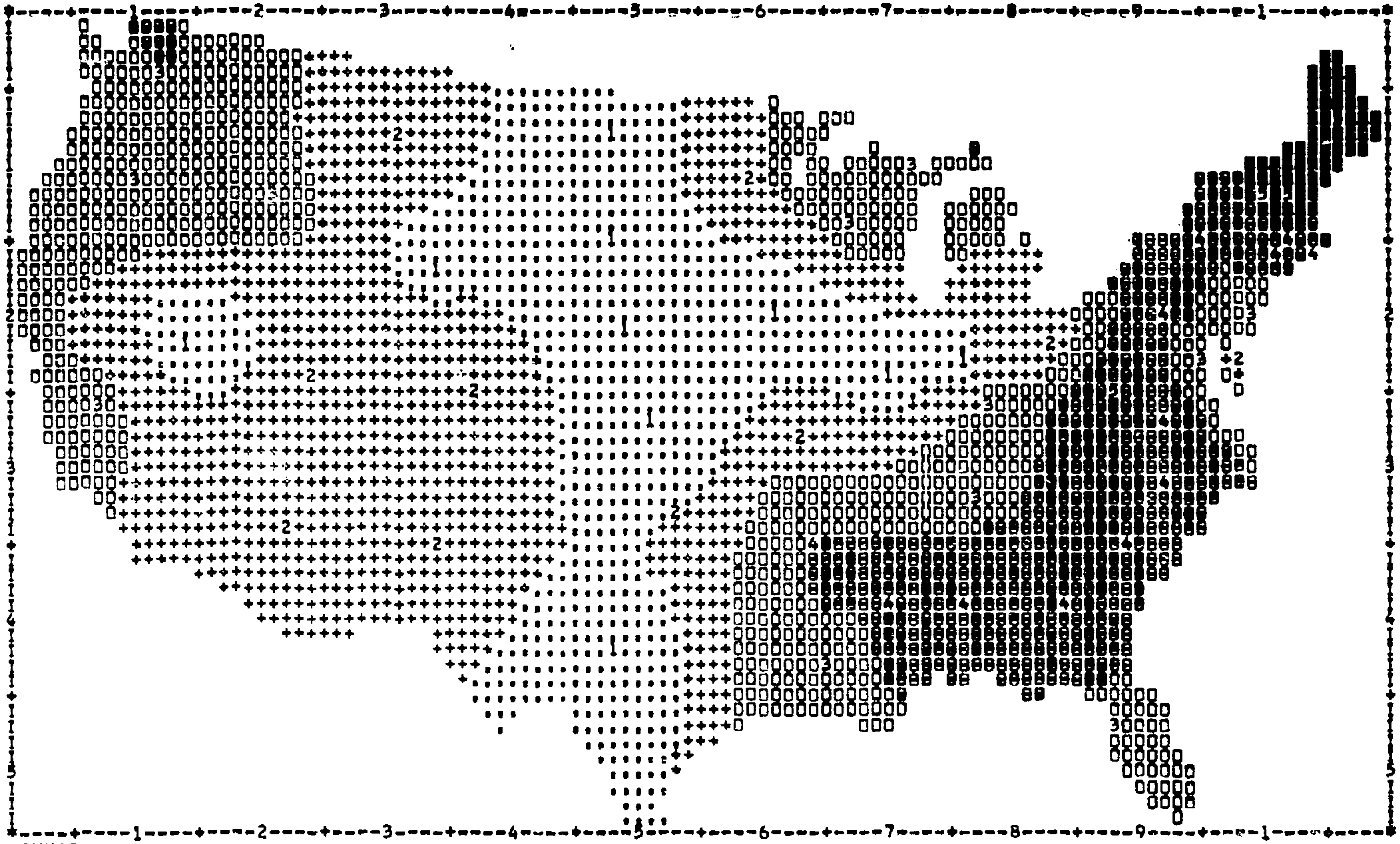
<u>Map 2</u> primary productivity pattern of the US

Average annual net primary production in conterminous United States after C. W. Thornthwaite Memorial model developed by Lieth and Box, and average annual water balances computed by C. W. Thornthwaite Associates.



MAP 3

percent forest of total land area by country after Windhorst (1978).



DATUM	VALUE
1	60.00
2	90.00
3	59.00
4	87.00
5	60.00
6	76.00
7	31.00
8	42.00
9	60.00
10	37.00
11	62.00
12	76.00
13	53.00
14	36.00
15	10.00
16	0.80
17	43.00
18	11.00
19	17.00
20	4.00
21	3.00
22	48.00
23	29.00
24	2.00
25	25.00
26	64.00
27	63.00
28	64.00
29	49.00
30	68.00
31	66.00
32	56.00
33	50.00
34	55.00
35	51.00
36	19.00
37	14.00
38	49.00
39	54.00
40	40.00
41	41.00
42	24.00
43	16.00
44	25.00
45	34.00
46	11.00
47	23.00
48	30.00

SYMAP

0.203318 MINUTES FOR MAP

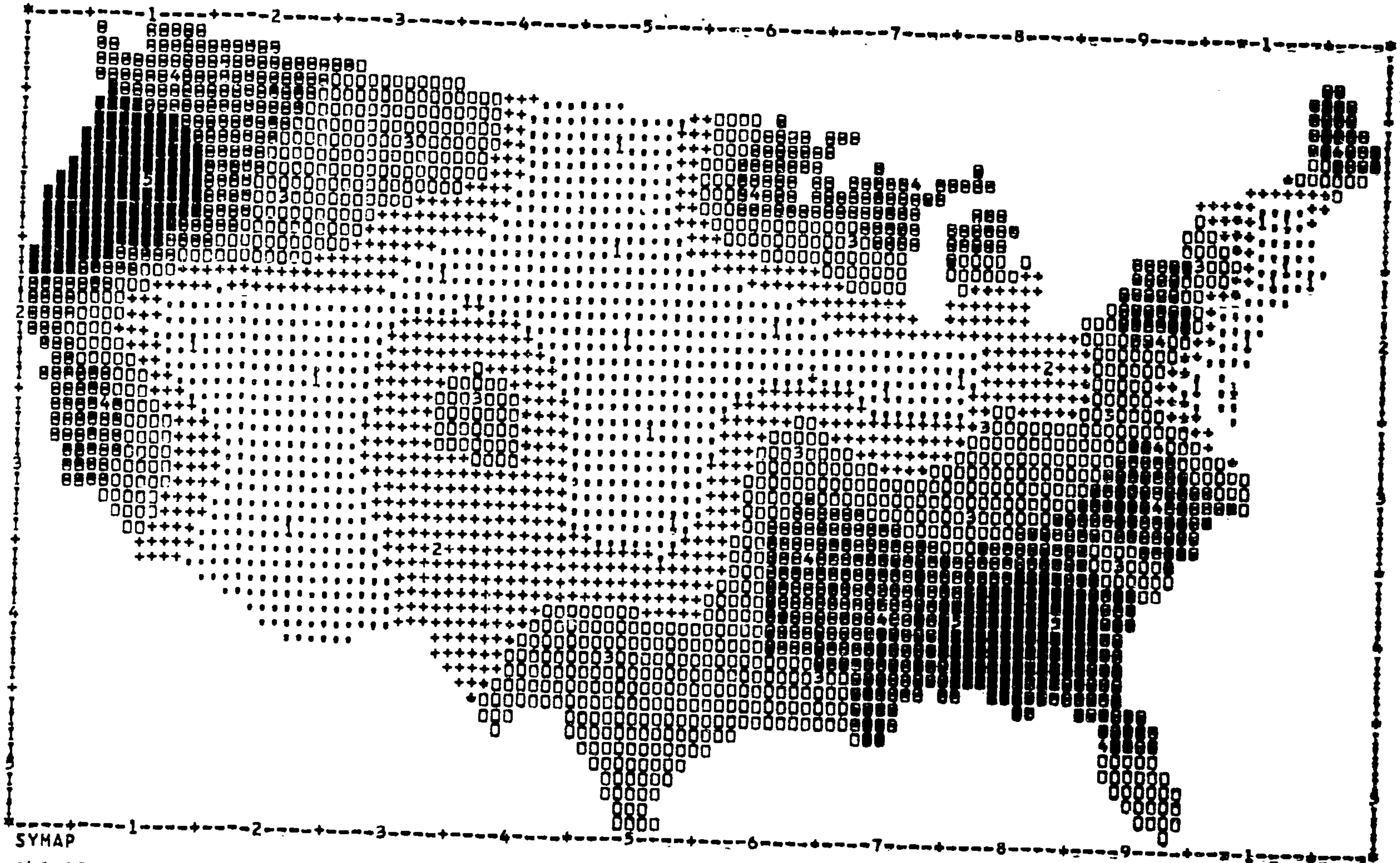
PROZENTUALE WALDFLAECHE
PRO BUNDESSTAAT
USA 1977

MAP 4 A

DATA VALUE EXTREMES ARE 0.80 90.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	·····1····	++++2++++	000030000	888848888	██████
FREQ.	10	10	12	12	4
MINIMUM	0.80	18.64	36.48	54.32	72.16
MAXIMUM	18.64	36.48	54.32	72.16	90.00



DATUM	VALUE
1	18356.00
2	168943.00
3	27977.00
4	46920.00
5	3953.00
6	44299.00
7	3844.00
8	25227.00
9	16568.00
10	144980.00
11	174780.00
12	114837.00
13	167752.00
14	161000.00
15	4050.00
16	2230.00
17	144780.00
18	36923.00
19	38150.00
20	14602.00
21	11870.00
22	119019.00
23	122846.00
24	7888.00
25	64220.00
26	195622.00
27	121761.00
28	159388.00
29	153300.00
30	248123.00
31	213331.00
32	168919.00
33	128198.00
34	182067.00
35	145266.00
36	43234.00
37	125125.00
38	244350.00
39	179220.00
40	163030.00
41	135406.00
42	143594.00
43	43342.00
44	38956.00
45	113167.00
46	1343.00
47	53375.00
48	34046.00

SYMAP

0.211201 MINUTES FOR MAP

FLAECHE DES WIRTSCHAFTSWALDES : ALLE BESITZFORMEN

MASSEINHEIT 100 ACRES

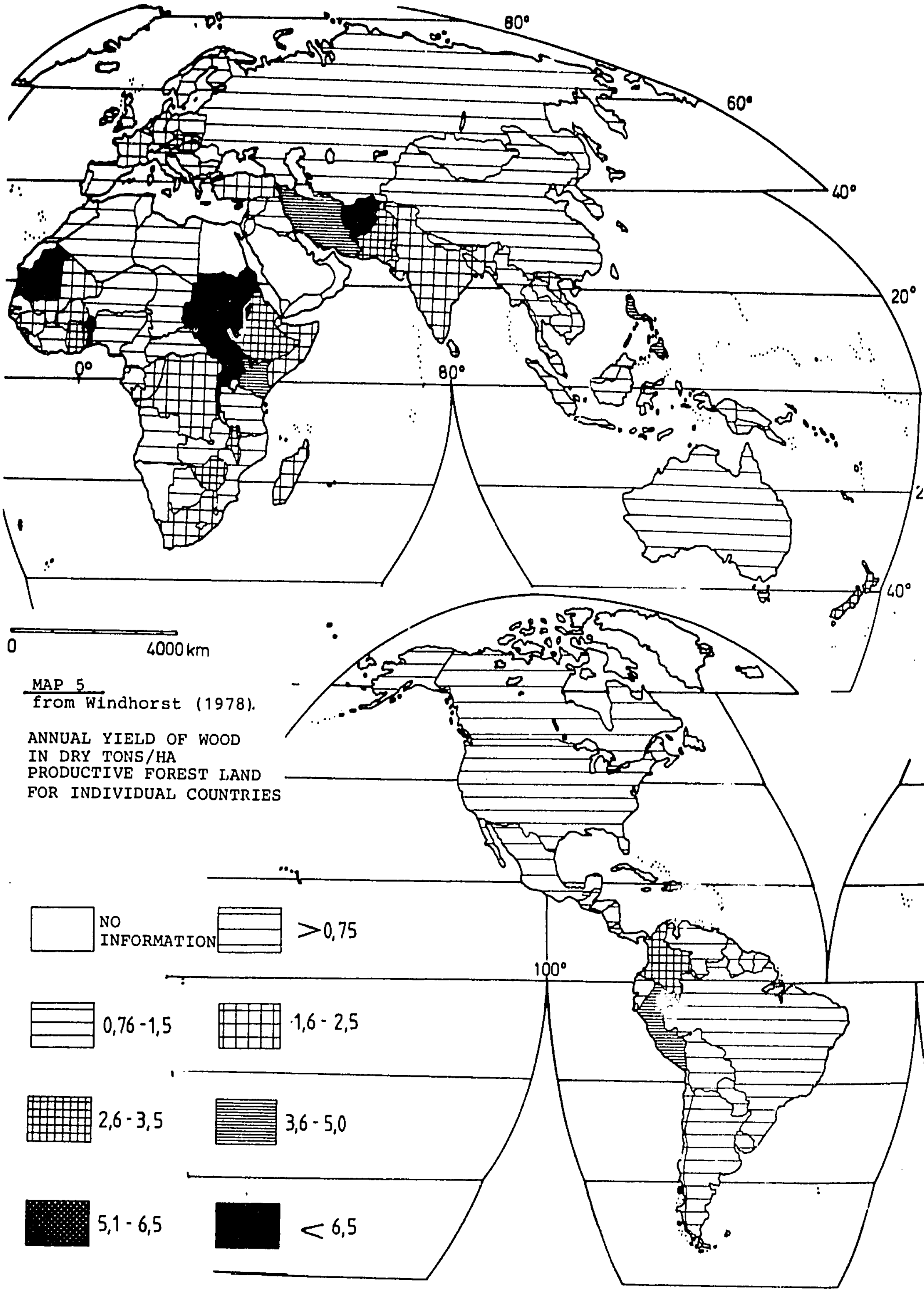
JAHR:1977

MAP 4B

DATA VALUE EXTREMES ARE 1343.00 248123.00

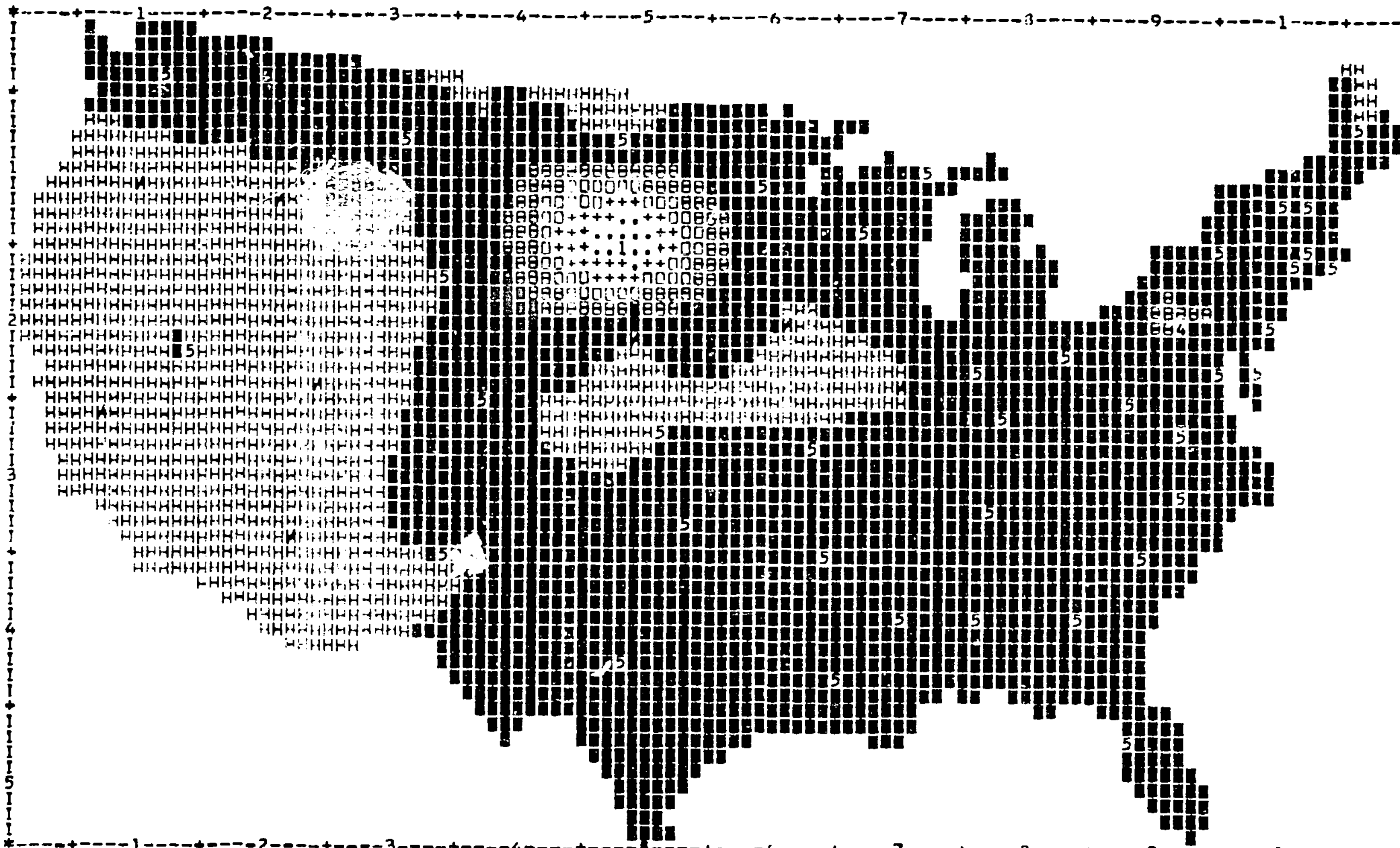
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
MINIMUM	1343.00	50699.00	100055.00	149411.00	198767.00
MAXIMUM	50699.00	100055.00	149411.00	198767.00	248123.00



MAP 5
from Windhorst (1978).

ANNUAL YIELD OF WOOD
IN DRY TONS/HA
PRODUCTIVE FOREST LAND
FOR INDIVIDUAL COUNTRIES



SYMAP RECHENZENTRUM UNI OSNABRUECK

DIFFERENZ DES RELATIVEN LAUBHOLZVORRATES
1970 — 1977 IN 10^{-1} cft./acr.

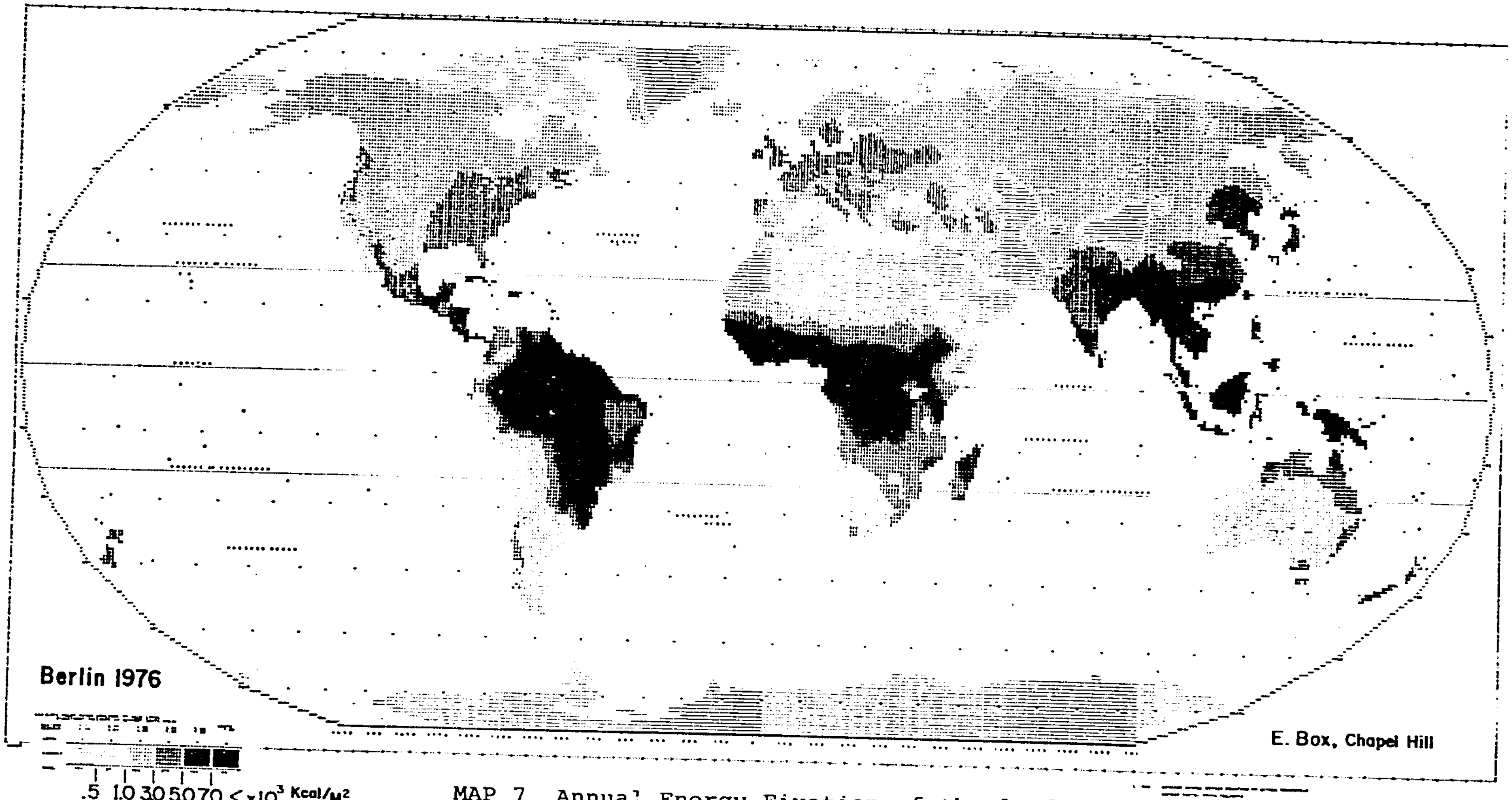
MAP 6.

LEVEL	1	2	3	4	5	H
SYMBOLS	.	+	0	8	■	H
FREQ.	1	0	0	1	38	8

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	-5756.00	-4604.80	-3453.60	-2302.40	-1151.20	ABOVE 0.0
MAXIMUM	-4604.80	-3453.60	-2302.40	-1151.20	0.0	

DATA VALUE EXTREMES ARE -5756.00



MAP 7 Annual Energy Fixation of the land vegetation; from Lieth (1977).

ACCUMULATION OF ENERGY IN FORESTS

Taisitiroo Satoo [1/]

Abstract.--Influence of conditions of forest and environment on aboveground net production and leaf mass of plantations and woodlands are presented, and the differences in net production due to some of the conditions were analyzed in terms of mass and efficiency of leaves. Silvicultural implications of management of "energy plantation" were also discussed.

INTRODUCTION

Since time immemorial, we have extracted materials and energy produced by forests to support our life. In what form we extract them depends on the way of life. They could have been in the form of wood for fuel and timber, or foods like fruits, mushrooms and games, or minor products like fibres, gums, resins, dyes and medicines, or non-material products like amenity values. With intention toward more efficient use of forests, technology of manipulation of forests, or silviculture, was initiated by applying the laws of nature. It is true that the technology of silviculture has focussed on the production of wood, but it is able to respond the changing need of society, because it is based on the laws of flow and turnover of materials and energy in forests as ecosystems. The functions of forests for wood production as well as water production and amenity values are based on biomass and productivity of forests, which are the result of flow and turnover of materials and energy in the forests. Use of forests as a source of energy and organics is one of the variety of ways of extraction of energy and materials accumulated by forests.

After the oil crisis, much are talked about "energy from forest biomass", in spite of the long history of use of wood as energy source not only in home use but also in industries; even motor cars used wood and charcoal as energy sources during the World War II in Japan. Many part of the harvested woody materials are still used as a source of energy. So, "energy from forest biomass" perhaps means the use of forest biomass as energy in different ways from just burning them. We are not yet sure whether it can compete other sources of energy and other uses of woody material. However, these problems are outside the scope of this paper. This paper deals only with biological aspects of accumulation of energy and materials in forests.

A forest accumulates radiant energy or serves as a reservoir to delay the flow of it. Ecologically, the process of accumulation starting from photosynthesis of green plants, primary production, is described as

$$Pn = Pg - R$$

$$Pne = Pn - R'$$

Some of the total energy fixed by photosynthesis of green plants in an ecosystem, or gross production (Pg), is expended in the plants' own respiration (R) and the rest goes into new tissues, or net production (Pn). Some of the net production, whether alive on trees or after the death, is used by consumers which expend most of it in respiration (R') and some as growth of themselves, secondary production. Most of the net production which was not used by consumers contributes to net ecosystem production (Pne) together with growth of consumers. In a mature forest Pn is equal to R' and Pne becomes null. Being accumulated for years, the huge amount of energy and organics are stored in a forest ecosystem as biomass and soil organic matters. Forests are the terrestrial ecosystem that holds greatest reserve of energy and organics per unit area of land.

However, when we think of energy for human use, a large part of net ecosystem production is not usable. Those stored as litter on forest floor and as soil organic matter can not be used without difficulties to collect them and without causing serious impacts on natural cycling of nutrient elements in the system. Utilization of roots also destroys the stability of soil on a steep hillside and may

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bring about erosion. The energy and organics that could be harvested by man from a forest may be limited to those stored in aboveground parts of plant and those in some of animals. However, the quantity of energy and organics stored in animals is negligible compared to the huge mass of plant materials and soil organic matter: generally a few kilogram against a few hundred tons per hectare. For example, in a subalpine hemlock forest with aboveground tree biomass of 255 t/ha and 268 t/ha of soil organic matter, biomass of consumers was only 6.2 kg/ha (Kitazawa 1977). Another example is a ponderosa pine forest with 82 t/ha of tree biomass which had 8 kg/ha of consumer biomass including 6.7 kg of domestic cattles (Clary 1978). Biomass of consumers falls into the range of error of estimation of plant biomass. So, it may be reasonable to confine present discussion to aboveground biomass production of plants.

The proportion of the biomass accumulated by a forest or a plantation which is used by man varies greatly depending on the relationship between demand and supply. On this problem Jackson and Ojo (1973) in Nigería presented an interesting paradox. They wrote, "In neem (Azadirachta indica) plantation in Maiduguri not only are the stems and branches down to one inch girth or less cut and stacked for firewood, but after felling women enter the plantation and sweep up twigs and chippings into baskets for their household fuel. Then tree there is almost complete utilization. In contrast to this, in the tropical rain forest" "only a small portion of trees is felled" "hence," "a neem plantation under 20 inches of rainfall may produce a higher useful yield as measured in cubic feet per acre per annum than rain forest under 80 inches, though the total (biological) production of the latter is much higher." Though not so extreme as this paradox, there are wide variations in this respect, and so the discussion here will deal with whole net production as aboveground part, mainly of the tree layer.

Because of the diversity of species and slow growth rate, natural forests in temperate and tropical regions might not be appropriate for production of energy and organics. Natural regeneration of desired species is also difficult because of diversity of species and competition from other vegetation (Satoo 1978). Improvement of species composition in coppice stands had been rather successful in the fuelwood production in the past. Percentages of oaks, which give top quality charcoal, increased by very careful management (Mine 1950). However, species and dimensions of trees suitable for regeneration by the coppice system are limited.

From these reasons, the presentation here will deal mainly with plantations. Second growth of pioneer species will also be dealt with because their structure and species composition are as simple as plantations. However, the most important reason for the limitation of the type of forest to be dealt with here is the quantity of data available. During and prior to the International Biological Program, data on standing crop of hundreds of forest stands, mainly conifer plantations, and aboveground production of dozens of them had been collected in Japan. Although their values as sources of energy and organics are not known well yet as they have been grown for timber production, facts and trends induced from these data would be also of use as the basis for establishing management technology of "energy plantations".

NET PRODUCTION

Standing Crop of Forests

One of the features of the forest is their immense biomass, they have the largest standing crops among the terrestrial plant communities. Though there is not yet any example of the enormous biomass among the investigations of the whole organisms in a forest as an ecosystem, examples of the huge standing crop of stem wood of mature natural forests are reported from the west coast of the United States. Two examples (Halin 1934, Fujimori 1977) of Sequoia sempervirence forests with more than ten thousand cubic meters of stem wood per hectare, and an example of mature Douglas fir forest with western hemlock having stem volume more than five thousand cubic meters per hectare (Worthington 1958) are known. As for planted forests, two examples, respectively, of 120- and 130-year-old plantations of Cryptomeria japonica with more than 2,800 cubic meters of stem volume per hectare are reported (Mine 1958). 2,800 cubic meters of wood weighs more than one thousand metric tons, and adding the weights of other organic matter like needles, branches and roots of Cryptomeria trees and whole natural vegetation invaded after planting trees, the rate of accumulation of organic matter may be close to ten metric tons per annum per hectare. However, standing crop of forest does not represent the rate of net production; while new tissues are added to the standing crop by net production old tissues die and go into the pool of organic matter on and in the soil which in turn expended by consumers and decomposers.

Net Production

Because measurements of production of organic matter by forests were carried out mainly from the viewpoint of traditional forestry science, measurements on overstorey

Table 1.--Net production by overstorey trees and undergrowth of different forest stands (Satoo 1973).

OVERSTOREY SPECIES	OVERSTOREY	UNDERGROWTH
	t/ha	t/ha
Betula ermanii	7.6	1.4
Populus davidiana	8.7	3.6
Cinnamomum camphora	13.6	1.6
Larix leptolepis	14.5	0.6
do.	12.6	2.7
Metasequoia glyptostroboides	16.2	1.0
Abies sachalinensis	14.5	+
do.	12.5	+
Picea abies	11.7	1.4
do.	12.4	1.6
do.	11.4	1.4
do.	7.3	1.4
Picea glehnii	7.4	+
Thujopsis dolabrata	11.8	+
do.	13.0	+
do.	19.2	+

trees are rather abundant while only very few of them have been combined with the measurements of net production by undergrowth from second storey trees down to ground vegetation. Examples of the combined measurements, which are not many, are presented in Table 1.

Net Production by the Undergrowth of Forests

Net production by the undergrowth of forest is dependent first of all on the leaf mass of the canopy of overstorey trees. Figure 1 shows the relationship between net production by undergrowth of forests and leaf area index over it. Logarithm of net production by the undergrowth decreased linearly with the increase of the leaf area index of the storeys shading it. The exponential extinction of light by passing through the strata of leaves (Monsi and Saeki 1953), the importance of light as the limiting factor for photosynthesis of undergrowth, and decrease of leaf mass with decrease of radiant energy penetrating the leaf layers above it are main causes of this relationship. Figure 2 shows the relationship between leaf area index of undergrowth and canopy of overstorey trees of deciduous broadleaved forests in Japan. Leaf area index of the undergrowth decreased with increase of leaf area index of the canopy. The slope of the straight line approximating this relationship in Figure 2 was very close to 1 which suggests that the sum of leaf area index of the two layers is constant or within a very narrow limits for a given type of forest. As seen from Table 1, contributions of the undergrowth vegetation to the net production by forests are

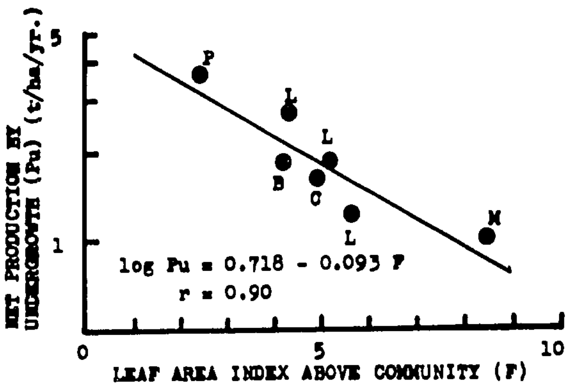

Figure 1.--Relationship between net production by undergrowth and leaf area index of overstorey canopy (Satoo 1973).
P: Populus davidiana forest
B: Betula ermanii forest
C: Cinnamomum camphora plantation
L: Larix leptolepis plantation

higher in the forests of less shade tolerant species, which have less foliage leaves in the canopy.

Net Production by the Overstorey Tree Layer

There are an abundance of measurements of net production of the overstorey tree layer but many of them lack the measurements on roots. Not only the measurements of root production are laborious and difficult, but there are not yet any standardized method for the measurement of it, and our knowledge on production and life span of fine actively growing roots is very

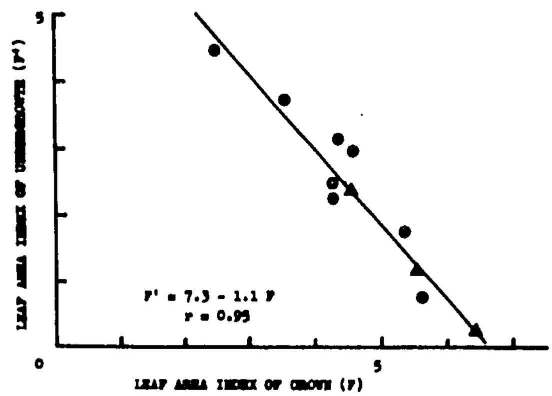

Figure 2.--Relationship between leaf area index of canopy of deciduous broadleaved forests and their undergrowth (Satoo 1973).
closed circles: birch forests
triangles: beech forests

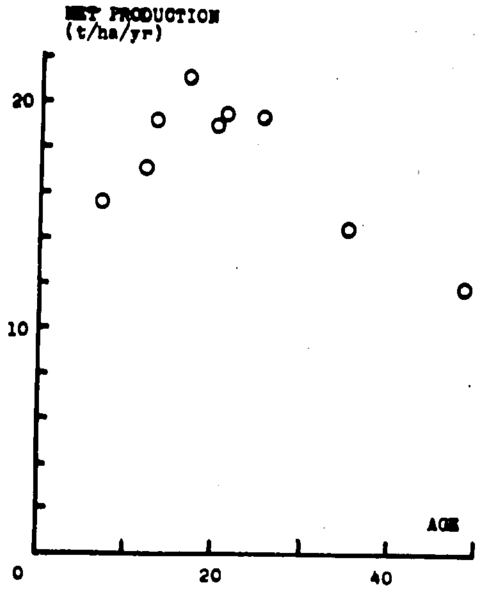

Figure 3.--The change with age of aboveground net production of overstorey pines in woodlands of Pinus densiflora (adopted from a table in: Hatiya and Totiaki 1968).

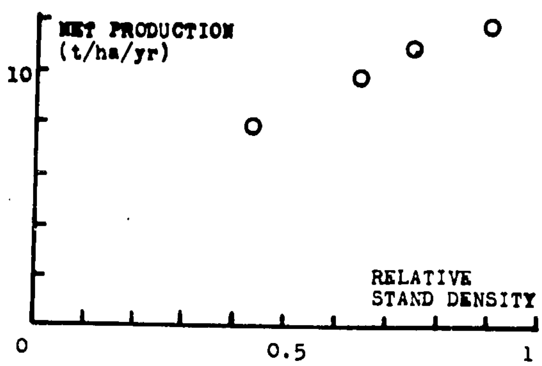

Figure 4.--Relationship between aboveground net production and relative stand density among 43-46-year-old woodlands of Pinus densiflora (modified from a table in: Hatiya et al. 1965).

limited. There are only a few trials to measure the net production by roots together with aboveground parts. Satoo (1968) presented 1.3 t/ha/year of root production in a naturally regenerated woodland of Pinus densiflora with 14.5 t/ha of aboveground net production, and Yamakura et al. (1972) reported 2.3 t/ha of root production in a 30-year-old plantation of Chamaecyparis obtusa with 12.9 t/ha of aboveground net production.

As most of net production as aboveground parts takes the forms of stem, branch, and leaves, measurements are done mostly by

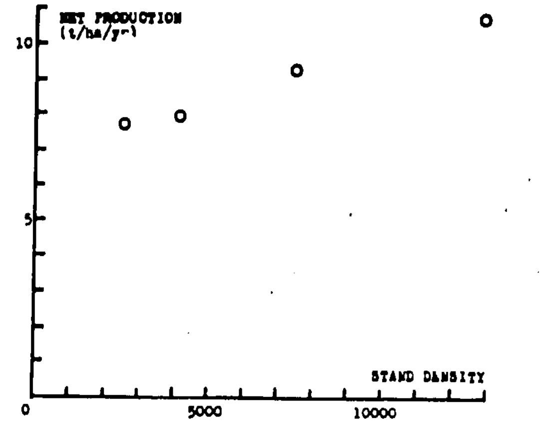

Figure 5.--Relationship between aboveground net production and stand density among 15-year-old experimental plots of Pinus densiflora with sufficiently high relative stand densities (adopted from a table in: Satoo et al. 1955).

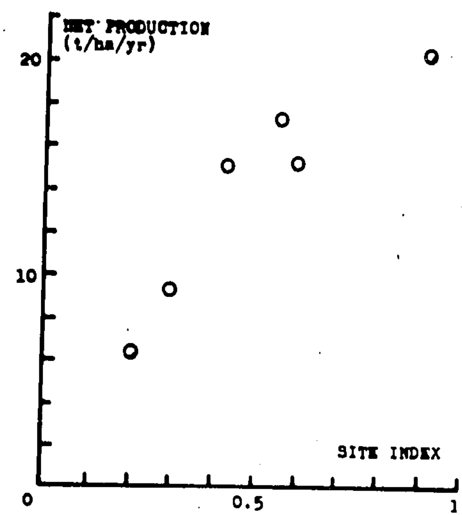

Figure 6.--Relationship between aboveground net production and site quality expressed by relative height among 20-21-year-old woodlands of Pinus densiflora (from a table in: Hatiya et al. 1966a).

measuring separately with separate techniques on these three parts and summing them up. Minor components such as bark, flowers, fruits, seeds, premature shedding of leaves and leaves grazed by insects are generally neglected, and the reported measurements of net production could be of somewhat underestimate. According to Saito (1974), for example, who collected for six successive years litter in a 40-year-old plantation of Chamaecyparis obtusa with 14.7 t/ha of aboveground net production, reported that, as the mean values, 222 kg of green leaves, 8 kg of new shoots, 29.8 kg of reproductive organs including cones, seeds and male flowers, and 114 kg of bark were collected annually per hectare, suggesting that these minor components are by no means negligible. Importance of production of flower and seed in the estimation of net production was pointed out by Ovington (1963).

The relationships of net production of aboveground parts of overstorey tree layers to conditions of forest and environment are not much different from those between increment of stem wood and these conditions, of which informations have been accumulated in the long history of forestry science.

Age of Stand -- Up to a certain age net production increased with age and then decreased. Figure 3 shows the relationship between aboveground net production of naturally regenerated woodlands of Pinus densiflora and age of stands. Similar trends were reported on plantations of Scots pine, Pinus silvestris (Ovington 1957) and forests of European beech, Fagus silvatica (Moller 1945).

Stand Density -- Stand density is usually expressed as number of trees per unit ground area of stand. Stand density of planted forests varies largely by initial spacing and thinning regime. As trees in a stand grow, maximum number of trees that is able to grow in a unit ground area of forest decreases. A linear relationship on a double logarithmic scale is recognized between mean diameter of trees in a stand and the maximum number of trees in it (Reineke 1933). The ratio of actual stand density to the maximum density for a given mean diameter may be called relative stand density. Except for a group of stand given with experimentally different stand densities, it is more adequate and convenient to use the relative stand density instead of absolute stand density when comparing them each other. As seen from Figure 4, which shows the relationship between aboveground net production and relative stand densty of 43-year-old woodlands of Pinus densiflora, the higher the relative stand density, the larger net production, suggesting the full use of productivity by stands of higher relative stand density. As shown by Figure 5, among experimental plots of sufficiently high relative stand density net production was also larger in denser stand.

Site Quality -- As tree height is rather stable against the change of stand density while diameter and stem volume of trees are greatly influenced by it, tree height is often used as an index of site quality. Productivity, or site quality, of a stand is expressed relatively with relative height, which is the ratio of height of a stand to the height at the same age of site class I in the respective regional yield table. Figure 6 shows the relationship between aboveground net production of 20-21-year-old woodlands of Pinus densiflora

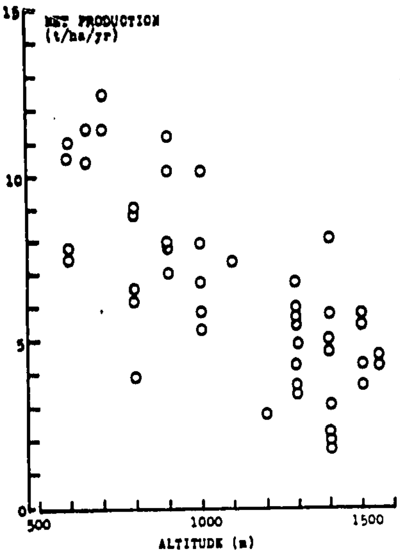

Figure 7.--Net production of climax beech (Fagus crenata) forests in relation to altitudes from sea level (from a table in: Maruyama 1971).

and relative stand density. The larger the relative height, the greater was the aboveground net production. Similar trend was observed among stands of Norway spruce, Picea abies, planted in northern Japan (Satoo 1971a).

Fertilization -- Fertilization increases net production. In an experiment made by Kabaya (unpublished), in which large amount of fertilizers were given to a sand dune plantation of Pinus thunbergii, fertilized plot resulted aboveground net production of 16.2 t/ha/year whereas unfertilized control plot produced only 9.8 tons.

Altitude -- In higher altitudes, environmental conditions are not favorable for photosynthesis of plants, like low temperature, and shorter growing season, insufficient radiation due to bad weather. According to Maruyama (1971) who studied production relations in climax beech forests (Fagus crenata) covering altitudes from 550 to 1550 m above sea level in central Japan, net production showed decreasing trend with altitude (Figure 7). According to him, decrease of leaf area index with increasing altitude also played an important role in the decrease of production in addition to the factors mentioned above.

Though influences of many factors on net production are conceivable, there are not yet any data to support them.

In Figure 8 are summarized tha data on aboveground net production of forests in Japan.

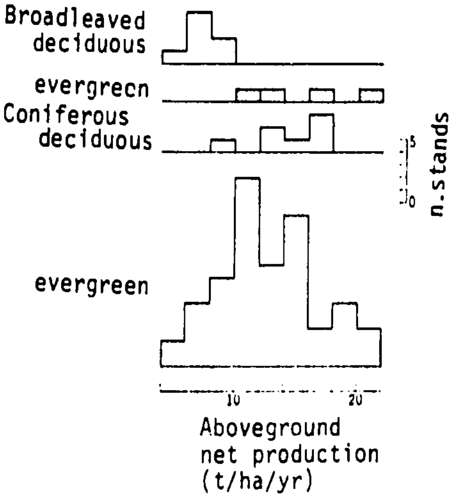

Figure 8.--Frequency distribution of aboveground net production of forests in Japan (Satoo 1973).

Difference by the group of species is minimum except that deciduous broadleaved forests gave lower values than others. When aboveground net production of overstorey tree layers of various kinds of forest within a circle of several kilometers was compared, except for a Norway spruce plantation on a very poor soil, conifer plantations gave greater net production than second growth of deciduous broadleaved forests (Satoo 1970)

Distribution of organic matter produced by the overstorey trees into stem, branch and leaves is important in view of not only its utilization by man but also of flow and turnover of energy and matter. Production of stem wood, which has been utilized by man, depends not only on the rate of net production but on the ratio of distribution of products into the stem. The ratio of distribution can be modified by silvicultural means. For example, when relative stand density is high enough, distribution of the product into stem is larger in denser stand (Satoo et al. 1955). As stem lives longer than leaves and branches, by increasing the distribution to stem slow down the rates of flow and turnover of energy and organics. By increasing the distribution to leaves production in the next period of time of individual trees will be enhanced. In Figure 9 the pattern of distribution of product into the three main parts is summarized separately for coniferous and broadleaved forests. Though the difference is very slight, distribution into branch is rather larger in broadleaved forests and the one to the stem is slightly larger in coniferous forests. Roughly speaking , out of ten, five goes to stem, two to branches and three to leaves. Pattern of distribution of net products may differ somewhat by conditions of forest and situation of trees within a stand.

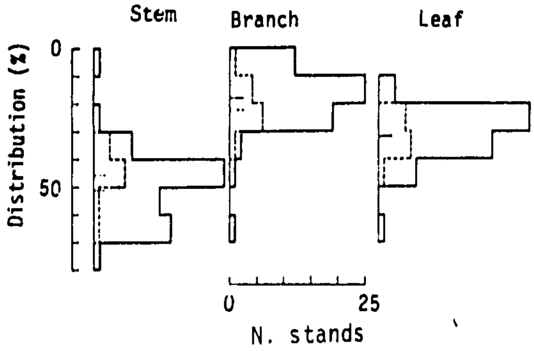

Figure 9.--Frequency distribution of the percentage distribution of aboveground net production of forests into leaves, branches, and stems (Satoo 1973).
number of samples: coniferous forests (——) 60, broadleaved forests (----) 12.

ANALYSIS OF NET PRODUCTION

Net production is influenced by many factors. The difference in net production can be analysed by dividing net production into two components, the amount of leaves, F, and net production per unit amount of leaves, Pn/F, as

$$Pn = F \times Pn/F$$

Pn/F represents the efficiency of leaf in net production but it does not represent photosynthetic efficiency of leaves itself. When gross production is divided in the same way, Pg/F respresents photosynthetic efficiency itself, but Pn/F includes other components like consumption by respiration of leaves and non-photosynthetic tissues and the ratio of the amount of non-photosynthetic tissues to the leaves. This relation was formulated by Iwaki (1959) as

$$Pn/F = (a - r) - C/F \times r'$$

where a and r are rate of phtosynthesis and respiration per unit amount of leaves, respectively, C is the amount of non-photosynthetic tissues, and r' is consumption by respiration per unit amount of them.

The efficiency of leaves in net production, Pn/F, is a simplified version of "unit leaf rate" or "net assimilation rate" (NAR) calculated in classical growth analysis (Evans 1971). This kind of growth analysis is usually made on agricultural crops for various phases of growth and using more precise mathematical formulae. For forests it is general practice simply to use leaf biomass and net production on an annual basis and measured by the harvest method to determine F and Pn, respectively. In evergreen forests, the total

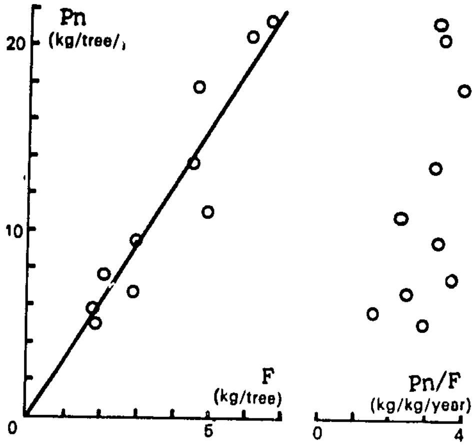

Figure 10.--Aboveground net production of individual trees in a 21-year-old plantation of Larix leptolepis in relation to amount and efficiency of leaves (Satoo 1971b).

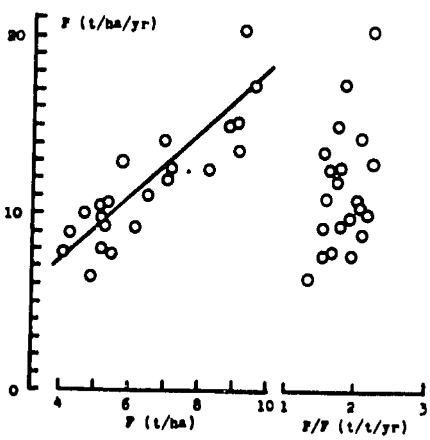

Figure 11.--Aboveground net production of stands of Pinus densiflora in relation to amount and efficiency of foliage leaves (Satoo 1968).

leaf biomass and its age composition change during the year (Figure 23) and the values of Pn/F obtained are approximate.

By use of this method we can find out whether variation in net production is due to differences in the amount of leaves or caused by the difference in leaf efficiency. Such information may be useful in developing methods for increasing production. However, it must be pointed out that, as leaf biomass increases the radiation incident on the leaves of the lower crown decreases and their photosynthetic rate decreasess; in another word, leaf eficiency and amount are not independent.

Amount and Efficiency of Leaves

The approach outlined above can be used in analyzing the variations in production between individual trees in a forest stand or between forest stands per unit ground area. As shown in Figure 10, the net aboveground production of individual trees within a 21-year-old stand of Larix leptolepis is linearly proportional to their foliage amount and the relationship can be expressed by a straight line passing through the origin. In this case, net production is not related to leaf efficiency. The same relationship was found also among trees within stands of Pinus densiflora (Satoo 1968), Betula maximowizciana (Satoo 1970), Abies sachalinensis (Satoo 1974a), Thujopsis dolabrata (Satoo et al. 1974), and Metasequoia glyptostroboides (Satoo 1974b). The same relationship was found among forest stands as shown by Figure 11. Net aboveground production per unit ground area of woodlands of Pinus densiflora was linearly proportional to leaf biomass and unrelated to leaf efficiency, though the variation is rather large. The same relation was found among stands of Betula maximowicziana (Satoo 1970) and Larix leptolepis (Satoo 1971b).

Examples of Analysis of Net Production

As seen in Figure 11, there are wide variations in net aboveground production among stands having the same leaf biomass and in leaf efficiency among stands having the same aboveground net production, when we combine all the data available and, therefore, include a wide variety of forest stands. From these data, some subsets showing rather large differences in net aboveground production may be selected for closer study.

Figure 12 contains data for the stands shown in Figure 4 and in which aboveground net production increased with relative stand

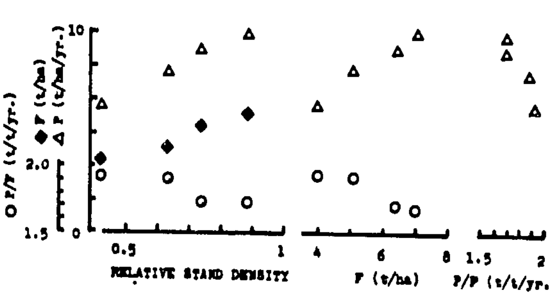

Figure 12.--An analysis of aboveground net production of 43-46-year-old woodlands of Pinus densiflora with different relative stand densities (Satoo 1973, data: Hatiya et al. 1965).

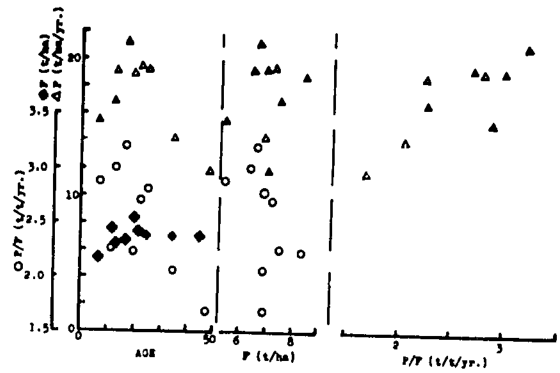

Figure 13.--An analysis of aboveground net production of woodlands of Pinus densiflora of different ages (Satoo 1973, data: Hatiya and Totiaki 1968).

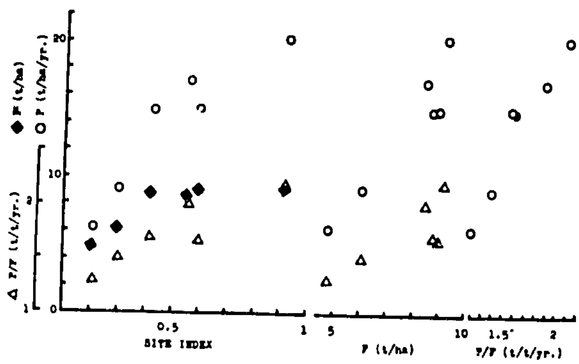

Figure 14.--An analysis of aboveground net production of 20-21-year-old woodlands of Pinus densiflora with different site index expressed as relative height (Satoo 1973, data: Hatiya et al. 1966a).

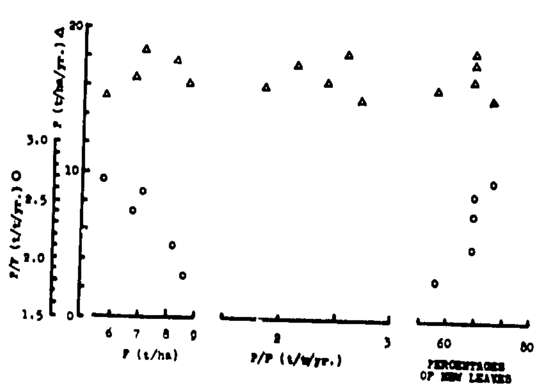

Figure 15.--An analysis of aboveground net production of 20-year-old woodlands of Pinus densiflora with similar rates of aboveground net production (Satoo 1973).

Table 2.--Effect of fertilization on amount and efficiency of needles of a sand dune plantation of *Pinus thunbergii* (Kabaya, unpublished).

FERTILIZATION	ABOVEGROUND NET PRODUCTION	NEEDLE MASS	LEAF EFFICIENCY
	t/ha/yr	t/ha	t/t/yr
+	16.21	7.85	2.04
-	9.75	6.96	1.40

density. Net production increased with leaf biomass and was inversely related to leaf efficiency.

Figure 13 includes the same stands as shown in Figure 3 which showed that net aboveground production changed with age. Net production was independent of leaf biomass but increased with increasing leaf efficiency which is in contrast to the example shown in Figure 12.

Figure 14 contains the same stands as shown in Figure 6 which demonstrated that aboveground net production increased with increasing site index when the latter was expressed as relative height. Net production increased with both amount and efficiency of leaves. A similar trend was found in a heavily fertilized, coastal sand dune plantation of Pinus thunbergii. Both the amount and efficiency of leaves were larger in fertilized plot which produced larger amount of dry matter (Table 2).

As seen from these four examples, differences in net production were due, in one case to differences in leaf biomass, in another case to leaf efficiency, and in two cases to a combination of the amount and efficiency of leaves. There could be other combinations of the causal elements. The first example suggests that higher production could be obtained by increasing leaf biomass either as a result of keeping a higher relative stand density or by other means. The second example indicates that leaf efficiency changes with age. The third and fourth examples suggest the processes by which soil fertility works on production and tree growth.

The final example is a group of plots with very similar amounts of aboveground net production (Figure 15). The small sample plots were located in a young natural regeneration of Pinus densiflora and were felled and measured in November 1968, March, April, October and November, 1969. The slight differences in net production cannot be related to either the amount or the efficiency of leaves taken independently but leaf efficiency decreased with increasing leaf biomass and the two

Table 3.--Efficiency of leaves of upper crown and undergrowth (Satoo 1973).

CANIPY SPECIES	LEAF AREA INDEX OF CANOPY	LEAF EFFICIENCY	
		CANOPY	UNDER-GROWTH
		t/ha/yr	
Larix leptolepis	4.3	2.95	1.04
Metasequoia glyptostroboides	8.5	1.90	1.04
Cinnamomum camphora	4.9	3.38	0.89
Betula ermanii	2.9	1.92	0.52
do.	4.2	1.89	0.64

factors compensated each other to result minimal differences in net production. Leaf efficiency increased with the amount of new leaves as a proportion of total leaf mass. It is well known that photosynthetic rate decreases with leaf age. It has also been observed that leaf efficiency of plantations of Norway spruce in Japan was higher in stands having a larger proprotion of new needles to total needle biomass (Satoo 1971a).

Factors affecting leaf biomass will be discussed in detail later. Leaf efficiency seems to decrease with stand age and is higher on better sites or in fertilized forests.

There is little information on the leaf efficiency of the understorey in forests. Leaf efficiency of undergrowth is lower than that of the overstorey tree layer due to the interception of radiant energy by the upper crowns (Table 3).

Leaf Efficiency in Different Forest Types and Different Species

Leaf efficiencies have been calculated from all available data having values of both net aboveground production and leaf biomass and are arranged in the rank order of efficiency by species in Figure 16. Among coniferous forests deciduous species like larch have the highest efficiency, pines are intermediate and other evergreen conifers lowest. Differences between evergreen and deciduous broadleaved forests were slight with values very close to those of deciduous conifers. The rank order of leaf efficiency seems approximately inversely correlated with leaf biomass. The mean values of leaf efficiency of coniferous forests are plotted against their mean values of leaf biomass (Figure 17). As seen from the figure, leaf efficiency decreased with increasing leaf biomass and these two parameters were linearly related when plotted on a double logarithmic scale (Satoo 1971b). A similar linear relationship was reported for crop plants on a linear scale by Watson (1958) and for forests (including both coniferous and broadleaved) between leaf mass and logarithm of leaf efficiency by Yoda (1971). The decrease in leaf efficiency in forests with an increase in leaf biomass could be explained by a lower mean

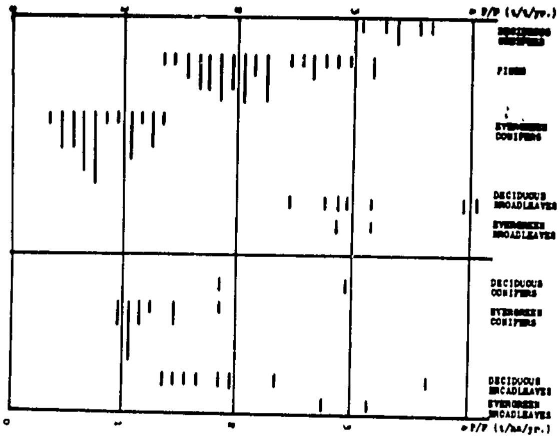

Figure 16.--Leaf efficiency of forests in Japan (Satoo 1973).

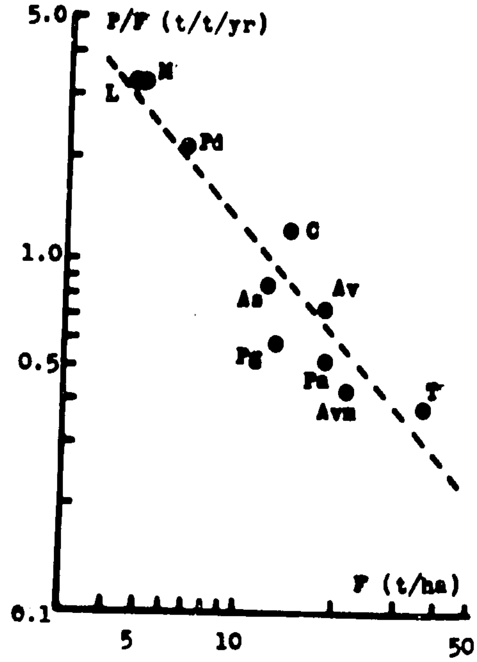

Figure 17.--Relationship between efficiency and amount of leaves of stands of different species of conifers (Satoo 1974d).
As: Abies sachalinensis, Av: A. veichii, Avm: a mixture of A. veichii and A. mariesii, C: Chamaecyparis obtusa, L: Larix leptolepis, M: Metasequoia glyptostroboides, Pa: Picea abies, Pg: P. glehnii, Pd: Pinus densiflora, T: Thujopsis dolabrata.

photosynthetic rate of their canopies due to reduced light intensity in the lower canopy and also by an increase in average leaf age, therefore, by a decrease in photosynthetic rate.

AMOUNT OF LEAF

As the analysis in the previous chapter, amount of leaf plays an decisive role in determining net production of the overstorey tree layer of forest in many of the cases. The efficiency of leaves involves many processes and it can not be easily analyzed by simply investigating the implications of individual factors, and informations on them are very limited. As considerable amount of data on the amount of leaves in many kinds of forests have been accumulated, discussion will be given here on the factors influencing the amount of leaves.

Moller (1945) reported that leaf biomass of a closed forest is independent of various factors, including site index, age and stocking. Monsi and Saeki (1953) pointed out that as leaf mass in a plant community increases, consumption of photosynthate by leaf respiration increases in proportion to leaf mass whereas total photosynthesis by leaves reaches an asymptotic upper limit dependent on radiation intensity, thus there is an optimum leaf mass for maximum production. The possible existence of an upper limit of leaf mass for the crown canopy of a given species or a group of ecologically similar species was discussed by Satoo (1952, 1955, 1965). Let us examine the relationships between leaf biomass and various factors.

Age -- When a forest is clear-felled and replanted, or regenerate on open ground, leaf biomass starts at zero and increases gradually with age until the crown is closed. For closed forests many different trends and patterns are reported. Moller (1945) reported that leaf biomass of forests of European beech and Norway spruce increased slightly with age, but according to Vanselow (1951) leaf biomass of Norway spruce forests increased up to a maximum value at about the 40th year and then decreased greatly. Kittredge (1944), using allometric equations expressing the relationship between stem diameter and leaf mass on tree in conjunction with yield tables, reported that leaf biomass of ponderosa pine forests reached their maximum at the 40th year and then gradually decreased, but in another table in his paper showing values of a simila nature, leaf biomass increased with age up to the 69th year. In forests of Scots pine (Ovington 1957), a mixture of Abies veitchii and A. mariesii (Oshima et al. 1958), Cryptomeria japonica (Ando et al. 1968), and Pinus densiflora (Hatiya and Totiaki

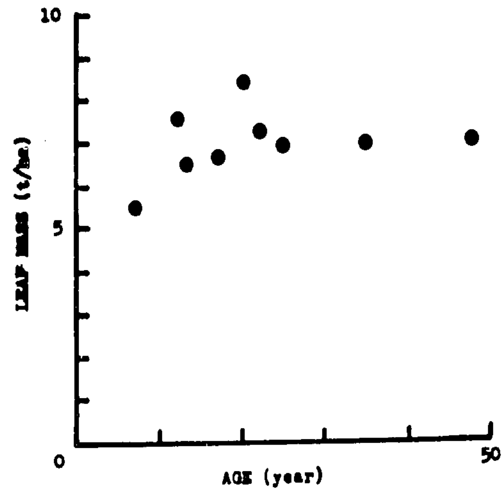

Figure 18.--Change of leaf biomass with age in the canopy of woodlands of Pinus densiflora (from a table in: Hatiya and Totiaki 1968).

1968) leaf biomass increased until a maximum value was attained at an age dependent on the species and then decreased a little to maintain a steady state for a long time. Figure 18 shows this pattern in a group of Pinus densiflora woodlands as an example. Whether the slight decrease in leaf biomass after an age of maximum foliage development is real or not is subject to doubt owing to the inaccuracy of foliage biomass estimations. It is also necessary to take into account the change of relative stand density with age. Most of managed forests have a tendency to a lower relative stand density as a result of thinning (Sakaguchi 1961). Data so far available on the leaf biomass of forests of Cryptomeria japonica with relative stand densities above 0.4 did not show any clear change of leaf biomass with age (Satoo 1971b). As long as stand density is high enough it is known that even very young experimental populations of tree species have leaf biomasses comparable to mature forests (Tadaki and Shidei 1960, Kawahara et al. 1968, Satoo 1968).

Site Quality -- Moller (1945) reported that among forests of European beech and Norway spruce there was no difference in leaf biomass among forests on site qualities ranging from site index 1 to 4 in the Danish yield table. However, Kittredge (1944) suggested that forests on better sites have larger leaf biomass. Data so far available on leaf mass of forests of Cryptomeria japonica with relative stand density above 0.4 increased with increasing relative stand density (Satoo 1971b). Management practices for Cryptomeria forestry in Japan vary considerably among regions. Data from three regions having different management practices are illustrated

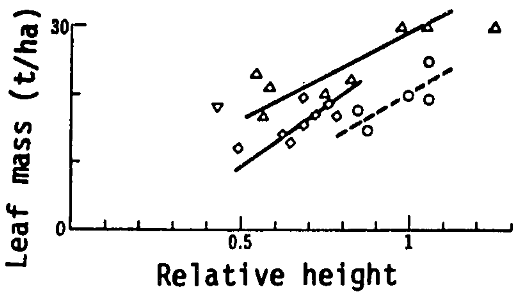

Figure 19.-Relationships between site quality expressed as relative height and leaf biomass of canopy of plantations of Cryptomeria japonica of different regions (Satoo 1966). circles: Yosino, triangles: Akita, squares: Kumamoto, broken line: statistically not significant.

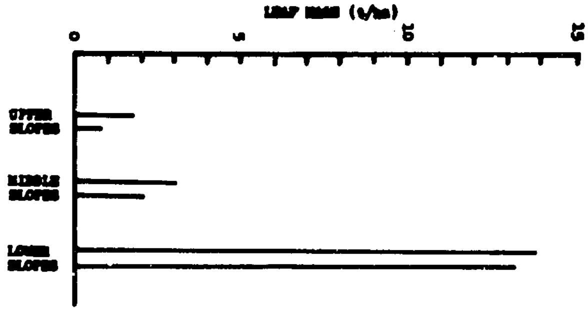

Figure 20.--Canopy leaf mass of plantations of Cryptomeria japonica with a wide spacing on a steep slope (from a table in: Hatiya and Ando 1965).

in Figure 19. In Yosino, central Japan, trees are planted with very narrow spacing and thinned intensively. In Kumamoto , southern Japan, selected cultivars are propagated exclusively by means of cuttings and used as planting materials. They grow very uniformly. In Akita, northern Japan, management practices are less intensive than in the other two regions. In each region leaf biomass increased with site index. Stands with relative stand density between 0.4 and 0.6 selected from data of Mori et al. (1969) showed a similar trend. However, data of Hatiya et al. (1966a) treated in the same way showed that leaf biomass increased with increasing site index among forests on poor sites but the increase was very slight among stands on better sites. Among Norway spruce stands planted in Japan, leaf biomass did not show a systematic trend with site index (Satoo 1971a). All existing data on leaf biomass of Pinus densiflora treated similarly to that for Cryptomeria (Satoo 1971b) showed that the upper limit of leaf biomass increased with increasing site index, but the lower limit was independent of site index (Satoo 1968). While there are conflicting conclusions based on existing information it may be said that leaf biomass is larger on better site at least until more definitive studies are completed.

Fertilization -- In spite of the fact that there is a trend towards increasing fertilization of forests all over the world and many fertilizer experiments exist, information on the effect of fertilization on leaf biomass of forest is very limited. Heilman and Gessel (1963) found higher foliage mass on Pseudotsuga menziesii fertilized with nitrogen. Madgwick et al. (1970) reported that potassium fertilization of Pinus resinosa increased needle longevity but not annual needle production. Kabaya (unpublished) found that leaf biomass of a sand dune plantation of Pinus thunbergii increased after applying large amount of fertilizers (Table 2).

Position on a Slope -- It is often observed that soil properties and growth of trees differ greatly between the top and bottom of a steep slope. On the upper part of the slope a dry soil type develops and tree growth is poor while on the lower part of the slope soils are moister with a rich accumulation of organic matter and growth is good. These differences are also reflected in leaf biomass as in the case of site qualty and can often be seen especially in plantations which have not yet closed. Figure 20 shows an extreme example of a plantation of very wide spacing in which this trend is very clear.

Altitude -- Many factors affecting growth are severe at higher elevations and leaf biomass of forest under these conditions is small. This trend has been reported for Norway

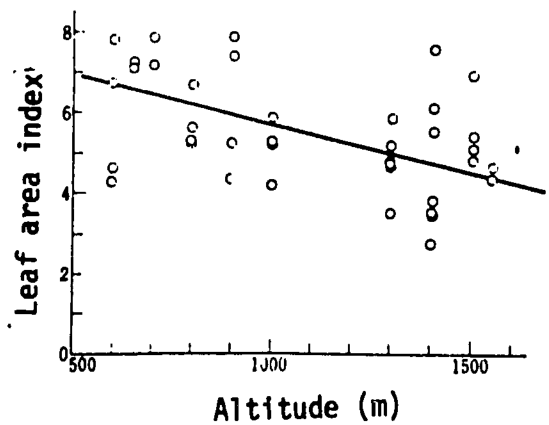

Figure 21.--Leaf area index of canopy of climax beech (Fagus crenata) forests in relation to altitude (Maruyama 1971).

spruce forests of Switzerland (Burger 1941) and for beech forests in Japan (Figure 21).

Stand Density -- Stand density of a forest can be controlled by the initial number of trees planted or by the number of trees removed by artificial thinning or by competition resulting in death of suppressed trees. There is no doubt that in young stands which have not fully closed canopy, leaf biomass is larger in denser stands. Thinning results in a decrease in leaf biomass by an amount equal to the leaf mass of the thinning. Leaf mass then increases gradually to reach the level before thinning. Moller (1945) reported that in European beech stands which had been differentially thinned to basal areas ranging from 17 to 35 at age 50, leaf mass was unaffected by thinning intensity after recovery from the effects of thinning was complete. Eighteen years after thinning, plots of eastern white pine, Pinus strobus, planted in Japan which had been thinned by removing 0 to 70% of their volume, no difference in leaf biomass due to the intensity of thinning was observed (Senda and Satoo 1956). Many spacing experiments show similar trends. No difference in leaf biomass due to the differences in stand density was found in experiments on Jack pine (Adams 1928) and Pinus densiflora (Satoo et al. 1955, Senda et al. 1952). In very young experimental plots, 4- and 5-year-old, leaf biomass was not different from closed 13-year-old stands provided that they had a high stand density (Satoo 1968). A larger foliage biomass in heavily thinned stands having low stand densities may be inferred from their greater crown depth but this inference is incorrect since differences in crown depth only compensate for differences in spacing so that leaf biomass was similar in stands of very different densities having crown lengths ranging from 36 to 64 % of height (Satoo et al. 1955). However, there are many reports stating that leaf biomass is larger in forests having higher stand density. Sakaguchi et al. (1955) found this trend amonsg young natural regenerations of Pinus densiflora. Leaf biomass is correlated with relative stand density , as shown in Figure 22. A similar trend was found when existing data on the leaf biomass of Cryptomeria plantations from different sources were treated in the same way (Satoo 1971b). Thus two apparently contradictory effects of density may be seen. Leaf biomass may be independent of stand density or leaf biomass may increase with increasing stand density. The first trend has been found only in experimental plots with differences in spacing or thinning and these plots all have high relative stand density. The second trend is found generally among forests managed for timber production and these forests have widely different relative stand densities. In the spacing experiment of Pinus densiflora (Satoo et al. 1955), for example, all plots had a relative stand density

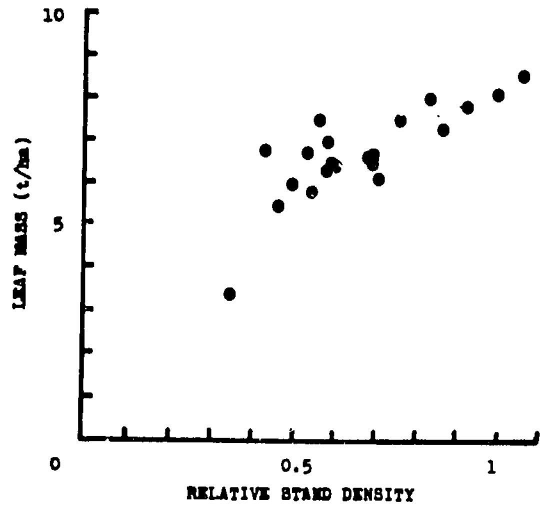

Figure 22.--Relationship between canopy leaf mass of 55-year-old woodlands of Pinus densiflora and relative stand density (based on a table in: Mori et al. 1969).

above 0.7. In a five-year-old experimental plots , leaf biomass increased rapidly up to a stand density of 30,000/ha where leaf mass per unit ground area was very close to 15-year-old plots with high relative stand densities (Satoo 1968). Among managed forests of Cryptomeria, leaf biomass increased very rapidly up to relative stand density of 0.4 above which the slope of the trend decreased (Satoo 1971b). From these two apparently contradicting conclusions, it may be said that leaf biomass is not affected by stand density as long as relative stand density is high but it increases with increasing stand density if relative stand density is not high enough. In other words, leaf biomass is affected by relative stand density rather than by absolute stand density, and forests managed using general forestry practice have relatively low relative stand densities.

Silvicultural System -- Burger (1942) reported that leaf biomass of a selection forest of Norway spruce and European fir did not differ from that of single-storeyed forest. The leaf area index was 10 in the selection forest compared with 11 in the single-storeyed forest. Selection forests may appear to have a larger leaf biomass as their crowns are deeper as a result of the complexity of their crown structure.

Region -- Cryptomeria forests in Japan are managed in quite different ways from region to region. However, no differences in leaf biomass were found among regions when stands of relative density above 0.4 were compared (Satoo 1971b).

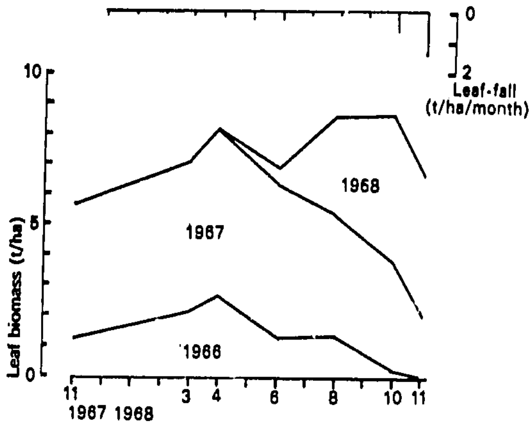

Figure 23.--Seasonal change of crown leaf mass in a 20-year-old woodland of Pinus densiflora (Satoo 1971b).

Seed Provenance -- Burger (1941) reported that seed source did not affect foliage biomass of stands of Norway spruce grown from seeds collected from forests at different altitudes.

Change of Weather -- According to Moller (1945), leaf biomass of beech was unaffected by differences in weather over a 3-4 year period. This finding was confirmed by Olson (1971) for Liriodendron tulipifera but is in disagreement with the litter fall data of Miller and Hurst (1957) and Saito (1974).

Air Pollution -- It has been observed that leaf and leaf litter production of plantations of Chamaecyparis obtusa near a source of sulfur dioxide was smaller than on more distant forests (Satoo, in press).

Seasonal Change -- After flushing in spring, leaf biomass of a 3-year-old experimental population of Ulmus parvifolia increased until May and then gradually decreased until leaf fall in the autumn (Tadaki and Shidei 1960). No comparable data is available from mature deciduous broadleaved forests. There is a possibility that there are some differences in the pattern of seasonal development between very young and mature stands. In most of evergreen conifers old leaves die and fall as new leaves are produced and develop. Figure 23 shows the seasonal change of biomass and age composition of foliage on a 20-year-old woodland of Pinus densiflora. Similar trends are reported on a woodland of the same species (Hatiya et al. 1966b) and Cryptomeria plantation (Ando and Takeuchi 1968). General trends may be observed in spite of sampling errors.

Species -- Leaf biomass data for forests of many species of trees in Japan are shown as dry weight in Figure 24. The values shown are

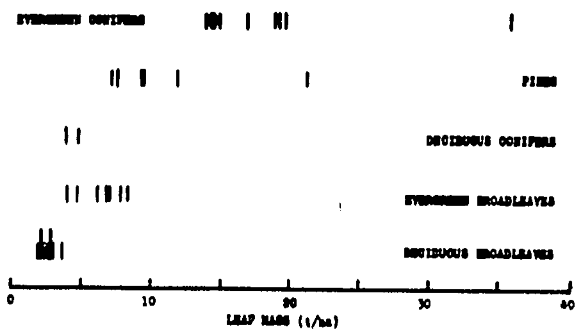

Figure 24.--Canopy leaf mass of forests of different groups of species (Satoo 1973). bars represent mean values for species.

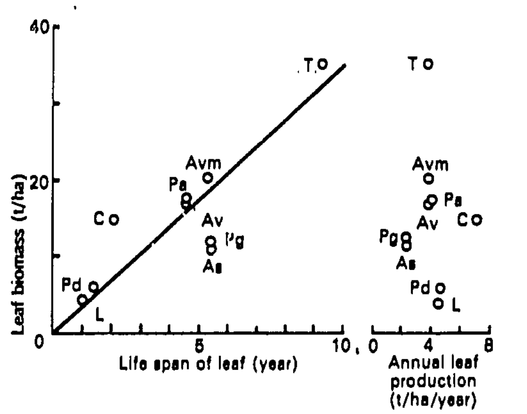

Figure 25.--Canopy needle biomass of stands of different species of conifers in relation to average life span and annual production of needles (Satoo 1971b).
As, Av, etc: see the caption of Figure 19.

mean values for existing data for every species. Leaf biomass differs not only by species, but also by the group of species. Species having similar ecological characters seems to have similar leaf biomass. Leaf biomass of birches and beeches of Japan and Europe was compared. The data for each genus are similar for these widely separated geographical locations even though the species involved are different (Satoo 1970). The leaf biomass of stands of conifers differs widely by species, with a maximum nearly ten times the minimum in strong contrast to the very narrow range of leaf biomass of deciduous broadleaved forests. Leaf biomass (F) can be divided into the average life span of leaf (F/dF) and annual leaf production (dF), as

$$F = dF \times F/dF$$

F/dF is calculated by dividing F by dF which may be estimated for each stand. In Figure 25, mean leaf biomass is plotted against both the mean life span of leaves and the mean annual leaf production for each species. Leaf biomass increases linearly with average life span, whereas total leaf biomass and annual leaf production are uncorrelated. Annual leaf production does not differ greatly among species and average annual leaf production for all species examined was 3.5 t/ha. This trend was not changed by the addition of a value for a stand of Metasequoia glyptostroboides (Satoo 1974b). The large differences of leaf biomass among species were mainly due to differences in average life span of leaves but not to any difference in the ability to produce leaves (Satoo 1971b). Average life span of leaves seems to be longer in more shade-tolerant species. Monsi (1960) pointed out that life span of leaves plays a significant role in shade tolerance from the viewpoint of economy of photosynthate.

SILVICULTURAL IMPLICATIONS

In the traditional silviculture, the main objective has been production of wood of stem. However, technology of silviculture has changed by increasing demand of wood as the source of cellulose and decreasing use of wood for construction and housebuilding. For housebuilding and other construction works, quality of wood like dimensions, mechanical properties, color and grain, etc. has been important, and, accordingly, silvicultural technology was focused on operations like thinning and pruning to control ring width, taper and knotlessness beside the works to improve growth. If the accumulation of energy and organics is the main objective of growing tree, these considerations in silvicultural practices will lose their significance, as in the forestry to produce industrial raw materials and fuels. Further, stem wood would not be the sole objective and net production itself will become the objective of silvicultural practices. In this case, maintaining the leaf biomass as large as possible will be one of the measure to attain higher rate of net production. For example, by keeping relative stand density as high as possible, larger leaf mass will be maintained and hence the higher rate of net production.

Of net production, branches and leaves are shed relatively earlier but most of stems remains until the time of harvest, and represent the largest part of standing crop. Hence, the production of stem wood remains as important as in the traditional silviculture, so, an increase of distribution of net production into stem wood will be one of the measures to increase the accumulation of energy and organics. For example, distribution of net production to stem is larger in denser stand when relative stand density is high enough. The original spacing and thinning regime which compose the whole cycle of stand density control will be modified from the present one, though considerations of snow and wind damages are necessary.

By complete utilization of aboveground net production, the yield will increase but the price per unit weight will be lower compared to the case when only stem wood is harvested. The lower price of products requires more advanced mechanization especially of harvesting, and silvicultural technology will have to be modified so as to facilitate mechanization of harvesting. However, mechanization of harvesting will easily bring about the larger unit of harvest, which is represented by large area clear-felling in pursuit of the merits of scale. In many countries the land allotted to forestry is marginal land including steep slopes. Large area clear-felling on steep slopes accompanies many problems related to the productivity of soil such as washing away of fertile surface soil and erosion. As a highest rate of net production appears in a relative young age of stand (Figure 3), rotation will become shorter, as many of pulpwood plantations are now. The utility of forest to man other than production of energy and organics, such as water production and amenity values depends largely on biomass and production of leaf. Large area clear-felling and shorter rotation bring about the space or time period with minimal biomass and these kind of utilities of forest will be lowered. It is probable that leaves will be harvested together with stems and branches for utilization and also for the sake of increasing the efficiency of logging. Operations of whole tree logging for the purpose of the latter is practiced in many

Table 4.--Estimates of export of nutrients from conifer plantations by clear-felling (modified from Tsutsumi 1962).

	CRYPTOMERIA JAPONICA, 40-YEAR-OLD			*PINUS DENSIFLORA*, 43-YEAR-OLD		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
amount of nutrients	kg/ha					
in bole	275	19	255	235	59	117
in others	289	53	240	187	37	106
return by litterfall	495	88	340	328	69	206
total uptake	1060	160	835	750	164	429
export of nutrients by harvesting	% of total uptake					
only bole	26	12	31	31	36	27
total tree	53	45	59	56	59	52

forests. However, harvest of leaves increases export of nutrient elements from forest ecosystem and results impoverishment of soil. Calculation by Tsutsumi (1962) shown by Table 4 presents good examples. Tamm (1969) also presented example of loss of nutrient by whole tree harvesting. Fertilization to supplement these losses may be an answer in some situations, but evaluation of the consequence for the future tree productivity of the export of nutrients in harvested materials is an important task. Management of nutrient economy of forest will become an important branch of "energy silviculture". To utilize forests as a tool of accumulation of energy, like hydroelectric dams, it will be an urgent task to modify not only silvicultural technology to increase net production but also the technology to take out energy accumulated by them from the harvest to the final use. For this purpose development in sciences of forestry and forest products supported by researches based on a new standpoint is expected.

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THE ENERGY RELATIONSHIPS INVOLVED WITH THE USE OF MANGROVE FOREST ECOSYSTEM OF THAILAND FOR ENERGY AND ORGANICS[1/]

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Abstract. Mangrove forests are important sources of energy and organics reaching their maximum development and greatest luxuriance in Southeast Asia. The countries in this region especially in Thailand are attempting to maximize the use of their mangroves particularly for the production of forestry and fisheries. But it seems that at the present time the benefits derived from mangrove forests are small. Moreover, some countries make no use at all of their mangroves for lack of knowledge and technology. However, this regrettable waste of resources can be overcome if scientists pay serious attention to mangrove ecosystems and employ their knowledge in managing mangrove resources to the maximum without destroying the ecosystem. This will increase the energy resources available to the Southeast Asian countries, considered to be the region of the world best endowed with mangrove forests. Moreover, this will also contribute to mitigating the energy and food crisis the world is presently facing.

INTRODUCTION

The objective of this paper is an attempt to show the essential energy input/output relations when the mangrove forest is used for energy and organics. However, the mangrove ecosystem is quite complicated, unlike other forest ecosystems, since it consists of many kinds of aquatic plants and animals. Moreover, available data are limited and widely scattered. This paper is thus necessarily incomplete, but its substance may serve as a guideline in improving this ecosystem which is important because of its high productivity in energy and organics. We believe that scientists will be interested in the study, improvement and management of mangrove ecosystem so that it will be even more significant source for energy and organics in the future. Moreover, this paper will include data on various characteristics of the mangrove forests especially in Thailand, South and Southeast Asia.

Mangrove ecosystem is important source of energy and organics. Mangrove forest is one of the primary features of coastal ecosystems throughout the tropical and subtropical regions of the world, reaching its maximum development in Southeast Asia. It generally embodies two different concepts which firstly refers to an ecological group of evergreen plant species belonging to several families but possessing marked similarity in their physiological characteristics and structural adaptation to similar habitat preferences. Secondly, it implies a complex of plant community fringing the sheltered tropical shores. Such communities usually have a border of trees which are normally species of <u>Rhizophora</u> associated with other trees and shrubs growing in the zone of tidal influence both on the sheltered coast itself and inland lining the banks of estuaries (Du, 1962).

The importance of mangroves to the human population of many tropical countries is becoming better recognized. People particularly in Southeast Asia have depended on mangrove tree for many purposes including firewood, charcoal, timber and other minor products, e. g. tannin and wood tar. The significance of mangrove forest in fishery production has also been recognized. Many commercially important fishes, crabs, prawns and various kinds of molluscs use mangrove as nursery ground and also shelters during their juvenile

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stages. The potential of mangrove areas for aquaculture is gaining attention particularly in Thailand owing to the increasing demand for protein food sources and declining yield of marine fisheries. Moreover, mangrove forest still plays an important role in constituting alluvial plain, protecting land agaist tidal bore, cyclone as well as soil erosion.

MANGROVE FORESTS IN THAILAND AND ELSEWHERE IN SOUTH AND SOUTHEAST ASIA

It is well-known that mangroves reach their maximum development and greastest luxuriance in South and Southeast Asia, Indonesia and Borneo (Macnae, 1968). Therefore this part will discuss the extent and importance of mangrove forests of some countries in these regions so that readers may envision potential uses whether in terms of energy or organics. The discussion will not be too detailed since very little relevant data in these countries are available, but such information may serve as a guideline in the development, management and study of the mangrove ecosystems in these countries in order to make maximum use of their energy and organics without destroying them.

Thailand

The mangrove forest covers an area to be approximately 312,700 ha of which 63 % is on the west coast (Vibulsresth et al., 1976) about 178,764 ha is under the management of the Royal Forest Department (Boonyobhas, 1975). The major uses of mangrove forest are sustained forestry, fisheries and aquaculture. Some areas were converted to fish pond, shrimp farm, salt pond and agricultural land.

Australia

Mangroves occur as far south as Corner Inlet, Victoria on the east coast. The richest mangroves are found in Queensland (Clarke and Hannon, 1967). No data on definite area of the country covered by mangrove forests. The utilization of mangroves are commercial fisheries breedings and feeding ground especially for oyster culture, sport fishing, subsistence collecting and fishing.

Bangladesh

Mangroves occur over the coastal region, in south coast Sunderbans, especially Khulna and Patuakhali and southeast coast. The richest mangrove forest is covered·the area in Sunderbans. The major uses are forest products, e. g. charcoal and timber, capture fisheries and aquaculture (Alim, personal communication). No publication recorded the definite area covering by this type of forest in this country is available.

India

The area covered by mangrove forest is approximately 700,000 ha (Sidhu, 1963). It occurs along the west coast and east coast with abundance in western Sunderbans. The uses of mangrove in this country are mainly forest products, capture fisheries, and some areas are used for tiger and crocodile conservation.

Indonesia

Mangrove forest in Indonesia is estimated to cover a total area of approximately 3.5 million ha (Sukardjo, 1978). The greastest extent is found in Sumatra, Kalimanton and Irian Java. In Sumatra it occurs along the east coast, from Aceh in the north to Lampung in the south. The major uses are the production of forestry and Fisheries. Someparts of mangrove forest are converted to fish pond and agricultural land.

Malaysia

The mangrove forest of peninsular Malaysia covers an area approximately 110,800 ha, almost all occupying the west coast (Watson, 1928). The mangrove is managed for sustained yield forestry, sustained for shoreline and river bank protection and also capture fisheries. In someparts of mangrove forest, extensive development for agriculture was made.

Papua New Guinea

The largest area of mangrove locates in the Gulf Province stretching from the Omati River in the west to the Vailala River in the east with a frontage of about 130 km. Liem and Haines (1977) estimated the Gulf Province Forests including mangrove swamp, mixed mangrove swamp forest and mixed mangrove/Nypa swamp to be approximately 321,600 ha. The economic importance of mangroves are building material and fuel, subsistence and small scale commercial fishing, subsistence wildlife utilization and prawning industry.

Philippines

The occurrence of mangrove forest is confined in certain coastal stretches, especially on sheltered tidal flats. The total area is about 251,577 ha (Arroyo, 1978). The mangrove forest in this country is managed for forest products for export and also for local use, capture fisheries and fish pond.

Singapore

Mangrove forest is now extremely limited in extent owing to the land reclamation schemes, only a small area remains on the coastline at the straits of Johore (Johnson, 1978).

The use of mangrove products is very limited only for the firewood by the local people. Mangrove charcoal is imported from neighbour countries.

South Vietnam

The richest mangrove forest in SVN covers an area around the south tip of the country at the Ca-Mau Peninsula, Rung-Sat between Saigon and Vung-Tau, and along the east coast near cam-Ranh Bay (Zinke, 1974). Rollet (1962) estimated the mangrove area by using aerial photography taken in 1952-1953 to be approximately 290,000 ha. The major uses are forest products, e. g. timber and charcoal and capture fisheries. Some areas are converted to agricultural land.

From this fundamental information we can see that there are extensive mangrove forests in South and Southeast Asia. There are also many countries possessing mangrove forests which cannot be discussed here for lack of data, e. g. Burma, Pakistan and Sri Lanka. The efficient exploitation of the energy from the mangrove forests in these countries remains unsatisfactory because of the lack of basic knowledge on mangrove ecosystem.

ECOLOGICAL STRUCTURE AND FUNCTIONING OF MANGROVE FOREST ECOSYSTEM IN THAILAND

Of the countries in Southeast Asia, Thailand probably makes the most use of the mangrove forests. Efficient exploitation of the energy and organics from the mangrove forest depends on the knowledge of their structure and functioning. However, in general the structure of the mangrove forest in Thailand differs little from other countries in the region. The most obvious difference lies in their functionings, e. g. growth, regeneration and productivity. Details and data on the characteristics of the structure and functioning of mangrove forest particularly in Thailand will be discussed in this part, although data are regrettably very limited.

Structure

Mangrove forests are generally composed of species numbering 20 to 40 belonging to several unrelated families but possessing similar physiological and structural adaptations with similar habitat preference (Haig *et al*., 1958). Watson (1928) listed some seventeen "pricipal" and twenty-three "subsidiary" species in the mangrove forest on the Malayan coast.

In Thailand, more than 27 genera of trees and other plants are commonly found in the mangroves. Among these genera, *Rhizophora* is the most abundant and has a widest geographical distribution (Aksornkoae, 1975).

In most mangroves, different species dominate certain bands of zones which are clearly delimited from the others. This characteristic zonation pattern results from differences in the rooting and growth of seedlings of the competitive adventages which is species has along the gradient from below the low water to above the high water lines (Kuenzler, 1968). However, tne factors influenced the zonation of mangrove species are frequency of inundation (Watson, 1928), soil and water salinity (de Hann, 1931; Macnae, (1968), drainage and soil moisture (Thom, 1967). Aksornkoae (1976) described the mangrove in southeast Thailand that the community structure varied from the edge of the estuary to inland sites, with *Rhizophora apiculata*, *R. mucronata* and the palm, *Nypa fruticans*, the dominant species along estuary and channel edge. *Avicennia* and *Bruguiera* associated with *Rhizophora* but they formed a more distinct zone further inland. On areas adjacent to the *Avicennia* and *Bruguiera* zone which have drier soils and are less subject to tidal inundation, *Xylocarpus* and *Excoecaria* become the dominant species. Within this zone, *Ceriops* and *Lumnitzera* are usually found to colonize those areas with a low topographic relief and soils high in clay content. *Melaleuca* reaches its highest dominance further inland on drier and more elevated sites which are less subject to tidal flooding. The fern, *Acrostichum aureum*, occurred throughout the mangrove area but was most dense on disturbed sites. The Shannon index for species diversity was found to be 0.88 which is relatively higher than diversity value (0.41) of the mangrove stand in Florida (Lugo and Snedaker, 1973). The stand-volume is approximately between 180-240 m^3/ha.

Functioning

Annual phenological cycle

In Thailand, there is at present limited data on the phenological cycle of the mangrove species. Knowledge on flowering, fruiting, leaf shedding, the production of new leaves and growth periods of variouse plant species and how these phenophases relate to environmental factors are still incomplete. However, a few studies on these subjects have been done only for *Rhizophora*, a dominant and valuable species in mangrove forest. Dun-Indr (1976) reported that *R. mucronata* showed heavy flowering in October and viviparous fruits appear in November to December. Fruits start falling in February and continue through September with a peak fruit fall in April to May while flowering of *R. apiculata* takes place in

November with heavy flowering in December to January and the fruits fall in February through September with a peak in April. Raksakaeo (1974) also recorded that minimum flowering age of Rhizophora species is 6 years, at this age, the circumference at 10 cm above root collar was approximately 20 cm.

Regeneration

The productive ability of mangrove species under natural condition is high. Rhizophora, Bruguiera, and Ceriops are viviparous, germinating before falling, Avicennia semi-viviparouse. Other species, e. g. Xylocarpus and Lumnitzera are not vivipary. Mangrove species normally have high light requirement for regeneration and growth (Macnae, 1968; Du, 1962). Hence regeneration under shade is poor. Aksornkoae et al. (1978) recorded that the seedlings of mangrove species varied from the edge of the estuary to inland sites. The seedlings of R. apiculata and R. mucronata were highest at the edge of the forest with the average values of 2163 and 605 seedlings/ha respectively and tended to decline to inland areas. Bruguiera and Avicennia seedlings covered the area closed to the forest margin with values of 1270 and 282 seedlings/ha respectively while Xylocarpus showed low density at this area but high at the landward side approximately 320 seedlings/ha. Ceriops and Lumnitzera also showed high density at landward side with the values of 1033 and 128 seedlings/ha respectively. Melaleuca leucadendron seedlings occupied on landward side where the area becomes flooded during only extreme high tide with the density of 339 seedlings/ha. In mangrove forests where areas were disturbed or clear cut are mostly occupied by the fern, Acrostichum aureum. The dense growth of the fern may interfere the natural regeneration.

Growth

Few studies exist on the growth characteristics of mangrove seedlings. Aksornkoae et al. (1978) found that regeneration under the natural forest canopy, the total annual height-growth of R. apiculata, R. mucronata, B. gymnorrhiza were 44, 38 and 39 cm respectively. They also reported that the total annual height-growth of R. apiculata, R. mucronata and B. gymnorrhiza planted under natural forest canopy were approximately 38, 28 and 39 cm respectively. However, these growth rates were lower than the annual height-growth was found by Aksornkoae (1975) who planted species of R. apiculata, R. mucronata and B. gymnorrhiza on the cleared area and recorded the total annual height-growth to be about 56, 58 and 54 cm respectively. The heigh-growth of Avicennia alba, Ceriops sp and Lumnitzera seedlings under the natural mangrove canopy after one year growing showed slowly growth with the total height of 6, 11 and 10 cm respeotively (Aksornkoae et al., 1978).

In the natural forest, Boonyophas (1975) recorded the annual girth increment of Rhizophora species in south Thailand to be in between 1.2 to 2.2 cm. The growth of different aged Rhizophora plantations with spacing 1 x 1 m was studied by Aksornkoae (1975). He reported that the average diameter at breast height (dbh) of the 3, 6, 9, 1., 12, 13 and 14-year-old plantation were 0.44, 3.21, 4.94, 5.28, 5.88, 6.37 and 6.97 cm with the total height of 1.9, 4.3, 6.6, 8.2, 9.2, 10.3 and 12.3 m respectively. No data at present, are available for growth increment of other mangrove species both in natural forest and plantation.

Mortality

Only a few authors have studied mortality of mangrove species. Aksornkoae et al. (1978) found that the mortality for seedlings of R. apiculata, R. mucronata, B. gymnorrhiza, A. alba, Ceriops sp and Lumnitzera under the natural mangrove forest canopy observed after a one-year growing period were 52 %, 41 %, 50 %, 80 %, 56 % and 71 % respectively. They also reported that the mortality of R. apiculata, R. mucronata and B. gymnorrhiza planted with spacing 1 x 1 m under the mangrove forest canopy from the estuary edge to inland site were 81 %, 18 % and 80 % respectively which showed very high mortality rates as compared to the mortality of these three mangrove species planted on the cleared area while the mortality rates were only 5 % for R. apiculata, 4 % for R. mucronata and 9 % for B. gymnorrhiza (Aksornkoae, 1975).

Biological productivity

Mangrove ecosystem is one of the important type in the tropical and subtropical regions which gives a high productivity. Very little work has been done on mangrove productivity. Available data on productivity are obtained by the biomass measurements. Christensen (1978) studied in a mangrove in south Thailand particularly R. apiculata and found that the total biomass above the ground of the 15-year old stand to be 159 metric tons dry matter/ha. The annual increment in the form of trunks, branches and prop roots was estimated to be 20 metric tons/ha/yr during the last year of growth. The average biomass above ground of the 11 to 14-year old mangrove plantation was studied by Aksornkoae (1975) to be approximately 155 metric tons dry matter/ha with an average annual increment of 24 metric tons/ha/yr (calculated from the biomass values).

ENERGY RESOURCES OF MANGROVE FOREST ECOSYSTEM IN THAILAND

Mangrove forests possess many natural resources compared to inland forests since the former are an agglomeration of many animals and aquatic plants. We believe that the amount of energy to be derived from mangrove ecosystem is no less than from other forest ecosystems, and probably more. But certain data deficiencies, e. g. the amount of solar radiation received by mangrove forests, and the energy derived from various aquatic animals, prevent us from estimating the energy input and output in the mangrove ecosystems. However, generally speaking, the energy resources from mangrove forests on which we have data may be said to come from two sources: forestry and fisheries. Very little energy is derived from rice fields within mangrove forests and in fact no data are available for the moment.

Forestry

Mangrove forests in Thailand have been managed by the Royal Forest Department. Economically, the important species of the mangrove forest, e. g. R. apiculata and R. mucronata are mainly exploited for the production of charcoal and firewood both domestic use and exportation. The remaining species are mostly used for firewood. The utilization of mangrove trees was never meant for timber production. However, the use of timber then and now is strictly used by the local people for housing construction, but mostly low quality. The timbers are recently used for props mainly for ore rinsing trough, but this purpose is confined to only at the coastal area where the mining work is operated. The consumption of mangrove species for foundation piling post is also minimal. The extraction of tannin, crude methanol, acetic acid and wood tar from the mangrove trees has been done by the local people but they are of little quantity. Recently, the uses of mangrove trees for these purposes are supported by the government to be important industry.

Management and silvicultural system

The Royal Forest Department of Thailand has changed the cutting system for the mangrove working plan from "Shelterwood Cum Minimum Girth" system since 1968 to a "Clear Cutting in Alternative Strip" system. Details in Shelterwood Cum Minimum Girth System will not be discussed. However, it was found out that the management under this system, supervision and control of rule on shelter trees posed difficulty on limited officials in the field to properly enforce and consequently mangroves in many areas were in the stage of deterioration not only from depletion of the stock but also the worsening of the site. Some areas were dried up and covered with undesirable undergrowth, so severe that regeneration of mangrove trees was prevented. Some areas were left with only a noncommercial trees.

At present, a "Clear Cutting in Alternate Strip" system is adopted. It is hopefull that under this system, supervision and control of cutting rules can easefully operate and finally the management in such a way of sustained yield could be obtained. Under this cutting system, the rotation is set at 30 years with the felling cycles of 30 years. The area is only divided into 15 annual coupes which only half of the annual coupe will be cut each year in alternate strips. The remaining strips would be cut in the next 15 years. In practice, felling will be made within the prior marked strip in the annual coupe. Cutting strip would be alternated with the retained strip. Within the cutting strip no seed trees or shelter trees will be left except valuable seedlings under 15 cm in girth at breast height. The strip will be at the angle about 45 degree to the tide or waterway with the width of 40 m. This operation will assist in natural regeneration in the cleared strip. However, the cleared strip will be inspected one year after harvesting to observe natural regeneration. If it is sufficient, no planting is needed. Only improvement felling and weeding will be made. But if it is insufficient, the supplement planting will be done in the blank spot.

Firewood and charcoal production

Firewood and charcoal are important sources of energy of the mangrove forest. They are derived from both natural forest and plantation.

Natural forest.- The total mangrove areas set aside under the definite working plan for the production of firewood and charcoal is approximately 178,764 ha. This area is divided into 310 felling series. The remaining area, 133,936 ha is either privately owned or reserved for public uses. However, some parts of the remaining area are planned to be managed for production of firewood and charcoal in the future.

Mangrove charcoal has been accepted to be a high quality heat producing fuel. The charcoal production from mangrove in 1971 reported by Chua-Intra (1976) was 740,000 m^3. It was found the weight of 1 m^3 of charcoal to be approximately 325 kg. Therefore, the production of charcoal in term of weight was 240,500 metric tons. This amount of charcoal was high as compared to the production in 1976 being 468,528 m^3 or 152,272 metric tons (Jitt, personal communication). From the study on the recovery rate of charcoal, it was found that recovery rate of charcoal was approximately 58 % by volume of the firewood (Bun-Indr, 1976). The selling price varies according to the sale methods and locations. In 1975, the average selling price at the charcoal burning areas was approximately \$ U.S. 21.0/m^3 of charcoal for domestic use and \$ U.S. 23.0/m^3 for exportation. A little lower price for the former than the latter is due to the container type. At present, the price seems to be higher than the previous time, but no data are available. It is believed that in the future the charcoal production will increase because of employing more research knowledge in managing mangrove resources, expanding mangrove plantation, developing technology of charcoal processing and also increasing manpower. No data on the use of mangrove trees for other purposes, e. g. timber, foundation piling post and firewood have been recorded.

Plantation.- Due to the specific need for fuelwood and charcoal to rural individuals and villages becoming increasingly at present, the Royal Forest Department has planned to establish mangrove plantation particularly R. apiculata and R. mucronata to subsidize the firewood and charcoal which are insufficient obtained only from natural forest. In 1978, plantation was planned to be established approximately 80 ha annually for each mangrove unit. At present, there is 34 Mangrove Control Units located throughout the mangrove area in the country. In the past, the mangrove plantation has been established since 1960 in the disturbed mangrove area. So far up to 1978 approximately 1,280 ha has been planted. Although 15 year rotation was set for cutting cycle, the plantations over 15 year-old have not yet been harvested.

However, if the management is carried out as planned, it would be roughly estimated from the annual planting area, growth rate of plantation and the application of a Clear Cutting System with 15 year rotation that the mangrove wood will be harvested about 598,400 m^3 per annum. The charcoal production from this amount of wood will be approximately 347,072 m^3 equivalent to 112,798 metric tons per annum. This estimation is based on the growth rate of the 14-year old plantation planting 1 x 1 m spacing which the wood production is 220 m^3/ha (Aksornkoae, 1975) and the total planting area of about 2,720 ha per year.

Fisheries and Aquaculture

Fishery production from the mangrove ecosystem cannot be calculated because this type of fishery is a subsistence activity. However, it is accepted that the mangrove forest is a food source for various aquatic animals, e. g. fish, shelfish and crustaceans. The young of the many kinds of prawns must live in the mangrove forest for at least two or three months, leaving only when they are mature. Hard data on fishery production have never been recorded. However, it can be concluded that the mangrove forest is an important source of energy for fishery production for rural people and those living near the forest.

In regards to aquaculture, National Research Council of Thailand (1977) reported that at the present time the area of approximately 19,064 ha has been used for coastal aquaculture which includes shrimps, shelfishes, and sea basses. A total yield was obtained about 37,355 metric tons in 1976. The inventory of the coastal zone of the Department of Fisheries in 1976 revealed that the mangrove area or the tidal zone was suitable for shrimp culture approximately 62,884 ha with a yield per ha estimated to be 196.5 kg. Therefore, if the shrimp farming area expands as planned and the culture can be made once a year, the total output would be 12,356.7 metric tons per annum. However, shrimp culture in mangrove forest would be carefully made without destroying the ecosystem.

ORGANIC RESOURCES OF MANGROVE FOREST ECOSYSTEM IN THAILAND

The mangrove forest ecosystem is believed to be an important source of organics, large in quantity when compared to other forest types. This is so since mangrove forest sediments agglomerate organic matter. Our study reveals that these sediments contain approximely 26.5 % organic matter Aksornkoae et al. 1978, while the organic matter contained in the surface soil in dry evergreen forest is only 10 %, in hill evergreen forest only 11 % and in dry dipterocarp forest only 6 % (Khemnark et al. 1972). Mangrove forest contains such high organic matter because of the multiplicity of sources of organics in this forest, significantly including: litter, water and animals.

Litter

Litter is the important source of organic material in mangrove forest. Only a few investigations have been made on this subject. Aksornkoae et al. (1978) found in the mangrove forest in southeast Thailand, the total litter fall to be approximately 980 g dry wt/m^2/yr with the amount of the litter decomposition rate being about 500 g dry wt/m^2/yr. This amount of litter fall was high as compared to the mangrove forests in south Thailand found by Christensen (1978) to be 704 g dry wt/m^2/yr

(Pool and Lugo, 1973). There was no definite amount of litter decomposition rates recorded in both papers. However, in Florida, it was found that the rate was very high during the first 20 days and then gradually decreased.

Water

The rate of import, export and storage of organics in the mangrove forest is controlled by water particularly tides and runoff. This is due to in fact that mangrove ecosystem is open system connected to fresh water and/or terrestrial ecosystems and marine ecosystems. No data on input and output of organics in the mangroves from other ecosystems are available for the moment. Therefore, no discussion has been made on this subject.

Animals

The input and output of organic compounds in the mangrove forest from animals both benthic and pelagic sources is very diverse. Minute animals may be seen in samples from the surface layer on the mangrove sediment, e. g. flagellates, ciliates, nematodes and copepods. These animals will produce the organic material in the mangrove forest. Information regarding the quantity of this material being derived from these sources is not yet available.

Such macro consumers as mammals existing in mangrove area or migrating from other habitats also provide organics in mangrove forest. Certain kinds of birds, bats, primates, rodentia and canivora are commonly found in this region. Again, there is no data on this subject.

CONCLUSION

Even though this paper incompletely describes the essential energy input and output relations in mangrove ecosystems, it does reveal that they are high in yield and also important source for energy supply. Many Southeast Asian countries are attempting to maximize the use of their mangrove forests in the form of both energy and organics, especially in the rural areas which need energy, e. g. wood and charcoal for fuel and fishery production for food protein.

In Thailand, the production of charcoal from mangroves is in between 150,000 - 200,000 metric tons per year. No statistics on the use of mangrove trees for timber, firewood, foundation piling post, etc. have been recorded. The forest production will increase if the mangrove plantation program is successful.

Fishery production in the mangrove forest is a subsistence activity but high yield is obtained from aquaculture along the coastal zone estimated to be approximately 37,355 metric tons per year. In the future, shrimp culture is planned in the mangrove areas.

However, at the present time benefits derived from mangrove forests are small due to inadequate knowledge, especially regarding energy flows which have barely been studied. It is thus impossible to improve and manage this type of ecosystem to maximum benefit. Moreover, some countries make no use at all of their mangrove forests for lack of either knowledge or technology. This regrettable waste of resources can be overcome if scientists pay serious attention to mangrove ecosystem and use their knowledge in managing mangrove resources for both energy and organics to the maximum without destroying the mangrove ecosystems. This will increase the resources of energy and organics available to the countries of Southeast Asia, considered to be the region of the world best endowed with mangrove forests. Moreover, this will contribute to mitigating the energy and food protein crisis the world is presently facing.

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THE ENVIRONMENTAL CONSEQUENCES OF INTENSIVE FORESTRY AND THE REMOVAL OF WHOLE TREES

A. Carlisle and I.R. Methven[1/]

Abstract.--The report summarizes available information about effects of whole tree harvesting and short rotations upon the nutrient cycles of forests in North America, points out information gaps, and suggests future action. It is impossible to generalize about these effects; they are site and element specific. The effects should be considered in relation to forest management objectives and in the context of a resource use philosophy.

INTRODUCTION

The purpose of this report is to provide an overview of the impact of harvesting whole trees and use of short rotations for energy purposes in North America (United States, Canada and Mexico).

The original scope of the paper was very broad, including economic, social, wildlife, and soil impacts. It soon became apparent that to cover such a wide field in a short paper would mean resorting to superficial generalizations. Consequently, a decision was made to concentrate on the impact of harvesting for energy on soil fertility, soil being the ultimate resource. Unfortunately the authors were unable to obtain any data for Mexican forests.

The following report attempts to summarize the present situation, give examples, point out gaps, and prescribe for the future.

USE OF FORESTS FOR ENERGY

The success of plans to use the forests of North America on a large scale as a source of fibre for energy will ultimately depend upon environmental issues (Carlisle 1976).

Harvesting large amounts of fibre and conversion to liquid or gaseous fuels has been shown to be technically feasible, economically viable in some cases, and politically desirable. Harvesting forests on a large scale for energy, however, will not be practicable if it is found that too many demands are being made upon the forest environment, leaving a legacy of degraded soils to future generations. There is an urgent need to examine the biological feasibility of using forests for energy so that problems can be predicted and plans made to provide remedies.

Roundwood Harvesting

There is a great deal of information in the literature about the effects of conventional roundwood harvesting upon forest soils. Although there has been much controversy about the effects of such practices as clearcutting large areas, with consequence disturbance of water tables, wildlife, succession and aesthetic values, good forestry practice can overcome many of these problems. Where long rotations of 60 years or more are used, there is little evidence of serious soil deterioration following conventional roundwood logging, although some elements (such as phosphorus) may be removed more rapidly than they are replaced. There may be subtle changes in the soil about which we are not aware, but so far there has been no real cause for alarm. This should not, however, lull foresters into a sense of false security.

Harvesting for energy, however, is an entirely different matter. In order to use wood fibre for methanol, for example, it is economically desirable to harvest and utilize whole trees, or at least the above ground parts of the trees.

Whole Tree Harvesting

Harvesting whole trees (stems, branches, and leaves) on long rotations is already occurring in some places. During conventional logging operations for roundwood, whole trees

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are often skidded to landings and debranched. The stems are transported to the mill, and the branches left in piles to either decay or be burned. The products of decay or burning are not returned to the site directly, but leave the site as gases or are deposited on the soil of the landing. So far there is no evidence of site deterioration due to this practice, but there has not been sufficient time to make an assessment.

If harvesting is to be intensified foresters can no longer just hope for the best that all will be well. In the past there have been far too many loose, general statements that whole tree harvesting and short rotations are not likely to cause soil deterioration, based on results from one or two papers, or extrapolated from one specific situation. These statements tend to give managers and the planners a feeling that there are no serious problems. The more one examines the literature, the more confusing the picture becomes. It is impossible to generalize.

Energy Forests

The development of energy forests of fast-growing species harvested after short rotations of 2 to 10 years to provide feedstocks for alcohol plants and gasifiers is a major departure from conventional forestry practices. In such short rotation systems, trees are harvested in the juvenile phase when nutrient concentrations are highest, and the removal of cellulose and nutrients occurs at short intervals, with repeated site disturbance.

The use of forests for energy has attracted the attention of economists and engineers with little understanding of biological realities. They often refer to the branches and stems as "wastes" (i.e. not used), implying that to leave them behind serves no purpose. They may be a "waste" to man, but to the forest they are a vital part of ecosystem dynamics transferring carbon and nutrients to the soil, providing a medium for microorganism activity, providing shelter near the ground, and modifying the microclimate. Many managers - some of whom should know better - still seem to think that any degradation of the soil can be reversed simply by use of fertilizers, forgetting the high cost of fertilizers in terms of energy and dollars, and their rapid exit from the system if soil organic matter content and ion exchange capacity is too low.

These attitudes are a danger to good resource stewardship. They may lead a manager to postpone examination of the effects of harvesting, even though he agrees that environmental issues must be borne in mind. Harvesting, sale and transport of wood fibre present problems today; environmental problems take time to solve and are all to likely to be relegated to low priority in a program.

NUTRIENT BUDGETS

The amount of information in the literature about nutrient content of trees is overwhelming, but relatively few papers are directly concerned with effects of whole-tree harvesting (e.g. Boyle and Ek 1972; Jorgensen et al. 1975; Kimmins and Krumlik 1976; Malkonen 1976a, b; Norton 1976; Norton and Young 1975; Switzer and Nelson 1973; Weetman 1974; Weetman and Webber 1972; White 1974) or short rotations (e.g. Boyle 1975; Switzer and Nelson 1973).

To evaluate nutrients removed in harvesting whole trees the biomass and concentration of nutrients in each component is needed. These values are often not given in the published reports, and absolute nutrient contents of each component are often omitted. The researchers must have computed these values to evaluate whole tree nutrient content. A great deal of unpublished basic data must exist in theses and on researchers' files which could be used to calculate tree or ecosystem component nutrient contents, and a survey of this data would be most valuable for modelling purposes.

In many studies of ecosystem nutrient contents, authors present data for total soil nutrient content, or soil nutrient "capital" in kg/ha. Estimates vary from 15855 kg/ha of soil nitrogen on an *Abies amabilis* site (Turner et al. 1976, see Table 2), to 296 kg/ha nitrogen on a black spruce (*Picea mariana*) site (Weetman and Webber 1972). Obviously such differences reflect variations in soil fertility, but soil nutrient capital estimates depend a great deal upon the depth of sampling, particularly on deep soils. Sampling depths are often arbitrary, and it is difficult to assess what soil nutrient capital estimates in kg/ha really mean. The picture is also clouded by the problems of measuring nutrient availability, and the question of whether or not unavailable nutrients - the ecosystems' frozen assets - can be regarded as working, nutrient capital. To evaluate the impact of harvesting on nutrient budgets by calculating nutrient loss as a percentage of ecosystem nutrient capital (vegetation + litter + soil etc.) seems logical, but, in view of the above uncertainties, does not necessarily describe the impact in biological terms.

Nutrient Elements In Different Tree Components

Crude computations of nutrient contents of tree components are sometimes made from estimates of stem components to avoid costly field sampling, using an arbitrary % conversion. Such conversions may be possible in estimating whole tree biomass from stem biomass, but in view of the variability in space and time of nutrient concentrations, they cannot be used for conversions of stem nutrients to whole tree nutrients.

In Table 1 (Carlisle and Methven 1978, unpublished data) nutrient concentrations are given for five species of hardwoods. It is obvious that nutrient concentrations in leaves and small twigs are far higher than for stemwood. Nitrogen concentrations in the leaves and small twigs (1.05% to 1.61%) are more than ten times those in the stemwood (0.06% to 0.12%). The stem bark has higher nitrogen concentrations (0.29% to 0.56%) than the stemwood, but levels are still far lower than in leaves and branches. It is clear that when branches and leaves are harvested, tissues with high nutrient concentrations are removed from the site. Likens and Borman and their colleagues (1967, 1970, 1971a, b) have published data for nutrient concentrations in tree and understory vegetation tissues, and there are many other papers dealing with this topic.

Absolute nitrogen contents of different parts of the trees are given in Table 2. In the 36-year-old Douglas-fir stands studied by Cole *et al.* (1967) there were 125 kg/ha of nitrogen in the stems, 32 kg/ha in the roots and 163 kg/ha in the leaves + branches. The harvesting of stems + leaves + branches removes more than two times the quantities of nitrogen from the site than stem harvesting. A similar situation exists for species such as white spruce (*Picea glauca*), ponderosa pine (*Pinus ponderosa*), and Amabilis fir (*Abies amabilis*), and sycamore (*Platanus* spp.). In the case of lodgepole pine (*Pinus contorta*), jack pine (*Pinus banksiana*), alder (*Alnus* spp.) and poplar (*Populus*) the leaves and branches contain either less nitrogen (in absolute terms) than the stem tissues or a little more.

Table 3 gives the elements in branches and leaves expressed as a percentage of stem + branches + leaves. Nitrogen in the branches and leaves varies from 28% to 92%, phosphorus 20% to 83%, potassium 6% to 85% and calcium from 5% to 87% of the total quantities in parts of trees above the ground. These proportions are affected by age (e.g. 1 year and 9 year cottonwoods in Table 3), tree form, site, stand density, and time of year. The values in Table 3 give an idea of the increase in nutrient outgo if branches and leaves are harvested.

In the past most forest mensuration has been in terms of stem volumes, but today, with increasing interest in use of trees for energy, tree weights (biomass) have come to the fore. In North America a great deal of effort is being put into converting existing volume tables to biomass tables, and developing biomass inventory techniques. This work involves cutting down trees, and weighing oven-dried samples. This is a good opportunity to obtain missing tree nutrient content data, by analyzing these biomass samples for nutrient content, and devising regressions for total tree nutrient content on growth. Estimating biomass is the most laborious part of measuring tree nutrient contents, and the analysis (for the standard macronutrients N, P, K, Ca, Mg) can be done at low cost (e.g. $15 a sample).

Before embarking upon further measurement of stand nutrient content, however, we should find out what information is available, either published or unpublished. A great deal more information is available than most people realize, and there is no sense in repeating costly chemical analyses. A survey of unpublished data is urgently needed. Reviews of published data are being carried out by the authors and by Professor H. Kimmins of the University of British Columbia, Vancouver, B.C. with the aim of providing a bank of data for modelling purposes.

The removal of nutrients in harvesting must be considered in the context of other components of the nutrient cycle. Nutrient elements enter the system in precipitation (rainfall and snowfall), small particles (dust, aerosols), nitrogen fixation, weathering of soil minerals, and to some extent, movement of fauna. Nutrients leave the system in harvesting, leaching down the soil profile (when the soil water content reaches field capacity), gas movement (e.g. oxides of nitrogen and ammonia), surface run-off, erosion, and to some extent movement of fauna.

Nutrients In The Precipitation

A great deal of information is available in the literature concerning the chemistry of precipitation. The main interest has been in pollutants such as chlorine and sulphur dioxide, but data are available for macronutrients. Likens and his colleagues have studied the water chemistry of the Hubbard Brook Watershed in detail (Likens *et al.* 1967, 1970, 1971a, b). Most of the published data are in the form of nutrient concentrations, which can be converted to kg/ha/year if the rain quantities (in cm) are known. Some of this data is for precipitation only, with the collecting gauges

Table 1.--Concentration of nutrient elements in tree components. (Sampled July/August 1978).

Species	Stem Wood	Stem Bark	Branches + Bark	Leaves and Small Twigs
		% O.D.		
		Nitrogen		
Acer saccharum	0.06	0.42	0.16	1.05
Betula papyrifera	0.07	0.29	0.18	1.17
Populus tremuloides	0.07	0.33	0.14	1.49
Ostrya virginiana	0.12	0.56	0.20	1.61
Quercus rubra	0.11	0.37	0.26	1.42
		Phosphorus		
Acer saccharum	0.006	0.02	0.02	0.16
Betula papyrifera	0.005	0.02	0.02	0.09
Populus tremuloides	0.004	0.05	0.02	0.01
Ostrya virginiana	0.013	0.03	0.02	0.16
Quercus rubra	0.004	0.02	0.06	0.10
		Potassium		
Acer saccharum	0.12	0.39	0.20	0.69
Betula papyrifera	0.10	0.14	0.12	0.63
Populus tremuloides	0.10	0.33	0.14	0.89
Ostrya virginiana	0.14	0.25	0.13	0.80
Quercus rubra	0.21	0.18	0.25	0.64
		Calcium		
Acer saccharum	0.30	2.98	0.48	0.94
Betula papyrifera	0.29	1.69	0.68	0.67
Populus tremuloides	0.88	1.07	0.68	0.90
Ostrya virginiana	0.15	2.88	0.88	1.15
Quercus rubra	0.10	2.43	0.69	0.18
		Magnesium		
Acer saccharum	0.04	0.05	0.03	0.18
Betula papyrifera	0.06	0.06	0.06	0.21
Populus tremuloides	0.17	0.19	0.09	0.24
Ostrya virginiana	0.04	0.06	0.04	0.25
Quercus rubra	0.01	0.04	0.07	0.20

Carlisle, A. and I.R. Methven. 1979. Unpublished data for mixed-hardwood stand, Chalk River, Ontario.

Table 2.--Example of nitrogen contents of tree stems, leaves and branches in North America (kg/ha).

Species	Age (yrs.)	Stems	Branches	Roots	Leaves	Soil	Litter	Total	Author
						kg/ha			
Conifers									
Douglas-fir	36	125	61	32	102	2809	175	3304	Cole, 1967
Ponderosa pine	50	194	95	37	109	354	413	1202	Welch and Klemmedson, 1975
Red pine	32	54	32	--	71	--	--	--	Fornes et al., 1970
Jack pine	40	118	76	37	65	2312	689	3297	Alban, 1978
Lodgepole pine	125	142	17	--	43	--	--	--	Kimmins and Krumlik, 1976
White spruce	40	102	127	67	153	2542	752	3743	Alban, 1978
Black spruce	65	70	31	--	65	296	1214	--	Weetman and Webber, 1972
Abies amabilis	175	129	18	--	173	15855	650	--	Turner and Singer, 1976
Hardwoods									
Red alder	34	309	23	176	100	5450	877	6935	Turner and Singer, 1976
Eastern cottonwood	9	95	50	--	60	--	--	--	White, 1974
Hybrid poplar	40	199	82	89	87	2542	752	3751	Alban, 1978
Sycamore	3	15	5	--	32	--	--	--	Wood et al., 1977

All information computed as kg/ha from basic data in listed publications.

Table 3.--Proportion of elements in branches and leaves (as % stem+branch+leaves).

Species	Age (years)	N	P	K	Ca	Author
Amabilis fir	175	60	52	38	31	Turner et al., 1976
Balsam fir	?	70	71	51	58	Weetman and Webber, 1972
Alpine fir	>350	53	60	44	32	Kimmins and Krumlik, 1976
Douglas-fir	36	57	68	51	60	Cole et al., 1967
Black spruce	65	58	54	51	40	Weetman and Webber, 1972
Red spruce	65	80	78	77	57	Weetman and Webber, 1972
White spruce	40	73	44	72	65	Alban et al., 1978
Jack pine	20	83	83	68	72	Morrison, 1973, 1974
Jack pine	65	52	65	42	29	
Lodgepole pine	125	30	33	6	5	Kimmins and Krumlik, 1976
Ponderosa pine	50	51-60	--	--	--	Welch and Klemmedson, 1975
Red pine	40	68	63	70	49	Fornes et al., 1970
Red alder	34	28	20	41	47	Turner et al., 1976
Sycamore	3	71	51	34	52	Wood et al., 1977
Eastern cottonwood	1	92	80	85	87	White, 1974
Eastern cottonwood	9	54	50	53	41	White, 1974
Hybrid poplar	40	46	44	31	29	Alban et al., 1978

Data computed from basic data of listed authors.

closed during rain free periods to exclude particulate matter and aerosols. In other cases rain quantity and rain nutrient concentration are measured on an "event" basis, for different types of storms. For nutrient budget calculation we need total nutrient income in kg/ha/year, and care is needed when converting published rain quantity and nutrient concentration data to be quite sure what type of measurements were made. Unless the measurements were continuous and the gauges unshielded the results can be misleading.

There are a great deal of data on precipitation nutrient content data available in the USA, particularly for the northeast (e.g. New York State). For Canada, however, there are very few data. Examples are given in Table 4, showing that nutrient income in precipitation varies a great deal. High nitrogen values occur near industrial centres (e.g. Windsor, Ontario; Akron, Ohio). Apart from these high values, nitrogen income in precipitation ranges from about 1.9 to 10.0 kg/ha/year. Phosphorus income is very low (0.2 to 2.9 kg/ha/year) and many researchers exclude phosphorus, an important nutrient element, from their measurements due to the great difficulties of assaying this element in precipitation. Potassium income ranges from about 1.0 to 8.6 kg/ha/year in general with a few higher (e.g. 10.0 to 12.0 kg/ha/year). Calcium income is generally about 2.9 to 10 kg/ha/year, with some high values of up to 23.5 kg/ha/year, and one very low value for Fresno, California (0.9 kg/ha/year). Magnesium income is fairly constant at 0.7 to 4.0 kg/ha/year, with one high value (13.4 kg/ha/ year) for Grimsby, Ontario. Nutrient content is influenced considerably by pollution, proximity

Table 4.--Examples of nutrients in precipitation in North America.

	N	P	K	Ca	Mg
			kg/ha/year		
CANADA					
1. Lake Superior (Andren et al. 1977)	6.8	0.2	1.6	4.0	0.7
2. Lake Huron (Andren et al. 1977)	8.7	0.2	5.4	7.0	1.4
3. Lake Erie (Andren et al. 1977)	13.6	0.3	6.0	9.0	4.0
4. Lake Ontario (Andren et al. 1977)	10.8	0.3	4.7	16.0	3.4
5. Windsor, Ont. (E.) (Sanderson 1977)	31.2	0.9	5.6	8.2	5.7
6. Stratford, Ont. (W.) (Sanderson 1977)	3.0	1.2	10.1	11.6	4.1
" " (NW) (Sanderson 1977)	41.4	1.0	8.6	7.7	4.3
" " (S.) (Sanderson 1977)					
7. Grimsby, Ont. (Sanderson 1977)	39.5	1.2	5.5	16.0	13.4
8. Ottawa, Ont. (Sanderson 1977)	6.8	--	--	--	--
9. Mount Forest, Ont. (Wiebe 1974)	8.1	--	1.0	6.5	1.5
10. Muskoka, Ont. (Jeffries 1978)	10.0	0.4	1.6	6.8	1.0
11. Rawson L., Kenora, Ont. (Schindler 1976)	4.8-7.2	0.2-0.5	1.0-1.6	2.8-5.2	1.0
USA					
12. Woodstock, Vt. (Pearson et al. 1971)	4.5	--	1.3	4.9	1.1
13. Houlton, Maine " " " "	1.9	2.9	2.9	13.0	1.2
14. Corinna, Maine " " " "	2.5	--	4.3	7.5	1.2
15. Hubbardston, Mass. " " " "	2.2	--	5.6	4.9	1.1
16. Taunton, Mass. " " " "	2.3	--	2.0	2.9	1.4
17. New Hampshire (Likens et al. 1971)	3.8-7.4	--	0.6-2.5	1.6-3.0	0.3-1.1
18. St. Albans Bay, N.Y. (Pearson et al. 1971)	9.4	--	3.6	23.5	2.0
19. Salamanca, N.Y. (Pearson et al. 1971)	7.2	--	3.9	9.9	1.9
20. Thomaston, Conn. (Pearson et al. 1971)	2.5	--	1.6	4.9	1.3
21. S.E. Virginia (Fisher et al. 1968)	3.0	--	1.1	7.5	2.0
22. East. N. Carolina " " " "	3.1	--	1.6	9.5	2.3
23. Cape Hatteras, N.C. (Carroll 1962)	4.4	--	3.3	6.0	--
24. Akron, Ohio (Carroll 1962)	12.0	--	0.9	6.1	--
25. Tallahassee, Fla. (Carroll 1962)	3.0	--	1.8	6.0	--
26. Indianapolis, Ind. (Carroll 1962)	6.7	--	1.2	6.9	--
27. Athens, Pa. (Carroll 1962)	--	--	1.0	5.6	0.7
28. Tacoma, Wash. (Carroll 1962)	5.3	--	12.0	--	--
29. Fresno, Calif. (Carroll 1962)	5.7	--	2.7	0.9	--

All data computed as kg/ha/year from basic data of listed authors.

of the ocean (affects Ca, K and Mg levels), and agricultural activity (fertilizers in dust etc.). Furthermore an unknown proportion will not be retained, but will be lost through soil pores, root channels, and overland flow. Again, one cannot generalize. Every site must be considered on its own.

Nitrogen Fixation

Income from nitrogen fixation varies a great deal depending upon the soil and vegetation. Fixation by free living soil organisms in the absence of symbioses with higher plants is quite low, usually not much more than 1 kg/ha/year. Nitrogen fixation requires a great deal of energy, and in the absence of a carbohydrate supply from higher plants, the free living organism's activity is limited. In symbioses with higher plants, however, N-fixing organisms can fix 112 kg/ha/year or more in agricultural systems, and about 50 kg/ha/year (and occasionally up to 300 kg/ha/year) in alder (Alnus spp.) stands (Fessenden 1976; Holmsgaard 1960). This is many times more than the income in precipitation (see Table 4). Nitrogen fixing symbioses can, therefore, play a major role in maintaining soil nitrogen levels.

Soil Mineral Weathering

Measurement of nutrient income from soil mineral weathering is a major problem. Rates of release of nutrients from soil minerals (e.g. phosphorus from apatite) and from soil organic matter (e.g. nitrogen from insoluble organic compounds) can be measured but conversion to kg/ ha/year is more difficult, requiring estimates of total minerals and total soil organic matter within the systems. Boyle et al. estimated that fertile soils of an aspen-mixed hardwood stand in Wisconsin released about 1% of organic nitrogen in the soil each year, more than enough to replace whole tree harvesting on a 30 year rotation. Boyle and Ek (1972), Boyle et al. (1973), and Johnson et al. (1968) have studied rates of release of nutrients from weathering of silicates, but data are scarce for most forest soils. This is an area which requires much more research.

The importance of nutrient losses from the system by leaching down the soil profile, surface run-off, erosion, and fauna movement will vary a great deal with the site. Again one cannot generalize.

NUTRIENT BUDGETS IN WHOLE TREE HARVEST OF MATURE STANDS

It is difficult to find detailed case histories of the effects of whole tree harvesting on the flux of nutrients in mature forests. Kimmins and his colleagues at the University of British Columbia (e.g. Kimmins and Krumlik 1976) have studied the forests of British Columbia for a number of years, and have shown that in a spruce-fir site in McGregor, B.C. atmospheric inputs of nitrogen and phosphorus are considerably less than the losses of these elements in whole tree harvesting. On the other hand, atmospheric input of bases such as K, Ca and Mg exceeded harvesting losses. This did not take into account other forms of nutrient input, such as those from weathering soil minerals, and the authors point out that on some sites these additional inputs could be considerable. Weetman and Webber (1972) examined balsam fir-spruce stands in Quebec and found that whole tree harvesting would not reduce the growth of the next tree crop due to soil nutrient depletion. Boyle and Ek (1972) found that reserves of N, P, Ca, K and Mg in the soil of mixed-hardwood stands in central Wisconsin were greater than nutrient losses in whole tree harvesting. Complete tree harvest (including roots) could, apparently, deplete N, P and K in the soils of the softwood forests of Maine (Norton 1976). One could continue listing incomplete results from studies of different forests, but no clear overall picture would emerge. Whether or not whole tree harvesting depletes the sites depends upon soil nutrient levels, nutrient turnover rate, the extent to which the nutrient cycle is closed, nutrient availability, soil minerals, tree species, precipitation, location relative to industry and the oceans, and many other factors. The meagre evidence obtained so far has not shown whole tree harvesting to cause disastrous nutrient depletion, but the range of forests sampled so far is very small, and the evidence is far from conclusive.

THE IMPACT OF SHORT ROTATIONS

So far the nutrient income and outgo has been considered in whole tree harvesting systems only on relatively long rotations. The recent trend in forestry to grow trees on rotations as short as 2 to 10 years has presented new problems. Not only are the yields (Table 5) of the order of 2.5 to 18.6 O.D. tons/ha/year m.a.i., but the trees are harvested in the juvenile phase when the average nutrient concentrations for the whole trees are relatively high. These systems supply fibre in the form of young coppice sprouts which can be used for pulp, energy, chemicals, or cattle feed supplements. The sprouts can be harvested with or without leaves. As far as nutrient cycling is concerned, harvesting when the leaves have fallen is preferable, but when the materials are to be used for cattle, it is necessary to take the leaves as well (Anderson and Zsuffa 1975a,

Table 5.--Biomass yields from short rotation forestry systems.

Species	Rotation (yrs.)	Location	Biomass production o.d.t./ha/year	Author
Populus euramericana	2	Ontario	16.3	Raitenen, 1978
" "	4	"	10.1	" "
" "	5	"	8.4	" "
" "	6	"	7.5	" "
" "	10	"	6.4	" "
" "	15	"	5.3	" "
" "	20	"	4.2	" "
Populus tristis No. 1	8-15	Rhinelander, Wisconsin	15.6-18.6	Ek & Dawson, 1976 Dawson et al., 1975
Platanus occidentalis	4	Georgia	11.2	Belanger & Saucier, 1975
" "	2	Piedmont, Georgia	2.5-4.6	Steinbeck & May, 1971
Alnus rubra	1-2	Washington	4.2	De Bell et al., 1978
" "	3-4	"	5.3	" " " " "
" "	5-6	"	7.7	" " " " "
" "	7-12	"	15.2	" " " " "
" "	13-14	"	13.0	" " " " "

b, 1977; Belanger and Saucier 1975; De Bell 1975, 1978; Heilman et al. 1972; Louden 1976, Saucier et al. 1972; Steinbeck and Brown 1976; Steinbeck and May 1971; Zsuffa 1971; Zsuffa et al. 1977).

These systems are sometimes referred to as "agriforestry" or "agroforestry" systems, inferring that they are analogous to agriculture (Raitenen 1978). They are similar to agriculture in that they are short term monocultures making considerable demands on even the more fertile soils, are ecologically unstable, and require considerable effort by man to establish and maintain them. Agriculture, however, produces crops of high value per unit area of land, with sufficient profits to allow replacement of nutrients and soil organic matter, and maintain soil fertility. The short rotation forestry systems have a relatively low value crop per unit land area, and it remains to be seen whether or not the costs of establishment, tending and maintenance of these stands result in a cost/benefit ratio below unity (Dutrow and Saucier 1976; Pfeiffer 1978).

These systems are all on relatively fertile soils with more resilience to abuse than the less fertile soils. Soil nitrogen reserves are sometimes considerable. Quantitative data for these systems are scarce, and the effects of shortening rotations to less than 10 years are not yet clearly understood.

Switzer and Nelson (1973) investigated the effects of shortening pine rotations in the southeastern USA and found, for example, that harvesting Pinus taeda stands at 20 year intervals rather than 40 year intervals increased the demands of the trees upon the site for nitrogen, phosphorus, potassium and calcium by 27%, 22%, 15% and 17% respectively. Boyle and Ek (1972) also cautioned that while on fertile soils nutrient reserves can be many times greater than nutrients removed in harvesting, and natural inputs supplement these returns, on short rotations these reserves may not balance nutrient removal.

White (1974) reports that harvesting cottonwood (Populus deltoides) on 7 to 9 year rotations in Alabama depletes soil nutrients (P, K, Ca, Mg) even when the leaves are left on the site. In one stand, harvesting at 8 years removed an amount of phosphorus equivalent to 194% of the available phosphorus in the soil. Not harvesting the leaves, reduced the phosphorus loss to 150% of the available soil phosphorus. Results varied a great deal from stand to stand, but this illustrates the need for caution.

An approximate calculation of nitrogen drain for short rotation (2-4 years) poplar in Ontario (Carlisle 1976), suggests that if both stems and leaves are harvested at a rate of about 8 t/ha/year, the nitrogen removed in harvesting would be about 53 kg/ha/year. Allowing for nitrogen income in rainfall and free living nitrogen fixing organisms results in a net nitrogen deficit of about 50 kg/ha/year. This nitrogen deficit could not be sustained for long periods without soil deterioration. The nitrogen would have to be replaced by fertilization or use of nitrogen fixing symbioses. An examination of potential deficits of bases and phosphorus is required before conclusions can be drawn. Phosphorus particularly could be a problem. Unless there are phosphatic minerals in the soil, there is a likelihood of a phosphorus deficit, since very little enters the system in precipitation. Predicted shortages of phosphatic fertilizers could also be a problem.

DISCUSSION

The available evidence suggests, but by no means confirms, that whole tree harvesting of mature trees does not necessarily result in major nutrient depletion, although there may be a net deficit of some elements (particularly nitrogen and phosphorus) on some sites. On the other hand there is a considerable nutrient deficit in the highly productive, short rotation systems being used for species such as poplar and sycamore.

There are large gaps in the data, particularly concerning soil nutrient availability, nitrogen income by nitrogen fixing organisms (both free-living and in symbioses with higher plants), phosphorus income in the rainfall in both USA and Canada, and the total nutrient content (in kg/ha/year) of precipitation in Canada. Relatively few forests have been studied in depth. There are considerable amounts of unpublished data on tree biomass and nutrient content of tree components and of lesser vegetation that would contribute greatly to our knowledge of nutrient distribution in the forest if they could be located and tabulated. We are in the paradoxical position that we know enough to realize how little we know. It is all too evident that one cannot generalize.

The effects of harvesting on soil fertility are not just a matter of nutrient accounting. Repeated harvesting of leaves and branches, on both short and long rotations, removes from the forest considerable amounts of carbohydrate and protein, the organic matter upon which the soil microorganisms (the driving force of soil processes) depend. We can only guess at the effects of removing this organic matter from the site, as studies of the carbon cycle in the forest, and the role of the organic matter in ecosystem dynamics are few and far between.

If we demonstrate that there is a nutrient deficit under a particular harvesting system, we must ask ourselves what this deficit really means in terms of site productivity. We cannot yet assess how large a deficit has to be to cause concern, or what the time scale of effects could be. The empirical approach of assuming that all is well with the forest if tree growth continues at acceptable levels may not be reliable. There could be slow, subtle changes in the biology, chemistry and physics of the soil (e.g. pathogen dominance, microorganism activity and diversity, ion exchange capacity and organic matter characterization) that may not, at least for a time, limit tree growth. When they do limit tree growth the problems may be very difficult to solve. It may also be misleading to assume that because harvesting leaves and small twigs only removes a small proportion of the total nutrient capital in the system, it is of no importance. As Kimmins and Krumlik (1976) point out, "A small capital of rapidly circulating nutrients may sustain a greater productivity than a large capital of slowly circulating nutrients." To remove such key components as leaves and twigs, with their relatively available nutrients (except in certain acid conditions where proteins are immobilized by polyphenols), could have great effects on productivity even though the quantities involved are small.

Understanding the effects of whole tree harvesting and short rotations depends upon our knowledge of forest soil processes. A great deal of work has been done on soil dynamics in the USA, but forest soil science in Canada has been of low priority for many years, and there is little knowledge available about soil dynamics in the vast boreal forest. This hiatus needs to be filled if we are to manage forests by intensive management from a position of knowledge. Until we know more we should rely on the basic principle of good resource management (so often ignored) that if more is taken out of the system than is returned, this is bad stewardship. Any nutrient deficit should be regarded as a management failure, quite regardless of magnitude.

There are no simple answers to maintaining soil nutrient levels in forests where whole tree harvesting and short rotations are used. It has been suggested that after the wood fibre has been used for energy, that the ash can be transported back to the forest and distributed (Nautiyal 1978). Quite apart from the logistic and economic problems, the major limiting nutrients (nitrogen and phosphorus) would still have been lost, as these elements volatilize during combustion.

Monitoring soil fertility and nutrient flux should be an integral part of all intensive forestry systems, particularly where very short rotations are involved. Many managers are reluctant to include such assessments in their budget, as they are traditionally costly and labour intensive. However, it is hoped that in the near future, models of the affects of harvesting on nutrient cycles (such as those being developed by Kimmins and his colleagues at the University of British Columbia with the support of the federal Canadian Forestry Service and at several centres in the USA) will help to minimize sampling, define information gaps, and indicate long term effects. A laborious piecemeal approach to understanding the effects of whole tree harvesting is neither necessary nor practicable, even though the effects are site specific. Coordination of the work, and the development of predictive models, will reduce the risk of duplication of research and reduce costs. It is suggested that an effort is made to coordinate work in this field in North America, and to establish a central data bank of existing data for input and output components. The complexity of the problems make their solution a real challenge for the future.

Assessment of impacts of whole tree harvesting is partly a technical matter and partly philosophical. Impacts should be regarded in the context of forest management objectives, and viewed in relation to the kind of forest the manager wants to achieve. The development of a resource use philosophy is essential if we are to decide how much site disturbance is acceptable.

CONCLUSIONS

1. The success of using forests on a large scale for energy will ultimately depend upon environmental issues.

2. Conventional roundwood harvest on long rotation does not appear to cause major nutrient depletion, nutrient concentrations in stem tissues being low.

3. Harvesting whole trees means the removal of twig and leaf tissues which contain high nutrient concentrations, and account for 28% to 92% of the nitrogen, 20% to 83% of the phosphorus, 6% to 85% of the potassium and 5% to 87% of the calcium in the above ground tree components. Although leaf and twig biomass may be low, these tissues play an important role in the forest nutrient cycle. Engineers and economists tend to regard leaves and branches as wastes. They may be a waste to man but not to the forest.

4. Harvesting whole trees on long rotations may or may not result in a nutrient deficit, depending upon the element and the type of forest. It is impossible to generalize.

5. Highly productive, short rotation (2 to 10 year) systems result in major nutrient deficits, even when the leaves are left on the site. These losses will need to be made good if soil fertility is to be maintained. These intensive systems, in which the trees are in the juvenile, nutrient rich stage, are ecologically unstable monocultures requiring major expenditure to maintain. Whether or not costs and benefits will permit major expenditures on soil fertility maintenance (as in agriculture) and protection is still a point in question.

6. It is impossible to generalize about the effects of whole tree harvesting, since impact is site and element specific. Neither can simple conversions be made from stem nutrient content to whole tree content; nutrient concentrations and leaf/twig biomass are too variable. However, a general statement can be made to the effect that shortening rotations greatly increases the risk of serious nutrient depletion.

7. Impact of whole tree harvesting and short rotations is not just a matter of nutrient accounting. A rapidly circulating small amount of nutrients may have more effect on productivity than a slowly circulating large nutrient capital. Magnitude of nutrient losses may be less important than where the losses originate (e.g. in leaves and twigs).

8. Little is known about the effects of whole tree harvest and short rotation forestry on soil organic matter levels, the carbon cycle and associated microorganism activity. In some areas the carbon losses could be of more importance than nutrient losses.

9. Replenishment of soil nutrients depleted by whole tree harvesting and use of short rotations is not just a simple matter of fertilization. Fertilizers are often in an unacceptable form for uptake by the trees, can be leached from the system, are costly in terms of dollars and energy, and must be considered in the overall cost/benefit context.

10. There are major gaps in our knowledge of nutrient input and output in forest ecosystems. Very little is known about nutrient income in precipitation in Canada or how much is retained in the system, and little is known about income of nutrients to the forest cycle from soil minerals. It is difficult to prepare a full nutrient budget.

11. A great deal of biomass and nutrient concentration data remain unpublished in theses and files which would be invaluable in computation of regression equations for absolute tree nutrient content on diameter necessary for efficient modelling. It is

suggested that these data are solicited from scientists and a central data bank established. There is also a need for coordination of nutrient cycle work in North America to avoid any ad hoc approach and duplication of effort.

12. Understanding the real meaning of nutrient and carbon losses due to whole tree harvesting and short rotations is greatly hampered by our lack of understanding of soil processes, particularly in Canada.

13. Monitoring nutrient budgets and soil fertility should be an integral part of intensive forestry management, particularly where short rotations are involved.

14. Labour intensive, high cost measurements of nutrient budgets could be greatly simplified by the development of models which indicate what type of samples and how many should be taken to achieve a particular objective. These models would also assist with identifying information gaps.

15. Assessment of impacts of whole tree harvesting and short rotations is partly a technical problem and partly philosophical. Each impact, and the decision about whether or not it is acceptable, must be considered in the context of forest management objectives, and the kind of forest we wish to establish and maintain.

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CAN WE HARVEST MEDITERRANEAN TYPE ECOSYSTEMS TO OBTAIN ENERGY AND ORGANICS?

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Abstract.--Lack of both energy and organics in mediterranean climate areas can be confronted by harvesting mediterranean type ecosystems every ten years.Since these ecosystems early or late will be burnt out with accompaning loss of their biomass,such a possibility seems feasible.

INTRODUCTION

Energy problem

Since April 1979 there is a limitation in the circulation of private autocars in Greece. According to the last figure-odd or even-of their circulation license number they are permitted to move alternatively every second week-end. Having in mind that there are in Greece about 700,000 cars,population is 9 millions,the Governement claims that by this means an energy saving at the level of 3% can be attained. There follows a whole series of relative limitations with the goal of saving foreign currency since Greece is obliged to import all the necessary quantity of oil.

Problems of wood and paper lack

Paper consumption in Greece rises, nowaydays,to about 40 Kg/man/year. Greece has to import large quantities of paper since its production is very low,attaining only 10% of the imports. A relative situation prevails in the case of raw timber imports wich covers 75% of the country needs.

Problems of fires in forests and shrublands

A look at the Greek newspapers during the summer months will reveal that among the most frequent and striking topics are fires in forests and shrublands wich burn out an area of about 15,000 ha,every year.

Could a combination in confronting the above problems solve all three of them?

Plants dominating mediterranean type ecosystems haveevolved adaptations which permit them to recover after fire. Having in mind that 40% of the surface of Greece is occupied by ecosystems of this kind,it is probable that a harvest of plants before a fire attack and a parallel proper use of their biomass could lead to a combined solution of all these problems.

NATURAL ENVIRONMENT

The total area of Greece is $13X10^6$ ha,of which 30% are under cultivation , 20% occupied by forests,40% by mediterranean type ecosystems while the rest 10% represents urban agglomerations , roads etc.

We will be mainly occupied with mediterranean type ecosystems since we consider them as a valuable source of energy and organics,which will be lost after their burning out. According to their main adaptive strategy in confronting summer stress of water deficiency, which characterises mediterranean type climate,we can discern two types of ecosystems. In the first type,<u>maquis</u>, found at the wet end of the percipitation gradient,the main adaptation of dominating plants is evergreen scleroplylly. In the second type,<u>phrygana</u>, dominating plants have evolved(Orshan,1964) seasonal dimor-

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Table 1.--Plants dominating mediterranean type ecosystems in Greece

PHRYGANA	MAQUIS
Phlomis fruticosa L.	*Olea europea* L.
Sarcopoterium spinosum SPACH;	*Quercus ilex* L.
Thymus capitatus HOFF.et LINK	*Quercus coccifera* L.
Euphorbia acanthothamnos HELDR.et SART.	*Pinus halepensis* L.
Teucrium pollium L.	*Ceratonia siliqua* L.
Anthyllis hermanniae L.	*Pistacia lentiscus* L.
Calycotome villosa L.K.	*Arbutus unedo* L.
Genista acanthoclados D.C.	*Arbutus andrachne* L.
Thymelaea tertoraira (L.) ALL.	*Nerium oleanter* L.
Thymelaea hirsuta ENDL.	*Laurus nobilis* L.
Lavandula stoechas L.	*Myrtus communis* L.
Ballota acetabulosa BENTX.	*Smilax aspera* L.
Cistus sp	*Phillyrea media* L.
Globularia alypum L.	*Juniperus oxycedrus* L.
	Juniperus phoenicea L.

phism and it is by this adaptation that they drastically reduce their traspiring body during the dry summer months; this type is found at the dry end of the precipitation gradient. The main plant species of these ecosystems are given in Table 1.

The aboveground net primary production of maquis and phrygana is about 600 and 400 g/m^2/year respectively(Lossaint,1973,Margaris,1976). The aboveground biomass is 6 and 2 Kg/m^2 respectively. Data concerning solar energy utilization in a phryganic ecosystem in Greece are inserted in Table 2.

FIRES IN MEDITERRANEAN TYPE ECOSYSTEMS

The vigorously alternating atmospheric conditions of mediterranean climate cause a quick dehydration of the shrubby and herbaceous vegetation(Biswell,1974). Furthermore,Shantz(1947) citing many sources names plant communities of these regions "fire-climax" or "fire-type" .

Naveh(1973) in his detailed description of fire history in maquis and batha (=phrygana) of Israel,proved that the factor "fire" has been very important not

Table 2.-- Productivity and solar energy utilization in a phryganic ecosystem in Greece(Margaris,1976).

	$g.m^{-2}.d^{-1}$	Solar energy conversion (%)
1.Aboveground net productivity		
1.1.October-April	4.52	0.81
1.2.May-September	-3.68	-
1.3.Mean annual	1.13	0.14
2.Total net productivity		
2.1.October-April	8.38	1.50
2.2.May-September	-8.94	-
2.3.Mean annual[1]	1.99	0.24
Mean annual[2]	2.27	0.29
3.Annual gross productivity	5.94	0.74

[1]Without estimation of root turnover
[2]With estimation of root turnover

not only in Israel but in the whole mediterranean basin during the last interglacial period.

The surface burnt every year in Greece (Moulopoulos,1935,Kailidis et al, 1975) is the following:

Year	Area burnt (ha)
1922	90,205
1923	18,622
1924	11,320
1925	17,324
1926	7,199
1927	13,490
1928	24,597
....	....
1965	27,030
1966	11,613
1967	8,153
1968	9,058
1969	9,233
1970	9,189
1971	10,563
1972	8,581
1973	19,514
1974	31,869
1975	16,523

The impression that bursting fires, today, are more than they were other times,in Greece, is quite mistaken. Each year a total area of about 15,000 ha is burnt; a relative situation prevails in the other mediterranean countries(Table 3)

Table 3.--Burnt areas in some mediterranean coumtries (Le Houerou,1973)

Country	Area burnt per year (Hectares)	Period of measurement
France	38,000	1960-1971
Spain	31,000	1960-1971
Italy	19,000	1960-1971
Greece	12,500	1956-1975
Israel	3,300	1963-1966
Cyprus	1,100	1963-1966
Algeria	40,000	1853-1945
Morocco	2,500	1924-1945

From the available data of the forest Administration of Greece it can be deduced that the fire cycle is very low in comparison with those of California (25 years,Biswell,1973) and S.France (20 years,Le Houerou,1973).

POSTFIRE RECOVERY

Fire acts in such a way as a selective force in mediterranean type ecosystems that,as already noted, they can be considered as "fire-induced" or "fire adapted" (Jopson,1930,Shantz,1947 , Naveh,1967). Plant adaptations are,therefore,homeostatic responces of ecosystems following fire-induced disturbances.

With the exception of Pinus , Cistus and Thymus spp. where recovering is made possible by means of activation of seed germination almost all other plant species reveal a resprouting behavior (Naveh,1973,Arianoutsou,1979).

According to Trabaud(1973),Naveh (1973),Arianoutsou(1979) ,five years after the fire attack, the ecosystem has completely overcome and returned to the before-fire situation, in such a degree that it is quite difficult to discern the burnt from the unburnt regions.

There is ,from the other side, the hypothesis of Muth(1970) that plant communities subjected to frequent fires over thousands of years have developed features which make them very flammable. This hypothesis seems quite logical since,if fire occurence is early or late inevitable it is preferable for the ecosystem to be burnt as soon as possible because excessive fuel accumulation when fire comes, produce very high temperature leading to real catastrophes. The aromatic and resin nature of many mediterranean plants can be for example in some way correlated with the above.

WHAT WILL HAPPEN IF WE HARVEST PLANTS INSTEAD OF LETTING THEM BE BURNT?

We have mentioned above that after a 5-10 year period, plants completely recover in such a way that there is no difference between burnt and unburnt areas.

The quick recovery is mainly due to the fact that resprouting plant species have broader leaves with a higher chlorophyll content resulting to a higher photosynthesis rate(Arianoutsou,1979). Our experiments in a phryganic ecosystem in Greece have shown that resprouting plants retain their sprouting ability even if they are cut at the level of the ground. Thymus and Cistus spp. which have not a resprouting behavior can germinate quite well even without fire occurence(Argyris,1977). Therefore,if " a harvest" take place during summer,it will not severely disturb the ecosystem as far as plant species are concerned. The fact that almost 50% of plant species in mediterranean regions represent therophytes,which at this time are in the form of seeds,is another favourable point of this hypothesis.

WHICH IS THE ENERGY OFFER?

Mediterranean type ecosystems in Greece cover an area of 5 000 000 ha.In half of them above ground biomass is about 6 Kg/m^2 while in the rest about 2 Kg/m^2. Concise data for their energy content are given in Table 4.

We can every year "harvest" plants in the 1/10 of the above area, that means in about 500,000 ha. Maquis can give amounts of plant biomass of the order of magnitude of $15X10^6$ ton or $7X10^{13}$ Kcal and phrygana about $2.4X10^{13}$ Kcal. Therefore the total energy offer is of the order of magnitude of $94X10^{12}$ Kcal which corresponds to 80% of our oil imports. Undoubtedly, the whole situation is not so simple but there is still a possibility of such an exploitation since these ecosystems will be burnt in any case with a consomitant loss of energy.

Quite indicatively we mention that our estimations,using Earl's(1975) conversion factors,show that the above mentioned amount of energy is sufficient for the operation of 50 power stations of 150 Megawatt.

WHERE ELSE "HARVESTED" PLANT BIOMASS CAN FIND USE?

Heating

During the last two decades preference for using oil as heating fuel is very strong. It is quite indicative that only during the period of 1970-1975 production of oil stoves rose up to 600,000 items. If from the total population of Greece is substracted that part,living in flats with central heating (of course with oil as fuel),then for this six year period there is one oil stove for 10 persons. Results of this preference are the reduction of wood cutting with an accompanying increase of the ecosystem fuel content. This fact,in combination with the fire suppression policy which Greece follows nowaydays,is very dangerous since it can lead, in the future, to the occurence of catastrophic fires. Unfortunately, because of bad information, the term protection of the environment is almost synonymous to "protection" of forests. Therefore, the tendency of oil utilization for heating purposes is still strengthening while at the same time consumption of timber from mediterranean type ecosystems is only as high as 6,000 ton/year.

Timber

Greek forests cover only 25% of the country needs for timber.The rest of it has to be imported in the form of row wood.Imports are given in Figure 1. It can be seen that from 1960-1976 they are increased more than 30fold. The com-

Table 4.--Caloric content of woody plants in maquis and phrygana.

Woody plants from:	Number of plant species analysed	Caloric content ($cal.g^{-1}dw$)		
		Leaves	Bark	Wood
Maquis				
Evergreen sclerophylls	15	4667± 61	4207± 78	4250± 37
Deciduous	8	4375± 47	4128±150	4278± 59
Phrygana				
Seasonally dimorphics	34	4488±142	4345± 73	4674±173

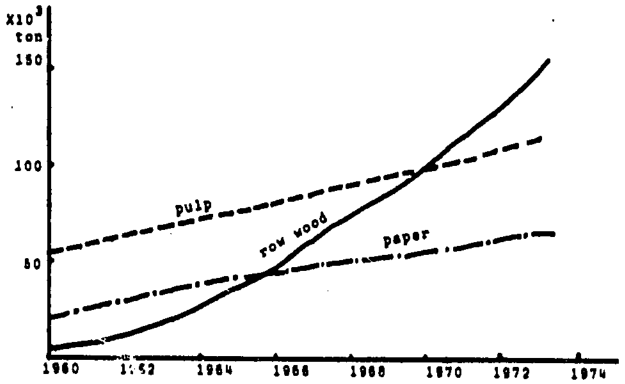

Figure 1.--Imports of wood and paper in Greece (From National Statistical Service of Greece).

pletely insufficient exploitation of mediterranean ecosystems ,at least for the construction of material like"novopan" quite illogical since it could save much of currency exports.

Paper

Import of paper and paper pulp severely aggrevates the National Economy since only 10% of the country needs are covered by local sources. Imports are presented in Figure 1. Cellulose utilization from mediterranean ecosystems is quite difficult but not unattainable.

Aromatic plants

Phryganic ecosystems are dominated by plants characterised by an aromatic nature, mainly due to terpenes and phenols. Because of this feature ,aromatic plants have long been used in cosmetics, medicine, cooking etc. Greek Governement pays too much attention to their cultivation. The income from their exports is now of the order of 15 million $.

It is sure that in case of harvesting large quantities of such aromatic plants will be available.The most important from them are in Table 5.

Table 5.--Some plants with econimic value occuring in phryganic ecosystems (After Margaris and Vokou,1979)

Plant species	Used in:			
	Cosmetics	Medicine	Cooking	Other
Anethum graveolens	-	+	+	-
Calamintha sp	+	-	-	+
Cistus creticus	+	+	+	-
Lavandula stoechas	+	+	-	+
Lavandula vera	+	+	-	+
Matricaria chamomilla	+	+	+	+
Melissa officinalis	+	+	+	+
Mentha longifolia	+	+	-	-
Mentha pulegium	-	+	+	-
Mentha reverchoni	+	-	-	-
Mentha spicata	+	+	+	+
Origanum dictamnus	+	+	+	+
Origanum heracleoticum	+	-	-	-
Origanum vulgare	+	-	+	-
Rosmarinus officinalis	+	+	+	+
Salvia cretica	-	-	+	-
Salvia triloba	-	-	+	+
Salvia officinalis	+	+	+	-
Salvia pomifera	-	-	+	-
Salvia sclarea	+	-	-	-
Satureia thymbra	-	-	+	-
Sideritis cretica	-	+	+	+
Sideritis lanata	-	+	+	+
Sideritis montana	-	+	+	+
Sideritis purpurea	-	+	+	+
Sideritis scardica	-	+	+	+
Sideritis resere	-	+	+	+
Thymus capitatus	+	+	+	+
Tilia platyphyllos	+	+	+	-

Latex production

Quite recent is the question arisen concerning production and utilazation of hydrocarbons from plants of the Euphorbiaceae family (Nielson et al,1977).Species of this family are very abundant in Greece and in some regions they contribute to the aboveground biomass with over 30%.

Animal food production

Leaves

Most of mediterranean plants have leaves which can be used as animal food (*Quercus coccifera*,*Ceratonia siliqua*,*Olea europea*,*Pistacia lentiscus* etc.). Nitrogen content in them is about 1% in evergreen sclerophylls and about the double in seasonal dimorphics. The fact that the green biomass is about 20% of the aboveground is in favour of their utilization for such a purpose. Another interesting point is protein amino-acid profile(Table 6) which can be considered as very important.

Single cell protein production

Data concerning with the possibility of utilization of *Ceratonia siliqua* (carob) fruits for the production of microbial animal food are inserted in Figure 2. Tate and Lyle Co.,Enland claims that this production will be very profitable.

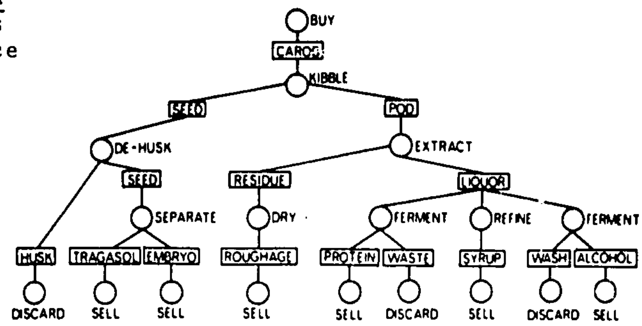

Figure 2.-- A proposal for single cell protein production using carob fruits (Tate and Lyle Co.England).

Production of other valuable compounds

Besides the above mentioned there are also possibilities for production of other compounds like artificial cacao from carob fruits,chlorophyll,which is now imported to Greece and others.

Table 6.-- Protein amino-acid profiles (moles/100 moles) in the leaves of some plants of phrygana (Margaris,1978).

Amino acids	*Phlomis fruticosa*		*Sarcopoterium spinosum*		*Euphorbia acanthothamnos*		*Cistus sp*	
	NOV	APR	NOV	APR	NOV	APR	NOV	APR
Asp	14.3	13.7	8.8	12.7	13.7	13.6	11.2	12.5
Thr+Ser	16.9	17.7	12.3	14.5	12.8	14.8	16.0	14.0
Glu	9.1	12.5	11.7	11.7	11.9	11.8	10.1	9.4
Gly	12.0	10.5	14.1	14.0	11.0	12.9	12.0	10.9
Ala	9.9	9.7	11.0	9.7	9.5	10.6	9.5	10.4
Val+Cys	5.2	7.9	6.2	6.5	7.5	5.8	4.7	5.8
Met	0.3	2.1	2.9	0.4	1.4	0.8	0.7	0.4
Ile	0.4	5.9	4.4	4.5	3.7	4.8	3.9	5.0
Leu	9.8	6.8	9.5	10.5	12.2	9.4	10.1	11.0
Tyr	3.1	4.2	4.7	3.7	2.8	2.7	2.5	2.5
Phe	5.9	2.4	4.4	4.8	6.1	0.9	5.8	5.4
Lys	5.9	2.1	5.0	2.3	3.8	6.4	7.0	5.4
His	1.9	2.2	1.8	1.4	1.4	1.4	1.6	0.8
Arg	5.2	2.2	3.3	3.5	2.2	4.1	4.8	6.3

PROBLEMS ARISING

Removal of nutrients from the ecosystem

The harvestin method suggested poses the problem of nutrient removal from the ecosystem.However in Table 7 there are our estimations for the loss of nutrients after harvesting every ten years together with rainfall input of nutrients in a period of ten years(data from S. France according to Lossaint,1973) prove that there not any severe disturbances from such a removal.

Table 7.--Estimation of nutrient losses (Kg/ha) due to harvesting every ten years in mediterranean ecosystems.Data for rain inputs are from Lossaint(1973).

Nutrients	Losses with harvest	Coming with ten years rains	Difference
N	200	150	50
P	20	10	20
K	100	20	80
Na	30	200	-
Mg	80	15	65

A final comment

Everything just mentioned is merely a suggestion,for the realization of which technological advances are required. However the wish for a national energy resource with probabilities of future exploitation forced the author to write the present paper.

ACKNOWLEDGMENTS

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AN OVERVIEW OF THE ENVIRONMENTAL CONSEQUENCES OF TREE REMOVAL FROM THE FOREST IN INDONESIA

Kuswata Kartawinata[1]

Abstract. Logging of primary rainforest results in damage of residual trees and soils, genetic erosion and loss, and soil erosion increase. It changes also the regeneration pattern, behavioral patterns of animal, chemical and physical properties of soils, and water quality and yield. Better control, improved logging techniques and research are needed.

INTRODUCTION

The total forest land of Indonesia covers about 122 million hectares or about 64 percent of the total land area. This consists of primary dryland forest, peatswamp forest, freshwater swamp forest, mangrove forest, planted forest, secondary forest, and alang-alang (Imperata) grassland. The forest land has been designated also as production forest (40 million hectares), protection forest (47 million hectares), and nature reserves and recreation forest (10 million hectares) (Anonymous 1975). Out of 40 million hectares of production forest only two million hectares are planted forest, mainly consisting of teak and conifer plantations.

Past and present exploitation and destruction have decreased the extent of the primary forest. This includes the shifting cultivation practices and the currently intensive mechanized logging operations of the vast primary forest area. Despite its economic benefits, the timber extraction has created various environmental problems. The following account is a brief overview of the effects of exploitation of Indonesian forests, in particular the lowland primary forest.

FOREST EXPLOITATION

Before the World War II, forestry was mainly concerned with wood (timber, charcoal, firewood) production from teak plantations in Java. Wood production from natural forests in Sumatra and Kalimantan (Indonesian Borneo) was much lower than that from teak forests. After 1967 the situation is reversed, when timber has been extracted mostly from the lowland primary rainforest (especially dipterocarp forest) from the islands outside Java. In 1977 the total log production was 26.6 million cubic meters (Djajapertjunda 1978), about 95 percent of which were from the lowland primary rainforest. In the year 2000, the log production is estimated to be about 50 million cubic meters. In 1976, 407 concessionaires were given the right to exploit 38.093 million hectares of natural forests with the total investment of more than US$ 1 billion (Djajapertjunda 1978).

The exploitation and management system of the teak forest is very well established, where the method of clear-cutting followed by replanting has been used for many years. It involves felling, replanting, tending, and protection against fire, grazing, and pests and diseases. The 'tumpangsari' or taungya system is incorporated also in this method.

The exploitation and management of primary forests in the islands outside Java are entrusted to private companies through forestry agreement. In this agreement forest concessionaires are required to observe 'good timbering and ecological practices' (Soemitro 1975). They have to comply with rules and regulations pertaining to sustained yield and principles, to be responsible for maintenance of reforestation of the cut-over forests, to undertake aerial photography, to make 25 percent inventory of the concession

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areas, to submit detailed annual working plan as well as five- and ten-year operating plans, and also to ensure that harvesting operations are carried out in accordance with the cutting rules (CIDA 1974, Subagio 1974). Three cutting systems may be employed (Direktur Jenderal Kehutanan 1972), i.e. (a) the Indonesian selective cutting, (b) the clear-cutting and conversion into man-made forests, and (c) the clear-cutting over natural regeneration. The selective cutting system is, however, at present the choice of the concessionaires.

The selective cutting rules specify the minimum size to be taken and the number, spacing, and size class of residual trees per hectare to be left standing as core trees. These depend on the cutting cycle. With the cutting cycle of 35, 45 and 55 years, the lowest diameter limit of trees to be cut is 50, 40 and 30 cms, with the number of core trees of 25, 35 and 45 trees per hectare respectively.

Almost all concession holders employ the Indonesian selective cutting method. However, most of them do not closely observe the rules and regulations specified in the system. Consequently the conditions of the logged-over forest are generally not as good as expected to be. Clear cutting is currently employed by a few concessionaires, particularly in harvesting mangrove forests.

Shifting cultivation has been practised for hundred of years mainly on the islands outside of Java. This has transformed productive forests into unproductive secondary forests and alang-alang (*Imperata cylindrica*) grassland, whose total area amount to about 16 million hectares. The rate of increase of the alang-alang field is estimated to be 150,000 - 200,000 hectares per year. A large number of people is involved in the shifting cultivation practices. The extent of shifting agricultural land currently managed amounts to about two million hectares, of which 0.5 million hectares derived from forest (Soedarma 1970). Both shifting cultivation and logging operations have created undesirable ecological and sociological consequences.

Conversion of primary forests into resettlement (transmigration) areas and agricultural lands have depleted further the extent of primary rainforest. Most critical ecological and sociological conditions are found in the islands of Java and Bali, where the forest area (including planted forest) covers only less than 30 percent of the total land area of the islands, and the deforestation process up to now still continues. This is due to the extremely high population pressure (565 persons per square kilometer in Java, and 377 persons per square kilometer in Bali). The environmental effects of this situation can be felt by anyone on almost all parts of the islands.

THE EFFECTS OF TREE REMOVAL

People living near or in the forests have been traditionally extracting forest products (timber, food, medicinal plants, etc.) for their livelihood. Such practice does not create too much disturbance when the population is still sparse, and the product is used only for their own needs. When the population pressure becomes greater, and when the motive of extraction is profits, then the disturbance becomes serious and creates environmental problems. Currently the most intensive and extensive tree removal is the mechanized logging operations in virgin forests and the practice of shifting cultivation in the other islands outside Java (Sumatra, Kalimantan, Sulawesi, Irian Jaya, etc.).

The impact of tree removal on the forest environment may be grouped into impacts on plant community, animal community, soil and water (Ewel and Conde 1976). The discussion in this paper will follow this order and will be focused mainly on the effects of tree removal in virgin forest, since its exploitation will eventually have long-range environmental consequences over extensive areas.

Plant Community

In the selective cutting practices currently employed in Indonesia, the felling operation and log extraction are the two factors that damage the plant community. Felling damage includes the breakage of crowns and stems of saplings and trees, peeling of bark, and the covering of seedlings by the crowns and boles of the felled trees. Log extraction, on the other hand, is more damaging than the felling as all the impacts of felling are incurred during extraction, and it also exposes mineral soils and disturbs large areas of forest floor (Ewel and Conde 1976). The damage caused by felling and the extraction is related to the size of individuals and the number of trees per unit area removed, and the size of extraction equipments (Fox 1969, 1972; Nicholson 1958; Syachrani et al. 1974; Tinal and Palinewen 1978). The residual stands damaged by these operations is up to about 50 percent (Abdulhadi 1978; Syachrani et al. 1974; Tinal and Palinewen 1978), and a similar figure was observed also in Malaysia (Fox 1969, 1972; Nicholson 1958; Wyatt-Smith and Foenander 1962). Most of the damage is not due to felling, but to the extraction process (Burgess 1971; Fox 1969; Iskandar et al. 1975). In Malaysia, Burgess (1971) observed that 55 percent of trees were damaged in extraction operations. Trees of smaller diameters are usually damaged most (Abdulhadi 1978; Nicholson 1958; Tinal and Palinewen 1978). Relogging of exploited forest, which is frequently exercised by many concessionaires, resulted in more destruction of the residual stands. This is a most undesirable process silviculturally, since it retards the process of succession and recovery, and makes the forest poorer in desirable timber species but richer in weed species (Burgess 1971).

There is a controversial view concerning the effects of high-lead logging and tractor extraction, although currently there is a tendency to view that high-lead logging is less damaging than tractor logging (Burgess 1971; Fox 1969; Nicholson 1963).

Skid trails, haul roads and logyards, occupy a substantial area of the logged-over forest. In East Kalimantan such bare area covers up to about 30 percent of a logged area (Abdulhadi 1978, Kartawinata et al. 1978a). Nicholson (1958) and Fox (1969) recorded in Sabah (Malaysia) that 14 – 17 percent of the logged area was covered by roads, and Serevo (1949) in the Philippines found that roads covered 25 – 40 percent. Skid trails and haul roads frequently cut across water courses, thus resulting in the formation of semi-permanent ponds. In such a situation not only seedlings and saplings but also mature trees are killed (Kartawinata 1978). Locally it might be insignificant, but cummulatively it covers an appreciable area.

Bare extraction paths are favorable only to the growth of pioneer species, that almost always become dominant within a short period of time (Kartawinata 1978). In poorer sites, such as cleared heath forest on podsol soil, the invasion is very slow and the growth is less vigorous (Kartawinata et al. 1978b). Often times climbers do not only invade bare ground, but also overgrow individual trees, whose growth appear to be affected.

Only a few desirable woody species can grow on such disturbed areas (Kartawinata 1978), and their rate of recolonization is generally slow (Fox 1968). The recovery of the logged area to the condition similar to the unlogged forest is also slow. Meijer (1970) found in Sabah that 40 years after logging the disturbed portions of the forest could still be seen, as characterized by the presence of Anthocephalus chinensis, a fast growing pioneer with a relatively long life span. The undisturbed portions, on the other hand, had returned to primary forest conditions. It has been shown experimentally (Kramer 1926) that the rate of recovery depends on the size of forest opening.

The seedling population in logged-over areas are very much less compared to those in undisturbed primary forest. The reduction is attributed to the impacts of felling, skidding and yarding. Hamzah (1978) showed that the average seedling density in an undisturbed primary forest in South Kalimantan was 53,000 per hectare. He found that the least number of seedlings occurred on skid roads. In undisturbed sections of logged-over areas, however, the seedling density was greater (19,000 – 62,500 per hectare), almost comparable to that in undisturbed primary forests. He found also that seedling distribution was discontinuous, and was related to the skidding intensity. Similar trend was observed also in East Kalimantan (Sastrosoemarto 1978; Soekotjo and Dickman 1978) and elsewhere (Fox 1969; Liew and Wong 1973; Nicholson 1958; Wyatt-Smith and Foenander 1962).

The current destruction of primary forest, especially the lowland rainforest which has a very high species diversity, will lead to the loss and degradation of genetic materials (Sastrapradja et al. 1978). Two types of genetic material degradation may be recognized, i.e. genetic erosion and loss of species (Ewel and Conde 1976). The current practice of selective logging is in fact a process of creaming the best individuals of the current commercial species, in particular those of the genera Shorea, Dipterocarpus and Dryobalanops (Dipterocarpaceae). It thus leaves only undesirable, smaller and genetically inferior individuals in the residual stands to provide seeds for the next crop. Ashton (1978), Blanche (1978), Sastrapradja et al. (1978) and Whitmore (1975) have warned against this problem with respect to the lowland dipterocarp forest is Southeast Asia.

The more serious problem than the potential genetic erosion is the possibility of the loss of species (Ewel and Conde 1976; Jacobs 1978; Meijer 1968). Many of these species are unknown to science, and this is particularly true for Indonesia, where not more than 50 percent of the flora is known. Kartawinata (1978) suspected that the loss of species is proportional to the loss of individuals, in view of the fact that most of the tropical rainforest species have low number of individuals per unit area. Meijer (1968) warned that the practice of girdling and poisoning residual trees, which were usually not harvested, will accentuate the irrevocable loss of species. The loss of species diversity, in terms of original species composition of the primary forest, is evident from the comparison of data on the number of tree species of 205 per 1.6 hectares in primary forest, and 159 per two hectares in nearby logged-over forest in East Kalimantan (Abdulhadi 1978; Kartawinata et al. 1977). Many species of unknown use as well as those that are already used other than for timber and their relations (e.g. fruit trees, tuber crops, and rattans) may be lost during logging operations. In Malaysia, seventeen species and genera of horticultural and pharmaceutical potentials were found in 676 hectares forest plots (Whitmore 1971; see also Jong et al. 1973). Out of 205 tree species occurring in 1.6 hectares forest plot in East Kalimantan listed by Kartawinata et al. (1977), around forty species are those with edible fruits and/or having potentials for other uses.

Logging operations change the microclimatic conditions of the forest and the change is evident to any observer. Light, humidity, temperature and wind, are the factors that undergo changes after logging. These changes affect directly the growth of residual trees, saplings, and seedlings, as well as the new seedlings. Soekotjo and Thojib (1975), for example, reported that increased light intensity stimulated the growth of seedlings. Very few data are available from Indonesia on the changes of microclimate in unlogged and logged forests. Some data, however, are available on Malaysian forests. Chew (1968), for example, found that the vertical patterns of temperature and moisture from the forest floor up through the canopy were modified by clearing the surrounding forest. Whitmore and Wong (1958) considered that the light is the most important single factor that is changed. Because of this change, the arrested growth of saplings are renewed, but the saplings have to compete with the light-loving plants.

Increased light intensity results in higher air and soil temperatures. Soil temperature within lowland tropical rainforests fluctuates very little; daily and monthly variations range between 23°C and 26°C (Richards 1952), but after logging it may reach as high as 40°C (Meijer 1968). The increase of temperature results in the increase of soil evaporation and transpiration of the seedlings, that may result in the death of the seedlings. Soil desiccation prevents also the germination of the dipterocarp seedlings which require moist and cool environment.

Changes in microclimate results in crown-dieback, sunscalding of the trunk and branches, water stress and insect attack (Blanche 1978; Ewel and Conde 1976; Fox 1968; Nicholson 1965), that may lead to the death of residual trees, although Nicholson (1965) pointed out otherwise. Seedling's response to the changed environment varies considerably. Lukito and Hardjono (1965) reported in Irian Jaya (West New Guinea) the survival of only two percent, while Soekotjo and Thojib (1973) recorded in East Kalimantan the survival of more than 80 percent with the best growth at light intensity of 150 – 299 light candles. Liew and Wong (1973) found in forests of Sabah that seedlings responded to canopy opening with increased growth, while Brown and Mathews (1914), Serevo (1949), and Asiddao (1950) pointed out that many seedlings may be dead because of experiencing shock from canopy opening. Undesirable light-loving weeds, on the other hand, respond favorably to canopy opening and on relatively good soils they easily take over the site within a short period of time.

Animal Community

As indicated by Whitmore (1975), no complete study on the effect of logging on rainforest animals has been undertaken. In Indonesia, even there has been very little study on animal populations inhabiting primary forests. Logging certainly affects significantly the animal life. Loss of habitats is clearly the greatest threat (Harrison 1968; McLure 1965; Rabor 1960; Whitmore 1975; etc.). This will most seriously affect arboreal mammals (Whitmore 1975), and their consequences are most serious in Sumatra and Kalimantan than in other parts of the country. Browsing mammals on the other hand, appear to be less seriously affected, and in fact the lush secondary growth of weedy and herbaceous species improves their habitat. However, drastic and regressive effects on the fauna will occur if the primary forest is completely replaced by secondary growth (Whitmore 1975).

Studies on primates in Sumatra and East Kalimantan indicate that the effects of selective logging operations depend on the degrees of disturbance and on the species. In response to this, the species can either significantly decrease in density, adjust to the altered habitat, maintain a breeding population, or can be adversely affected (Rodman 1973; Wilson and Wilson 1975, 1978; Wilson et al. 1976). Some endangered species, such as orang utan and proboscis monkey, live only in undisturbed forest. It holds true also in the Malaysian rainforest (Chivers 1971, 1973; Davis 1962; McKinnon 1971; Medway 1970; Rodman 1973; Southwick and Cadigan 1972). Harrison (1968), who investigated the effects of forest clearance on small mammals, pointed out that progressive destruction of the native rainforest would result in progressive elimination of the native mammal fauna. He further indicated that selective logging caused the least effect, but if the rainforest is completely destroyed only introduced rats would remain. By comparing mammal populations in undisturbed and selectively logged forests, Yong (1978) found that selective logging with regeneration in productive forest has only a minimal effect on the native mammal fauna.

Birds, especially those living on the top canopy, are possibly more seriously disturbed by logging (Wells 1971). It is indicated that when the forest is logged, the population became agitated and wandered through the surrounding forests, and such canopy-top birds as hornbills and eagles require large areas of forest for maintaining abreeding stock and over mature trees for nesting (McLure 1968; Medway and Wells 1971).

Soils

The impact of logging on soils is due for the most part to the process of skidding, hauling and yarding. It has been pointed out earlier that the land surface destroyed by this oparation covers about 30 percent of the logged forest. The degree of damage and its effects depend on the nature of soils, the intensity and method of extraction, the size and number of equipment used, and topography. The physical and chemical properties are the aspects that are clearly affected by logging operations. One of the most conspicuous physical results is erosion. No data so far on the erosion in selectively logged-over forest in Indonesia. Various studies on erosion elsewhere indicate that erosion increases during and after logging (Burgess 1971; Kellman 1969; Liew 1974; Wyatt-Smith 1949).

The erosion takes place along the roads and skid trails, although Liew (1974) showed that in Sabah the erosion on tractor paths was less than in places away from tractor paths, which might be attributed to the compaction of the soil by tractors. Personal observations in East Kalimantan and South Sumatra indicate that the soils especially on the sides of the roads and skid-trails are seriously subjected to erosion during the first and second year after logging, after which the weedy pioneer plants take over.

The erosion hazard in the clear-cut forest is much greater than in the selectively logged area, and becoming worst when clear-cutting is followed by burning as traditionally done in shifting cultivation practices. This has been shown by Wyatt-Smith (1949) in Malaysia. Clear-cutting of forest that has resulted in the serious environmental degradation can be exemplified by the case of the severely eroded upper Solo River Basin in Central Java. The Basin has a total area of 10,252 square kilometers, covering mountainous and hilly terrains, and consisting of highly erodable margalitic, lateritic and limestone soils. About sixty years ago, the area was covered by natural forest (Ramsay 1975), but clear-cutting for shifting cultivation and other agricultural purposes, that did not take soil conservation measures into account, have transformed almost half of the area into a moderately to severely eroded land with very low productivity, and the regular burning of the undergrowth in the teak forest has enhanced further the erosion process (Dames 1955). Ramsay (1975) noted that 24.4 percent of the land was seriously eroded. In 12.7 percent of the area, the erosion has reached a critical stage, where agriculture has been abandoned or almost abandones. Erosion and flooding are widespread, where 8.6 million tons of soil were carried by the Solo River passing through the City of Solo during the five months of rainy season of 1970 – 1971 (McComb and Zakaria 1971; Ramsay 1975). This is equivalent to the soil removal of four milimeters per year over the entire watershed. The soil removal varies from one meter on the ridges and ten meters on the gullies. The effects of forest clearance have been shown also by Dijk and Vogelzang (1949) in the Cilutung River Basin, West Java. A comparison of records of sediment loads carried by Cilutung River in October 1911 to September 1912, and October 1934 to September 1935 indicated a marked deterioration from 821,000 tons in 1911 – 1912 to 1.79 million tons in 1934 - 1935. They attributed this increase to the misuse of the land, i.e. increasing deforestation, reckless cultivation methods and pasturing after 1917. At Ciwidey, Gongrijp (1941) showed the value of terracing for erosion control. In the mountain forest on volcanic soil in

West Java, he recorded that during the first year after clearing the virgin forest, the erosion was negligible; but in the second year after clearing the sediment yields amounted to 25 tons per hectare per year on terraced clearing, and 50 tons per hectare per year on unterraced field. He found that the erosion increased with the decrease of humus content of the soil. The erosion on shifting cultivation area may be comparable to the unterraced fields, or perhaps worst in view of burning before cultivation.

Other effects of logging on soils are the compaction and loss of structure. Hamzah (1978) found in the logged-over forest in East Kalimantan that the average bulk density of soil to a depth of 20 cms on skid roads, under cable line, and on undisturbed parts of the forest near the skid road, was 1.56, 1.65 and 1.21 respectively. Inthasothi (1975) on the other hand, found that in 2 - 4 year old logged area, in another part of East Kalimantan, the bulk density to a depth of 4 cms in undisturbed and heavily disturbed soils was 0.96 and 1.27 respectively. He indicated also that the porosity of the surface soil in virgin forest (63.66 percent) was higher than in the logged-over area (52.0 percent). In the logged-over area the porosity increased and the bulk density decreased with time. Coulter (1930) found that the soil of virgin forest was better structure than that of the cleared area.

The degree of physical damage of the soil, to a greater extent, depends on the logging techniques practiced. No data for Indonesia are available to compare the effects of various harvesting techniques, but elsewhere it has been known that animal logging causes in the least total damage, whereas tractor logging results in more damage than high-lead logging (Brown 1955; Russel 1974; US Environmental Protection Agency 1976). The high-lead logging, however, poses a greater erosion hazard than tractor logging in view of the fact that it is usually employed in steeper terrain (Ewel and Conde 1976).

Logging has significant effects on the nutrient status of the soil. In tropical forests, the above ground plant biomass holds most of the nutrient reserve and forms the source of colloidal organic matter contents that largely contribute to the CEC (cation exchange capacity) of the soil. The removal of trees from the forest will consequently reduce the CEC value, through the reduction of organic matter inputs in the form of branch and leaf fall. It has been reported that the rate of decomposition in cleared areas was lower than in mature vegetation (Ewel and Conde 1976), resulting in less supply of colloidal organic matter.

Inthasothi (1975) found, in rainforest plots in East Kalimantan, that the CEC value in two-year old logged-over forest was lower than in virgin forest, but found it higher in the four-year old logged-over area. Soerianegara (1970) compared the soils of the lowland rainforest and that of abandoned shifting agricultural land in West Java, and found that deforestation followed by cultivation and abandonment resulted in the decrease of organic matter, total N, and available phosphorus, potasium and calcium in the soil. He pointed out that after a few years these increased again. Similar trend of quick recovery in soils under secondary growth and fallow vegetation has been shown also in Irian Jaya (Reynders 1961). On the other hand, Satjapradja and Masud (1978) and Soedjito (1978) indicated that available phosphorus, potasium, calcium and magnesium, and organic matter contents in undisturbed forest and secondary growth did not show consistent differences.

The role of microorganisms in soil fertility are well known. However, research on the ecology of soil microorganisms in relation to forest clearance is lacking. Available data indicate only that microorganisms in soil under alang-alang field, agricultural land, and forest plantation are dominated by bacteria and fungi (Carlyle et al. 1961; Saono 1968). In Malaysia, on the other hand, Coulter (1950) showed that the bacterial and fungal population in undisturbed forest was higher than in burned grass and plantations. In the Philippines (see Blanche 1978) it was reported that a logged area had more bacteria, actinomycetes and fungi than nearby primary forest. Tropical soil microorganisms are suspected to have no resistance in their life cycles as those of the temperate zones do, hence they will be drastically affected if their micro-environment is greatly altered (Ewel and Conde 1976) by forest clearance. This suggests that it may lead to the degradation of the soil quality in the cleared forest. Mycorrhizal fungi have been recorded to be present in primary forest trees of West Java (Janse 1897). It is likely that many other forest species especially those growing on poorer soils such as podsolic soils and white sand podsols, may possess also mycorrhizal fungi. How their fate is after forest destruction and what will be the effects are unknown, and research along this line needs due attention.

Water Yield and Quality

Hamzah pointed out that there are three types of land in the logged-over forest which are vulnerable to exessive run-off and erosion, i.e. daylighting areas (cleared areas on both sides of the road), skid roads and logyards. In one concession area in East Kalimantan, he calculated that with a 500 km road network, the daylighting area alone covered about 40,000 hectares. In such an extensive open area, where the soil is partially compacted, the hydrological conditions of the forest may be degrading. Comparison of infiltration rates revealed that the rate was 6.0 mm per minute in undisturbed soils, while on skid roads there was no infiltration at all. This means that the run-off will be greatest on the skid roads.

In Java, Coster (1938) studied the run-off and soil loss in various types of vegetation. He found that the run-off on cleared and weeded area was 20 – 50 percent greater than in the dense rainforest. He further observed that the least favorable types of vegetation were tuft grasses, Imperata grassland, sod forming bamboos and lowland forest without undergrowth. In West Malaysia the run-off in semi-forested and partially urbanized catchments accounts for 60 – 65 percent of the rainfall, which is considerably higher than in natural forest (Leigh and Low 1973; Low and Goh 1972). Run-off in rainforest areas and in partially forested catchments is relatively low, ranging from 30 – 50 percent (Brunig 1970; Low 1972; Wyatt-Smith 1964). This is attributed to the closed nature of the canopy and the multi-layered vegetation (Wyatt-Smith 1964), where the rainfall is partially intercepted. When trees are removed, less rainfall is intercepted, while the removal of the ground cover results in the development of a denser rill network on the slopes; and on clay soil, swelling of particles will reduce the absorbent capacity of the soil, which will cause an increase of overland flow (Douglas 1968; Leigh and Low 1973).

There have been very few studies on the effects of logging on water quality. Hamzah (1978) measured the silt content of water from a river away from the logging area, a river near the logging area, and a ditch near the skid road, and found the silt content of 0.01, 0.05 and 0.10 percent, respectively. As yet no study has been undertaken to show that logging has accelerated the siltation in rivers. However, newspaper reports have indicated the urgent needs to dredge many big rivers in Sumatra and Kalimantan, and flying over these islands one will see a spectacular view of reddish brown rivers meandering through the forest. The sediment loads in rivers within deforested areas are considerable. This has been exemplified by the Solo River that carried eight million tons of sediment during the five-month rainy season (McComb and Zakaria 1971; Ramsay 1975), and the Cilutung River which carried 1.79 million tons of sediment in the year of 1934 – 1935 (Dijk and Vogelzang 1949). The increased rate of siltation has possibly brought about the more frequent occurrence of floods.

Soerianegara (1970) attributed the death of Bruguiera trees in the mangrove of Cilacap, Central Java, to frequent flooding, that reduced the salt concentration and the raise of soil surface brought about by rapid siltation. This is apparently related to the heavy deforestation of the upriver area.

In addition to water quality change brought about by the increase of sediment loads, organic matter inputs into stream may increase oxygen demand and turbidity of the water (Ewel and Conde 1976). In their study of streams in a forest area in East Kalimantan, Kartawinata et al.(1978a) found the increasing values of turbidity, carbon dioxide, and algal population, and the decreasing concentration of dissolved oxygen from primary forest to secondary forest, newly cultivated areas and to settlements.

It should be pointed also that it is a common practice in logging operations to spray fresh logs with pesticides to prevent fungal and insect attacks. The effects of pesticide spraying on the forest environment and on rivers, where logs are transported by rafts to the loading points, are at present not known. Another effect of logging to the environment, though indirect, is the potential hazard resulting from effluent discharge from wood industries to the rivers. The rivers are the lifeline of most people living in Kalimantan and in some parts of Sumatra.

DISCUSSION AND CONCLUSION

The Eighth World Forestry Congress Declaration (1978) indicates that large areas of forests in developing countries have suffered a significant deterioration in quality and reduction in size, and that the greatly expanded rate of removals over recent years has concentrated on prime species, leaving a poorer quality and badly damaged forest. This is particularly true for Indonesia. The selective cutting method, which is currently used by concession holders, has left and will expand further a special type of forest, i.e. primary forest intercalated by a network of secondary forest, containing secondary tree species and inferior individuals of prime species.

Relying on natural regeneration without any silvicultural intervention, as is the case at present, the future of the above forest, whether it will be less or more productive than before, is uncertain. The ecological basis for the presently used cutting methods has never been established (Ashton 1978), yet the method has been practiced indiscriminately without due considerations to ecological conditions of the sites. Ashton (1978) stressed that the selection techniques for regeneration will have to depend on the aim of management whether to yield a few preferred export species or all acceptable and exploitable species. He further emphasized that in the selective cutting method 'it is young trees, from poles to the minimum exploitable size, which will form the next crop; the seedlings contribute to successive crops thereafter'. This is not satisfied by the present selective cutting practice, as young trees are mostly damaged (Sastrosumarto 1978; Tinal and Palinewen 1978). It is estimated that about one third of the damaged residual trees will die before maturity, and that with the currently accepted cutting cycles, there is a possibility of a decline in yields at each successive cycle (Ashton 1978). Hamzah (1978) also doubted that trees for the second crop would mature within the specified cutting cycle.

Current practice of logging has resulted in too great a damage on vegetation, animal population, soil and water conditions. The damages are attributed not only to the shortcomings of the present logging method, but also in many cases to the failure of logging operations to comply with the existing rules and regulations. Ecological considerations are frequently neglected in favor of short term 'economic efficiency'. While the current method is being improved, tighter control of logging operations should be exercised. Immediate measures to reduce or minimize logging damages and its environmental consequences have been suggested by various authors (Ewel and Conde 1976; Fox 1969; Kartawinata 1978), such as (a) minimizing the width of extraction paths, (b) refraining from making unnecessary tractor paths, (c) avoiding excessive wet weather yarding, (d) make use of winching to avoid crawling over small hills, (e) restricting the radius of landings, and (f) reopening blocked water courses.

In recent years, the idea of applying environmental impact assessment to forestry has been advocated (e.g. Helliwell 1978; Sinden 1978; Soerianegara 1978). Several methods, especially for selecting forestry projects, are available (Sinden 1978), although they appear to be sophisticated and costly to exercise. Soerianegara (1978) proposed a method that can be used in assessing the impact of logging. He stressed that the assessment should be undertaken before, during and after logging, and this will produce necessary data to minimize negative effects.

To prevent genetic erosion in the utilization of tropical forest, it is suggested that in the logging operation it should be considered to spare a few good quality trees, usually trees with large diameters. These will form the core trees that will provide seed crops. It is a practice, at present, to cut all trees bigger than the specified minimum diameter limit. The so called core trees specified in the Indonesian Selective Cutting System are those having diameters less than the diameter limits. There is no assurance that these core trees are of good quality and will have produced seeds before the second cutting cycle.

In situ conservation is the only answer and the most effective way to prevent the loss of genetic materials. The importance of this has been stressed time and again, and the Eighth World Forestry Congress specifically urged Governments 'to preserve, as part of normal balanced land-use, adequate areas of every type of forest and give them full and permanent legal protection as National Parks or often protected areas'. Indonesia is presently moving in this direction, with the ultimate goal of setting aside ten percent of the land area of Indonesia (± 20 million hectares) as the conservation areas. In addition to formal designation of conservation as separate entity, it has been also suggested to set aside undisturbed virgin forest plots within the managed or logged forests as reserves (Kartawinata 1975; Kartawinata and Atmawidjaja 1974; Roche 1978; L.J.Webb, personal communication). In this way then, the total loss of species in any logging area can be at least reduced.

More than 16 million hectares of secondary forest, *Imperata* grassland and other degraded land, which were mainly the product of shifting cultivation, need rehabilitation and/or utilization. They are environmentally undesirable and economically unproductive. Some of these, particularly the degraded land, are now being reforested by the Government, for which about US$ 55 million have been allocated for the fiscal year of 1979/1980. To prevent further reduction of primary forest area, it is wise if such program as forest plantation, agricultural expansion and resettlement programs make use of idle grassland and secondary forest, rather than clearing primary forest.

From the previous account, it is evident that available data on almost every aspect of logging are very meager and to some extent rather contradictory. Therefore, a comprehensive investigation, including comparative studies of logging techniques and their effects, should be instituted. Other aspects of investigation have been suggested by various authors (e.g. Ewel and Conde 1976; Fox 1968; Kartawinata 1978; Kartawinata and Atmawidjaja 1974; Suparto et al. 1978). For this research, large areas of primary forest would be required, and Ashton (1978) suggested to set aside 2000 hectares for each representative forest type. To make data, obtained from various investigations, comparable, it is suggested to employ standardized methods, such as those proposed by the MAB Project 1 Workshop at Hamburg in 1977 (Brunig 1977).

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THE ENVIRONMENTAL CONSEQUENCES OF INTENSIVE FORESTRY AND THE REMOVAL OF WHOLE TREES FROM FORESTS: THE SITUATION IN LATIN AMERICA

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The environmental consequences of intensive forestry and the removal of whole trees from forests in Latin America will, in general, be more severe than from North America for three reasons: There are more oligotrophic forests which are extremely susceptible to nutrient loss; Opening of mountain areas often results in erosion due to indigenous agriculture; Uninterrupted growing seasons result in continuous exponential growth of parasites in monoculture plantations.

INTRODUCTION

The popular impression is that there is a tremendous potential for biomass production in Latin America. For example, Jose Goldemberg (1977), coordinator of an energy policy group at the University of Sao Paulo, Brazil, stated, "An energy strategy based on biomass is a natural for Brazil. We have lots of land, lots of water, and an ideal climate for growth."

Not only are many Latin American planners and politicians convinced that biomass production is a cheap and easy energy source, but directors of multinational corporations also believe that tropical forest ecosystems have a tremendous exploitable potential. Daniel Ludwig, of National Bulk Carriers, paid three million dollars to a group of Brazilian families for a 4650 square mile area of rain forest in Para state, Brazil, in the lower Amazon Basin. The corporation has clear cut the area and planted it to various exotic species such as Gemilina (Gemelina arborea) (Jahoda and O'Hearn 1975) with the idea of helping to meet the future world shortages of lumber and wood pulp.

Indeed, even among professional ecologists, there is almost unanimous agreement that productivity in tropical forests is higher than in any other forest type or the world. Murphy (1975) states, "forests receiving abundant year-round rainfall and lacking distinct seasonality in leaf fall are, on the average, the most productive of any of the terrestrial ecosystems measured to date. Total annual net primary production averages 2400 $g/m^2/yr$. The maximum value is 3210 $g/m^2/yr$. for lowland forest in Sarawak." Lugo et al. (1973) say "Tropical ecosystems are more productive than their temperate counterparts. Tropical forests as a whole, with a mean annual net primary production of 2160 g/m^2, exceed temperate forests, averaging 1300 $g/m^2/yr$., by a factor of 1.7, and boreal forests, averaging only 800 $g/m^2/yr$. by a factor of 2.7." In a recent review of Lugo et al., Murphy (1977) concluded that their estimates of tropical productivity were around 3000 $g/m^2/yr$. too low.

According to Golley and Lieth (1972), "Tropical forests have an average net primary productivity of 2530 $g/m^2/yr$., ranging from 520 to 4840 $g/m^2/yr$. There seems little doubt that on the average tropical forests are more productive than temperate forests." Rodin and Bazilevich (1967) calculate the annual productivity of tropical forests to be between 2700 and 3450 $g/m^2/yr$., and they conclude that this "indicates a very high rate of annual organic matter increment in the tropical and subtropical belts, considerably greater than in the plant communities of temperate latitudes. . ." Whittaker and Likens (1975) also rank tropical rain forests as first in rate of production among natural terrestrial ecosystems, with a normal range of 1000-3500 $g/m^2/yr$.

A few reviewers consider productivity in tropical forests significantly higher than the above figures. Westlake (1963) suggested that the range of productivity of tropical forests to be 2600-5200 $g/m^2/yr$. On the basis of available solar radiation, Brunig (1968) calculated the "maximum

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potential gross assimilation rates" in tropical forests to be between 5600 and 8900 $g/m^2/yr.$, and stated that "The average potential productivity of the vegetation in the tropical rain forest is several times greater than in continental boreal coniferous forests on comparable average productive forest sites." He concluded that "World-wide planning of forestry production in the future will have to consider the relatively high potential of the tropical rain forest area for inexpensive timber production."

However, not all scientists share the opinion that tropical vegetation represents a great potential for cheap and rapid production of wood and/or energy. Whitmore (1975) after a comparison of herbaceous growth versus woody growth in tropical rain forests, dissents from the view that tropical forests have higher production rates than temperate forests. He states, "We can note that the luxuriousness and appearance of unbridled growth given by the vegetation of the perhumid tropics does not therefore arise from an intrinsically higher growth rate than exists amongst temperate species. The unfamiliar life-forms of palm, pandan, the giant monocotyledonous herbs, and the abundant climbers make a vivid impression of "vegetative frenzy" on the botanist brought up in a temperate climate. The appearance of rapid growth of pioneer trees of forest fringes and clearings, which forms the other part of the impression, does not result, as far as we yet know, from a particularly efficient dry-weight production or energy conversion, but arises from the architecture of the tree, which results from the capacity for unrestricted elongation of internodes and production of leaves in the continually favorable climate."

Kato et al. (1974), after studying the production of the Pasoh forest in Malaysia, also had doubts about the supposed high wood production in tropical forests. They state "The amount of evidence is too scarce, but these (their) figures seem to show that the traditional belief in the high rate of wood production by tropical rain forests is mostly probably an illusion."

Leigh (1975) in his review and comparison of wood production in tropical and temperate areas concluded that while wood production varied greatly from year to year, "rates are roughly comparable for tropical and climax temperate forest."

How can this disagreement between ecologists about whether productivity in the tropics is higher than in other latitudes be explained? In a series of papers (Jordan 1971a, 1971b, Jordan and Murphy 1978, Jordan 1979) I have developed the idea that productivity of natural forests actually is higher in the tropics, but only because leaf production is much higher in the tropics than in the temperate and boreal regions. If we consider only wood production, rates of productivity in the tropics are not different from rates at other latitudes. In Jordan (1979), I have divided the continents into five zones, corresponding to northern, temperate, south temperate, subtropical, and tropical regions, and calculated wood production and litter production separately. An analysis of variance showed that while there was a statistically significant difference in litter production between zones, wood production was not significantly different. A summary of these results is given in Table 1.

There are, of course, difficulties in comparing rates of natural forest production due to differences in the methods used in different studies. Even more difficult are comparisons of plantations because of differences in establishing and caring for the plantations, methods of seed bed preparation, fungicide application, pesticide usage and fire protection. The more of these cultural inputs or "energy supplements" to a plantation, the greater will be the harvest. Nevertheless, by assuming equal energy supplements in all plantations, I calculated the average production of 89 temperate plantations to be 1343 ± 894 $g/m^2/yr$ and the average of 65 tropical plantations to be 1193 ± 741 $g/m^2/yr$ (Jordan 1979).

This introduction pointing out that potential tree productivity in tropical America is not necessarily greater than potential productivity in temperate zones is directed toward dispelling any notions that environmental consequences of whole tree harvesting in the tropics is any less serious than whole tree harvesting in temperate zones because tropical trees supposedly grow faster. The fact is, that environmental consequences may be more serious in Latin America, particularly the tropics, than in temperate zones. The reason is, that in addition to environmental problems encountered in the temperate latitudes, such as contamination by pesticides and fertilizers, salinization by irrigation, limitation of genetic variability, destruction of wildlife habitat, compaction of soil, and change of the carbon dioxide balance, there are two problems which are potentially more severe in the tropics: 1. Nutrient loss via leaching and/or erosion; 2. Exponential growth of parasites and predators in monocultures due to an uninterrupted growing season. Since I assume these former problems will be dealt with in detail by other participants

Table 1.--Wood and litter production of broad-leaved species in five latitudinal zones

Zone	Wood g/m²/yr.	Standard Deviation	n	Leaf Litter g/m²/yr.	Standard Deviation	n
Northern	968	± 399	14	281	± 133	23
Temperate	658	± 248	11	328	± 111	24
South Temperate	610	± 537	22	367	± 116	35
Sub-tropical	758	± 290	3	644	± 204	20
Tropical	734	± 275	10	957	± 362	33

in this symposium, I will devote this paper to the latter two which are particularly critical in tropical Latin America.

THE NUTRIENT PROBLEM

A common primary classification of the major forest biomes of the world separates tropical forests and temperate forests. We often talk about and contrast tropical forests with temperate forests. This classification is useful when dealing with certain structural characteristics such as species diversity. However, when dealing with dynamic functional characteristics such as productivity and nutrient cycling, such a classification tends to obscure rather than illuminate. Jordan and Herrera (1979) contrasted productivity and nutrient cycling in oligotrophic forests (forests growing on nutrient poor soils) and eutrophic forests (forests growing on nutrient rich soils), and found that oligotrophic forests in the tropics resembled more oligotrophic forests in the temperate zone than they did eutrophic tropical forests. Likewise, eutrophic forests in the tropics resembled more eutrophic forests in the temperate zone than they did oligotrophic tropical forests.

This is an extremely important point. If we are trying to compare environmental consequences of whole tree harvesting in the tropics with consequences in the temperate zone, the results will vary greatly depending upon whether the soils on which the forests grow are rich or poor in nutrients.

Most of the forests in the United States grow on relatively rich soils. The major oligotrophic forest region is the pine, pine-oak forest on the outer coastal plain of southeastern United States, although scattered stands such as those of jack pine in Michigan would also qualify as oligotrophic. However, in South America, oligotrophic forests constitute a much greater proportion of all forests. The soils of most of the central and eastern Amazon Basin are old, highly leached, and low in available nutrients (Fittkau et al. 1975, Stark, 1971). The soils are acidic, with a low ion absorption capacity, making them particularly susceptible to leaching (Aubert and Tavernier 1972).

The sediments which are now found in the central and eastern Amazon basin have not been produced and deposited where one observes them today, in one single weathering and erosive cycle, but in a series of such cycles. They have been exposed, also within the basin, to various cycles of meteorization, erosion and sedimentation. As a consequence, the weathering products have been thoroughly leached and deprived of the nutrients they may have contained originally. The younger sediments of Central Amazonia which have been submitted to more of the above mentioned cycles than older sediments, are consequently the poorest in nutrients (Herrera et al. 1978a).

Despite the low nutrient content of the soils, some Amazon forests have a biomass of 400 tons per hectare or more (Jordan and Uhl 1978), which is comparable to eutrophic temperate forests. How can this biomass be maintained in spite of the very poor soil? In the oligotrophic forests of central and eastern Amazonia, there are various nutrient conserving mechanisms which occur, and apparently have evolved to prevent nutrient loss from the forest.

What are some of these mechanisms? The most striking is a layer of roots and organic matter on top of or close to the surface of the mineral soil. The layer can reach a thickness of 20 or 30 cm.

In the non-flooded sites (tierra firma) of the Amazon Basin, the surface layer on top of the soil is an aerobic network of fine roots that feel, to the foot, like a mattress. Mixed in this network of roots is organic matter in various stages of decomposition. In Central Amazonia, in the most nutrient poor region, this mat can be up to 30 cm thick. As one travels away from Central Amazonia, for example toward the Guiana Shield to the north, the root mat becomes thinner.

Direct observation of this root mat on tierra firma soils gives some idea of its role in nutrient conservation. The rootlets do not seem to be geotropic responsive, and when leaves, fruit, or branches fall, the roots soon cover and attach to the decomposing litter. A few months later, all that is left is a shell of roots, showing the shape of the decomposed litter.

Direct transfer of nutrients from litter to roots, as a nutrient conserving mechanism, in regions of soil with low nutrient retention capacity, has been hypothesized by Richards (1952) and Walter (1971). Went and Stark (1968) have hypothesized that one of the direct nutrient cycling mechanisms is mycorrhizal fungii (simbiosis between plant roots and fungii), which grows between decomposing litter and roots. We have observed mycorrhizal threads in our study site in the upper Rio Negro region by gently pulling fine roots away from the litter to which they are attached. Herrera et al. (1978b) demonstrate movement of radioactive nutrients from litter to living roots through the fungal hyphae.

Micorrhizal fungi, however, are not the only nutrient conserving mechanisms of the surface root and organic matter layer in Amazonian forests. Stark and Jordan (1978) have shown that when a radioactive solution of phosphorus and calcium is sprinkled on top of the root mat, 99.9% of the activity is taken up and eventually translocated to nearby trees. Apparently the immediate retention mechanism is surface absorption on organic material, and later, gradual uptake by living roots. These results plus the fact that up to 50% of the biomass of some Amazonian forest occur in the roots (Klinge and Herrera 1979) is evidence that the root mat itself constitutes an important nutrient conserving mechanism because it increases nutrient absorption capacity.

In our experimental plots in the upper Rio Negro region, we are currently carrying out a project that is demonstrating that destruction of the root mat and vegetation on the soil surface, during slash and burn agriculture or rubber tree plantings, releases large quantities of nutrients into the upper mineral soil. If a crop, or secondary successional vegetation is established rapidly enough, much of the nutrients released may be recovered, but during harvest, and establishment of a second crop, nutrient losses continue, so that in most cases, a third crop is not feasible. An extended fallow period is then needed before the soil can be used again.

This problem of nutrient loss during agriculture appearsto be most severe in the regions of the Amazon with relatively low soil fertility. Among other examples, in the Amazon region of Perú, near Yurimaguas, Villachica et al. (1975) found that increasingly heavy applications of fertilizers are necessary to maintain crop production.

Epiphyllous organisms, such as mosses, algae, lichens, and bacteria also play an important role in nutrient conservation in the undisturbed forest. Some of these fix nitrogen from the air. Presumably this nitrogen becomes available to the trees when the leaves are shed, and the roots invade the litter. These organisms also may play an important role in scavenging nutrients from the rainfall. For almost all the nutrients examined, Jordan (unpub. data) found that nutrient concentrations in throughfall were lower than concentrations in rainfall, apparently the same phenomena reported by Witkamp (1970) for radioisotope scavenging in a tropical forest.

The effect of the various nutrient conserving mechanisms is that the Amazon forest, along with its associated microorganisms, acts as a giant ion-exchange column that extracts nutrients from water passing through the ecosystem (Klinge and Fittkau, 1972). The net result is that concentrations of many nutrients in the stream flow that drains an ecosystem is lower than the concentrations in the rainfall entering the system (Jordan ms in prep.).

The common factor about all the nutrient conserving mechanisms is that they are all part of the living, natural forest, and they are all destroyed when the forest is cut and used for agricultural purposes or for forest plantations. When forest openings of a hectare or less are made, as is traditional in slash and burn agriculture, no permanent damage to the ecosystem occurs, because organic matter from the surrounding forest quickly fills in the opening after the site is abandoned. However, when hundreds of hectares or more are destroyed, the biological resources which can develop the nutrient trapping mechanisms that would serve to replenish the nutrient capital of an area are too far removed to fill in the area. The retention capacity of the soil is not enough to prevent the nutrients from being leached and in consequence the modified ecosystem impoverishes rapidly. Furthermore the ability to trap nutrients coming with the rain is lost and nutrients are leached out of the mineral soil as fast as rainfall brings them in.

Certain tree crops such as gmelina and cacao, which are now frequently being planted in large scale in Amazonia, appear to have the capability of establishing their own root mat relatively quickly, and thus may be able to prevent large nutrient losses. However, nutrients are not the only factor to consider in large Amazonian monocultures. Perhaps more important are insects, fungi, and other predators and parasites which can take advantage of the unique conditions in monocultures, i.e. the unlimited, genetically undifferentiated resource coupled with a hot wet climate unbroken by dry or cold seasons which could interrupt the predators exponential growth.

However, before I deal with these problems, I will talk about the nutrient problem in eutrophic forests is South America.

EROSION IN EUTROPHIC REGIONS

Generally speaking, eutrophic forest ecosystems in Latin America are coincidental with mountainous regions, where gradual erosion brings the nutrient rich, unweathered parent rock into reach of the roots of the trees. Natural organic acids decompose the rock, and make the mineral elements available for cycling in the ecosystem.

The eutrophic region in Latin America extends along the Andes through Central America and down the West Coast of South America. It also occurs in the mountainous regions of the Caribbean Islands. Of course growth in some of these regions is limited by water scarcity, and in these regions, deserts and savannahs predominate. However, in this discussion, I am concerned only with the regions of ample rainfall.

Despite potentially rich soils in many Latin American mountain regions, productivity of many managed ecosystems is low. Why? Because in contrast to mountainous regions in the United States and Canada, where many mountain regions that are used for forestry and grazing are managed to prevent soil erosion, land use practices in mountainous regions of many Latin countries causes severe soil erosion. And while gradual erosion as mentioned above is necessary for the release of nutrients from deeply buried rocks; rapid erosion causes loss of topsoil along with the associated nutrients and leaves the dense sub-soil exposed. Rainwater does not easily infiltrate into this dense soil, and each succeeding storm carries away more valuable top soil. In addition, roots of tree and crop seedlings do not grow well in the heavy, exposed subsoil.

The problem of soil erosion is particularly critical in Central America, Haiti, Dominican Republic, and Jamaica. Why is there no proper land management in these areas? There are forest reserves which are supposedly off limits to the campesinos who come with their saws and axes, and try to establish a crop. But in many cases there are inadequate wardens to safeguard the fragile mountain areas. And often, even if there are wardens, it is difficult for the warden to prevent campesinos from establishing his own farm. The farmer has a wife and many children, all of whom are hungry, and their only hope of survival is to cut a patch of land and exploit it maximally for a few years until it all erodes away, and then move on to another patch of land.

The basic problem, of course, is that the population exceeds the carrying capacity of the land. Until population can be brought under control, talking about environmental effects of plantations and whole tree harvesting is like worrying about high levels of lead dissolved in the blood of a person who has been shot.

Of course there still are many mountainous regions in Latin America which have not been exploited. The forestry school at the University of the Andes, Merida, Venezuela, is conducting research on forest productivity in mountainous regions, and we have no reason to think that plantations in the Andes, if managed properly, would cause any more environmental degradation than similar mountain plantations in the United States.

SEASONALITY

The lack of strong seasonality in many of the rain forest areas of Latin America contrasts strongly with the distinct summer-winter seasonality we are accustomed to in the United States. This lack of seasonality is an argument put forth by many proponents of biomass for energy in Latin America (see first section of this paper). Their idea is that with no cold season, and with a dry season that often is indistinct or lacking, there is more opportunity for tree growth. Ironically, it is this very lack of seasonality which has the greatest potential for environmental consequences in plans for energy plantations and whole tree harvesting. Insects, fungii, virus, and other plagues which are parasitic upon crop plants and trees exhibit an exponential growth curve. In temperate United States, the end of the growing season and subsequent freezing temperatures often kill back the parasite populations, or at least causes them to retreat to a dormant state. The active, consuming populations are effectively set back to zero, where they will again begin their exponential growth in the spring, but only after the crop plants have a good head start.

In contrast, there are no freezing temperatures to decimate the parasite populations in the tropical rain forest regions. An insect population in a monoculture forest plantation could be disastrous. In many cases, the dry season is not long enough or severe enough to be really effective against any potential parasites.

How do the natural forests avoid this insect plague problem? The natural forests have a very high species diversity. In our experimental plot near San Carlos de Rio Negro, Venezuela, we found over 198 tree species in a 4 ha. plot (Jordan and Uhl, 1978). Most species had less than 4 individuals in the study area. What this means is that any pest species which begins preying on an individual of a tree species in the tropical rain forest has a difficult time finding another individual of the same species to attack. And it is not simply a matter of finding another individual of the host species. While the pests are looking for another host individual, the pests themselves are subject to predation by a tremendous variety of insect carnivors, especially birds. In monoculture plantations, the number and types of these predators are of course greatly reduced.

It is the high diversity of the tropical rain forest, coupled with the high diversity of the predators, which compensates for the lack of seasonality in tropical forests in keeping pest populations under control.

Genetic diversity within a species also increases resistance to certain types of plagues, and plantations often tend to reduce within-species diversity. However, this is a problem which is not necessarily unique to the tropics, and therefore I will not pursue it here.

SOME EXAMPLES

Uverito, Venezuela

Environmental consequences of biomass plantations should be considered in the context of alternative land uses. For example, one of the largest plantations in Latin America, almost 140,000 ha, located close to the mouth of the Orinoco in Venezuela, is growing on coarse sands which previously supported only open savannah. At the time the Venezuelan government acquired the land, only a few wild burros grazed on the sparse vegetation. The present rate of wood production is around 16-20 m^3/ha/yr., or 8-10 t/ha/yr., not a spectacular yield, but compared to the alternative use, it is very good.

Species in this plantation are primarily Pinus caribaea, but there are presently experiments with eucalyptus. The environmental consequences of the plantation are much the same as in pine plantations in the United States. There is a build up of humus and duff, a lowering of the pH, mobilization of aluminum, and crowding of trees around 10 years of age. Fire is also a hazard. Possibly the most serious question is whether there will be enough nutrients left in the soil to support a second crop, if there is a whole tree harvest including leaves. If there is this danger, a harvest of stems only might be wise, since nutrient concentrations in leaves are much higher than in stems.

Interestingly, the population of wildlife has increased noticeably since the establishment of the plantation, possibly because the young forest offers more cover than the open savannah.

Puerto Rico

One of the best reliable reported yields of Pinus Caribaea in the tropics is from the mountains of Puerto Rico, where productivity averaged around 25 t/ha/yr. (Liegel 1976). The site has plenty of rain, and the soils have a base saturation of around 5 meq/100 g which the authors characterize as relatively low, but which are high in relation to the coarse sands of Uverito Venezuela.

Liegel (1976) considered erosion to be serious in the areas, and presumably the plantations would decrease the erosion problem. In light of alternative uses of the land, there probably are no important environmental consequences of biomass plantations.

Para-Brazil

The problem of nutrient depletion in the Amazon has already been discussed. Although there are no generally available reports on the progress of the plantations of National Bulk Carriers, apparently the first tree crops have become established. This is not surprising, because if seedlings are planted amidst the ashes or debris and organic material of the original forest, the young trees can take advantage of the available nutrients before they are leached away. The important question is, what will happen after the first harvest, when the nutrients will be physically removed from the site as part of the harvested biomass. There may not be enough nutrients for a second crop.

Economic consequences also deserve mention. It is difficult to imagine the economics of a project which destroys thousands of hectares of wood biomass, at a cost of millions, only to replace them with other woody species. If the trees survive 20 years, will they be economically competitive with pines which are growing much nearer the potential markets? Of course, if the company does sustain a loss, it will be a tax deduction, and in effect, the U.S. taxpayer will be subsidizing the destruction of the Amazon forest.

Sociological impacts too also must be considered in an undertaking the size of the Brazilian project. Thousands of workers were brought in, and their livelihood depends upon the continuation of growth of exotic species in the jungle. If the project fails, these people would be a disruptive force to the remaining Amazon forest.

CONCLUSION

The major point of this paper is, that while rates of wood production in the tropics are roughly equal to that in the temperate zone on a yearly basis, environmental costs are higher. Higher environmental costs come about because: much of the lowland forests in the Amazon Basin are highly susceptible to nutrient leaching, due to poor soils; some montane forests are susceptible to invasion by campesinos, as soon as access roads are constructed, with a resultant danger of forest destruction and soil erosion; lack of seasonality in much of the tropics permits dangerous build-ups of parasite species.

Another important point with regard to plantations is that in temperate regions, the infrastructure for plantations and whole tree harvest, transportation, processing, and use already exists. In Latin America, for the most part it does not, and the costs of establishing this infrastructure must be added to costs of the plantation itself when calculating start-up costs.

So, except in special cases such as Puerto Rico where nutrients and water are not limiting, where there is opportunity to control invasion by campesinos, and where logistical facilities are reasonably well developed, the prospects for plantations and whole tree harvesting in Latin America are not bright.

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DRY FORESTS OF THE DOMINICAN REPUBLIC AND THEIR ENERGY PRODUCTION CAPACITY

Penelope Jennings[1/]

INTRODUCTION

The human population of the Dominican Republic, 49.6 percent urban, reached 4,978,000 in 1977 (BID 1978). The cost of living rose an estimated 12.7 percent in that same year, hitting hardest at the poorest (BID 1978). One of the important elements basic to human survival is fuel, and any change in alternatives and price structures touches all levels of society.

Since the Dominican Republic, situated between 18 - 20° N in the Caribbean Sea, is a tropical country, and since most of the population lives below 1,000 m elevation, very little fuel is needed for heating purposes. But the rising cost of petroleum-based energy (including electricity, since 88 percent of Dominican electricity is produced by burning fuel oil (CODIA 1975)) is forcing the poor to look for other sources of cooking energy.

The capital investments for electricity and bottled gas, principally a properly adapted stove and installation costs and deposits, have always been outside the reach of the poorest of the urban areas. Charcoal has been the basic urban fuel, since firewood is heavy, difficult to transport, and not easily available in towns and cities. As the cost of living rises unaccompanied by wage increases, more and more people, both urban and rural, have had to reduce or change their use of fuels.

The dry forests (xerophytic forests) of the country, covering about 12 percent of the national area, have been the traditional sources of charcoal. It is widely believed that the removal of firewood for such commercial enterprises as tanneries, bakeries, and sugar mills, as well as the production of charcoal for principally private consumption, is destroying the dry forests.

The objectives of our investigation of the national production of charcoal and firewood from dry forests are to:

1. estimate the "standing crop", or the total potentially available for the production of charcoal/firewood.

2. estimate both the actual growth and the growth potential of the dry forests.

3. estimate the total amount of firewood and wood for charcoal being removed annually.

4. study the methods of charcoal production, their efficiencies, and their economic costs and benefits.

5. study the marketing channels for both products, from forests to consumers, analyzing limiting factors, costs, and benefits.

6. study patterns of consumption.

By combining the information gained from these six categories of investigation, we hope to be able to show not only the relative importance of dry forest fuels nationally, but to analyze present and future environmental problems arising from their extraction. Finally, we hope to be able to make a positive contribution to the preparation of a long-term management plan for the dry forests so that charcoal and firewood can be produced without damage to the forest environment.

BIBLIOGRAPHY

Biological Studies

The dry forest is not an inviting place, and to date very few studies have been made upon it. There is never any free water, unless it be a river originating elsewhere and passing through. The heat is intense most of the year, and the feathery leaves of most tree species afford little shade. The ubiquitous cactus, the five-centimenter thorns, and the wasps' nests do not add to its attractions. Perhaps it is because of its forbidding aspect that it has been little studied; perhaps it is because of its low profitability for large-scale exploitation as forest. Whatever the reason, biological, ecological, and forestry studies are very few.

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Holdridge (1978) defined dry forest within a three-dimensional matrix involving exclusively climatic factors. His definitions have worked out well for Central America and the Caribbean Islands when compared with reality on a broad scale, but micro-conditions (frequently undocumented) cause apparent contradictions.

Using Holdridge's classification system, OEA (1967) analyzed the Dominican Republic in terms of ecosystems (life zones), present land use, and proposed land productivity. OEA further organized all the information available regarding biogeological studies (see appendix 1). OEA states that the species of plants shown in table 1 are common in the dry forest.

A forest inventory was conducted in the Dominican Republic by the Food and Agriculture Organization (1972), but no data regarding true, dry forest were published. The FAO (1969) also assisted in a compilation of agro-climatologic data for the northern Cibao Valley, expanding the existing climatologic data available from INDRHI (1978), the National Hydrological Institute. A summary of a few of the key stations is found in table 2.

The previous documents give us the climatic data needed to make the first tentative delineations of the extent of the Dominican dry forests. The OEA (1967) study published a map of present land use, parts of which can be seen in appendix 1. This map eliminates some areas under irrigation from dry forest, and more have been removed since 1962. Irrigation and drainage studies generally indicate the extent of the area expected to be under irrigation rather than those irrigated in fact, which does not aid our study, except as it relates to future land area under dry forest. However, no inventory or cruise information specifically pertaining to dry forests, either in the Caribbean, South America, Central America, Mexico, or Africa has been uncovered.

Charcoal Production

The production of charcoal, however, has been rather more carefully studied, although not in the Dominican Republic. The neighboring Republic of Haiti has been studied by Dr. D. E. Earl (1976) through FAO, and by a team of scientists headed by Dr. M. Benge (1978) through USAID. In both cases, the studies were even more limited than this one under consideration. In the FAO report, only four

Table 1.--Species of plants common in the dry forest.

Common Dominican name: North	Common Dominican name: South	Latin Bionomial
cambron	bayahonda	Prosopis juliflora
aroma	cambron	Vachellia farnesiana (sic)
baitoa	baitoa	Phyllostylon brasiliense
guayacan	guayacan	Guaiacum officinale (sic)
guayacancillo	vera	Guaiacum sanctum (sic)
almacigo	almacigo	Bursera simaruba
frijol	frijol	Capparis spp.
cayuco	cayuco	Cephalocereus polygonus
alpargata	alpargata	Opuntia moniliformis
tuna	tuna	Opuntia spp.

Table 2.--Climatological data.

Station name	Location: Latitude	Location: Longitude	Elevation (m)	$\bar{x}$ Annual tempera- ture °C	Annual averages (mm): Precipi- tation	Annual averages (mm): Evapo- ration	Annual averages (mm): Deficit
Monte Cristi	19° 51' N	71° 39' W	5	26.5	690.0	1593.2 x	903.2
Villa Vasquez	19° 45' N	71° 27' W	24	27.3	699.5	1699.8 x	1000.3
Mao, Valverde	19° 35' N	71° 04' W	78	27.3	750.0	1700.1 x	950.1
Santiago	19° 26' N	70° 42' W	175	26.2	972.1	1539.6 x	567.5
San Juan de la M.	18° 49' N	71° 13' W	415	24.9	1014.2	1724.0 *	709.8
Azua	18° 27' N	70° 44' W	83	27.0	665.0	N.D.	N.D.
Barationa	18° 13' N	71° 06' W	10	26.1	1124.4	1568.0 *	443.6

x = ET Potential (Thornthwaite)
* = A tank

charcoal kilns of traditional construction were measured and observed, while the USAID report and suggestions were based upon national official statistics of production and consumption of charcoal, rather than upon specific studies.

Dr. M. Vahrman (1978) of the University of Guyana reports upon the construction and use of modified New Hampshire kilns, while the 1958 report of the New Hampshire Forestry Service also presents data on the use of portable steel kilns. These production data are to be found in table 3.

Table 3.--Production data.

According to:	Kiln type	kg Charcoal/Stere*	kg Charcoal/ m^3 solid wood	kg Char/ kg wood	Percent
Earl (1975)	N.S. (ideal)	110.5 kg	170 kg	0.20	20
Earl (1976)	Earth	68.0 kg	105 kg	0.12	12
Baldwin (1958)	New Hampshire	91.0 kg	140 kg	0.16	16
Vahrman (1978)	New Hampshire	71.4 kg	110 kg	0.13	13

*1 stere = 1 m^3 stacked wood

PHYSICAL BIOMASS EVALUATION

Definition of Area to be Inventoried

For the purposes of this study, dry forest has been defined as any area populated with trees, where undisturbed crown cover is not less than 50 percent over one or more ha, and where the trees, when mature, exceed 2 m in overall height, and where the rainfall ranges between 500 to 1,000 m. This classification excludes areas presently under cultivation, but includes abandoned areas if the trees are, or will be when mature, greater than 2m in height. Excluded also are chapparal areas where species do not reach the height of an average man, deserts, and areas so badly degraded (whether through natural or artificial means) that 50 percent crown cover is not achieved over a large area.

Method

Forest Classification

The goal of the dry forest inventory is twofold: to estimate the total available biomass and to attempt to predict the growth and thus long-term yield. The perfect answer can be obtained only by measuring every tree in every dry forest, a process too slow and entirely too costly, as well as unnecessary.

Since our present level of information regarding the dry forest is essentially at 0, any information is useful. It is important at this point to distinguish between data, or collected numbers representing variable parameters, and information, which is the useful and applicable result of processing the data into an acceptable format. However, the more accurate the information, the more successful the plans for utilization, so that as much data should be collected as necessary, given the needs of accuracy.

The field work in forestry is simple in concept and tediously lengthy in execution. Unfortunately, the large areas of dry forest are neither easily accessible nor easily penetrated, and neither time nor funds permit a statistically significant series of randomly placed plots. To reach many areas would require a full day's hike with a brigade of men cutting a trail.

One way to greatly reduce the number of inventory points needed is to subdivide large areas into similar subareas, a process called stratification. To assist in this process, maps and area photographs can be used. The best maps available of the dry forest areas are 1:50,000 (1 cm = 0.5 km) topographic (showing altitude as well as planimetric features) with vegetation types (cultivated/uncultivated) superimposed. The ground work for these maps is 5 to 15 years old, (depending upon the edition) and in several areas large-scale changes have taken place. There are areas where the dry forest has reclaimed old cultivated fields, and areas where irrigation or the promise of it has caused large areas to be cleared.

The best aerial photographs available are in black and white, 1:20,000 scale, flown in 1966 and 1967. Now nearly 13 years old, they are useful where man has not been at all in the interim, where the forests remain untouched. The southwest delfoid peninsula south of the Oviedo-Pedernales line is a good example of this type of area, as are some of the hilly areas north of the Santiago-Monte Cristi line.

Inventory Technique

Within an area as stratified (as previously explained), a plot center is chosen at least 10 m from the road, but further afield if it is clear that the road disturbance zone is wider. The choice is based on the general visual similarity of the area to other similarly classified areas. No statistical significance can be attached to such selection, but it at least gives a first estimate of volume.

Once the center is chosen, the circular plot is measured with a radius of 5 m, thus representing 78.54 m^2 or 1/127 ha. Information regarding the plot in general is recorded: soil color, texture, and erosion; present and past land use; and density and type of understory. It is hoped that volume and growth can be correlated to these parameters to provide information for land use planning.

Tree Measurements

In many fields of study, the parameter of interest can be easily and cheaply measured, but in forestry this is virtually never so. Volume and weight, two important parameters for estimation of available wood, are expensive, difficult, and frequently destructive to measure. To weigh the usable wood from a tree, for example, you must first cut down the tree, thus eliminating the resource you were measuring. But wood weight can be accurately estimated, if density is known, through measurement of volume. While perfect measures of volume also require the felling of the tree, estimates of volume can be made if diameter, height, and form are measured, without molesting the tree at all.

Thus, the following parameters are measured on each tree on the plot:

1. diameter at breast height (cm) (precision ± 1 mm).

2. total height to top branch (m) (precision ± 50 cm).

3. crown diameter (m) (precision ± 50 cm).

4. species.

5. injuries.

6. number of principal trunks $\geq$ 5 cm d.b.h.

Use of Collected Data

Preliminary studies of cambron (Prosopsis juliflora) show that volume, the sum of the basal areas, and height are related as follows:

$$V = H \times \sum_{i=1}^{n} ba_i \times 9 \times 10^{-5}$$

or

Volume (m^3) = Height (m) x Sum basal areas x Form Factor x Conversion factor.

Where the form factor = 0.9 and the conversion factor = 1 m^2/1 x 10^4 cm^2, sum basal areas = sum diameters squared times π over four.

$$\sum_{i=1}^{n} ba_i = \frac{\pi}{4} \sum_{i=1}^{n} di^2$$

following the general formula that

$$ba_i = \pi R_i^2 = \pi (\frac{d_i}{2})^2 = \frac{\pi d_i^2}{4}$$

where i is the index for the principal trunks and n is the total number of principal trunks.

Volume is calculated per species, per plot, and per general forest type.

Available weight is based on a density of 0.85/cm^3, or 850 kg/m^3.

PRELIMINARY RESULTS

Intensive Survey, Mao, Valverde

In a transect cruise of a section of closed dry forest in Mao, Valverde, 64 plots were set on a paired basis on a 5 km east-west line. The results, tabulated according to the 14 most common species (95 percent of the volume), can be seen in table 4 below.

Table 4.--Survey results, Mao, Valverde.

Common Name	Frequency percent	Trees/ ha	b.a./ ha	b.a./ tree (x)	$\bar{x}$m height	Vol/tree x $10^{-2}m^3$	Vol/ ha m^3	Percent samples in which dom.	Percent dom. Percent freq.
baitoa	63	587	25,772	44	3.7	1.47	8.6	38	60
cinaso	45	101	4,121	41	3.1	1.14	1.1	6	13
brucon	41	74	2,316	31	3.3	0.92	0.7	2	5
quina	31	82	1,416	17	3.9	0.60	0.5	2	6
candelon	28	95	4,477	47	3.7	1.57	1.5	9	32
quayacan	25	60	1,231	21	2.8	0.53	0.3	2	8
guatapanal	25	46	4,169	91	3.1	2.54	1.2	9	36
cambron	25	87	3,315	38	3.2	1.09	1.0	6	24
almacigo	22	21	5,220	125	4.9	5.51	2.3	8	36
frijol	20	38	1,516	40	3.5	1.26	0.5	2	10
sangre de toro	19	38	1,154	32	2.6	0.75	0.3	2	11
aroma	17	34	1,313	39	2.9	1.02	0.3	0	0
uvero	17	34	2,009	59	3.3	1.75	0.6	3	18
palo negro	16	38	1,222	32	3.2	0.92	0.4	0	0
ostros	--	--	--	--	--	--	1.0	5	--

Average volumes per hectare are as follows:

charcoal species	=	9.4 m^3/ha
baitoa and almacigo	=	10.9 m^3/ha
Total volume		20.3 m^3/ha

Extensive Surveys and Approximate National Estimates

It has been found that approximately 12 percent of the national area is dry forest (5,905 km^2). This total area was divided according to stratification by general volume class, as shown in table 5 below.

Table 5

Type name	Volume/ ha	Growth Vol/ha/ano	Hectares Type	Volume Type	Growth volume per year per type
Mao	9.4	5	30,000	282,000	150,000
Lajas	10.0	5	74,000	740,000	390,000
Linea	6.5	3	35,500	230,750	106,500
Segunda	7.0	3	299,500	2,096,500	299,500
Tristeza	4.0	2	44,500	178,000	44,500
Cortado	3.0	1	107,000	214,000	107,000
Totals	(6.3)	(2.9)	590,500	3,741,250	1,721,000

CHARCOAL PRODUCTION

Information Needed

In order to understand the production of charcoal, one must have information not only about the physical process, but also about the costs, profits, marketing, and socio-economic status of the work. To this end, a questionnaire was designed as a guideline for conversations with charcoal producers.

As the interviewers gained experience, it became clear that the questionnaire was in need of streamlining and improvement. An experimental second format, using phraseology more familiar to the participants, was developed and is currently being tested.

Preliminary Results

Physical Process

The production of charcoal almost always accompanies any clearing for agriculture in the dry forest. Under a clearcut situation, the charcoaler takes advantage of all trees suitable for production in a given area, even including the stumps and roots. But the continuous production of charcoal without cleaning requires more skill and energy on the part of the woodcutters, since it is technically illegal to fell live trees.

To get around the law, the woodcutters either cut only some of the branches or stump-sprouts, leaving the tree reduced but alive; or else they work well away from roads and vigilance to take the whole tree.

The preferred species are (in order):

Guiacum officianale (guayacan)
Guiacum sanctum (vera, guayacancillo)
Capparis spp. (frijol)
Prosopis juliflora (cambron, bayahonda)
Acacia farnesiana (aroma, cambron)

In the Northwest, virtually all charcoal is made from *P. juliflora*, since it is the most resistant to continuous coppicing, seeds rapidly, and colonizes abandoned lands. The other species have been unable to resist the continuous pressure for firewood. In the South, the charcoal is made from a variety of species. It is still possible in the South to order and purchase sacks of pure *G. officianale* or *G. sanctum*, although the species has been much reduced.

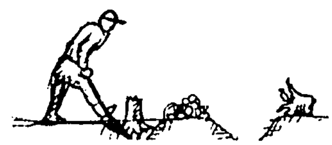
Trunks are cut with axes, branches with machetes. Neither saws nor motorized equipment of any kind are used. The wood is lopped into approximate 1 m lengths. Smaller branches (down to 2 cm diameter) are used to fill the spaces between the larger sections of trunk (up to 50 cm diameter). Wood is carried to the central kiln site by hand.

Two kinds of earth kiln are built on the spot. For either type, the area must be first cleared (including roots) and leveled for an area approximately double that which the finished kiln will occupy. Rocky and sandy soils are avoided where possible, since they cannot seal the kiln properly and can result in the loss of a kiln (fig. 1).

The "conical" kilns are usually built by those with more experience in charcoaling, the "rectangular" kilns by those who only charcoal occasionally, although this is not a fast rule. It is said that the "rectangular" kilns are more time-consuming and less efficient to build, but do not require the preplanning and balanced setting of the "conical" kilns.

Figure 1.--Charcoal manufacturing.

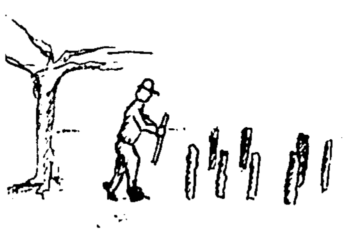
1. Trees are felled with axes and machetes.



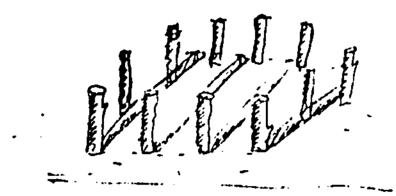
2. Sometimes stumps and roots are removed and used.

3. Land leveled and cleared.

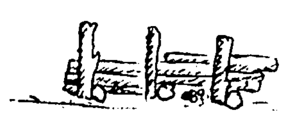
RECTANGULAR KILNS



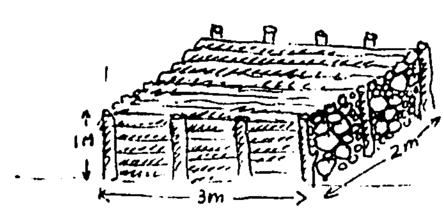
1. Stakes are placed around planned kiln.



2. Spacing logs or branches or cactus trunks to provide air circulation.



3. Wood stacked carefully against the placed stakes. Wood brought as cut, not all at once.



4. Finished stacked kiln.

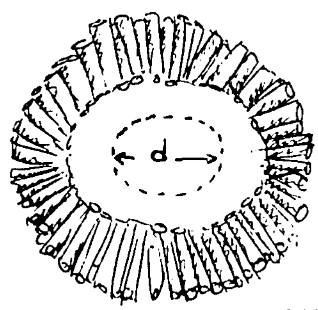
5. Kiln covered with leaves, branches, etc., to keep the earth from smothering the flames.

6. Kiln sealed with earth (free of rocks, largc sticks, etc.).

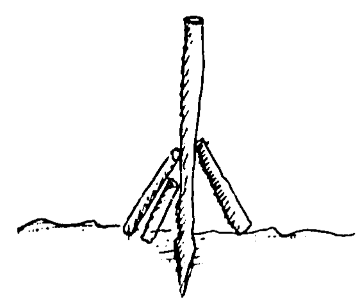
7. Fire is introduced from below with flaming kindling.

8. Kiln in the process of charcoaling--rate of burn monitored by amount and color of smoke and controlled by amount of earth seal.

CONICAL KILNS



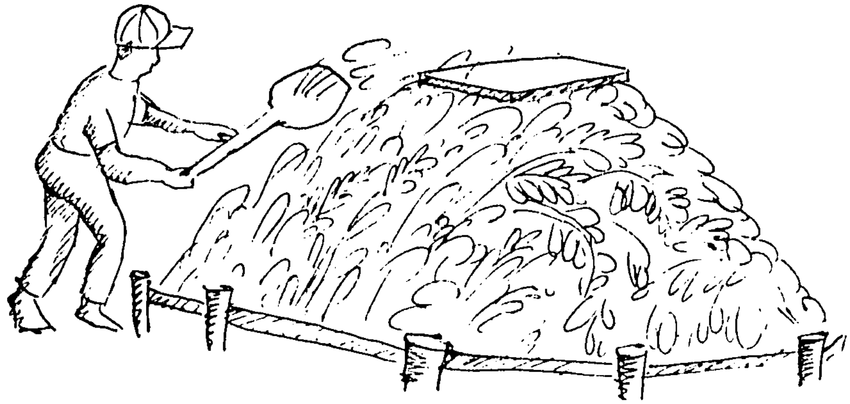
1. All wood is gathered to kiln site first and formed in a ring around the expected kiln diameter.



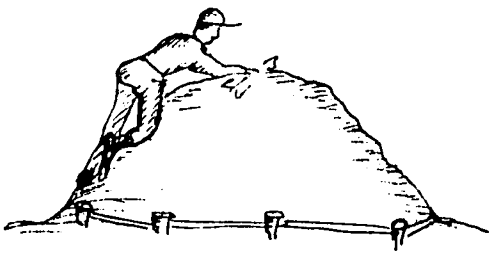
2. A stake is driven to support the stacking of the wood.

3. Stacked kiln. Stake is removed before firing.

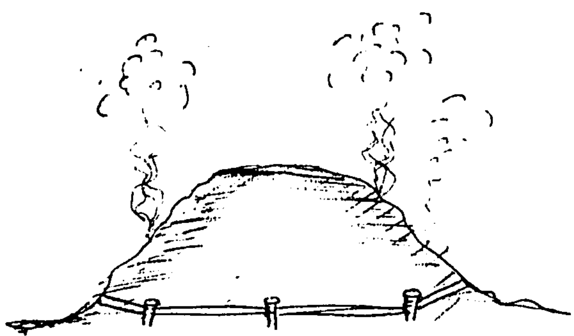
4. Covering kiln with branches and leaves.



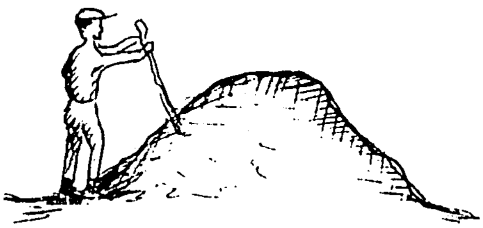
5. Sealing the kiln with earth. The top hole is protected with an old bit of aluminum tin can, and the stakes below help keep the earth from sealing completely, serving as a smoke (and thus burn) control mechanism.



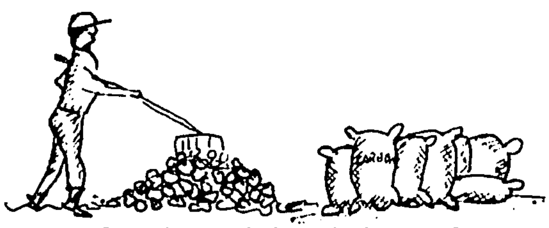
6. Firing the kiln. The hole where the stake was is filled with dry kindling, and the flaming charge is added.



7. Smoking kiln. Control and monitoring as for rectangular kilns.



8. When burn complete, seal broken by opening holes in the leaf cover, thus allowing earth to fall on burning charcoal and extinguish flames.



9. Charcoal is raked out of the pile, leaving the fines and very small pieces, and bagged by hand.

Charcoal makers are able to estimate well the amount of charcoal a given kiln will yield, but they are always careful to specify that there are a number of problems in attaining this yield. The dampness of the soil (extremely dry soil admits too much oxygen, reducing yield), the amount of breeze (heavy winds for one or more days also reduce yield by admitting too much oxygen), rainfall, if any, and the amount of care given to smoke control all contribute to the final yield. If a kiln is located at great distance from the charcoaler's residence, he usually prefers to seal it almost completely and count on a long, slow burn. If a kiln is nearer, he will usually risk a less-sealed, faster burn, although it requires almost constant surveillance. Burns last from one to six days, with the majority of kilns lasting three to four days. The great variation in production results (table 6) is due to difference in skill of the charcoalers, in estimated size of kiln, and in the variation in both volume and weight of sacks. Nonetheless, it would appear that large, conical kilns are lower in efficiency than those of 25 sacks or less. There is not a sufficient amount of data regarding rectangular kilns as yet to judge efficiency. One hundred kg of charcoal per m^3 of solid wood or 12 percent weight efficency might be a good first-estimate average for all kilns (see also published results in bibliography).

Table 6.--Production yield of charcoal by type of kiln.

Type of kiln	Estimated[1] size (m^3 stacked)	No. sacks produced	No. sacks charcoal/[2] m^3 solid wood	kg charcoal/[3] m^3 solid	kg charcoal/[4] kg wood percent
conical	3.5	17	7.5	2,631	31
conical	25.2	30	1.8	63	7
conical	169.0	100	0.9	32	4
conical	8.8	19	3.3	116	14
conical	7.7	23	4.6	161	19
conical	5.3	11	3.2	112	13
rectangular	4.3	20	7.2	252	30
rectangular	4.0	7	7.2	95	11
rectangular	6.2	5	1.2	42	5

[1] rectangular = length x width x height, m^3
conical = $\frac{\pi}{3}$ • radius^2 x height.

[2] 0.65 m^3 solid = 1 m^3 stacked (Earl 1975).

[3] assuming each sack weighs 35 kg on the average.

[4] assuming green wood use, with a density of 0.85 g/cm^3.

CONCLUSIONS

The first and easiest conclusion to draw at this point in the study is that a great deal of information is still needed. Not only the conclusion of this research project, but many more projects and student theses will be required to meet the total information need. The most important topic yet to be dealt with carefully in the biological realm is that of growth; on what does it depend, how can it be cheaply and accurately predicted, what relation does it have with stocking, etc.? Still remaining is a carefully controlled and measured study of efficiency and its variables in the production of charcoal.

However, it is clear--even from cautious first estimates--that the country is growing more wood than it is using. It is just as clear that certain areas are untouched, while others are overexploited. The problem, then, is not the absolute amount of growth, but the growth on areas near populations of people. Some areas should be left strictly alone for five years, others should be thinned, others harvested. As the price of alternative fuels rises, it becomes more valuable to rationally manage forest resources. As the country begins to acquire competent technicians and professionals through national forestry education, a rational plan for conservation and undamaging utilization can be prepared and followed.

Charcoal and firewood are not necessarily damaging to the forest ecosystem: the important variable is how much biomass per year can safely be removed. Areas which are totally cleared, used for perhaps five years, then abandoned, lose both agricultural and forest productivity. Nomad agriculture is far more damaging to the forests than firewood cutting. The man who lives from charcoal production is not likely to destroy his source of income, and in fact, does not when he can command a sufficiently large area as his to work. On the other hand, the farmer, who knowing he is losing his effort, tries to grow corn or yucca in the dry forest ecosystem has no perceived need for the native vegetation and may, in fact, view it as a nuisance. It is far more important to control his activities than those of the wood user.

Charcoal production in earth kiln is very inefficient, but requires very little capital investment (with an axe, a shovel, and a rake, a man can live from the income of his charcoal). It is very labor intensive, which in this country is an advantage. Before the use of "portable" steel kilns is recommended, a careful study must be made of the campesino's capacity to purchase or the government's capacity to provide and maintain the kilns. In any case, the use of kilns should be part of an integrated forest management plan.

It is both socially and economically desirable to maintain at least 10 percent of the national area (4,342 km^2) in fuelwood production. The driest and hilliest areas within the life zone are the natural choices for forest production, leaving the flatlands and the higher rainfall areas to irrigated agriculture and extensive pasture, respectively.

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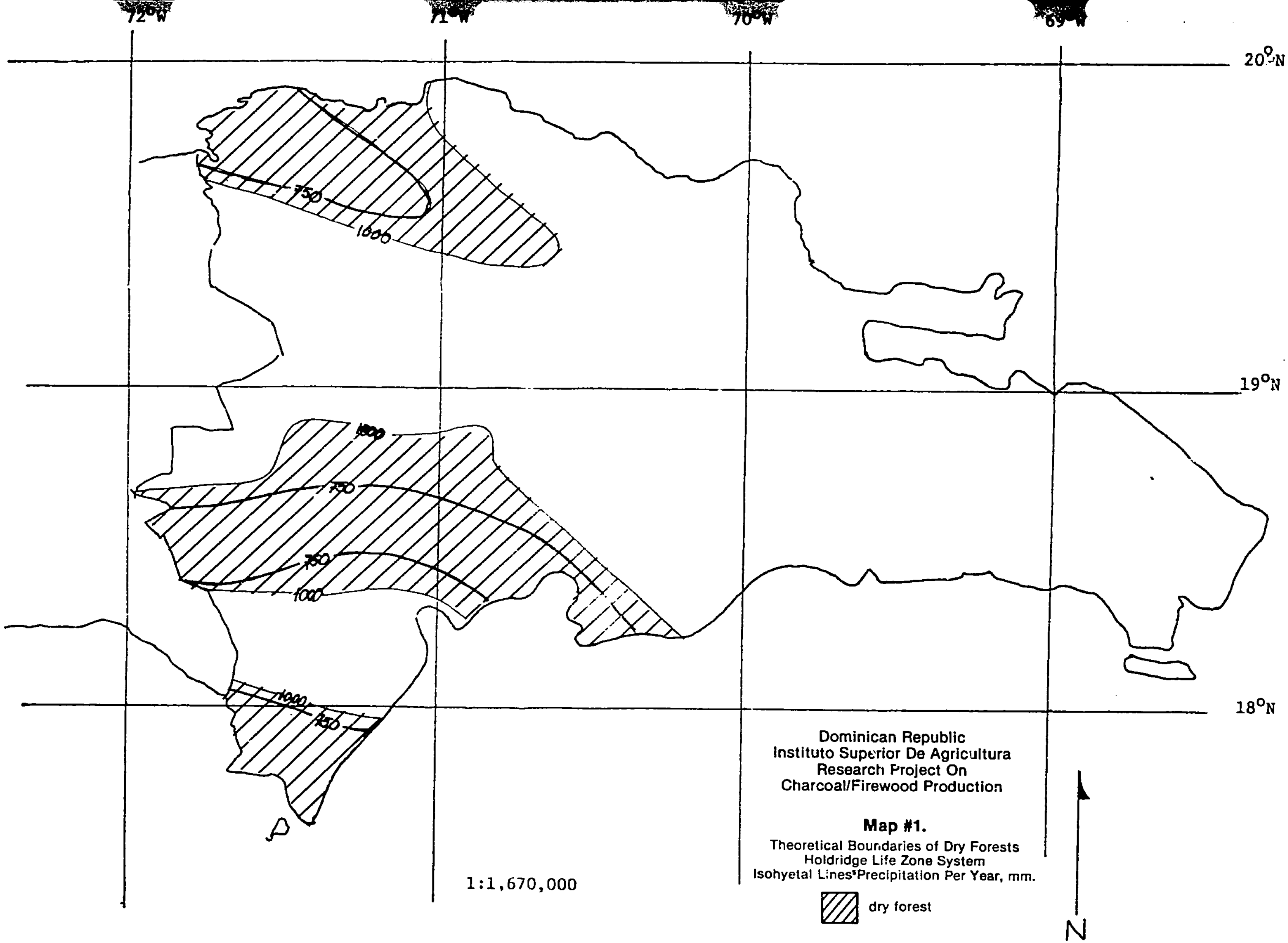
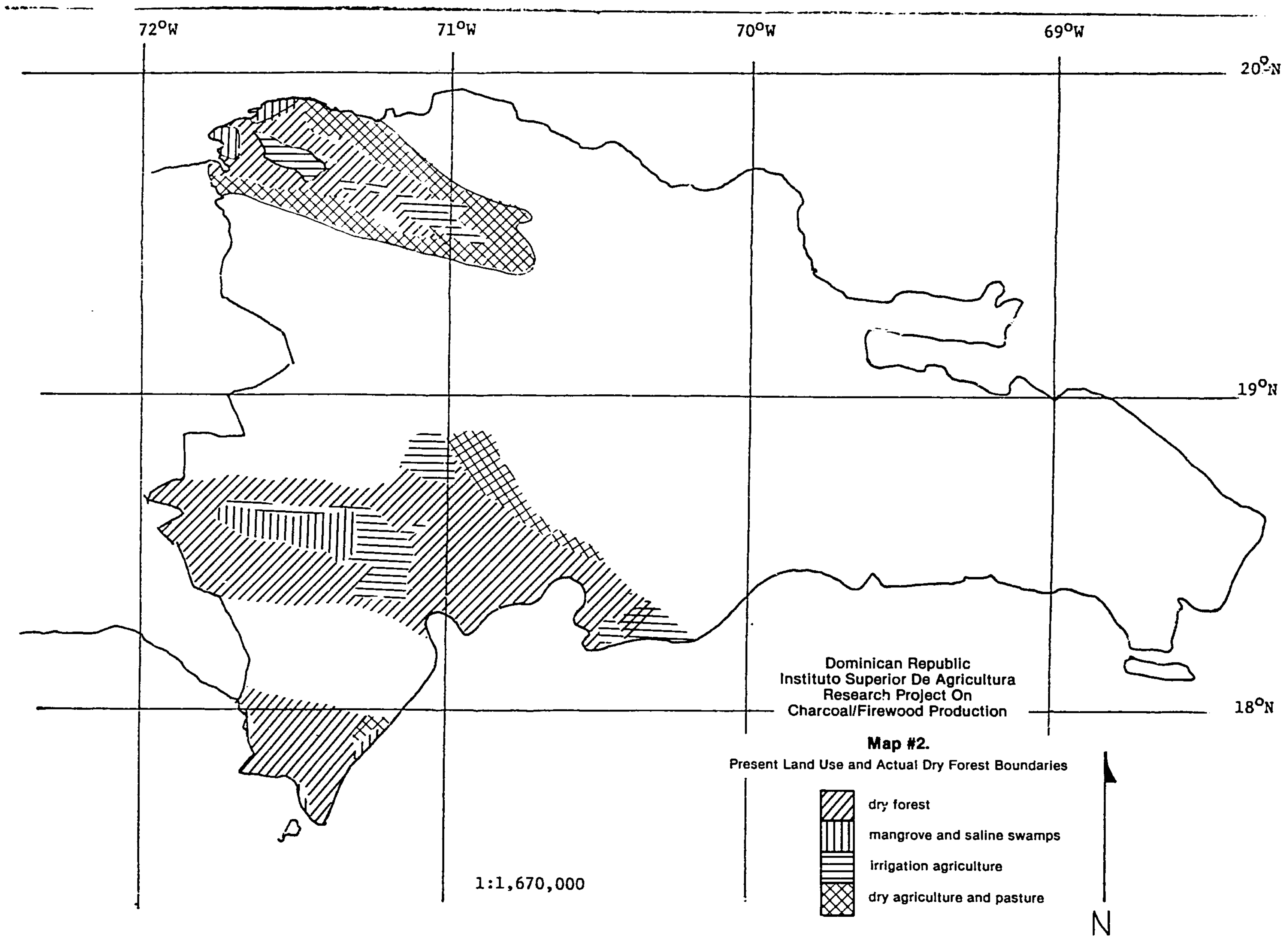
APPENDIX I

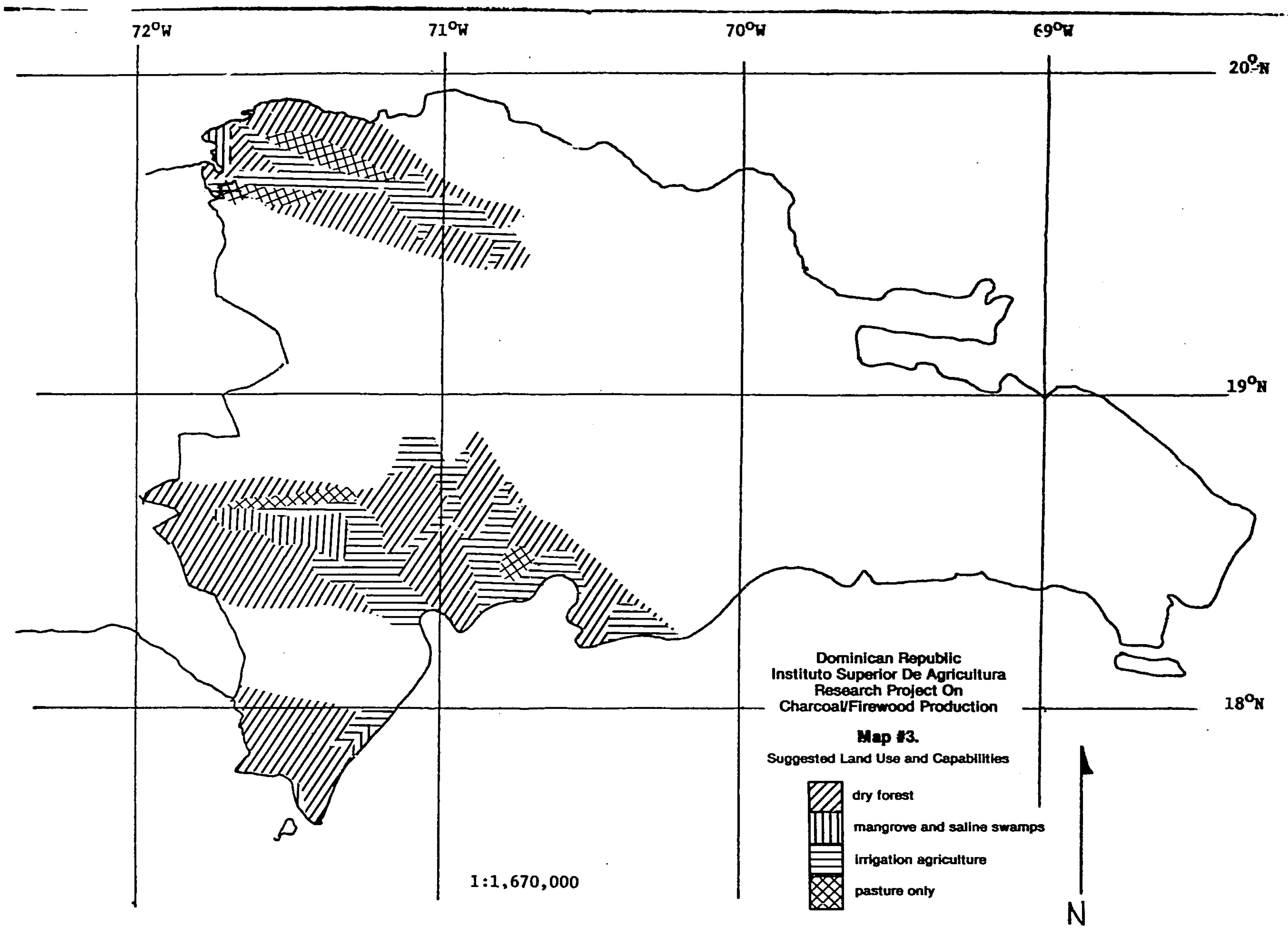
MAPS



Dominican Republic
Instituto Superior De Agricultura
Research Project On
Charcoal/Firewood Production

Map #1.
Theoretical Boundaries of Dry Forests
Holdridge Life Zone System
Isohyetal Lines Precipitation Per Year, mm.


72°W
71°W
70°W
69°W
20°N
19°N
18°N
Dominican Republic
Instituto Superior De Agricultura
Research Project On
Charcoal/Firewood Production
Map #2.
Present Land Use and Actual Dry Forest Boundaries
dry forest
mangrove and saline swamps
irrigation agriculture
dry agriculture and pasture
1:1,670,000
N


72°W
71°W
70°W
69°W
20°N
19°N
18°N
Dominican Republic
Instituto Superior De Agricultura
Research Project On
Charcoal/Firewood Production
Map #3.
Suggested Land Use and Capabilities
dry forest
mangrove and saline swamps
irrigation agriculture
pasture only
1:1,670,000
N

FOREST RESOURCES FOR ENERGY IN EGYPT

A. Talaat El-Wakeel[1/]

Egypt is an arid-irrigated country; it does not have any natural forests. Wood production in Egypt comes mainly from woody trees planted along the sides of canals, drains, and roads or around the farmers' fields. However, a few man-made forests have been established in Egypt during the past 25 years, in areas where the soil is not suitable for production of agricultural crops, and which is considered to be wasteland.

A tree planting project was started in Egypt 15 years ago. About 2 million trees were planted. Woody trees growing in Egypt are predominantly Casuarina and Eucalyptus; however, several other species which attain appropriate sizes, such as Acacia, Morus, Sisso, Populus, and Tamarix, are scattered all over the country, mainly around cities and around farmers' homes and barns in the villages.

All the projects carried out during this period have been the concern of government authorities (The Ministry of Agriculture and The Ministry of Irrigation). Farmers, in the meantime, were very much concerned about the planting of woody trees as shelterbelts or windbreaks around their fields or fruit groves.

Today the Ministry of Agriculture gives planting of woody trees more importance in its agriculture policy. In the meantime, research and experimentation is carried out to plan for the kind of trees to be planted in every new location, and to use the most appropriate, fastest growing species needed for the different plantings.

Afforestation projects in the future will be concerned mostly with the newly reclaimed lands or with new agricultural sites; e.g., the lands surrounding Lake Nasser by the High Dam and the sewage farms of the new cities. Trees also will be planted along the main highways, canals, drains, and railways, whether in new areas, or as replacements for trees that have been cut down.

A five-year research project begun in 1975 with assistance from the U.S. Research Program entitled "Windbreaks and Shelterbelts, Their Effect in a Useful Way on the Agriculture Crops and Soil Conservation", is helping to compile information needed for the implementation of the forestry policy in Egypt.

Its objective is the selection of tree species suitable for the establishment of shelterbelts, and for crop protection, soil conservation, and other purposes.

A new five-year plan which started in 1978 called for planting approximately 15 million trees in accordance with the following plan:

1. Afforestation of newly reclaimed lands for windbreaks, shelterbelts, and for fixation of sand dunes.

2. Planting trees along primary and secondary roads, main irrigation canals, and drains for a distance of about 15,000 kilometers.

3. Planting collective plantation as recreational, man-made forests and shelters on sites selected for new cities, and for newly reclaimed land ready for agricultural production.

4. Around Lake Nasser, by the High Aswan Dam (almost 25,000 acres).

In the last fifteen years, many trees were uprooted along sides of roads, canals, and drains to widen or to establish new roads or industrial buildings. Several thousand also were felled in some of the man-made forests. Whenever possible, the wood was used in the wood technology industry. The government has encouraged the production of fiberboard, particleboard, and the manufacture of pulp and paper from local materials. A large amount of the wood obtained in Egypt is either used for fuel in the villages, by local industries for the manufacture of agricultural implements, or for construction of buildings in the villages.

A good and thorough extension program is carried out by the Ministry of Agriculture. Specialists and technicians of the Horticultural Research Institute are advising and teaching the farmers how to plant and maintain woody trees and to value them for their wood.

General and special courses in forestry and wood technology are included in the universities and agricultural secondary schools.

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BIOLOGICAL AND SOCIOLOGICAL REFLECTIONS FOR A BETTER USE OF THE FRENCH FOREST FOR ENERGY PRODUCTION

A. Riedacker[1/]

Managing forests for a more efficient use of their resources cannot overlook that the ecosystem should not be degraded. The different proposals in this paper take this fact into account.

To optimize the energetic budget of the forests, we must look closer at the various outputs and inputs. The outputs are timber, pulpwood, fuelwood, and even sometimes meat, when cattle can graze in the forests as is done in the French Mediterranean forests.

Amongst the inputs, we must take into account energy necessary for making forest machines, gas for planting, cultivating, harvesting, and for preserving the forest from fire.

PRESENT POSSIBILITIES

According to the data obtained by the French Forest Inventory Service, our forests produce, at the present stage, 47.4 million m^3/year, without taking into account the trees along the roadsides and the hedgerows (Parde 1979). The annual consumption is about 42 million m^3 but only about 32 million m^3 are harvested (Guillon 1975). Apparently, to meet the consumption we should cut more conifer for pulp and particleboard. In 1973 the deficit was due almost only to a lack of conifers (7.6 million m^3 out of the 7.7 million m^3 of pulpwood that we imported). This deficit could also be reduced to some extent by increasing recycling of waste papers.

But even then, to meet our present demand for wood, we should cut more wood. Some authors (Parde 1969) think that we could harvest up to 35 million m^3. This implies that we should continue to import conifer wood. If we want to reduce the importation of wood as much as possible, we should at least cut 38 million m^3.

In these different situations the following amounts of wood would remain for energy production:

---15 million m^3 or 7.5 million tons (Present situation).

---13 million m^3 or 6.5 million tons (Parde's hypothesis).

---10 million m^3 or 5 million tons (Our hypothesis).

THE POSSIBLE IMPROVEMENTS

1. Parde (1969) estimates that around the year 2000, the present forest will produce about 55 million m^3 per year of wood above ground.

The forest inventory--we must lay emphasis upon it--takes only partly into account the branchwood, which is important in hardwood forests. This is not negligible, since 2/3 of the French forests consists of hardwoods. We could, therefore, immediately increase the quantity of wood usable for energetic purposes.

This would leave at least--supposing for the moment that the wood consumption for energy will not increase--about 18 million m^3 for energy or *9 million tons of wood.*

2. Wood of stumps and thick roots could be harvested on certain sites in the Landes Forest for instance. According to Parde this could produce about *1 million tons of wood.*

3. According to the same research worker, utilization of 80% of the present non-used woodwaste from the industry would yield *2 million tons of wood.*

4. Coppices at a 20-30 year rotation period. At present we have about 3 million ha of coppice out of the Mediterranean area which produce only 3 t/ha/year. But we do not know how this production has decreased with the time due to the aging of the root systems. According to the studies we made on the aging of eucalyptus coppiced stumps in Morocco (Riedacker 1973), we may put forward that their production could be at least doubled. *Ten million tons could therefore be added for*

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fuel.

In the Mediterranean forests (1 million ha of coppice), wood production can probably only be slightly improved. This is partly due to the rainfall distribution and the soil. But it would be most profitable to reintroduce cattle grazing in these forests. This would transform the solar energy into meat on one hand, and allow to reduce the energetic input necessary to protect the forests and the inhabitants from the forest fires on the other hand.

5. Improvement of high forests and of coppices with standards. Decourt and Lemoine (1969) have shown that by keeping the Landes Forests of Pinus pinaster at a closer spacing, the yield of wood could be increased 1 to 2 m^3/ha/year.

This means that the total production of the Landes could be increased an amount ranging from 1 to 2 million m^3 a year.

Planting of more rapid-growing hardwood species, or planting of selected oak strains vegetatively propagated (Garbaye and others 1978) could lead also to an increase of the productivity of the high forests.

More timberwood could, therefore, replace products made of iron or aluminum, which need on the same weight basis, respectively, more than 20 and more than 100 times more energy for their production and their transformation.

We do not propose, therefore, to add this increase of yield to the quantity of wood usable for the energy production.

6. Short rotation forestry plantations. There are at present about 3 million ha of agricultural land which are no longer planted. We think, therefore, that about 2 million ha could be added to the present forest area and planted with coppice (populus plantanus, etc.) with short rotation (5 to 10 years) and on which with selected strains we could produce about 10 t/ha/year (Steinbeck 1968). This would add *20 million tons of wood.* Adding the different improvements would lead to an increase of 9 + 1 + 2 + 10 + 20 = 42 million tons of wood or 42 x 0.4 = *16.8 million tons of petroleum equivalent (tep).*

The Alter (1968) project concluded, starting from a different approach that 18.3 million tep could be produced but by increasing slightly less the present forest area. Parde (1969), starting from the view point that only 1.2 million ha can be planted up to the year 2000+, concluded that 13.6 million tep/year could be produced in this case. The latter figure represents nevertheless, about 10% of the present energetic consumption.

None of these figures take into account the energetic plantation which could be produced by farmers.

SOCIOLOGICAL CONSTRAINTS OF THESE IMPROVEMENTS

In all cases, improving forest management for energy production implies:

---improvement of 3 million ha of coppice.

---plantation of 2 million ha (or 1.2 million ha) of new forest land managed under short rotations.

---reintroduction of cattle grazing in the Mediterranean forest.

During a fifty-year period this means, every year at least, improvement and/or planting of about 100,000 ha. This is feasible, but two main obstacles for this enterprise can be identified; a labor problem for both improving or planting the forest, and for taking care of the cattle, and a legislative problem concerning the utilization of land.

A Labor Problem

There are, at present, (Mouton 1978) about 55,000 woodcutters, 20,000 of them being immigrated workers, about 1,800 workers in the nurseries and 20,000 workers--also most of the time from foreign countries--in the planting enterprises and at the Office National des Forets (ONF). In the latter organization, many work only occasionally for the ONF. Only in Alsace and Moselle is all the work done in the forests made by the ONF under the so-called "regie" system.

At present the labor market for woodcutters is deeply segmented; on one hand you find the woodcutters for high quality timber, mostly local people, which do not harvest the branches and the fuelwood, and on the other hand the woodcutters of wood for pulp and particleboard, mostly immigrated people, which have very poor living conditions. The two groups do not work in the same kind of forests and do not have the same salaries.

Improving the working conditions in forestry seems to be an imperative, both to allow to find the local labor willing to work in the forest and to allow a better harvest of the forest products.

Union organizations (CFDT 1968) ask for generalization of the regie system, in use at present only in some areas of the country.

Some political parties, for instance, propose the setting up of "Centres de travaux et de gestion des forets" (PSU 1968), which should improve both working and management conditions. These centres should also, according to them, be allowed to keep shepherds, for instance, in the Mediterranean area.

We do think, in any case, that the working conditions should be made more attractive; otherwise, the improvement of the existing coppice stand and the planting of sufficient new forest land will remain a vow. But this project appears also to be a chance for partly solving the present labor problem.

A Legislative Problem

At present the Forest Service is only able to put through the desirable transformation in the national forests (1.8 million ha out of 13 million) and partly in the communal forests (2.5 million ha).

One could imagine that the Forest Service could be given the possibilities to put through the policy decided by the collectivity, either by incitements as suggested in the Bertrand de Jouvenel's report (1968) or by running the land or forests in place of the failing owners.

In any case, improving the forest for a higher production of wood for energy seems to need a determined policy, mainly on the human and legislative level. The scientific level, however, although of smaller importance, should not be neglected.

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UTILIZATION OF FOREST RESOURCES IN GUYANA AND RESEARCH NEEDS

J. J. Niles[1/]

Abstract.--This paper outlines the modes of utilization and conversion of forest resources in Guyana, draws attention to the increasing human impact to which forests will be subjected in the thrust for development, and emphasizes the need for research and data collection to ensure rational procedures.

INTRODUCTION

Guyana occupies an area of 21,496 km^2 (83,000 mi^2) in Northern South America approximately between latitudes 1° - 9° N and longitudes 52° - 56° W. It is bounded on the west by Venezuela, on the east by Suriname, and on the south and southwest by Brazil. The country faces the northeast trade winds along 434 km (270 miles) of Atlantic seaboard, along which lies a flat coastal plain of fertile clay of approximately 4,143 km^2 (1,600 mi^2), varying in width from 2 miles at its western extremity to 40 miles in the east. The climate is tropical.

Behind the coastal plain, except for intermediate savannahs 502 km^2 (194 mi^2) and the far interior Rupununi Savannahs 11,654 km^2 (4,500 mi^2), the country is heavily forested, including rain forests, dry evergreen forests, swamp forests, and mangroves. The more accessible of these forests grow on infertile white sands covering 17,094 km^2 (6,600 mi^2). The total forested area is about 168,349 km^2 (65,000 mi^2). The population of Guyana is now estimated at 800,000; of this, 90% is to be found in the coastal towns and villages and the bauxite mining town of Linden. 41,350 Amerindians practice shifting agriculture and lead their traditional life in their forest communities. Up to ten years ago there was hardly any pressure on the forest from coastal dwellers, except for the extraction of timber and firewood from the more accessible areas.

The move towards development has dictated greater use of the forest for settlement agriculture, greater volume of timber extraction, and exploitation of the water resources in terms of hydroelectric potential. The latter has been assessed at 3,000 MW, of which only 1% has been tapped so far. Further, the fuel crisis has stimulated the search for new energy sources. Guyana's expenditure on fuel in 1978 was 200 million Guyana dollars (U.S. $80 million), while its total budget allocation for 1979 is 850 million Guyana dollars (U.S. $320,200,000). The search for alternative energy sources is a Caribbean regional project supported by the Commonwealth Science Council and the United States Agency for International Development.

Guyana's concentration in this project is on solar drying, mainly for fruits and other agricultural produces, but this will not reduce the tendency for the greater use of forests for calorific energy in the form particularly of charcoal.

This presentation on Guyana forests and their utilization will be mainly descriptive and qualitative; little or no data is available on which to base methodologies for precise ecological management. Guyana forests have been utilized for lumber, firewood, and food and fiber (this latter mainly by the indigenous Amerindians) but hardly managed except for the traditional management by Amerindians through shifting agriculture. Hunting, fishing, and the capture of wildlife (particularly birds) are occupations for pleasure and profit, and the trade in ornamental fishes and wildlife is at present a foreign exchange earner under the control of a Wildlife Advisory Committee which fixes quotas and declares closed seasons. Even this is done with scanty data on population numbers, breeding seasons, clutch size, reproductive rates, natural mortality rates, and other factors of population dynamics. Wildlife legislation is scanty and enforcement absent.

Up to the middle of this century, the forests were considered the home of the Amerindian, and but a temporary sojourn for itinerant coastal dwellers who braved the jungle and river rapids in search of gold and diamonds and for the collection of latex, such as balata and chicle. The value of the forests

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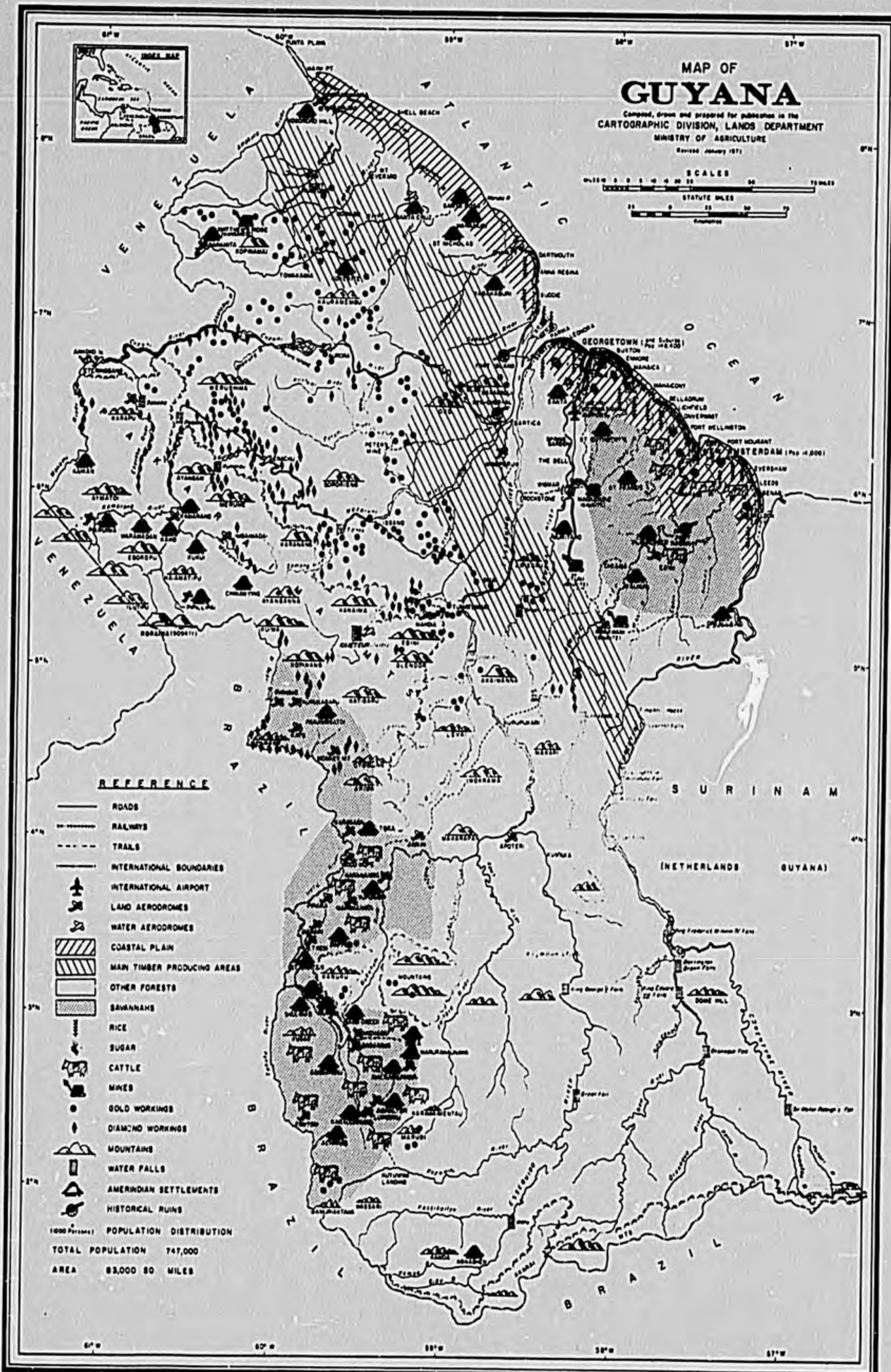
MAP OF
GUYANA
CARTOGRAPHIC DIVISION, LANDS DEPARTMENT
MINISTRY OF AGRICULTURE
SCALES
STATUTE MILES
GEORGETOWN
ATLANTIC
OCEAN
VENEZUELA
BRAZIL
SURINAM
(NETHERLANDS GUYANA)
REFERENCE
ROADS
RAILWAYS
TRAILS
INTERNATIONAL BOUNDARIES
INTERNATIONAL AIRPORT
LAND AERODROMES
WATER AERODROMES
COASTAL PLAIN
MAIN TIMBER PRODUCING AREAS
OTHER FORESTS
SAVANNAHS
RICE
SUGAR
CATTLE
MINES
GOLD WORKINGS
DIAMOND WORKINGS
MOUNTAINS
WATER FALLS
AMERINDIAN SETTLEMENTS
HISTORICAL RUINS
POPULATION DISTRIBUTION
TOTAL POPULATION 747,000
AREA 83,000 SQ MILES

for aesthetic enjoyment of the picturesque waterfalls, scenic grandeur, and education was constrained by the fact that most of the rivers are not navigable for more than 54 to 96 km (33 to 57 miles) from the ocean.

The construction of roads through the forests have done much to make the forests more available with a concomitant ecological backlash. Today the outlook is changing--there is an interior thrust. Settlements are being established in the forested areas and there is an agricultural push towards the hinterlands. This calls for a thorough understanding of the new environment and a variety of different kinds of management must be worked out in order to avoid adverse effects on forests, soil, water flows, nutrient cycling, and wildlife and the destruction of the very resources that we are seeking for overall development.

Guyana is a developing country, which naturally sees development as its goal, but it is not yet at grips with the ecological prerequisites for development. To this end we of the National Man and the Biosphere Committee of Guyana welcome workshops of this nature to which our members can be exposed.

The lack of precise data precludes a clear separation of the Guyana material under the three issues which are to be considered in the workshop. Our MAB Project 11 study, however, seems to fall naturally under Issue I..."the socio-economic consequences and constraints to the use of land and forests for energy and organics". The remainder of the material will have sporadic implications for both Issues II and III.

Issue I

Relative to Issue I of this workshop, the Guyana MAB Committee has, within the last three months, embarked on a UNESCO-sponsored study, under MAB Project 11, which involves the comparison of two groups of officially directed settlements which are growing up along two roads constructed through the white sands forests.

The Soesdyke-Linden Highway passes through dakama/muri (Dimorphandra/Humiria) scrub vegetation with remnants of wallaba (Epurea) growing on infertile white sands, and connects the capital city of Georgetown (200,000 inhabitants) at the mouth of the Demerara River and a 24-mile ribbon of riparian villages at one end, to a bauxite mining town (Linden, 28,000 inhabitants) at the other end, about 142 km (88 miles) up the river. This settlement area has had more than a century of exploitation for firewood, charcoal, electric poles, paling staves, and shingles. The main species thus exploited has been wallaba (Epurea falcata).

The second highway, recently constructed but not yet surfaced for all weather, stretches 362 km (225 miles) from the vicinity of a small, originally transit town, Bartica (6,228 inhabitants), at the limit of navigation 64.4 km (40 miles) on the Essequibo River and strategically placed at the confluence of the three large rivers, which drain the western part of the country. The road runs through high and less disturbed forests, also mainly on infertile sands and swamps to the proposed site of a hydropower installation. This Upper Mazaruni Hydropower project, when effected, would require a reservoir of 56,760 km^2 (21,913 mi^2) and a power transmission corridor 322 km (200 miles) long and 0.13 km (425 feet) wide. All of this, with concomitant clearings for townships, etc., will have a tremendous impact on the forest resources of the area.

In the latter area, the UNESCO study is restricted to Bartica and the proximal 19 km (12 miles) of road, but an extensive hinterland will be opened to which this area and the present settlements will relate, a hinterland previously denied by the dangerous rapids with which the rivers are studded above Bartica. No serious ecological or environmental studies have been initiated for the Mazaruni project.

The UNESCO comparative study is now gathering momentum and involves energy and material flows within the settlement area, between them and the build-up areas which they connect, and the forest environment in which they are set. The impact of these settlements on vegetation, soil, fauna, microclimate, water balance, land use, demographic factors, health, socio-economic factors, psycho-social factors, and general human well being is expected to be profound.

These settlements are by official conception agriculturally based, albeit on infertile white and brown sands. Bulldozers and fire are the implements of clearance, and for the most part water for crops depends upon natural rainfall.

From the standpoint of land capability, informed opinion is that these areas are unsuitable for extensive agriculture and that the situation is being made far worse by the clearing practice. Perhaps the potential of the area may be better realized in a poultry-pig-intensive small plot technique with woodlots of standing trees and orchards of suitable fruit trees, in industrial sites, and in special practices on the damper pegasse soils along the many creeks which intersect the region. Further, as one particular plant species, the dakama (Dimorphandra conjugata), is widespread, is fire resistant, and coppices freely when cut back, the area may be exploited as an "energy farm" and managed for energy by cropping dakama on a shifting basis for fuelwood and charcoal, either as a natural farm or as a plantation.

The objective of the study is, therefore, to try and arrive at an optimal utilization of this area ecologically, economically, and sociologically by integrated multiple-use before it is converted into useless scrubland. There is need also for establishing nature reserves in this rapidly changing region.

Issues II and III

Material under these issues is presented in the areas of logging, potential for organics, and shifting agriculture. Selective logging has been the main form of land use in the accessible interior areas of Guyana. Indeed, this procedure has been extremely selective in that six species alone provide 75% of the timber produced by volume. These are Octotea rodiaei (greenheart), Goupia glabra (Kabukalli), Peltogyne spp. (Purple heart), Mora excelsa (Mora), Ocotea wadenheimmi, and Humiria balsamifera. Of these, Octoea rodiaei alone provides 50%.

In general, only 15-20% of the forest is removed as merchantable commercial volume and operations are of an extensive rather than an intensive nature. In addition, all production at present comes from an area which is less than one-third (1/3) of the total forested area of the country. The forested area is approximately 166,400 km^2 (65,000 mi^2). At least 30 other species make up the remaining 25% of lumber production including Carapa quianensis (Crabwood), which is widely used for furniture and construction.

For the five-year period, 1973-1977, the average total timber production (lumber, roundwood, and split wood) was 219,534 m^3 (7,683,699 ft^3). Because of the nature of the operations, it is not possible to ascertain directly the area of forest cut, but estimates indicate that an average of 6,835 ha (16,882 acres) is covered annually to obtain this production.

In addition, there is a relatively large forestry project planned to begin operations in 1981. The estimated annual requirement in the first phase is 94,000 m^3 (3,290,000 ft^3) of timber. Under the same selective logging conditions, the area to be covered annually to achieve this will be about 2,995 ha (7,300 acres). This project is known as the Upper Demerara Forestry Project.

The project area comprises 22,500 ha (55,600 acres) of unexploited forest, representing 1.25% of the total forest in Guyana. Within this area fellings are to be selective and logging could remove 25 to 30 trees per ha (62 to 74 per acre) on the average in the rain forest and 8 to 12 per ha (20 to 30 per acre) in the wallaba forest.

Most of the terrain is gently undulating, but two major hill ranges rise to about 300 m above sea level. Here the topography is steep and broken.

Soils follow a catenary pattern with white sands on the ridges, brown sands on the slopes, and sandy loams or sandy clays in the valley bottoms. The greater part of the area is covered by rain forest, composed of an association with numerous facinations, dominated by a particular species, such as greenheart. Dry evergreen forests occur on the white sands on the ridges and are dominated by two species of wallaba (Eperua falcata and E. grandiflora). Mora (Mora excelsa) is the principal commercial species in marsh (seasonal swamps) and swamp forests which occur in the valley bottoms where drainage is impeded. There is also a type of savannah scrub characterized by dakama (Dimorphandra conjugata). These associations represent edaphic climaxes.

A village for mill workers, logging crews and their dependents is to be established near the mill site. It will eventually accommodate 1,500 people.

Offcuts, bark, sawdust, and other waste material produced by the mill will be burned to provide steam power for the drying kilns and electricity supply. C. W. Holloway (1975), in an Environmental Evaluation of the then proposed Upper Demerara Forestry Project, emphasizes a number of points, viz.: possibilities of the project operations effecting climate within the logging operations should eliminate the more serious forms of soil erosion, but special safeguards will be required in steep areas; flooding could constitute a hazard in the absence of adequate precautions, especially since there is a suggestion of an impervious subsurface layer below the sandy soils. The intensity of felling proposed will certainly promote prolific regeneration of pioneer trees, e.g., Cecropia spp., which, though not eliminating climax forest, will nevertheless add 20 years or so to their rotation age. Therefore, the rotation proposed for logging (50 to 60 years) may be too short so that one of two procedures might have to be adopted, either to reduce the coupe size or to initiate a programme of intensive research on regeneration. The former, though preferable from the ecological viewpoint, may, however, threaten the economic viability of the project, so that the latter is essential. Selective logging is likely to increase animal species associated with secondary forests and decrease species associated with climax vegetation and modify the successional stage of the logged areas as a whole with a consequent decrease in species. Diversity could threaten endemic plants and lower endemic animal life. According to Bourliere (1973), elimination of mammal populations alone could eliminate self-perpetuation of rain forests.

Holloway further recommends the exclusion of steep slopes and unmerchantable forests from the logging areas, that these be demarcated as natural reserves until more specific proposals are made for their management, and that a land use survey of Guyana, with particular reference to the forests, be instituted that would include a national park/wildlife conservation component.

Full forest harvesting or clear felling for timber does not occur in Guyana. This procedure is limited to the needs of agriculture and fuelwood. In the five-year period, 1973-1977, an average of 23,634 m^3 (827,195 ft^3) of timber was used annually for wood fuel directly, and 2,862 m^3 (100,154 ft^3) was used to produce charcoal, representing an annual clearance of 689 and 84 acres, respectively. The bulk of the vegetation is removed in contrast to the selectivity of logging.

Fuelwood and charcoal are not currently used on a large scale for domestic purposes. The gathering and/or production of these commodities is carried out by relatively few operators, rather than by a large number of peasants.

Manufacture of charcoal is believed to have been introduced into Guyana by indentured immigrants from Madeira during the last century. Production by the pit-tumulus method reached its peak during the period from 1950 to the early 1960's and was used both domestically and for export. The need for and use of charcoal declined with the availability of oil, gas, and electricity. In the face of the present fuel crisis, it is expected that the demand for fuelwood and charcoal will rise, and indeed the Ministry of Energy is encouraging charcoal production, not only by the pit method, but also by the kiln method. Active research is being done towards the production of high quality kiln charcoal using different species of trees which are not commerically exploited for timber. Usable wastes from sawmilling are estimated at 70,000 tons annually and this can produce 15,000 tons of high quality kiln charcoal.

C. A. John (1977), Conservator of Forests and a member of the MAB Committee, has reviewed the status of knowledge in Guyana under the theme of UNESCO MAB Project 1.

In general, there have been few or no studies concerning the succession of natural regeneration in the Guyana forest ecosystem. This sparsity of scientific data on rain forest regeneration and management has also been stressed by Holloway (1975).

Agro-silvicultural methods of artificial regeneration have never been applied, and investigations concerning plantation establishment in Guyana are still at the experimental stage. There are no data on the effects of cultivation and land use on soil structure and fertility.

No work had been carried out with regard to the assessment of genetic material contained within the natural forest ecosystem.

A fair amount of documentation was done by Fanshawe (1950) with regard to species yielding fibers (textile, brush, plaiting and weaving, thatching and filling); tannins and dyes; latex products (rubber, balata, and chicle); resins, oleoresins; food plants yielding nuts, fruits, vegetables, spices, beverages, and starch. In addition, a great deal of knowledge has been gleaned by the Amerindian population, though this is largely undocumented.

John proposed three five-year projects to be undertaken by interdisciplinary teams of researchers. These projects, which fell under MAB Project 1, are:

(a) An ecological study of the lowland white sand areas and their ecosystems;

(b) Studies to ascertain the effects of increased utilization of species on forest sites, especially those of the mixed forests; and

(c) Studies to ascertain the effects of large scale plantation establishment on forest sites and ecosystems.

The desirability for, and the objectives of, each of these studies are set out in his paper.

Due to constraints of finance and lack of manpower and expertise, it does not seem possible that Guyana will get down to the vast amount of research necessary for the rational use of its resources, and here I take note of items 2 and 4 of the specific objectives of this workshop in terms of cooperative programs and international cooperation.

Unfortunately there is no program such as the International Amazon Project in Venezuela, coordinated by IVIC and financed by Venezuela, USA, and the German Scientific Council. In Venezuela, international scientists are working in the San Carlos de Rio Negro on problems of the Moist Tropical Forest.

Medicinal Plants

Guyana possesses several indigenous timber trees, shrubs, herbs, and vines of importance for organics. The timber trees are now only used for timber, but the enormous amount of waste material--wood shavings, sawdust, leaves, barks, etc.--may contain chemical substances that may find use as gums, resins, perfumery chemicals, essential oils, pigments, insecticides and repellents, timber preservatives, and even drugs. Many plants used extensively in Guyana's traditional system of medicine are already documented (Fanshawe 1950; Rhagu Persaud 1972). More than 150 plant varieties are listed with reputed uses as drugs, stimulants, tonics, fish poisons, and anthelminthes.

Investigations of plants of possible medicinal value are being carried out by the Chemistry Department of the University of Guyana, but work on chemical screening for alkaloids, saponins, cardiac glycosides, essential oils, etc., within the National Science Research Council and have suffered a temporary setback.

The fruits of local indigenous palms, e.g., *Mauritia flexuosa* (Ite palm), *Maxilliana regia* (Kokorite), *Astrocaryum tucumoides* (Awara), and some other species, are being investigated as a source of edible oil. The oil from the mesocarp of these palm fruits is comparable to that derived from the mesocarp of the African palm fruit. Also, the kernels of the seeds yield an oil similar to coconut oil (high in lauric acid). Work is being directed towards the design of equipment (low cost) to produce oil from these sources.

Shifting cultivation as a form of land use has been on a small scale in the western highlands and southern portion of the country. This is largely a practice of the 41,000 indigenous Amerindians and some 5,000 itinerants from the coast, who are settled in mining areas.

Lesley Potter (1977) notes that rapid changes are taking place in the interior of Guyana. The Amerindians, whose numbers suffered decline following increased contact with coastlanders and their diseases (a decline which lasted until 1940), are now in the midst of a population explosion with a population increase rate approaching 3% per annum.

At the same time, increased communication with the coast, greater availability of education, and some stimulus from missionaries and administrators have led many Amerindians to desire a closer involvement with the money economy and improved living standards. Encouragement has been given to attempts at cash cropping for coastal markets, which have necessitated larger farm clearings. A few studies in particular districts have indicated signs of pressure on the most accessible forest areas and some reduction in the fallow periods. The recent decision to grant communal titles to Amerindian groups over lands traditionally used by them presupposes that the group will eventually become sedentary farmers raising cash crops.

No study has been undertaken of the present levels of productivity of the traditional systems and the general impact of introduction of a range of cash crops.

Two kinds of studies are immediately called for. They are:

(a) A general survey of existing systems noting signs of population pressure where these exist, and adaptations to cash cropping already made; and

(b) A more detailed and longer study of the productivity and ecological impact of shifting cultivation in a few selected environments.

In the utilization of Guyana's forests, there are many biological and sociological facts which need to be carefully studied.

Finally, while it may be conceded that Guyana is rich in forest resource potential, Guyanese must be reminded that many well-wooded countries have had their forest potential so ravaged and misused that they are subjected either to loss of soil and serious flooding, e.g., India and Pakistan, or to the substitution of xerophyt vegetation. In the Caribbean, the once well-wooded island of Boraive in the Netherlands Antilles is now covered with vegetation typical of the chapparal country of the United States.

SUMMARY OF RECOMMENDATIONS FOR EARLY ACTION AND RESEARCH IN GUYANA

1. Implementation of an intensive management program for Guyana forests, based on the Upper Demerara Forestry Project.

2. Compiling of comprehensive wildlife legislation, based on a scientific study of the faunal resources of the forest and population dynamics of species beginning with those species most used for food and export.

3. The early establishment of protected nature reserves and biosphere reserves.

4. A concerted program towards the utilization of all wastes from logging and milling activities, including biogas production.

5. An ecological study of the lowland white sands and their ecosystems.

6. Studies to ascertain the effects of large scale plantation establishment on forest sites and ecosystems.

7. Establishment on the marginal white sands area of a managed energy farm or plantation for firewood and charcoal within the programs of alternative energy sources, based on recommendation 5.

8. A survey of existing systems of shifting agriculture, noting signs of population pressure where these exist, and adaptation to cash cropping already made.

9. A more detailed and longer study of the productivity and ecological impact of shifting cultivation in a few selected environments.

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SOME SOCIO-ECONOMIC DETERMINANTS OF THE USE OF FOREST RESOURCES FOR ENERGY AND ORGANICS: A NIGERIAN SITUATIONAL OVERVIEW

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RECENT POLICIES ON POWER DEVELOPMENT

In recent decades, Nigeria, like many other developing countries, has attempted to broaden its energy base. In its rapid strides towards economic development, equally impressive steps have been taken to provide a proportionately increasing energy supply. In particular, the Federal Government has unquestionably adopted the view that:

> "The energy sector has come to play a very strategic role in the country's economic development. It provides inputs for manufacturing and service industries, contributes fuel to service the transportation system and has generally raised the quality of living of both urban and rural population. Its strategic role is borne out by the fact that when bottle-necks develop in the sector (as when there is electricity power failure or load-shedding or when there was dislocation in the refining of crude oil during the Civil War), they are promptly manifested in reduced output of goods and services, increased production costs, supply shortages and rising prices. With the increase in the tempo of economic activities expected after the end of the war, fuel and power (especially electricity and petroleum) will play a still more vital role in the nation's development process." (Federal Republic of Nigeria 1970, p. 158.)

The genuine concern of the Nigerian Government for an adequate supply of power to cope with the rapid expansion of the economy has, however, been geared to the development of the conventional sources of power, especially electricity and gas. This policy has been clearly articulated as follows:

> "In spite of the nation's obvious potential for vast thermal power generation, more emphasis will be placed during the next five years on hydroelectric power development, not only because this mode of generation involves less complex operational and maintenance problems, but additionally because the Authority has adequate management and maintenance manpower in the field as against a shortage of thermal expertise. In addition, vast alternative projects for the internal and external utilization of the nation's gas reserves are already far advanced and it is not certain that gas, either in terms of quantity and cost, will continue to be so readily available. In this situation the obvious course would appear to be to first exhaust our hydro possibilities with its multi-purpose advantages.... Any future consideration of projects for power generation will continue to be based on an investigation of alternative sources of power in the country and on the comparative economic and technical advantages of the technologies being considered." (Federal Republic of Nigeria 1975, p. 176-177.)

These quotes underscore the fact that there is hardly any thought in Government for nonconventional sources of energy. The primary ambition of the Government, with regard to the supply of power for the rural areas of the country is to provide what has been aptly described as rural electrification (Federal Republic of Nigeria 1975, p. 180). It is striking that the pattern of energy development in Nigeria seems to be following in the paths previously treaded by Western countries. The consequences and constraints of this type of development are not too difficult to imagine, as some of these have become already amply manifested in the developed countries. In Nigeria, the growing over-dependence on conventional energy sources in a poorly developed, infrastructural and technological milieu has continued to generate peculiar problems of frequent shortages and irregularities of power supply. Worse still, over-concentration of conventional sources does not take advantage of opportunities afforded by the environmental

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resources of the area. Continued development of alternative energy sources does not consider those which are renewable, accessible, easy to handle, and adaptable to the socioeconomic circumstances of the inhabitants of the area.

FOREST RESOURCES FOR ENERGY AND ORGANICS

Fuelwood, which is a primary and major energy source of heat throughout the country, is a typical example of an alternative energy source. In recent years, as much as 91% of all energy consumed in Nigeria comes from fuelwood. The position is closely similar in other developing African countries such as Tanzania with as high as 96%; Uganda, 90%; and Malawi, 89% (French 1978). A considerable proportion of the forest resources of many developing countries is being extracted mainly for fuelwood. It is also a well known fact that the vast majority of the inhabitants of the developing countries, especially those in the rural areas, continues to depend on fuelwood as the main, if not the only, source of energy, especially for cooking.

For a deeper insight into the socioeconomic determinants of forest resources in a developing country like Nigeria, it is necessary to consider the use of forest resources when imported technology was not in use and the indigenous culture was still in tact. The forest provided almost all the energy and organics in use then. Virtually all the tree species had specific uses. The bulk of the extracted wood was for fuel and the variable burning qualities of the different species were known in fine detail. The various herbs, as well as roots, barks, and leaves of some trees, were used in medicine. Wildlife was hunted, especially for meat, although every major part of each animal had its use. The forest was a composite stock of the immediate requirements of the inhabitants of the area, including food, shelter, and clothing.

The palm tree, which is probably the most characteristic and distinctive plant of the tropical rain forest, is illustrative of the use to which forest resources were put in traditional times. Every part of the tree, from the leaves to the roots, was of some special use. The branches and leaves were made into roofing materials for thatch-roofed houses, as well as for covering wall-fences. The central stalk of a palm frond was used for fencing and in basket and rope making. The thin stalks of the leaves were bunched together to form brooms. The fresh, upshooting frond was prepared as cabbage for soup or as part of the dressing material for a class of masqueraders. The fruits yielded palm oil, palm kernel, and palm kernel oil. The fibres, which were left after pressing oil from the flesh of the palm fruit, were sun-dried to form materials for lighting and also for making fire. The palm kernel shell was also a product for generating heat in blacksmiths' furnaces. The fluffy material at the base of the branches provided the tinder for the local flint method of making fire. Palm wine was collected by tapping the tree at the base of the crown of leaves. The trunks of palm trees were made into beams for bridges. The fibrous roots were used for a variety of medicinal purposes. The decaying trunk of the tree yielded in its pith a particular type of beetle, <u>Rhynochophorus ferruginous</u>, which was highly prized as a source of meat. Many parts of the palm tree, when dried, were used as firewood, although it was not particularly ideal for this purpose and, in any case, there were other numerous trees with much better qualities as firewood. The oil palm tree is still being exploited today for nearly all the aforementioned purposes. In fact, the rate of exploitation has risen phenomenally, thereby necessitating its cultivation in large plantations.

The uses made of the oil palm tree were greater than for the other trees in the forest. The oil palm tree continued to be important from traditional to modern times, simply because it became an important cash tree crop in recent decades. It was not because of its use for energy and organics that it became a cultivated and plantation tree crop. It was more because of the fact that like cocoa and rubber, its products, particularly oil palm and kernels, entered the export market.

The shift of emphasis in the economy toward the export market was one of the major factors which diverted interest and attention away from the balanced exploitation of the forest resources for energy and organics. At the same time, it became more prestigious, and therefore fashionable, to use imported versions of local products. This substitution effect reinforced the irrational exploitation of the forest resources. Today, there are still many unexplored opportunities for the exploitation of the numerous products of the forest for energy and organics, especially for the domestic market sector.

The various vegetation zones in Nigeria, from the tropical rain forest of the South to the sahel savannah of the North, are replete with trees, shrubs, herbs, and grasses of numerous species which could provide energy and organics in one form or another. The tropical rain forest, of considerable diversity of species, occupies about 31% of Nigeria's forested areas (Redhead 1970). The tropical rain forest is also characterized by its rapid accumulation and synthesis of organic matter and its wealth of biological products, especially plants and animals of notable economic importance.

In spite of the abundance of the forest resources, the state of knowledge brought to light during the January 1979 Nigerian National Committee for Man and the Biosphere Workshop indicated, so far, little interest in or concern for the use of the forest resources for energy in particular. This position is understandable because only recently has there been a re-awakening to the use of forest resources for energy in the tropical rain forest zone of Nigeria. Relatively much more work has been done on the subject in the northern part of Nigeria, "especially on the northern savannahs in the vicinity of large cities" (Morgan 1978), where there has been a more incisive pressure for providing adequate fuelwood supply to meet the rising demand of the inhabitants.

DETERMINANTS OF USE OF FOREST RESOURCES FOR ENERGY

Considering the situation throughout the country, official and private attitudes toward the rational exploitation of fuelwood have been lukewarm, if existent at all. Emphasis has been laid on conventional sources, particularly electricity and gas, mainly because of certain prevailing socio-economic trends which are strongly in support of the development of conventional sources, as previously illustrated.

Similarly, there are some socio-economic trends which could be seen or regarded as positive determinants of the use of forest resources for energy and organics, while others constitute negative determinants. A more likely situation is that changes depend on the prevailing social, political, and economic circumstances of the country. To examine and illustrate these determinants, consideration will be confined here to the use of forest resources, primarily for energy.

There is still a heavy dependence on forest resources for energy in many parts of Nigeria, both in the rural and urban areas. Such forest resources for energy include firewood, charcoal, and waste from sawmills, referred to here, in short, as sawdust. In a survey conducted by the author (Ojo 1978), meant to be a prelude to a much larger study covering a variety of ecological settings in the southwestern part of the country, an attempt was made to measure the preferences of 180 respondents in respect of some seven fuel types. The fuel types were animal dung, charcoal/coal, sawdust, electricity, firewood, gas and kerosene. One hundred and fifty of the respondents were selected from Ile-Ife, a university town, while thirty were selected from a neighboring village (Osu), located 15 km away from Ile-Ife. Three subsets of respondents were made to comprise each sample in order to reflect the major differentials in education, income, and occupation. The subsets consisted of workers in educational institutions, government employees, and business persons.

Sixty persons (40%) used firewood always at Ile-Ife, while 15 persons (50%) used it to the same extent at Osu. Forty-five persons (30%) used it occasionally at Ile-Ife, as against 12 persons (40%) at Osu. Only 30% of the respondents at Ile-Ife do not use firewood at all, as compared to 10% in Osu.

As for charcoal/coal, only four persons used it always and 39 persons occasionally in the two settlements. Similarly with regard to sawdust, 16 persons used it always at Ile-Ife, as against none at all in Osu. Similarly 33 persons (22%) used it occasionally at Ile-Ife and only 5 persons (16-2/3%) at Osu.

From the study, other pertinent findings emerged. The ranking of the frequencies from first to seventh kinds of fuel by the respondents were as follows for first, second, and third questions respectively:

a. Ile-Ife: Kerosene - 89, 43, 14; Electricity - 27, 43, 49; Firewood - 18, 38, 38; Gas - 8. 26, 30; Sawdust - 2, 4, 12; Charcoal/coal - 0, 2, 9; and Animal Dung - 0, 0, 1.

b. Osu: Kerosene - 20, 7, 3; Electricity - 5, 6, 5; Firewood - 5, 12, 8; Gas - 0, 4, 4; Sawdust - 0, 0, 0; Charcoal/coal - 0, 0, 2; and Animal Dung - 0, 1, 0.

The fuel types suggested by respondents to be ideal for use in the city and in the rural area were broadly similar for the two areas. The order of fuel types as suggested for urban areas, as given by respondents in Ile-Ife, was (in diminishing importance) electricity, gas, kerosene, firewood, charcoal/coal, and animal dung. Under this heading, the respondents in Osu suggested electricity, gas, kerosene, charcoal/coal, and firewood. The order for fuel types to be developed for rural areas was given by Ile-Ife respondents as follows: kerosene, firewood, electricity, sawdust, charcoal, and gas; and by Osu as follows: kerosene, firewood, electricity, gas, and charcoal/coal.

Findings like the above, representing the preferences of the users of available energy sources cannot justifiably be ignored by those involved in planning alternative energy sources. This kind of information is broadly indicative of whether or not such alternative energy sources will be accepted or rejected by the potential users. It should be stressed that such preferences are an end product of what the users consider to be the built-in determinants of the use of the forest resources for energy.

The constantly changing socio-economic status of the people of the country tend to make them share expectations similar to inhabitants of the Western world. Such "rising expectations" are at the root of a growing attitude that is is an imperative of socio-economic development to leave behind the use of primary or primitive sources of energy (such as fuelwood) so as to be able to move to the use of secondary/tertiary sources (such as electricity or gas). On the whole, this tendency to live up to the socio-economic status of the Western world constitutes a negative determinant to the use of forest resources for energy. As borne out by the survey previously referred to, only a tiny proportion of workers in educational institutions used firewood or preferred to use it. The option was for electricity or gas or kerosene. In short, the upper class of the society who could afford to pay for the consumption of conventional sources of fuel are stoutly out of favor with firewood.

It was also apparent that when the income of a worker increased, he was most quickly disposed towards adopting what he considered to be a higher level of energy consumption. As used at present, firewood is a rather crude and unsatisfactory source of fuel for cooking in a modern setting, such that anyone who could afford to pay for a more sophisticated fuel type would be too happy to drop firewood. The generally rising income level in the country could, in many ways, adversely determine the development of forest resources for energy.

As the economy waxes and incomes rise, there could develop an increasing demand for land for a variety of other land uses not too close to the production of energy from forest resources. To keep the supply of forests for energy steady, the forest lands must be able to resist all undue incursions; in short, they must be able to compete effectively with other agricultural, manufacturing, and recreation industries, all of which require extensive land. In fact, all the other land uses could constitute a constraint on production for energy. To a lesser extent, pressure on forests for energy can be built up by demand for other forest products, especially timber. This could easily become another negative determinant, in fact, a constraint on fuelwood energy production.

Timber extraction and processing could have many side benefits for energy production. The thinnings obtained during timber cutting, the offcuts and other wastes, including sawdust, are substantial fuelwood sources for energy. Various forms of modern agricultural development pose constraints that must be resolved in favor of the use of forest resources for energy. Mechanization of agriculture leads undeviatingly to the removal of forests. It is only through agricultural practices which integrate forestry with crop cultivation (such as the taungya system) that the threat can be controlled, if not totally removed.

The existing land use tenure could hinder the introduction and adoption of fuelwood plantations because land may not be available in large enough sizes for such large scale projects. Worse still, as families modernize the ownership aspects of the land tenurial systems, fewer areas of land from which firewood can be fetched as a free good will become increasingly unavailable. As of now, firewood is being fetched at increasing distances from the city in fairly remote areas approaching "no man's land".

Most of the firewood and charcoal sold in Nigeria are stacked by the roadside, where those who operate vehicles have an advantage of being able to make purchases at relatively cheaper prices. Fuelwood sold at the urban wood markets normally cost more, because of the added freight charges. The increasing use of vehicular transport in the country has had a positive influence on the production and distribution of fuelwood. Firewood can be more readily extracted from locations far away from the consuming centers and charcoal can be produced in kilns located close to the raw materials in relatively out of the way places, as long as there is an assured means of transportation. It is important to stress the other side effect of increased use of transport, which is negative. Through improved transportation, the invasion of the forest by those harvesting its resources can become more penetrating and disturbing to the ecosystem if not controlled.

Similarly, through the increasing availability and use of imported technology such as the engine-operated, portable saw, severe damages can be inflicted on the forest environment within a short time. In spite of its positive advantages, the use of sophisticated equipment for fuelwood extraction can accelerate the depletion of the forest resources.

CONCLUSION

In the final analysis, no particular factor can constitute a favorable or positive determinant of the use of forest resources for energy and organics for all time, not even for any duration of time, unless the factor is properly understood, controlled, and managed. Most of the factors previously considered are indeed double-edged swords. It is therefore necessary to be able to exploit their positive aspects and minimize the negative influences for the use of forest resources for energy and organics through effective and rational management. It is obvious that such a consideration must be made within the context of the total development of the resources of the economy.

Furthermore, in considering the effects of the socio-economic determinants of the use of forest resources on energy and organics, it is necessary to be guided towards future action by the interest and welfare of those to be affected by the outcome of the policies being formulated. For instance, the preferences of the users for particular fuel types and the peculiar circumstances of their life styles must be taken into consideration in evolving alternative energy sources for them. Innovative devices for energy use must not only be appropriate, simple, and relatively cheap, but must be designed and produced within the framework of the socio-economic and cultural environments of the prospective users.

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BIOLOGICAL AND SOCIOLOGICAL USE BASIS FOR NATIONAL USE OF FOREST RESOURCES FOR ENERGY AND ORGANICS IN ARID AND SEMI-ARID AREAS IN TUNISIA, NORTH AFRICA

Hechmi Hamza [1/]

INTRODUCTION

The countries of North Africa were covered before the Phoenicians and Romans with large forests. These countries participated for the development of Mediterranean civilization with their forest possibilities and natural resources. They gave wood for ship building and improving communication between peoples and nations. A big quantity of fuelwood was given for domestic use and energy for starting small industries in this old region of the world.

After the long and heavy use of the forests and their destruction for wheat culture by the Roman and French colonization, very small natural forest remained in mountain tops or marginal lands.

Many natural resources, such as soils and water, are threatened by erosion and are decreasing to the extent that the Sahara Desert is creeping more and more every year to the North through agricultural lands.

FOREST RESOURCES AND FUELWOOD NEEDS

The natural forests in North Africa reach the total surface of 7,650,000 ha.

Regarding the total area of North Africa (Algeria, Tunisia, and Maroc), which occupies 2,982,000 km^2, the total rate of forest cover does not exceed 2.3 percent. This cover is not sufficient to protect the lands against water erosion and winds and cannot procure to the North African economy the total needs of wood (saw-wood, mine props, and fuelwood).

The needs of fuelwood used for domestic purposes and cooking are exceeding the forest production. For example, in Tunisia the last inventory made to evaluate the quantity of fuelwood used by rural and urban families showed that the total utilization of fuelwood in rural areas (700,000 inhabitants) reaches 820,000 tons, and in the urban area, 540,000 tons. The total use reaches the quantity of 1,360,000 tons. This quantity is equivalent to 2 million m^3. The use of wood per capita reaches 0.33 m^3. In the other countries of Algeria and Maroc, which have the same way of life and habits, if we take the same average, the total needs of fuelwood in Algeria and in Maroc reaches the quantity equivalent to: $41 \times 10^6 \times 0.33$ m^3 = 13,530,000 m^3.

All these figures demonstrate that the quantity of fuelwood used in North Africa are very large regarding forest production, which does not exceed a total of 6,630,000 m^3.

The extra amount of wood is taken from shrubs and natural vegetation out of natural forests, and mainly from fruit tree branches and small vegetation covering poor lands like Rosmarinus plants, Laurus, and others.

The last small plants are pulled out very often from the soil with their roots, and consequently many large lands become bared and exposed to wind and rainwater influence.

RATIONAL UTILIZATION OF NATURAL FOREST RESOURCES

Rational Exploitation

The forest departments of North African countries tried first to organize the exploitation of the natural forests and studied their management.

Table 1 shows the total forests studied for these purposes, except for Algeria.

In some forests, a relative quantity of fuelwood is offered to the local population, respecting their traditional right called "droit d'usage", or right of use in the forest.

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Table 1.--Natural forests studied for rational exploitation.

Country	Productive forests (ha)	Total surface of forests (ha)	Forests studied for management (ha)
Maroc	2,500,000	4,769,000	449,000
Algeria	578,000	2,107,000	--
Tunisia	500,000	780,000	272,000
Total	3,571,000	7,656,000	721,000

Afforestation

With afforestation, the governments of North Afric tried to extend the forest. The total area afforested reaches 710,000 ha: Maroc - 230,000 ha; Algeria - 330,000 ha; and Tunisia - 150,000 ha.

Extension of Oil Use Instead of Wood

It seems paradoxical that countries like Algeria and Tunisia, which have enough oil resources, continue--mainly in rural areas--to use fuelwood for domestic needs.

In many local and regional congresses organized in North Africa for fighting against the formation of deserts, it was recommended (mainly in Tunisia) to help rural population to use oil instead of wood and natural vegetation, by reducing in rural localities (in the Center and the South) the price of petrol. This recommendation has not been followed, because it is very difficult to be applied and presents many problems on economic and commercial levels.

The authority prefers to help the extension of oil and gas use by introducing new systems and apparatus in rural areas (combined light cookers, petrol apparatus, etc.). Oil or gas utilization instead of wood now appears as a provisional solution, but the needs of energy will increase in the future. The oil resources will decrease likewise, and a new solution must be found by coordinating all the efforts made by scientists and technicians in every field (solar energy, radioactivity, and forest energy).

The foresters in North Africa have a large responsibility to face these increasing demands of energy and must ask for research and an experimental program for forestry and energy.

FOREST RESEARCH AND EXPERIMENTATION

Tunisian Forest Research Program for Afforestation in General

The activity of forest research started in Tunisia in 1958 by establishing 45 arboreta in different bioclimatic areas of Tunisia.

These arboreta include quite 150 species of Eucalyptus, 30 species of Acacias, 15 species of Atriplex, and other pastoral plants.

The main objective of these arboreta is to improve vegetative material used for afforestation projects, which aimed to plant 10,000 ha every year in Tunisia from 1961 to 1973. (Recently this average area fell to 5,000 ha per year, due to many financial, land, and social problems.)

Many selected trees like *Eucalyptus camaldulensis*, *Eucalyptus gomphocephala*, *Eucalyptus astringens*, *Eucalyptus occidentalis*, *Acacia cyanophylla*, and *Acacia cyclopis*, which are all high-growing species, are used on a large scale in deep soils. The resiniferous trees like local *Pinus halepensis* and *Pinus pinea* are used in marginal and degraded soils.

These plantations now give a good production of wood, especially in sand coastal dunes. The artificial forests in these dunes are managed and exploited rationally. They give a large proportion of fuelwood (Acacias).

Research Program for Rural Forest Plantations and Windbreaks

Considering that there are no more forests and wood resources in agricultural areas and in many marginal lands, the National Research Institute of Tunisia started in 1968-1969 an experiment on rural forest plantations and windbreaks in agricultural lands.

First, the windbreaks are planted around irrigated areas to protect them against the strong winds blowing often from the North and Northwest. These windbreaks include two or three lines of species needing a good amount of water, like Poplar and Cupressus.

Secondly, windbreaks including dry species like semi-arid Eucalyptus (E. salmonophloia, E. sargentii) are planted mixed with Acacias on large bands (30 to 50 m). They are established all around the irrigated areas with bands situated at the distance of 400 to 500 m from each other.

Third, rural forest plantations are established in every space or land not used by agriculture, like small hills, riversides, poor soils, etc.

All these categories of plantations, if rationally exploited, can procure a good quantity of fuelwood to the rural population and help them to find energy at the proximity of their houses. The small vegetation and shrubs covering poor lands can, consequently, be relieved. But social and economic problems must be solved before the application and the large use of this system.

Besides these forest plantations, plants such as Acacias and Atriplex meet more and more attention from the rural population, because of their double use for wood and livestock.

Research for Improving the Yield of Charcoal Production

Traditionally in Tunisia and North Africa, coal is made by a very old process which consists of covering a mass of wood with vegetation and earth and putting slow fire in the wood, which is transformed progressively to coal.

The yields of this system are very low. The National Forest Research Institute prepared new coal apparatus made of iron. The yield is improved by nearly 40 percent.

Research for Organics

Many natural plants in Tunisia are exploited for their aromatic products such as Rosmarinus and Myrtus, which are distilled.

Research started last year in collaboration between the Tunisian University and the National Forest Research Institute for analyzing the chemical and organic compounds of Rosmarinus. This kind of research must be developed, but requires special materials and costly techniques, which cannot be supported by the budget of the National Forest Research Institute.

An international program for analyzing the organics of many species can be developed with countries which are ready to help developing countries for research on organics, mainly for organics which can be burnt and give gas energy. We must remember that Tunisia has an important collection of Eucalyptus (150 species) (IRT/Tunisia 1971) and Acacias. Eucalyptus are very rich in chemicals, and Acacias, which are leguminous plants, can fix nitrogen from the air. Acacias are not only interesting for their capacity to produce a good quantity of wood, but also add nitrogen to soils.

CONCLUSION

Tunisia has undertaken, since 1959, a program of research for afforestation. The scientific methods include ecology, pedology, forest genetics, forest mechanization, wood technology, forest entomology, and biometry.

Rural plantings of trees could improve fuelwood production in agricultural areas if the method is adopted by the population. A good extension program could help to resolve social and jurisdictional problems.

Research for organics can be started and developed if there is sufficient means and sufficient contact and coordination between forestry research in developed and developing countries.

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FORMAT OF THE WORKSHOP

PLANNING AND CONDUCT

The workshop was organized by a committee which included membership from the sponsoring MAB committees. The initial idea for the workshop was discussed at a meeting in September, 1976. The specific terms of reference were developed in subsequent meetings, and in November, 1977, invitations were mailed out to approximately 16 individuals in developed and developing countries who were selected to prepare background papers for each of the three issues. The authors were asked to have their papers in the hands of the workshop rapporteur by November 15, 1978. The rapporteur then reproduced the papers and mailed them to all workshop participants prior to the workshop.

Chairpersons were identified for each of the three issues by the spring of 1978. The chairpersons were asked to summarize available background issue papers and present an overview synthesis at the beginning of the workshop.

The workshop was scheduled to accommodate about 50 participants from developed and developing countries, with the idea being that discussions would be most effective if the sessions were limited to 15 individuals or less. Participants included the three session chairpersons, the 16 issue paper writers, and invited participants from other developing and developed countries. The organizing committee members generally played a passive role in the workshop deliberations.

During the workshop deliberations, the chairpersons moderated the discussions, summarized the results, and presented this information in plenary session. Each issue session also selected a rapporteur who assisted the chairperson in recording the results of the discussions and in preparing the final documentation after open plenary discussions. A resource person from the organizing committee was assigned to each of the issues to provide logistical assistance.

The working arrangements are outlined:

A. A chairman led each working group and presented the recommendations and conclusions to plenary sessions. Each chairman was assisted by a rapporteur selected by the working group.

B. The rapporteur, in conjunction with the chairman, was responsible for:

   1. Recording the key elements of workshop discussions, whether the discussion on any particular subject had unanimous support, was a concensus statement, or had definite divided views and, if so, what were the different views?

   2. Synthesizing discussions that were related to a particular topic.

   3. Recording recommendations and sorting them into appropriate categories.

   4. Recording suggested strategies for implementing recommendations.

   5. Assisting in the preparation of summaries of the workshop findings.

Participants were given the following instructions:

a. Recommendations may be directed to governments, research agencies, development agencies, and other appropriate organizations or individuals.

b. Recommendations may include the implementation of pilot projects, research projects, increased international cooperation, training, management actions, information exchange, or other steps.

c. Recommendations may be specific to certain regions of the world or general.

d. Recommendations may be on any aspect of the topic.

e. Each working group is asked to make an attempt to place their recommendations in some priority order, if possible.

f. To the extent possible, in the summation document each of the workshop sessions should:

(1) compile the state of knowledge and review selected case studies, both from developed and developing nations;

(2) identify priorities for future research and for the establishment of cooperative research programs;

(3) identify logistic needs for execution of programs, including methodological aspects; and

(4) reinforce the need for international cooperation in the management and use of forest resources.

AGENDA

"Biological and Sociological Basis
for a Rational Use of Forest Resources
for Energy and Organics"

An International Workshop for the
Man and the Biosphere Program
6-11 May 1979

Kellogg Center
Michigan State University
East Lansing, Michigan

6 May (Sunday)

5:30 p.m.	Registration - Kellogg Center	
7:00 p.m.	Welcome from MAB--Red Cedar Room	Donald King, Chairman
	Welcome from Michigan State University	John Cantlon
	Wood for Energy--A Legislative View	Lynn Jondahl
	Housekeeping Details	David Thorud
	Reception/Buffet	

7 May (Monday)

7:00 a.m.	Organizing Committee Breakfast	
8:00 a.m.-10:00 a.m.	Late Registration - Kellogg Center	
10:00 a.m.	All day local field trip - Lobby, West Door	
6:30 p.m.	Supper and free evening--Red Cedar Room	

8 May (Tuesday)

7:00 a.m.	Organizing Committee Breakfast	
9:00 a.m.	Plenary Session--Lincoln Room	Donald King, Chairman
	Overview on how workshop will be conducted and introduction of Organizing Committee members and the workshop rapporteur	David Thorud
9:30 a.m.	Synthesis of Background Issue Papers	
	Issue I - Socio-Economic Factors	G. J. Afolabi Ojo

10:00 a.m.	Issue II - Energy Input/Output	J. D. Ovington
10:30 a.m.	Coffee Break	
10:50 a.m.	Issue III - Environmental Consequences	S. G. Boyce
11:20 a.m.	National MAB Committee Reports	O. J. Olson
12:30 p.m.	Lunch--Red Cedar Room	
2:00 p.m.	Review and discussion of workshop procedures and assignment of participants - Room 104	David Thorud
2:30 p.m.	Issue I - Room 102	G. J. Afolabi Ojo, Chairman
	Issue II - Room 110	J. D. Ovington, Chairman
	Issue III - Room Vista	P. Roberts-Pichette, Chairman
3:30 p.m.	Coffee Break - Room 104	
4:00 p.m.	Completion of three concurrent workshop sessions	
5:30 p.m.	Adjourn	
6:30 p.m.	Supper--Red Cedar Room	
7:45 p.m.-10:00 p.m.	Continuation of three concurrent workshop sessions (optional)	

9 May (Wednesday)

7:00 a.m.	Organizing Committee Breakfast	
8:30 a.m.	Continuation of three concurrent workshop sessions	
10:00 a.m.	Coffee Break - Room 104	
10:20 a.m.	Continuation of three concurrent workshop sessions	
12:00 p.m.	Lunch--Red Cedar Room	
1:30 p.m.	Plenary Session - Room 104	David Thorud, Chairman
	Informal presentation and discussion of preliminary results of the three concurrent workshop sessions	

	Issue I - Room 102	G. J. Afolabi Ojo, Chairman
	Issue II - Room 110	J. D. Ovington, Chairman
	Issue III - Room Vista	P. Roberts-Pichette, Chairman
	Discussion on any needed adjustments in the workshop approach and methods	David Thorud, Chairman
3:30 p.m.	Coffee Break - Room 104	
4:00 p.m.	Completion of three concurrent workshop sessions	
5:30 p.m.	Adjourn	
6:30 p.m.	Supper--Red Cedar Room	
7:45 p.m.	Optional three concurrent workshop sessions	
	Completion of discussions and identification of recommendations	
10:00 p.m.	Adjourn	

<u>10 May (Thursday)</u>

7:00 a.m.	Organizing Committee Breakfast	
8:30 a.m.	Handwritten reports and recommendations from the three workshop sessions submitted to workshop organizers for typing and reproduction	
9:00 a.m.	Field trip to Morbark - Lobby, West Door	
6:30 p.m.	Supper--Red Cedar Room	
7:45 p.m.	Workshop reports distributed to all conference participants	

<u>11 May (Friday)</u>

7:00 a.m.	Organizing Committee Breakfast	
8:30 a.m.	Plenary Session - Room 104	W. Parham, Chairman
	UNESCO/MAB Report	Bernd von Droste
9:00 a.m.	Presentation of workshop reports	

	Issue I Report Recommendations Discussions	G. J. Afolabi Ojo
9:30 a.m.	Issue II Report Recommendations Discussions	J. D. Ovington
10:30 a.m.	Coffee Break	
11:00 a.m.	Issue III Report Recommendations Discussions	P. Roberts-Pichette
12:00 p.m.	Lunch--Red Cedar Room	
1:30 p.m.	Plenary Session - Room 104	P. Ffolliott, Chairman
	Summary by workshop rapporteur	S. G. Boyce
2:30 p.m.	Implementation and discussion of recommendations	David Thorud
4:00 p.m.	Adjourn	O. J. Olson
6:30 p.m.	Supper--Red Cedar Room	
8:00 p.m.	Farewell Social--Red Cedar Room	
<u>12 May (Saturday)</u>		
	Departure of Participants	
	Organizing Committee prepares material for publishing proceedings	

MAN AND THE BIOSPHERE

The Man and the Biosphere Program (MAB) is an integrated, interdisciplinary, problem-focused research approach to the management problems arising from the interactions between human activities and natural systems. The MAB approach focuses on:

---the general study of the structure and function of the biosphere and its ecological regions to provide an improved environmental information base for decision-making.

---systematic observation of changes brought about by man in the biosphere in order to provide new tools for environmental planning and resource management.

---the study of the effects of these changes upon human populations to improve our ability to predict these effects and to develop new strategies to lessen their disruption to human lives.

---the educational and information needs relating to these subjects.

MAB provides the mechanism for bringing together and coordinating national and international research, conservation, and training activities. As of now, MAB comprises more than 600 operational field projects in about 60 countries, involving the coordinated interdisciplinary research efforts of several thousand scientists all over the world. At present, 144 Biosphere Reserves provide for permanent conservation, research, monitoring, and training facilities in 39 countries. A number of training courses are supported through MAB to enhance man's knowledge in the field of ecological theory and its application to natural resource management. An information retrieval system has been set up for MAB field projects and Biosphere Reserves as a supporting measure.

The Way MAB Works

The MAB International Coordinating Council (ICC), consisting of representatives from 30 nations, guides and supervises the program. UNESCO provides the international secretariat.

Ninety-five nations presently participate in the MAB program. In each country, a national committee defines and organizes activities concerning particular national problems within guidelines from the ICC.

The subject of Man and the Biosphere encompasses the entirety of relationships humans have with their surroundings. Therefore, in order to embark on real, concrete tasks, the ICC selected 14 project areas. Projects 1 through 7 focus on particular kinds of geographic areas (forests, grazing lands, arid lands, fresh and coastal waters, islands, mountains, and tundra). Project 8 concerns the development of an international network of "biosphere reserves", protected areas for research, monitoring, and conservation. Projects 9 through 14 focus on what might be termed systems and processes (impacts of major engineering works, demographic changes, urban systems, pesticide use, environmental perception, pollution). Projects are not considered mutually exclusive, and actual research and training activities may cut across several project areas.

For further information and to obtain MAB documents concerning your field of interest, contact your MAB National Committee or write to the following address:

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