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Deforestation of Tropical Rain Forests

Economic Causes and Impact on Development

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Abbreviations and Acronyms

AETFAT	Association pour l'étude taxonomique de la flore d'Afrique tropicale
ASEAN	Association of South-East Asian Nations
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BRI	Indicator of biomass reduction
EC	European Community
ECE	Economic Commission for Europe (UN)
EEC	European Economic Community
EK	Enquête-Kommission des 11. Deutschen Bundestages "Vorsorge zum Schutz der Erdatmosphäre"
ERP	Effective Rate of Protection
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organization of the United Nations
FELDA	Federal Land Development Authority
FMI	Forest modification indicator
GDP	Gross Domestic Product
IBGE	Instituto Brasileiro de Geografia e Estatistica
ICITV	Institute de la Carte Internationale du Tapis Vegetal (UNESCO)
ICOLD	International Committee on Large Dams
IIED	International Institute for Environment and Development
ILO	International Labour Office
INCRA	Instituto Nacional de Colonização e Reforma Agraria
MME-DNPM	Ministério das Minas e Energia, Departamento Nacional da Produção Mineral
OECD	Organisation for Economic Co-Operation and Development
SUDAM	Superintendencia de Desenvolvimento da Amazonia
UN	United Nations

UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	US Department of Agriculture
VAC	Volume under bark of actually commercializable timber
VOB	Volume over bark of all standing timber

Preface

Since the beginning of the eighties the increasing deforestation of tropical forests has raised major concerns both in the respective tropical countries and in the industrialized countries. The reason for this is that the destruction of tropical forest ecosystems not only impacts on the economic and ecological well-being of tropical countries but is likely to incur changes in the world climate by aggravating the greenhouse effect. Nonetheless, the tropical countries have recognized that their forest areas are a major economic resource that can be exploited in order to foster economic growth and development.

The study assesses the contribution of various economic sectors to the deforestation and forest degradation of tropical moist forests and analyzes the impact on the economic development of 40 tropical countries. In many countries, logging and wood manufacturing have accounted for a sizable share of employment, income and export revenues. The same does not generally apply to industrial activities or agriculture on newly deforested land. In some cases, large-scale settlement programs have contributed greatly to deforestation.

In many cases, forest conversion does not follow a long-run economic rationale. This is due to the influence of economic policy measures that provide incentives for unsustainable forms of land use, and to the widespread neglect of ecological values in view of the seemingly endless forest resources. An appropriate policy reform should aim at low-intensity forest use and at the implementation of measures that would increase productivity in agriculture. The required transfers from the industrialized countries should be regarded as payments for ecological services rather than development aid. Restricting international trade in tropical hardwoods is not likely to be effective, since the bulk of industrial roundwood from tropical forests is consumed domestically. Instead, compensational payments are more likely to settle the North-South tensions that could possibly arise as a result of global environmental problems and the respective distributional conflicts.

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Kiel, April 1992 Horst Siebert

I. Introduction

1. Background

Since the beginning of the eighties the increasing deforestation of tropical forests has raised major concerns both in the respective tropical countries and in the industrialized nations. The reason is that the destruction of the tropical forest ecosystem does not only impact on the economic and ecological well-being of tropical countries (desertification, soil erosion, changes in the microclimate, decline in water resources) but incurs changes in the world climate by aggravating the greenhouse effect. Following Crutzen et al. [1989] and Houghton et al. [1987], the estimated share of carbondioxide emissions resulting from tropical deforestation in global carbondioxide emissions was between 10-30 percent in 1980. Following a more recent study by Myers [1989], this share was 30 percent for 1989.

Beside these effects on the global climate, tropical forest ecosystems feature a variety of unknown biological species. This genetic diversity has been a major research input for natural scientists all over the world. Following Lovejoy [cited in Enquête-Kommission (EK), 1990, pp. 495-509], between 33-55 percent of the 750,000 to 2,500,000 biological species in tropical rain forests will be extinguished in the 1980-2000 period depending on the trends in deforestation. Hence, the destruction of the tropical forest ecosystem leads to negative ecological effects both in industrialized and in the respective tropical countries.

All of these ecological effects cause considerable economic costs in tropical and industrialized nations:

- Due to the deforestation of tropical forests the respective tropical countries face problems like changes of the microclimate, soil erosion and decline of the water endowment. These effects lead to a decline of agricultural productivity. Moreover, some economic agents like, for instance, the native peoples in tropical forest areas have used the tropical forest as a renewable resource. These forms of economic uses, which do not reduce the regenerative capacity of rain forest ecosystems, are crowded out given the current speed of deforestation in tropical countries.

- The aggravation of the greenhouse effect is expected to destabilize the global climate and to cause fluctuations in climatic extrema like temperature and wind. In general, the economic effects of the greenhouse problem cannot be quantitatively assessed. The resulting increase in the variations of temperature and wind are likely to reduce the productivity in sectors which are highly dependent on climatic conditions, i.e., tourism, transport, agriculture, forestry. Though the climatic effects due to global warming are still disputed among natural scientists, insurance companies have started to adjust their risk charts showing the regional intensity and frequency of storms and floods.[1]
- The extinction of a number of biological species is expected to affect the research input available for the pharmaceutical and chemical industries and the producers of agricultural inputs. It has been reported that a third of all medical drugs used in the European Community (EC) includes a main ingredient which has been derived from wild plants or animals in tropical rain forests [EK, 1990, p. 559]. Moreover, the development of cash crops which are resistent against particular diseases is highly dependent on wild crops in tropical rain forests.[2] As a result, costs of research and development can be expected to increase in these sectors [Oberndörfer, 1988, p. 4].
- Many environmental economists have put forward that the mere existence of environmental goods like tropical forest areas, biological species or beautiful landscapes have a positive value in terms of consumer preferences. Thus, these environmental goods can be treated as ordinary consumer goods as there is a positive demand for them. The supply of these environmental goods is permanently declining, thus affecting the welfare position of consumers all over the world [Pearce, Turner, 1990, p. 265].

Given these effects on the economic welfare in all countries, the conservation of tropical forests should be in the interest of both tropical and industrialized countries. However, the tropical countries have re-

[1] For instance, the Münchner Rückversicherungsgesellschaft AG prepared a revision of its meteorological charts already in 1989 (Welternährung, Vol. 19, 1989, No. 3, p. 3).

[2] It has been estimated that illegal and legal trade with wild animals and plants from tropical rain forests accounted for 5 billion ECU in the eighties, which is not much less than the value of all tropical timber exports [EK, 1990, p. 559].

cognized their forest areas as a major economic resource that should be exploited to foster economic growth and development. In particular, tropical forest areas provide land reserves for the expansion of agricultural production, mineral commodities and wood that can be exported or used as an input for the development of a domestic wood industry. Since all countries with sizeable rain forest areas are developing countries, they regard the tropical forest areas as a part of their natural resource endowment which should be used to raise incomes, employment and exports, even though the decline of environmental quality causes economic costs to the respective countries. However, in the view of tropical countries these costs cannot outweigh the economic benefits derived from destructive rain forest exploitation. There are mainly two reasons for that. First, costs of environmental degradation become effective in the long run, while benefits accrue immediately after the economic exploitation. Given the developmental problems and the poverty prevailing in some parts of the population in many tropical countries, governments, consumers and producers have an interest in short-run improvements of their welfare position. Second, the economic costs of environmental degradation and economic benefits of exploitation may accrue to different people. If the beneficiaries are politically more powerful, the degradation of forest areas can be viewed as a consequence of the political process in these countries.

Hence, there are at least some people in tropical countries benefitting from the economic exploitation of tropical rain forests, while on the whole non-tropical countries suffer from the economic costs of environmental damages. This divergence of interest calls for international agreements leading to a coordination of policy measures. The recent literature on the conservation of tropical rain forests features a variety of international policy measures for the conservation of tropical rain forests, i.e., multilateral and bilateral development aid, debt-for-nature swaps, international funds providing compensation payments to countries conserving their tropical forests, international agreements on carbon-dioxide reduction, import barriers for those goods which are produced by using tropical forest resources.[1]

[1] For example, Ruitenbeek [1990], EK [1990], Oberndörfer [1988], Amelung [1989; 1990].

These international policy measures have to be complemented by domestic policy measures in the tropical countries in order to be effective. The main-stream theory of environmental economics provides a broad set of policy instruments such as taxes, licenses and regulations [Panayotou, 1990; Pearce, 1990; Heister et al., 1991]. These common instruments in environmental policy are supposed to discourage those sectors which use environmental goods intensively and thus tax the beneficiaries of environmental degradation relative to those people facing a loss of economic welfare.

Moreover, the structure of incentives to various economic sectors is determined by industrial policy and trade policy measures. Hence, the general economic policy of a country is a decisive element in the exploitation of rain forest, as government policies may either encourage or discourage sectors that use rain forest resources intensively. Thus, a change of the government's sectoral priorities is likely to affect the degree of deforestation.

However, the critical assessment of various policy measures has so far been quite tentative, since there is a lack of empirical evidence on the use of tropical forests as an economic resource. As a result, comparisons and analyses of alternative policy measures have been confined to rather conceptual discussions, while quantitative analyses of the effects of various policy measures were not feasible. The following study is meant as an input to the policy discussion by providing empirical data on the economic use of tropical forests.

2. Objectives of the Study

As outlined in the previous section, there is a need for a fact-finding study in order to enhance the discussion on suitable policy measures for the conservation of tropical rain forests. In this respect this study will attempt to develop evidence for the following empirical issues:

1) quantifying the contribution of various economic sectors to tropical deforestation;
2) assessing the importance of these sectors and their use of rain forest resources for the economy of the tropical countries;

3) measuring the importance of rain forest resources to the world economy;
4) identifying the government-induced incentives for sectors using tropical forest resources as an input factor.

The first of these issues is certainly one of the very crucial problems in the discussion of the tropical deforestation issue. In order to provide evidence, the users of tropical rain forest resources have to be identified on a country level by various economic sectors. Thereafter, their contribution to the destruction of rain forest ecosystems will be estimated by using various proxies. As Section II.3 will show, such estimations incur serious conceptual and empirical problems. Nevertheless, the empirical results may give important hints for the designing of effective policy instruments. The emphasis of the study is on those sectors that actually cause deforestation and forest degradation. Other economic activities, i.e, hunting and gathering, do not cause irreversible damages to the rain forest ecosystem. These economic activities which are in line with a sustainable economic use of the rain forest will not be analyzed in this study.

The second set of questions is related to the importance of tropical forest resources as an input to economic development in tropical countries. As already mentioned above rain forests form a resource base for a number of economic sectors which deplete this economic resource. The development of these sectors can be decisive for the future economic welfare of tropical countries. The relevance of these sectors for the domestic economy in tropical countries is a crucial issue for the discussion of policy measures. The assessment of the economic relevance of forest-consuming sectors may give an indication how costly a substitution of these forest-consuming uses for other economic activities could be for the economy if the respective tropical countries deliberately decide to conserve parts of its tropical rain forest areas thereby inducing structural adjustments in their economy. These adjustments can be costly and painful when the forest-consuming sectors contribute the bulk of employment, export earnings and gross domestic product (GDP) of the tropical countries or provide essential inputs to related industries. Hence, the importance of the rain forest depleting industries will be measured in terms of shares in sectoral output or GDP, shares in total employment and shares in total exports.

In the same vein, the importance of rain forest resources to the world economy will be assessed in terms of shares of exports extracted from tropical forest areas in worldwide exports of that commodity. This issue sheds light on the discussion whether a reduction in tropical deforestation will lead to major structural adjustments in the world economy.

Finally, the analysis of sectoral policies in tropical countries refers to the question to which extent domestic policies in tropical countries encourage or discourage the exploitation of the tropical forests. This analysis will show whether a reduction of government-induced distortions like subsidies, trade barriers and other regulations may simultaneously improve the economic welfare and the quality of the environment in tropical countries.

The report is structured as follows. Chapter II addresses various conceptual issues and definitions associated with the empirical analysis and provides a short overview on recent empirical studies on tropical deforestation. Chapter III discusses the role of the forestry sector in the destruction of the rain forest ecosystem and the importance of this sector to the economy of tropical countries and world timber trade. The conversion of tropical forest areas into agricultural land is discussed in Chapter IV. Since agricultural expansion into tropical forest areas can be often traced back to government-induced migration and infrastructure programs, the role of government policies and their impact on various segments of agricultural production in tropical forest areas will also be discussed in this chapter. Finally, Chapter V analyzes tropical deforestation due to large-scale industrial projects such as hydropower generation, mining and related industries.

Since this is first and foremost a fact-finding study, the possible effects of various policy measures, which can help to save the tropical forest ecosystem, will not be discussed in detail but rather briefly surveyed in the last chapter. The effectiveness and impact of various international and national policies will be subject to future research, for which this study may provide a valuable input.

II. Causes of Deforestation in Tropical Countries

1. Countries and Tropical Forest Areas Studied

The basic concept to delimit the tropical zones refers to the periodicity of the climate. Accordingly, tropical areas reveal on average higher daily than seasonal fluctuations of the temperature. Moreover, in tropical zones the number of day and night hours vary to a negligible extent across the year.

Following the classification of the Food and Agriculture Organization of the United Nations (FAO), forests are regarded as a vegetation type in which the dominant woody element is a tree with a height of more than seven meters. This study will not focus on all forest areas in this geographical zone but rather put an emphasis on those areas with tropical moist evergreen (or partly deciduous) forests (rain forests). Usually tropical moist evergreen forests occur at an altitude below 1300 m. However, for some countries even forests located at higher altitudes will be considered, such as the mountain rain forests in Indonesia and Central Africa as well as the highlands of the Amazonian rain forests reaching up to an altitude of 1800 m.

There are several reasons to confine this study on countries with tropical moist forests. First, the biological diversity and the release of carbondioxide resulting from deforestation as it was mentioned in Section I.1 is substantially higher in these types of forests than in tropical dry forests. Second, the tropical moist forests are much more sensitive ecosystems in the sense that the economic exploitation of these forest areas bear a high degree of irreversibility. As the soil in rain forest areas is predominantly of very low fertility, reforestation cannot be as successful as in boreal forests or tropical dry forests, once the clearing of forests has led to soil erosion. Due to the very limited regenerative capacity of moist tropical rain forests, reforested areas cannot be regarded as substitutes for primary moist tropical forests. For this reason this study will only cover natural closed forest formations neglecting all kinds of plantation forests monocultures, as far as the data allow for a separation. Natural forests comprise both primary and

secondary[1] forests. Even though primary and secondary forests may display quite different characteristics, a differentiation between these forest types is not possible. There are some countries where forests consist mainly of secondary forests. This will be indicated by a respective footnote in this study.

Because of a lack of accurate maps and empirical evidence for some countries tropical moist evergreen forests cannot be always distinguished from moist deciduous forests. This is especially the case in South-East Asian countries, where maps do not show the frontier between deciduous forests and moist forests. In the same vein, forest formations in the Latin American countries do not allow for a clear separation. Those cases in which a separation is not possible will be indicated by a respective footnote in the text.

Given this selection, this study will only cover countries with natural closed broadleaved forests of 1 million ha or more. According to the FAO, this category basically consists of all types of tree formations (except plantations) with predominance of broadleaved species, covering a high proportion of the ground and not having a continuous dense gross layer. Shrub formations, mixed forest-grassland areas (savannahs, cerrados), forests with predominance of coniferous species and young secondary forests which have not been cleared within the last 20-30 years (forest fallow) are excluded. This is to say, that there are still large ecological differences within this group, either in prevailing climatic conditions (evergreen, semi-deciduous or deciduous forests, i.e., wet, moist or dry forests) or in the degree of disturbance (primary and old secondary forests; the latter comprises forests that are in a reconstitution stage after intensive logging, forest fires or clearing by shifting cultivation). Whereas the first categorization has not been performed during the global FAO/United Nations Environment Programme (UNEP)-project, estimates for subcategories like "undisturbed forest", "logged-over forest" "intensively managed forest" and "unproductive forest" have been provided. Yet the delimitation of these subcategories raises some empirical problems [Lanly, 1982, p. 15]. For instance, it is difficult to distinguish between forests and forest fallow, especially if

[1] Secondary forests are natural regrown formations on previously cleared areas; young secondary forests are commonly termed forest fallow.

small-scale "mosaics" are dominating, or to separate degraded closed forest from open forest. In addition, it has to be emphasized, that the subcategory "undisturbed forest" by definition includes forests, which for the last time have been logged 60-80 years ago. These old secondary forests generally differ from untouched forests with respect to their ecological characteristics.

The selection of countries will change in the course of the study. Basically, data have been collected for 14 African countries (Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Nigeria, Central African Republic, Cameroon, Congo, Gabon, Equatorial Guinea, Zaire, Angola and Madagascar), 17 American countries (Mexico, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Guyana, Suriname, French Guiana, Ecuador, Peru, Brazil, Bolivia and Paraguay) and 12 Asian countries (India, Sri Lanka, Burma/Myanmar, Thailand, Kampuchea, Laos, Vietnam, Malaysia, Indonesia, Brunei, Papua New Guinea and the Philippines). The lack of empirical data does not allow for a treatment of all aspects listed in Section I. 2 for this broad set of countries. For this reason, some sections of the study will be restricted to Brazil, Indonesia and Cameroon. The forest coverage of these countries comprises almost half of all closed tropical forest formations in the world, while each country displays some of the typical characteristics of forest exploitation typical for the respective continent.

Summing up, deforestation of primary moist evergreen forests cannot be estimated, given the lack of data and conceptual problems of classification. Hence, the deforestation data used in this study include all tropical forests with a dominance of broadleaved species. Nevertheless, most of the countries listed above, especially Cameroon, Brazil and Indonesia, reveal a predominance of tropical moist forests, so that results derived from the deforestation data allow for conclusions concerning the tropical moist forests, which will be named tropical rain forests in this study.

2. Models Used to Quantify the Extent of Deforestation

In order to calculate the share of various economic sectors in the conversion of tropical forest areas, it is important to know the total extent

of deforestation. One of the major problems involved in quantifying the extent of deforestation is the definition of deforestation. Usually the term deforestation refers to the complete destruction of the forest cover. Following the FAO classification, deforestation implies a change of land use or depletion of crown cover to less than 10 percent [FAO, b]. Hence, changes within the forest class which severely affect the regenerative capacity of forests are termed forest degradation, even if the crown cover is reduced to less than 50 percent. As Section II.3 will show, this very narrow definition of deforestation is not well-suited to the analysis to be performed in this study.

Moreover, current estimations of deforestation in tropical countries are quite tentative in nature. There are several reasons for that:

- Before 1976 forest inventories have been compiled by using different concepts for the classification of forests. Depending on the concept, these forest inventories came up with different estimates of existing forest areas. An extensive forest inventory was performed by the FAO in 1979-1981 [Lanly, 1982]. This study is currently repeated for 1990. However, preliminary results will not be available before the end of 1991. For this reason, the deforestation rates that can be calculated by using the data processed in the 1990 inventory are not available for this study.
- Global forest inventories worked out, for example, by the FAO have been made irregularly. Hence, annual rates of deforestation are calculated by taking averages of 5-10 years. These averages may vary depending on the period considered.
- It is almost impossible to achieve a coherent picture of the state of tropical forests for one point in time. The reason is that the statistics of the particular countries may lag behind, while the methods of forest assessment are different across countries. Moreover, technical facilities of forest assessment have been improved substantially in the last decade, when remote sensing methods using satellite pictures were introduced. As a result, more recent studies, such as Lanly [1982] and Myers [1989] can be expected to be more reliable than older studies which have been mainly based on sample data and national statistics.
- Global forest inventories calculating forest coverage of all tropical countries for one year rely on trend extrapolations and sample data by using main-stream statistical techniques because country-specific data are not available for the same years. Hence, there are not only errors that can be attributed to the input data but also to the statistical models used.

As far as recent inventories of tropical forests are concerned, there are only two global forest inventories available. The first one is the FAO study by Lanly [1982]. This study provided an inventory of forest resources for 76 tropical countries for 1980. Deforestation rates for the 1976-1980 period were calculated by using at least two observations from this period. The resulting trend in deforestation was used to estimate the forest inventories for each of these countries at the end of 1980. Based on these data deforestation rates were calculated for the 1976-1985 period. Of course, these projections were built on a number of assumptions that had to be made concerning future developments in population increase, family size, migration, shifting cultivations, structure and level of agricultural production, logging activities, etc.

Table 1 shows the results of the 1980 estimates and the preliminary estimates of the 1990 assessment. While the forest areas reveal a high degree of convergence, there is a high discrepancy between the rates of deforestation for the 1976-1980 period and the preliminary results for the 1981-1990 period. This discrepancy is due to two factors. On the one hand, tropical deforestation has accelerated especially in West and Central Africa. By contrast, rates of deforestation in Latin America have only slightly increased. On the other hand, deforestation in some large Asian countries has been underestimated in the 1976-1980 data. Following the 1980 assessment, almost 60 percent of closed tropical forests were located in Latin America, which also accounted for almost 70 percent of undisturbed forests (Table 2). On the whole, the undisturbed forests comprise the majority of tropical forest areas, while logged forests are comparatively small.

The second global forest inventory was undertaken by Myers [1989]. Basically, Myers used the same methodology as the earlier FAO inventory. The classification of forest types in Myers's study is less detailed than in the FAO inventory. The 1989 inventory of Myers was calculated by using country studies on deforestation. Myers's results show that annual rates of deforestation in 26 countries and regions

Table 1 - Results of the 1980 and 1990 FAO/UNEP Tropical Forest Resources Assessment Projects

	1980 assessment(a)		1990 assessment(b)	
	forest area(c) 1980	average annual deforestation 1976-1980	forest area(c) 1990	average annual deforestation 1981-1990
	mil. ha	percent	mil. ha	percent
West and Central Africa (15 countries)	338	0.5	259(d)	0.9
Latin America (22 countries)	896	0.7	840(d)	0.9
Asia(e) (15 countries)	298	0.6	275(d)	1.2
Total	1,532	0.6	1,374	1.0

(a) Derived from the FAO/UNEP study, originally covering 76 countries. - (b) Preliminary results. - (c) Area of natural closed and open forest (excluding fallows). - (d) Changes (compared to the 1981 report) are probably due to a corrected delimitation between open forests and savannahs and upward corrections of forest fallow area. - (e) Papua New Guinea is not included.

Source: FAO [1991]; FAO/UNEP [1981].

Table 2 - Subcategories of Closed Tropical Forest, 1980 (mil. ha)

	West and Central Africa (15 countries)	Latin America (23 countries)	Asia and Oceania (16 countries)
Forest area (including fallow)	338 (426)	897 (1,066)	336 (409)
Closed broad-leaved forest	188	654	292
thereof:			
undisturbed	115	453	97
logged(a)	32	54	95
unproductive	42	147	100

(a) Managed forestry or exploitation.

Source: FAO/UNEP [1981].

amounting to 97.3 percent of total moist tropical forests was 1.8 percent, which is substantially higher than the FAO estimate.[1]

Table 3 shows the result of Myers 1989 assessment and the FAO 1980 assessment on the country level. The deforestation rates of Myers for 1980 go in harmony with the FAO assessment for 1981-1985. Nevertheless, there are some discrepancies between stock data of the FAO and those of Myers that are related to conceptual differences: First of all, Myers estimated the area of moist forest whenever possible and sometimes even primary forest only, whereas the FAO figures relate to total closed broadleaved forests. This may explain the discrepancy for all Latin American countries and for Madagascar. Second, Myers's figures obviously include open forests for some countries, for example, in Venezuela, Papua New Guinea and Thailand. Third, in some cases Myers gives estimates for what he calls "good quality forest" without relating this term to the FAO concepts, for example, in Congo and in India. On top of that, there is a substantial discrepancy between the FAO's deforestation data for the 1981-1985 period and the deforestation rates of Myers for 1989. On average, the latter are higher than the respective estimations of the FAO. This seems to confirm the preliminary results of the FAO 1990 assessment, which is not yet available on the country level.

The results of the FAO and Myers in Table 3 show that the bulk of tropical closed forests is located in Zaire, Brazil and Indonesia. Therefore, their absolute deforestation rates measured in sq km range among the highest in the world. In relative terms, however, deforestation is much higher in countries like Thailand, the Philippines, Nigeria, Ivory Coast, Madagascar and Vietnam, as can be shown by the percentage annual deforestation rates calculated from the Myers [1989] study. Relative rates are usually calculated by dividing the absolute rate of deforestation by the remaining forest area. For the latter countries relative deforestation rates range above 5 percent. Hence, these countries seem to use up their forests much faster than countries which have been at the center of interest in the debate about tropical deforestation, i.e., Brazil, Indonesia and Zaire.

[1] Percentage rates of deforestation are calculated by dividing annual deforestation by the stock of closed forests in 1980.

Table 3 - Tropical Moist Forests: Present Status and Deforestation in Selected Countries, 1976-1989

	Extent of closed forests		Average annual deforestation		
	FAO	Myers	Myers	FAO	Myers
	1980	1989	1976-1980	1981-1985	1980-1988
	1000 sq km				
Bolivia	440.10	70.0	0.75	0.87	1.5
Brazil	3562.80	2200.0	14.50	13.60	50.0
Colombia	464.00	278.5	4.60	8.20	6.5
Ecuador	142.30	76.0	2.20	3.40	3.0
Guyanas (French Guiana, Guyana and Suriname)	422.05	410.0	0.35	0.06	0.5
Mexico	265.70	166.0	6.10	4.70	7.0
Peru	693.10	515.0	2.90	2.60	3.5
Venezuela	318.70	350.0	1.10	1.25	1.5
Central America (excluding Caribbean States)	169.71	90.0	4.60	3.40	3.3
Cameroon	179.20	164.0	1.20	0.80	2.0
Congo	213.40	90.0	0.20	0.22	0.7
Gabon	205.00	200.0	0.20	0.15	0.6
Ivory Coast	44.58	16.0	3.80	2.90	2.5
Madagascar	103.00	24.0	2.00	1.50	2.0
Nigeria	59.50	28.0	3.10	3.00	4.0
Zaire	1056.50	1000.0	2.60	1.80	4.0
Burma	311.93	245.0	1.80	1.00	8.0
India	460.44	165.0	2.60	1.32	4.0
Indonesia	1135.75	860.0	6.60	6.00	12.0
Kampuchea	71.50	67.0	0.60	0.25	0.5
Laos	75.60	68.0	0.80	1.00	1.0
Malaysia	209.96	157.0	2.90	2.55	4.8
Papua New Guinea	337.10	360.0	0.70	0.22	3.5
Philippines	93.20	50.0	4.60	0.90	2.7
Thailand	81.35	74.0	3.40	2.44	6.0
Vietnam	74.00	60.0	1.80	0.60	3.5

Note: The FAO figures refer to closed broadleaved forest (excluding fallow areas); deforestation figures are extrapolations. Myers's figures refer to tropical moist forest (primary and secondary); his definition of deforestation includes severe cases of over-logging.

Source: FAO/UNEP [1981]; Molofsky et al. [1986]; Myers [1989].

In this study Myers's [1989] and Lanly's [1982] results will be used to quantify the share of various economic activities in deforestation. These data will be complemented by conversion rates, as they will be calculated in Section IV.1 of this study, World Bank estimations for Indonesia and rates of forest degradation, as they will be discussed in the next section.

3. Economic Sectors Involved in the Exploitation of Tropical Forest Areas

The tropical rain forest is an economic resource providing a multitude of products and input factors for a number of economic activities and industries. From the viewpoint of the respective tropical countries these resources should be exploited in order to enhance the development process, even if the exploitation of these resources incurs serious environmental problems in the long run. One of the most important forest resources is wood which can be extracted by either clearing, selective logging or sustainable forest management. Tropical timber is both an export product and an important input good for wood and construction industries in tropical countries.

Moreover, most tropical countries regard the land covered with tropical forest as an input factor for the expansion of agricultural production. Basically, there are two different subsectors within the agricultural sector using the land in tropical forest areas. On the one hand, there are shifting cultivations and small-scale holdings, which successively clear small forest areas in order to produce their own food and provide crops for regional markets. A part of these shifting cultivators can be regarded as belonging to the subsistence sector, as they are not even integrated in regional markets. Though in earlier times shifting cultivations were in line with a sustainable economic use of the tropical rain forests, the rising number of shifting cultivators since 1960 exceeds the carrying and regeneration capacity of tropical forests, thus contributing to their depletion. On the other hand, there are permanent and larger agricultural holdings as well as plantations producing food crops, export crops as well as livestock for the national markets. The establishment of these holdings usually requires the clearing of large

forest areas to obtain enough land eligible for extensive agricultural management.

Another major source of clearing in tropical forest areas is the industrial sector. Many countries in the tropical zone are endowed with a number of mineral resources attracting both extractive industries as well as establishments for further processing. In addition, tropical forest areas are usually well endowed with a sizeable hydropower potential facilitating the processing of minerals or the establishment of other industries with a high electricity intensity in production. Moreover, deforestation is caused by other related industries and infrastructure services that are linked to these extractive industries.

Finally, it has to be noted that beside shifting cultivations there are other traditional economic uses of tropical rain forests as they have been developed by the native peoples in tropical forest areas. Some of these activities are due to the subsistence sector such as hunting and collecting wild fruit and vegetables. However, some of these activites are integrated into regional or even international markets such as the collection of natural rubber or brazil-nuts or the production of rattan. These traditional activities use the tropical forest as a renewable resource in the sense that they do not cause deforestation but rather have an interest in the persistence of the prevailing ecological system. By contrast, the forestry sector, agriculture and industrial sectors use the forest as a non-renewable resource, thus causing the depletion of this economic source across time. For this reason, this study will rather focus on these sectors than on the traditional forms of rain forest exploitation.

One of the objectives of this study is to estimate the contribution of particular sectors to the conversion of tropical forest areas into other forms of economic use. In this respect, only few attempts have already been made. Table 4 gives an overview on earlier studies that have calculated the percentage contribution of various sectors or subsectors to worldwide deforestation.

The FAO study by Lanly [1982] has calculated the share of shifting cultivators by using estimates on population and migration in tropical forest areas as well as average land requirements of shifting cultivators. Taking structural data from 1980, land consumption by shifting cultivators was projected to amount to 35 percent of total deforestation in

Table 4 - Contribution of Economic Activities to the Worldwide Conversion of Tropical Forest Areas by Various Economic Sectors, 1980-1988 (percent)

	Lanly	EK	Bruenig(a)
	1981-1985	1981-1985	1980-1988
Forestry	.	10	10 (25)
Agriculture	.	90	.
Shifting cultivations and small-scale holdings	44	40	60 (50)
Permanent and large-scale agricultural holdings	.	50	.
Mining and related industries	.	0	.
Hydropower generation and related industries	.	0	30 (25)
Other industries	.	0	.

(a) Figures in parentheses include deforestation and degradation.

Source: Bruenig [1989]; EK [1990]; Lanly [1982]; own calculations.

Latin America in the 1981-1985 period. For Asia and Africa this share was considerably higher reaching 49 and 70 percent in the same period. These results point to the fact that differences between regions and between countries are quite substantial, thus calling for a country-specific analysis. On average, the contribution of shifting cultivators to worldwide deforestation was estimated at 44 percent, as Table 4 shows.

Based on the data set estimated by Lanly [1982], the report published by EK [1990, p. 191] provided a broader picture of sectoral contributions to tropical deforestation. According to this study, 90 percent of tropical deforestation can be attributed to the agricultural sector, while only 10 percent was due to forestry. It is interesting to note that this study regards the contribution of the industrial sector as negligible.

The low percentage shares of the forestry sector were confirmed by an earlier study by Bruenig [1989]. His estimates yield that 60 percent of deforestation were caused by shifting cultivators and small-scale agriculture. It is not possible to judge the reliability of this study because the author does not elaborate on data sources or estimation techniques.

Beside such problems of estimation, there is yet another conceptual shortcoming in all of these studies. The tropical forests provide not only one but a variety of input factors to various industries, namely land, mineral resources, wood, hydropower energy and other forest products. Depending on the economic activities and the particular tropical forest area these input factors can be provided simultaneously or successively. If such input factors are used by more than one economic sector at the same time, there is a joint use which makes it difficult to determine the sectoral shares in deforestation. There are several examples for that:

One of the preconditions for the establishment of industrial sites, livestock production, permanent holdings and plantations is the clearing of the particular forest area. Hence, these sectors use the tropical forest resource jointly with the forestry sector. Alternative use is only predominant when the clearing of forests is not profitable enough. In these cases the forest area has to be cleared by burning rather than by harvesting.

Moreover, there is strong empirical evidence for the successive use of tropical forests by selective loggers and other sectors especially shifting cultivators [Lanly, 1982; EK, 1990, p. 295]. The reason is that the forestry sector opens up primary forests for other uses by establishing an infrastructure that can be used by other sectors afterwards. Moreover, selective logging opens the forests for the exploration of mineral sources and hydropower potentials. It has been shown that in Costa Rica 90 percent of those forests that have been exploited by the forestry sector during the last 30 years have been cleared. In the same vein, more than half of the deforestation caused by small peasants or shifting cultivators in tropical Asia occurs in forests that have been under commercial logging [EK, 1990, p. 404].

Even within the shifting cultivation sector, there are joint products from the exploitation of tropical forests. In many cases, tropical forest areas are cleared by slash-and-burn methods, while some valuable logs

are sold on regional markets. This enables the shifting cultivator to finance costs of investment.

The joint use of tropical forest resources by various economic sectors incurs major empirical and conceptual problems. Following the concept of the FAO, selective logging does not lead to deforestation but rather causes degradation, even when the crown cover is reduced to less than 50 percent. Consequently, the successive activity, either agricultural production, mineral extraction or industries, that leads to a clearing of the forest (deforestation, i.e., reduction of crown cover to less than 10 percent), is identified as the only cause of deforestation. Hence, the share of the forest sector in total destructive exploitation of the rain forests is underestimated.

One solution to this problem is the inclusion of forest degradation as one form of destructive exploitation. In fact, the contribution of forestry in the destructive exploitation of the rain forests is much higher, if degradation is included. Table 4 reports the sectoral shares taking into account deforestation plus forest degradation by the forestry sector, as they have been estimated by Bruenig [1989]. The numbers in parentheses show that the contribution of the forestry sector increases from 10 to 25 percent, if degradation is included.

However, with the inclusion of forest degradation, the forestry sector's contribution to rain forest destruction is likely to be overestimated. In many cases wood harvesting in tropical forest areas is due to selective logging, which does not lead to an extensive clearing of the respective areas. Intensive logging leading to deforestation is only profitable when either a large share of standing timber is commercializable or when the tropical forest is to be converted to other economic uses. In the latter case the deforestation should be attributed to the sector using the land after clearing rather than the forestry sector. For instance, log harvesting on areas which are supposed to be flooded in the course of a dam construction project or converted into agricultural holdings should be attributed to the hydropower sector or agriculture rather than the forest sector.

In the same vein, the tropical forest used by other sectors is likely to be underestimated. This applies also to livestock production. For the case of Brazil, it has been reported that a fourth of the land for cattle ranching has been used by agricultural holdings before. The cattle

ranchers enhance this conversion into agricultural holdings because this reduces the costs of forest clearing [EK, 1990, p. 249].

Basically, the cause of deforestation should be attributed to those sectors that derive the highest value-added from the exploitation of tropical forest resources. However, this differentiation, which is used in economic theory to distinguish between main-products and by-products, is not possible. First, there are severe data problems, as far as the value-added of these sectors are concerned. Second, the value-added of particular joint products can be equal. Third, particular economic activities exploiting the tropical rain forest jointly use the same infrastructure, so that costs cannot be attributed to particular economic sectors or activities.

Hence, the determination of the main causes of deforestation is not possible. In order to avoid an underestimation of the role of the forestry sector, it will be attempted to take account of the extent of forest degradation caused by selective logging.

The identification of various economic sectors exploiting tropical forest resources will be done in two steps:

In the first step, the geographical delimitation of tropical forest areas has to be determined.[1] This will be done by using vegetational maps for tropical countries.[2] Thereafter, in the second step, economic activities are identified by using infrastructure maps and a wide range of sources revealing the geographical location of various economic activities,[1] i.e., mines, dams, crop areas etc. Depending on the sector, the set of countries that is subject to analysis might change. This is because of the lack of sectoral data in some tropical countries.

For the purpose of this study only deforestation caused by economic activities in the seventies and eighties will be considered. Basically, most economic activities in tropical countries must have caused deforestation, since many tropical countries were almost entirely covered with tropical forests at the beginning of this century. As the interest of this study centers on the recent dramatic increase of deforestation, deforestation by economic activities prior to 1970 will not be analyzed.

[1] As far as the forestry sector is concerned, there is no need for using map data because for most countries it can be assumed that wood production is due to closed tropical forest formations, while exceptions will be taken into account (Chapter III). Basically, the use of vegetational maps serve to identify mining activities and their related industries, dams, crop areas and pastures in tropical forest areas.

[2] If not indicated in the text, vegetational maps and infrastructure maps have been derived from Bundesanstalt für Bodenforschung or Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Bundesstelle für Außenhandelsinformation, Länderberichte (country reports) of the Statistisches Bundesamt, Michelin maps for West Africa, Kartographisches Institut Bertelsmann [1984], Garcia and Falcon [1986], Instituto Geográfico Militar [1950], Dut and Geib [1987], Djambatan Amsterdam Publishers and Cartographers [1964], Deutsch-Südamerikanische Bank [1967], Instituto Brasileiro de Geografía e Estatística (IBGE) [1959], National Atlas and Thematic Mapping Organization [1980], Fund for Assistance to Private Education [1975], Voss [1982], Rand McNally and Company [1969], J. Schmithüsen [1976], Institut de la Carte Internationale du Tapis Vegetal (ICITV) [1980], UNESCO/AETFAT [1980].

[1] Since vegetational maps usually lag behind, especially when they are published by government agencies, the extension of tropical forest areas is likely to be overestimated. For instance, plantations and mines might be identified in areas where tropical forests had already been severely depleted before these economic activities were established.

III. Tropical Forests as a Resource Base for the Forestry Sector and Related Industries

1. Production and Export of Tropical Hardwood

Customarily two types of forest are distinguished: the closed forest which has a closed tree canopy, and the open forest, where trees predominate but without constituting a full tree canopy. A third category (other wooded land) includes areas with forest regrowth following clearing for shifting cultivation, and shrubland. It is estimated that 1.2 billion ha of closed forest were in the tropical zone in 1980, 55 percent thereof in Latin America, 27 percent in Asia and Oceania and 18 percent in Africa [Lanly, 1982].

Since in most tropical countries basically all of these forests are logged, it is difficult to quantify the volume of wood produced in closed tropical forests. The estimates for wood removals in tropical countries provided in the FAO Yearbook Forest Products distinguish between coniferous wood (softwood) and broadleaved wood (hardwood). These categories are further disaggregated according to the final use, namely fuelwood, sawlogs, pulpwood and other roundwood (poles etc.). These estimates do not allow for a separation of wood removals from closed forest, open forest and shrubland or from natural forest and industrial plantation. In a first approximation one can use the figures for broadleaved logs and other broadleaved roundwood as estimates for wood removals from closed forests and those for pulpwood as estimate for wood removals from industrial plantations.[1] An assessment of fuelwood or charcoal production using roundwood from closed forest is less accurate. The bulk of fuelwood and charcoal consumed by private households is removed from open forests and shrubland, whereas only a minor part is collected in closed forests, especially in the follow-up of logging activities. Industrial consumption of wood for energetic use (for example, in mining areas) is assumed to be removed from industrial plantations and

[1] This simplification is justified on the grounds that commonly only fast-growing wood species are used for the production of wood pulp.

to some extent from natural closed forest areas. However, a separation along the final uses is not possible on a global level.[1]

According to the estimations of the FAO, the world production of roundwood (= total wood removals) reached about 3.4 billion cubic meters (m^3) in 1988, of which only 35 percent were produced in tropical countries (Table 5). The major part of this, namely 80 percent or 955 million m^3 was produced for energetic use, either directly as fuelwood or for the production of charcoal. Only 237 million m^3 of the wood removals in tropical countries were used as input for further manufacturing (= industrial roundwood), thereof 38 million m^3 coniferous wood which is mainly produced in Brazil, Mexico, Honduras, India and Indonesia, and 20 million m^3 broadleaved wood for pulp production. Large producers of pulpwood are Brazil, Mexico, Colombia, Ecuador and Congo.

Table 5 - Wood Production in Tropical Countries, 1988 (mil. m^3)

	World	Tropical countries			
		Total	Asia and Oceania	Latin America	Africa
Total removals	3,431	1,192	633	340	219
for energetic use	1,767	955	510	251	194
industrial roundwood	1,664	237	123	89	25
thereof:					
coniferous wood	1,146	38	3	35	0
non-coniferous pulpwood	135	20	3	16	1
non-coniferous woodlogs	284	146	100	31	15
other non-coniferous wood	98	32	17	6	9
Tropical hardwood(a)	-	178	117	37	24

(a) Non-coniferous industrial roundwood excluding pulpwood.

Source: FAO [a, 1988].

[1] For country estimates of fuelwood and charcoal production, see Table A1.

The remaining 178 million m^3 of non-coniferous logs and other non-coniferous roundwood will be referred to in the following as "tropical hardwood" (Table 5).

Logging is only the first step in wood processing, which provides the input for subsequent steps. Therefore, the relevance of tropical forests as a resource base has to be judged by their contribution to all levels of processing. In the following, a detailed analysis of production and trade of unprocessed tropical hardwood, of sawnwood, wood-based panels and secondary wood products in tropical countries is performed for the eighties. A separate analysis of product groups is necessary, because there are large differences among countries in the degree of domestic processing and in the product specialization. Production of wood pulp, paper and paperboard is described only briefly, because the supply of tropical hardwood for these industries is negligible.

As Table 5 shows, total production of tropical hardwood is estimated as 178 million m^3 in 1988, two-thirds of which were produced in Asia and Oceania, 20 percent in Latin America and 14 percent in Africa. Table 6 shows that only a relative small share of tropical hardwood was exported without further processing, namely about 26 million m^3 (or 15 percent of production). This accounted for 21 percent of world trade in industrial roundwood.

Major exporters of industrial roundwood in the eighties were Malaysia and Papua New Guinea, both of which accounted for 80 percent of world trade in unprocessed tropical hardwood; both countries exported more than 50 percent of their roundwood production (Table A2). Indonesia had played a major role in roundwood trade until the beginning of the eighties, when it covered 40 percent of world exports of rough tropical hardwood. By then, the government had begun to foster the development of timber-processing industries absorbing a high share of domestic timber production. African countries accounted for 14 percent of exports of tropical hardwood, which corresponds to their share in closed tropical forest area. Major exporters are Gabon, Liberia, Cameroon and Ivory Coast. The export share was relatively high in Gabon and Liberia with 75 and 60 percent of production, whereas Cameroon and Ivory Coast have forced their export share down (to 20 and 16 percent) in favour of domestic processing. Latin America played virtually no role in the world trade of roundwood with total exports as

Table 6 - Production and Exports of Industrial Roundwood, 1980 and 1988

	Production		Exports		Exports/production	
	1980	1988	1980	1988	1980	1988
	mil. m^3				percent	
World	1450.9	1663.7	114.2	123.1	7.9	7.4
Tropical countries(a)	153.8	177.7	38.1	26.2	24.7	14.7
Asia and Oceania(a)	96.3	116.5	32.0	22.4	33.2	19.2
Latin America(a)	33.6	37.1	0.1	0.1	0.3	0.3
Africa(a)	23.9	24.1	6.0	3.7	25.1	15.4
	percent					
Tropical countries/world	10.6	10.7	33.4	21.3		

(a) Tropical hardwood only.

Source: Table A2.

low as 0.08 million m^3 in 1988. Only in Guyana, exports accounted for more than 10 percent of domestic production.

In absolute numbers, the production and export of tropical hardwood has been reduced in countries like the Central African Republic, Ivory Coast, Bolivia, Peru and the Philippines. This can be attributed to the growing scarcity of wood in these countries. The major producers, however, have dramatically increased their production, including Malaysia, Indonesia, Burma, Paraguay and Cameroon.

Major importers in the eighties are Japan and other East-Asian countries (Taiwan, South Korea), which absorbed 119 million m^3 (45 percent) and 8.5 million m^3 (35 percent) of all unprocessed tropical roundwood exports (Table A5). European countries, which almost exclusively import their tropical roundwood from African countries accounted for about 10 percent of world imports of tropical hardwood. Tropical countries imported 5 percent of tropical roundwood exports while all of these countries with the exception of Thailand were net exporters.

Sawnwood (planed or unplaned lumber) is the most important group of primary tropical wood products in terms of production and trade which have experienced high growth rates in the last decade. This development can be attributed to the promotion of domestic processing, especially in Indonesia, Ivory Coast and Ghana. Total production of non-coniferous sawnwood in tropical countries is estimated as 54.3 million m^3 in 1988, almost two-thirds of which were produced in Asia and Oceania, 25 percent in Latin America and 10 percent in Africa (Table 7). This is to say, that about 60 percent of total tropical hardwood production were processed in saw mills located in tropical countries. This lends support to the hypothesis that the forestry sector has developed strong forward linkages in tropical countries. About 9.4 million m^3 (or 17 percent of production) were exported, which accounted for 9 percent of world trade of sawnwood.

Major exporters in the eighties were Malaysia and Indonesia, the Philippines and Ivory Coast (Table A3). These countries exported more than 50 percent of their sawnwood production. Malaysia and Indonesia

Table 7 - Production and Exports of Sawnwood, 1980 and 1988

	Production		Exports		Exports/production	
	1980	1988	1980	1988	1980	1988
	mil. m^3				percent	
World	415.0	506.4	79.6	99.6	17.7	19.7
Tropical countries(a)	41.6	54.3	7.0	9.4	16.8	17.3
Asia and Oceania(a)	24.4	34.3	5.3	7.8	21.7	22.7
Latin America(a)	12.5	14.6	1.1	0.8	8.8	5.5
Africa(a)	4.7	5.4	0.6	0.8	12.8	15.2
	percent					
Tropical countries/world	10.0	10.7	8.8	9.4		

(a) Tropical hardwood only.

Source: Table A3.

accounted for 75 percent of the world trade in tropical sawnwood. By comparison, Brazil's sawnwood production is relatively inward oriented, since only 5 percent of production was exported. In the same vein, India, Nigeria, Ecuador and Thailand belong to the group of major producers with a large domestic market and low export shares.

Major importers in the eighties were the East-Asian countries (especially Taiwan and South Korea) with 3.7 million m^3 (40 percent) in total exports of tropical sawnwood (Table A6). According to the FAO production statistics, Sri Lanka, Bangladesh and even Thailand were net importers. Moreover, Singapore plays a large role as an importer, though the bulk of tropical wood products is reexported. European countries absorbed about 2.8 million m^3 (30 percent) of world exports, distributed equally among all three tropical regions. Japan added another 1.3 million m^3 (15 percent). Moreover, some Central American states (Mexico, Venezuela) have become important importers in this region.

Another major category also belonging to the primary wood products, comprises all kinds of wood-based panels, which is a very heterogenous aggregate. It encompasses veneer sheets, plywood and similar boards, as well as particleboards and fibreboards. With the exception of Brazil, which serves almost exclusively the domestic market, there is virtually no production of particleboard in tropical countries. This is due to high investment needs for production facilities as well as due to climatic conditions in tropical countries which do in general not allow for consumption of particleboard. The same applies to the production of fibreboard. In addition, there is probably a high input share of coniferous wood and other ligneous fibres (for example, rice straw or bagasse) in the production of both particleboard and fibreboard.

By contrast, tropical countries accounted for a large share of world production of veneer sheets (31 percent compared to Europe with 40 percent) and of plywood (21 percent compared to North America with 40 percent) in 1988, as Table A7 shows. The total production of wood-based panels in tropical countries, which amounted to 15 million m^3 in 1988 against 8 million m^3 in 1980, had dramatically increased in the last decade. This was the result of huge investments in plywood mills, especially in Indonesia, but also in Malaysia and Ivory Coast. African countries are more specialized on veneer sheets, whereas Asian countries are almost exclusively producing plywood and similar boards. Neverthe-

Table 8 - Production and Exports of Wood-based Panels, 1980 and 1988

	Production		Exports		Exports/production	
	1980	1988	1980	1988	1980	1988
	mil. m^3				percent	
World	101.1	125.9	16.3	25.5	16.1	20.2
Tropical countries	7.8	15.0	2.1	8.9	27.4	60.0
Asia and Oceania	3.3	9.4	1.3	7.9	39.6	84.3
Latin America	3.7	4.7	0.6	0.8	14.8	16.7
Africa	0.8	1.0	0.3	0.2	32.7	24.6
	percent					
Tropical countries/world	7.7	11.9	13.1	34.9		

Source: Table A4.

less, Malaysia is the largest exporter of unprocessed tropical veneer sheets, followed by Congo and Paraguay.

Following Table 8, about 9 million m^3 of wood-based panels or 60 percent of domestic production were exported in 1988. This accounted for 35 percent of world trade.[1] As Table A4 shows, Indonesia has become a major exporter, which has reached an export share of 95 percent in production. Moreover, Malaysia and the Philippines are major exporters. With the exception of Congo which recorded an export share of 62 percent in 1988, African countries exported only a minor share of their production. Brazil, as another major exporter, produces mainly fibreboard and plywood for international markets.

Major importers of wood-based panels (including exports from non-tropical East-Asian countries) in the 1980's were Japan and other Asian countries accounting for 2.4 million m^3 (25 percent) and 2.9 million m^3 (30 percent) of tropical exports (Table A7). This group of

[1] Non-tropical East-Asian countries are producing panels almost exclusively from tropical hardwood. Their exports account for 1.9 million m^3 (or 7 percent of world trade).

importers absorbed more than half of the production of Asian tropical countries. Europe and North America (1.9 and 1.5 million m^3 or 20 and 15 percent of tropical exports) received their imports from any of the three regions. Some of the tropical countries were net importers of wood-based panels, especially Mexico, Venezuela and Nigeria.

To some extent, wood-based panels are produced in non-tropical countries, while the necessary inputs of roundwood are imported from tropical countries. For example, this applies to plywood produced in Taiwan and South Korea. Hence, import figures of industrialized countries should be corrected upwards for these "indirect imports" of processed tropical hardwood.

Apart from these primary wood products, there is a number of secondary products, for example, pallets, boxes, carpentry, furniture and other joinery, that are not included in the FAO statistics. Data on production and consumption cannot be provided on a global level. However, tropical countries seem to play a minor role in terms of their share in world trade in this product category. According to international trade statistics [UN, 1990b], in 1988 tropical countries came up for about 5 percent of the value of world exports of secondary wood products. These exports are mainly due to Mexico, Brazil and some Asian countries which have become exporters of furniture and parts thereof as well as of some other wood products. In 1988, more than 50 percent is imported by the USA, another 25 percent by European countries.

Furthermore, woodpulp accounted for about 20 percent of the global roundwood consumption in the eighties. Woodpulp is used as an input in the production of paper and paperboard and of particleboard. Only a few tropical countries, for example, Brazil, Mexico, India and the Philippines, recorded a sizeable production of woodpulp. However, the bulk of the fibre material does not stem from natural forests but from timber plantations, while a minor share is wood waste from saw mills.[1]

Summing up, tropical countries are still large producers and exporters of wood in the rough and have become major suppliers of sawn-

[1] In addition, domestic production of paper and paperboard in tropical countries relies on other fibre pulp (for example, from bagasse or rice straw) and, with the exception of Brazil and the Philippines, on wood pulp imports. Only few of these countries are able to meet their domestic demand.

wood and plywood. Because of the development of wood processing, the percentage share of exports in roundwood production was declining, while export shares for processed products revealed a dramatic increase. Thus, tropical hardwood seems to be a resource basis for industrialization of tropical countries.

2. Consumption of Tropical Hardwood in Tropical and in Industrialized Countries

Following Table 9, the total production of tropical hardwood amounted to 177.7 million m^3 in 1988. Thereof, about 32 million m^3 was used as poles, as pitprops or for other construction purposes in tropical countries, whereas about 145 million m^3 was produced in the form of sawlogs and veneer logs for further processing. After deduction of log exports to non-tropical countries, 121 million m^3 remained for the manufacturing of sawnwood and wood-based panels.[1] Thereof 46 million m^3 of sawnwood and 6.4 million m^3 of panels were consumed in tropical countries, a part of which was probably used as input for secondary wood products. An estimated 55-60 million m^3 of wood waste from saw mills and panel production were consumed domestically, probably for energetic use, either in households or in manufacturing.

This leads to the conclusion, that in the eighties roughly two-thirds of the total tropical hardwood production were consumed in tropical countries, whereas one-third was exported to non-tropical countries.[2] The share of domestic consumption was significantly lower in tropical Asia, but exceeds 95 percent in Latin America (Tables A5-A7).

Exports to non-tropical countries amounted to 24.7 million m^3 roundwood, 8.4 million m^3 sawnwood, 8.5 million m^3 wood-based panels and an unknown quantity of secondary wood products. The major share of these exports was consumed in Japan and other Asian countries.

[1] The production of particleboard and fibreboard may receive additional inputs of coniferous wood or other fibre material.

[2] As stated in the first section of this chapter, these estimates do *not* include wood production for energetic use and for the production of woodpulp. An inclusion of these quantities would result in a significantly higher share of domestic consumption.

Table 9 - Production and Consumption of Tropical Hardwood in Tropical Countries, 1988 (mil. m^3)

	Production	Exports	Imports	Apparent consumption(a)
Industrial roundwood(b)	177.7	26.2	1.5	153.0
thereof:				
poles etc.	32.1	0	0	32.1
logs	145.6	26.2	1.5	120.9
Sawnwood(b)	54.3	9.4	1.0	45.9
Veneer sheets	1.6	0.6	0.0	1.1
Plywood	10.6	8.0	0.2	2.8
Particleboard	1.6	0.1	0.1	1.6
Fibreboard	1.1	0.2	0.1	0.9
Total industrial roundwood and wood products (roundwood equivalents)		65(c)	5(c)	118(d)

(a) Calculated as production plus imports minus exports. - (b) Tropical hardwood only. - (c) Own estimations based on the Standard General Conversion Factors of the UN-ECE. For example, one m^3 broadleaved sawnwood accordingly is equivalent to 1.82 m^3 roundwood. - (d) Calculated as domestic roundwood production minus net exports of roundwood and wood wood products (in roundwood equivalents).

Source: FAO [a, 1988].

European countries consumed roughly 10 percent of roundwood exports and 25 percent of exports of wood products from tropical countries (Tables A5-A7). In the following, a more detailed analysis of the structure of wood imports and wood consumption of the EC is performed for the year 1988.

According to production estimates of FAO and official trade data for the EC, the share of tropical hardwood in total consumption of wood and wood products in the EC was below 10 percent in 1988 (Table 10). Wood consumption is traditionally dominated by coniferous wood species, so that tropical hardwood accounted for only 3 percent of roundwood and 6

Table 10 - Production and Consumption of Wood and Wood Products in the European Community, 1988 (mil. m^3)

	Production	Exports	Imports(a)		Apparent consumption(b)
			total	thereof: tropical hardwood	
Industrial roundwood	106.7	15.6	18.1	3.5	109.2
thereof:					
pulpwood	42.9	10.1	8.7	-	41.5
coniferous logs	42.0	2.1	2.1	-	42.0
non-coniferous logs	17.2	3.0	6.7	3.5	21.0
other	4.6	0.4	0.6	-	4.8
Sawnwood	32.4	5.1	31.7	3.3	59.0
thereof:					
non-coniferous	9.2	2.0	6.4	3.3	13.6
Veneer Sheets	1.2	0.3	0.7	0.2	1.6
Plywood	1.7	0.8	3.9	1.2	4.8
Particleboard	16.3	3.7	5.6	-	18.2
Fibreboard	1.7	0.6	1.4	0.1	2.5
Total industrial roundwood and wood products (roundwood equivalents)		32(c)	92(c)	13(c)	167(d)

(a) Calculated as production plus imports minus exports. - (b) Weight (from EUROSTAT) converted to volume with UN-ECE conversion factors. - (c) Own estimations based on the Standard General Conversion Factors of the UN-ECE. For example, one m^3 broadleaved sawnwood accordingly is equivalent to 1.82 m^3 roundwood. - (d) Calculated as domestic and roundwood production minus net exports of roundwood and wood products (in roundwood equivalents).

Source: FAO [a, 1988]; Statistical Office of the European Communities (EUROSTAT) [1990].

percent of sawnwood consumption in the EC. Particleboard was by far the largest component of the consumption of wood based panels (about

two-thirds) since the seventies, when this product had been introduced. However, within the subcategories veneer sheets and plywood, tropical hardwood accounted for 10 and 24 percent of the consumption respectively. In absolute numbers, tropical hardwood was to a large extent imported in the rough or as sawnwood.

The low share of tropical hardwood in world consumption and in EC consumption of wood lends support to the hypothesis that tropical timber plays a very limited role on world markets. However, the underlying assumption is that tropical and non-tropical wood are homogenous products in the sense that the former can be replaced by the latter. This leads to considerations about the interchangeability of tropical hardwood and other wood species in consumption. The characteristics of tropical hardwood (hardness, moisture resistance and in some cases appealing surface structure) are not unique, so that other than tropical wood, even coniferous species, reconstituted wood products or metal and plastic products can be used instead.

In the following, the EC consumption structure of three products - logwood, sawnwood and plywood - will be analyzed for the period 1970-1988 with respect to the hypothesis that timber from temperate regions has been regarded as a substitute for tropical timber. In general, one should expect a change in the consumption structure in favour of tropical wood, if the price relation of boreal wood to tropical wood rises.[1]

Concerning the structure of *logwood* consumption, an analysis of the price relations between non-coniferous logs from Africa and non-coniferous logs from West Europe shows that prices for tropical logs have in the long run risen faster than prices for European logs. Though, the share of tropical logs was rather stable at 23-25 percent of EC non-coniferous log consumption or 10-11 percent of total EC log consumption until 1980.[2] This gives an argument for the hypothesis that consumption

[1] Prices for the respective product categories have been derived from export unit values (i.e., average value of one m^3 of exported wood) for all wood exporting countries (Table A12). Data on the consumption structure are provided by a recent study of UN-ECE and FAO on the sawnwood and sawlogs sector (Table A13).

[2] At this time, consumption of tropical logs was reduced significantly, in absolute as well as in relative terms. This can be attributed to supply

of tropical logs does not react to price changes in the short run. This is to say that logs from alternative suppliers are not regarded as substitutes.

The opposite holds true for the European *sawnwood* market. The price relation between non-coniferous sawnwood from South East Asia and non-coniferous sawnwood from West Europe was rather stable over the whole period.[1] The share of tropical sawnwood in consumption had increased significantly in the mid-seventies and thereafter remained stable around 5 percent of total EC consumption of sawnwood. In absolute terms, consumption of tropical sawnwood had almost doubled in the mid-seventies, whereas consumption of other non-coniferous sawnwood declined since 1980 and consumption of coniferous sawnwood remained fairly stable in the long run. This could be an indicator for a high reagibility of sawnwood consumers to changes in price relations and a strong competition between the three market segments. This competition had become fierce when new suppliers from tropical countries entered the European sawnwood market in 1980.

Concerning the structure of *plywood* consumption, probably a similar argument applies. As for sawnwood, the price relation between East Asian and West European plywood remained fairly stable since the mid-seventies. In addition, the price relation between West European and North American plywood remained stable in the same period with the exception of the beginning of the eighties (this is probably due to exchange rate movements of the US dollar). This is an indicator for strong competition between the major suppliers and for a high degree of product homogeneity.

This preliminary evidence seems to suggest that substitutability between tropical hardwood and boreal wood is fairly high, except in the case of veneer. This lends support to the hypothesis that tropical hardwood plays a minor role in world timber markets, as its share in world consumption is relatively low.

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shortages caused by the shifting from log exports to veneer exports in tropical countries.

[1] This holds true for the entire period except for 1979, when prices of non-coniferous sawnwood from West Europe in terms of prices for Asian sawnwood had declined sharply.

3. The Role of Wood Harvesting and Processing for Economic Development in Tropical Countries

In this section, the role of tropical wood resources for the economic development of tropical countries will be assessed in terms of the forestry sector's and the wood industry's contribution to GDP, export performance and employment.

Basically, the forestry sector comprises both logging activities, i.e., the removal of wood and the selling of wood in a rough form, the collection of non-wood forest products, i.e., crops like nuts, fruit, natural rubber etc., and hunting. Usually, employment data for the forestry sector do not separate wood harvesting from other activities.[1] Moreover, the forestry sector is usually not separated from the agricultural sector in FAO statistics and in national statistical sources of most of the developing countries. Therefore, a reliable analysis of employment effect and income generation due to the tropical forestry sector cannot be provided, especially because people in tropical forest areas engage in a variety of economic activities that cannot be attributed to one sector (see also Section IV.2). Table 15 in Section IV.1 shows, to what extent the combined agriculture and forestry sector contributes to GDP and employment.

The share of timber exports in total export revenues indicates, to what extent the forestry sector contributes to the export performance and thus to the import capacity of tropical countries.[2] As Table A9 shows, there are only some small and less industrialized countries, where the export shares of tropical hardwood in total exports exceeded 15 percent in the eighties, namely Burma, Laos, Equatorial Guinea and Liberia. Some other countries had recorded high export shares in the past, for example, French Guiana, Central African Republic, Ivory Coast and Indonesia. However, these countries have expanded their domestic processing facilities, so that raw material exports could be reduced. The group of major exporters of tropical roundwood ranged in the 5-10 percent interval. All Latin American countries and the remaining countries

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[1] In addition, crops from natural forest areas cannot easily be distinguished from plantation crops.

[2] Official figures are probably underestimating export revenues due to smuggling (for example, in Paraguay and Burma).

in Africa and Asia, the Philippines included, earned less than 5 percent of total export revenues from roundwood exports. Nevertheless, the forestry sector in these countries may play an important role for employment and income, because it supplies inputs for the domestic manufacturing sector.

The wood *manufacturing sector* comprises all activities of primary and secondary wood processing and the production of wood pulp and products of paper and paperboard. As mentioned above, the latter is not relevant for the following analysis. National statistical sources, especially census results for a large number of tropical countries, give a more comprehensive insight into the relevance of wood resources for employment and income. The typical problem concerning the analysis of this data is that sample results do not cover small-scale firms and activities in the informal sector. This leads to an underestimation of the significance of labour-intensive, traditional sectors such as handicrafts and construction.

As Tables A10 and A11 show, an analysis of employment shares and value-added shares[1] in manufacturing allows for a grouping into three country groups: the first group encompasses Cameroon, Ghana, Ivory Coast, Malaysia and Papua New Guinea, where the wood industries exhibited about 20 percent of total employment and about 10 percent of the value-added of the entire manufacturing sector around 1980. Madagascar, Colombia, Cuba, Peru, Sri Lanka and Thailand form the second group, where the employment share was around 5 percent and the value-added share around 3 percent. Most of the other countries range in between: the data for Nigeria, Brazil, Ecuador, Mexico, Indonesia and the Philippines show employment shares around 10 percent and value-added shares around 5 percent of total manufacturing. Since all the census results date around 1980, an outlook to the second half of the eighties could be of some interest. As mentioned above, some countries have enforced their wood processing activities, for example, Indonesia, Ecuador, Brazil, Cameroon and Ivory Coast. Thus, it seems very likely that employment has increased in these countries. By contrast, some countries

[1] Basically, the census results reported in Tables A10 and A11 point to the fact that the wood processing sector is a highly labour-intensive industry. For this reason, the value-added per employee ranges around 50 percent of the average value for the manufacturing sector.

were forced to reduce their wood processing activities because of increasing wood scarcity, for example, Thailand, the Philippines, Colombia, Bolivia. In these countries the significance of wood manufacturing obviously has been reduced, compared to 1980.

If both export revenues from wood and wood products are related to total export earnings, little changes in the above introduced ranking, as it can be obtained from Table A9. Only Indonesia changes position and reached about 15 percent of its export earnings in 1988 from the wood sector, 10 percent of which are due to plywood. There are only a few countries in which exports of wood and wood products exceeded 20 percent in 1988, namely Equatorial Guinea, Liberia and Burma. However, there are a number of countries where these product categories contributed more than 10 percent to total export earnings.

The empirical evidence given above seems to suggest that the forestry sector and wood processing industries provided a significant input to national development in terms of employment and exports in some South-East Asian and African countries. However, for a number of countries this is not likely to be a long-run phenomenon. The forestry sector in tropical countries used the forests as a non-renewable resource, thus causing the depletion of tropical forests. Hence, except for countries with relatively large forest areas, for example, Brazil, Indonesia, Zaire, the Guyanas, this resource will have only a temporary impact on economic development given the current speed of depletion.

4. Contribution of Forestry to the Destruction of the Rain Forest Ecosystem

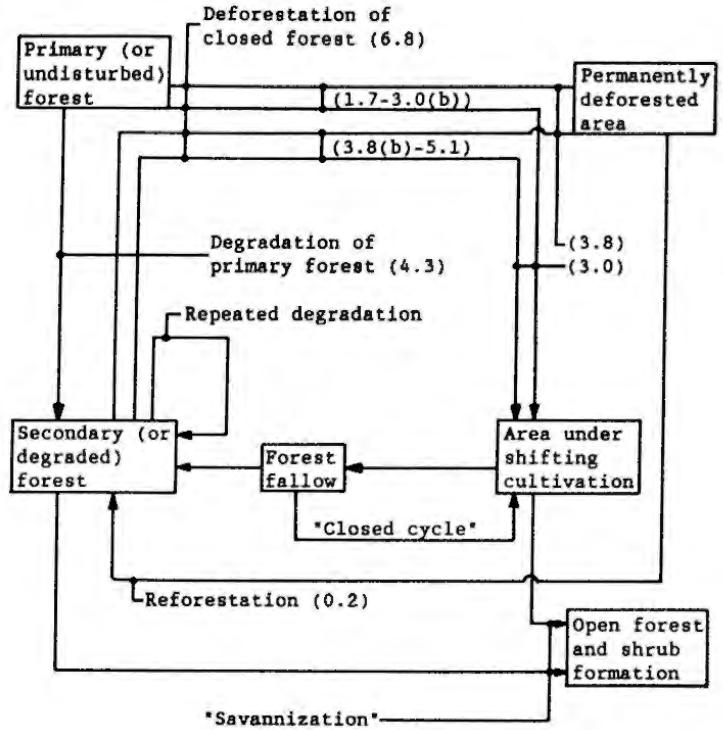
In most cases, the depletion of wood resources in tropical forest areas does not lead to deforestation in the FAO terminology, since the wood is predominantly harvested in the form of selective logging [Buschbacher, 1990], thereby leaving at least 10 percent of the crown cover behind. However, the forest degradation caused by selective loggers incurs serious environmental damages, that are also reflected in economic costs for the country. First, a seriously degraded forest loses its regenerative capacity, so that in the future harvesting of wood and other forest products is not possible. Second, conversion of closed forests to more

or less open forest formations enhances soil erosion and reduces both the genetic diversity and the capacity to absorb carbon [EK, 1990, pp. 293-296, 512]. Hence, environmental damages cannot be simply attributed to deforestation but also to degradation. Third, the forestry sector undertakes investments in a network of roads and paths, thus opening up the forest for other economic activities, especially small-scale farming, shifting cultivations and mineral exploitation.

The interrelation of different types of forest formations and stages of human interference is illustrated in Figure 1, which is based on the FAO classification. Deforestation takes place either in primary forests or in previously degraded secondary forests. Following the FAO data given in Tables 2 and 11, deforestation rates in secondary forests are substantially higher than in primary forests. The shares of shifting cultivation and permanent deforestation for agriculture and pasture are given as rough estimates, but without disaggregating for the subcategories undisturbed and degraded forests. By comparing the area estimates for degradation of primary and deforestation of secondary forests it becomes evident, that almost any newly degraded area sooner or later has been deforested completely. Alternatively, the process of forest degradation through repeated timber harvesting or too short fallow periods in the shifting cultivation cycle may have led to "savannization", i.e., predominance of open forest and grassland formations due to losses in soil quality and disturbed forest regeneration potential. Natural regeneration of forest fallows, that left the closed cycle of shifting cultivation, or artificial reforestation may have compensated part of the losses of secondary closed forests, but on a global level this has been negligible in quantitative terms.

Although it is conceded [Lanly, 1982, p. 88], that intensive logging activities especially in Ivory Coast, Central America or Insular South-East Asia came close to deforestation, no percentage shares relating to the role of forestry in deforestation have been provided by the FAO/UNEP project. But the rates of degradation of previously undisturbed forest, which have been estimated instead, may serve as a basis for own calculations. For the present report these estimations have been recalculated for 1980 and 1988 by dividing the volume of tropical hardwood production (Table A2) by country specific per hectare volumes of commercializable tree species in undisturbed forests (VAC), given by the

Figure 1 - Deforestation and Forest Degradation in Tropical Countries (mil. ha) (a)



(a) Figures refer to closed broadleaved forest in 39 countries; see Table 11. - (b) These figures result, if unproductive forest is completely regarded as undisturbed. Forest formations are classified as unproductive, if industrial timber harvesting is not possible due to difficult terrain conditions, low quality of wood or legal status of a reservation.

Source: FAO/UNEP [1981]; Lanly [1982].

FAO. The resulting area gives an indication of the size of tropical forest areas that were under production in the respective year. As Table 11 shows, our estimations of degradation in virgin broadleaved forests are on average twice as large as the estimations given by the FAO. There are mainly three possible explanations for that. First, in some countries, i.e., Brazil, Nigeria and India, a sizeable share of production was

Table 11 - Deforestation and Forest Degradation in Virgin Forests in Tropical Countries, 1980-1988 (1000 ha)

	Deforestation of closed broadleaved forests			Degradation of virgin broadleaved forests			Modification(a) of virgin forests
	FAO	thereof: virgin forest	thereof: unproductive forest	FAO	own estimation, based on industrial roundwood removals		FAO
	1981-1985 average				1980	1988	1981-1985 average
Cameroon(b)	80	3	2	197	366	448	200
Central African Republic	5	1	-	21	35	26	22
Congo	22	2	0	37	96	120	39
Gabon	15	0	-	135	135	122	135
Equatorial Guinea	3	0	0	8	1	6	8
Ivory Coast(b)	290	0	0	40	215	135	40
Guinea	36	15	6	5	80	91	20
Liberia	46	0	2	60	107	144	60
Madagascar	150	35	5	20	34	34	55
Nigeria(b,c)	300	0	20	52	210	225	52
Zaire	180	155	0	33	145	181	188
Bolivia(b)	87	25	12	77	36	12	102
Brazil(c,d)	1360	-	330	1330	4080	4770	1330
Colombia	820	605	120	81	128	121	686
Costa Rica(b)	65	16	17	30	51	46	46
Ecuador	340	163	95	81	135	180	244
French Guiana	1	1	0	11	27	27	12
Guatemala(b)	72	18	27	15	16	11	33
Guyana	3	0	1	10	10	10	10
Honduras(b)	48	9	13	4	3	4	13
Mexico	470	215	225	31	28	36	246
Nicaragua	105	60	-	40	54	54	100
Panama	36	13	9	8	11	11	21
Paraguay(b)	190	0	20	58	241	311	58
Peru	260	40	155	156	168	92	196
Suriname	3	1	1	18	22	12	19
Venezuela(b)	125	30	50	10	58	67	40
Brunei	5	5	0	1	2	3	6
Burma	102	62	-	174	197	266	236
India(c)	132	10	12	-	469	583	10
Indonesia(c,d)	600	0	0	880	1107	1442	880
Kampuchea	25	20	2	-	28	28	20
Laos	100	60	15	25	18	26	85
Malaysia	255	35	20	375	412	518	410
Papua New Guinea	22	12	8	47	44	81	59
Philippines(b)	90	0	0	80	91	62	80
Sri Lanka(b)	58	-	13	-	11	11	-
Thailand	244	107	57	100	189	193	207
Vietnam(b)	60	20	20	46	95	104	66
Africa	1128	211	35	608	1424	1532	819
Latin America	3985	1196	1073	1960	5068	5764	3156
Asia and Oceania	1693	331	137	1728	2663	3317	2059
Total	6805	1738	1245	4296	9155	10613	6034

(a) Degradation plus deforestation. - (b) Large share of exploited forests. - (c) Large areas of industrial hardwood plantations. - (d) Deforestation figures of virgin forests implausible.

Source: FAO/UNEP [1981].

harvested in forest plantations. These plantations are artificially reforested areas, which are not included in the area estimations of closed forest (for example, Table 1). Thus, plantation timber should be subtracted from total tropical hardwood. It is not possible, however, to separate wood harvested on plantations from wood removed from virgin forests. Second, the per hectare volumes calculated by the FAO refer to the average productivity of all forest areas including those which have not yet entered production because per hectare volumes are lower than those in forests under production [Andrae, 1984]. Since logging gradually expands into forests with lower per hectare volumes, our estimations of degradation are too high only for the past. Third, the FAO has underestimated deforestation and forest degradation, since data have been derived through the extrapolation of data from the late seventies. Hence, the increase of timber harvesting in the 1980s, which must have caused substantial degradation, is probably not reflected in the FAO data.

Nevertheless, our estimation of forest degradation should be interpreted as maximum rates, while the FAO data reflect probably the minimum degradation of tropical forests. However, both our estimation and the FAO estimation show that degradation was substantial compared to annual average deforestation. Following our estimations, the annual degradation has increased during the eighties. However, in some countries, for example, Gabon, Ivory Coast, Colombia, Costa Rica, Peru and the Philippines, degradation has decreased which can be attributed mainly to the recession of logging activities.

As mentioned above, there are several reasons to consider degradation as a contribution to the destruction of the rain forest ecosystem. Hence, it can be justified that a quantitative analysis of the sectoral share in destruction should include both deforestation and degradation. Basically, there are two ways to combine deforestation and degradation in one composite indicator.

The first method is based on the assumption that the ecological and economic damages caused by logging and other economic activities can be measured in terms of the reduction of biomass. Following EK [1990], it can be assumed that selective logging withdraws on average 28 percent of the biomass from utilized areas. Accordingly, the area of forest degradation enters the calculation of sectoral shares in deforestation with a weight factor of 0.28, while direct deforestation of virgin forests gets

Table 12 - Total and Commercializable Per Hectare Volumes of Tropical Hardwood in Closed Forests, Average 1975/80

	VOB(a)			VAC(b)	Degree of degradation through logging(c)	BRI(d)	FMI(d)
	virgin forest	exploited forest	unproductive forest	virgin forest			
	m^3/ha					percent	
Cameroon	280	270	100	6	0.05	10.0	98.5
Central African Republic	320	290	50	15	0.10	29.9	95.5
Congo	345(e)	223(e)	100(e)	8(e)	0.05	10.4	96.1
Gabon	250	220	200	10	0.10	45.0	100.0
Equatorial Guinea	220(e)	170(e)	193(e)	25	0.25	44.0	100.0
Ivory Coast	270	230	200	25	0.20	2.9	100.0
Guinea	180	165	90	7	0.10	1.2	25.0
Liberia	170	155	125	8	0.10	12.0	100.0
Madagascar	147(e)	100(e)	106	24(e)	0.35	5.4	36.4
Nigeria	205	160	120	35	0.35	7.2	100.0
Zaire	250	220	130	15	0.15	2.2	17.6
Bolivia	129(e)	64(e)	52(e)	12(e)	0.20	20.8	75.5
Brazil	156(e)	162(e)	83(e)	5(e)	0.10	6.4	100.0
Colombia	129(e)	90(e)	64(e)	19(e)	0.30	3.2	11.8
Costa Rica	175	125	50	25	0.30	16.4	65.2
Ecuador	124(e)	82(e)	67(e)	15(e)	0.25	6.8	33.2
French Guiana	290	270	200	7	0.05	35.5	95.6
Guatemala	140	120	75	10	0.15	3.7	45.5
Guyana	210	170	100	20	0.20	50.6	100.0
Honduras	140	120	80	10	0.15	1.4	30.8
Mexico	85(e)	65(e)	46(e)	13(e)	0.30	2.6	12.6
Nicaragua	135	115	70	10	0.15	5.7	40.0
Panama	180	130	80	30	0.35	9.0	38.1
Paraguay	80(e)	60(e)	35(e)	10	0.25	9.6	100.0
Peru	195(e)	144(e)	124(e)	12(e)	0.15	9.3	79.6
Suriname	210	180	100	15	0.15	56.0	97.3
Venezuela	154	134(e)	80	11	0.15	1.5	25.0
Brunei	301(e)	146(e)	117(e)	75	0.50	9.1	16.7
Burma	180(e)	133(e)	90	15(e)	0.20	24.1	73.7
Indonesia	265(e)	101(e)	176(e)	27(e)	0.20	44.0	100.0
Kampuchea	230	200	70	20	0.20	16.8	58.3
Laos	220	-	100	12	0.10	3.0	29.4
Malaysia	291(e)	178(e)	140(e)	69(e)	0.50	51.6	91.5
Papua New Guinea	130	70	130	30	0.50	50.7	79.7
Philippines	305	165	81(e)	90	0.60	49.2	100.0
Sri Lanka	200	60	20	60	0.60	30.8	100.0
Thailand	80	-	80	25	0.60	25.6	48.3
Vietnam	220	170	120	30	0.30	21.3	69.7
Africa	260(e)	213(e)	124(e)	14(e)	0.10	6.5	74.2
Latin America	158(e)	121(e)	84(e)	9(e)	0.10	6.8	62.1
Asia and Oceania	217(e)	113(e)	132(e)	31(e)	0.30	31.9	83.9
Total	185(e)	133(e)	106(e)	13(e)	0.15	10.4	71.2

(a) Standing VOB (total). - (b) VAC of actually commercializable timber. - (c) Calculated as 2 x VAC (virgin)/VOB (virgin). - (d) For the definition, see text p. 43. - (e) Weighted average of regional values.

Source: FAO/UNEP [1981]; own calculations.

a factor of 1.0, since 100 percent of the biomass is withdrawn at once. Moreover, deforestation of previously exploited forests gets a weight below 1. For the present report the respective weight factors have been calculated on country level, based on the estimated per hectare volumes from FAO/UNEP [1981] (Table 12). Some forests are logged over several times, leading to repeated degradation (Figure 1). Thus, the factor must refer to the maximum possible reduction of biomass through logging. In addition, clearing for forest paths, damage of remaining trees and wastage of logged timber has been taken into account by doubling the respective VAC figure. This measure will be referred to as the indicator of biomass reduction (BRI).

The second method is based on the assumption, that even a partial degradation of a given area should be valued like a total deforestation; this is the same as using a factor of 1.0 for degradation in the first method. A reason for this extreme assumption may be seen in the hypothesis, that the ecological quality of tropical forests is seriously affected even by selective logging although the natural recreation potential is not completely destroyed. Furthermore, it is assumed that all further degradation or deforestation can be traced back to the initial logging activities which provided the necessary infrastructure for further economic activities. In order to avoid double counting of repeatedly degraded areas as well as deforestation on previously degraded areas, only deforestation and degradation of primary forests, proxied by "undisturbed forests", will be considered. The resulting measure will be referred to as the forest modification indicator (FMI).

Using the FAO degradation data in Table 11, a calculation of BRI and FMI measures yields the following results (Table 12): According to the BRI, logging activities come up for about 10 percent of the global deforestation of tropical forests. The respective shares on country level vary largely, reaching about 50 percent for the whole of insular South-East Asia, Gabon, Equatorial Guinea and the Guyanas. BRI is below 10 percent for almost any other Latin American country (except Bolivia and Costa Rica) and for many African countries, even for the Ivory Coast. The calculation of the FMI measure leads to the result that logging activities are causing about 70 percent of the global "modification" [Lanly, 1982, p. 61] of previously undisturbed forests. For insular South-East Asia, the Guyanas and for most of the African countries

(with the major exception of Zaire), FMI ranges above 90 percent. This is to say, that virtually any deforested area in these countries has previously been degraded by logging activities. It has to be noted, however, that the degree of degradation through logging, i.e., the potential share of trees felled, differs across these countries (Table 12), varying between 0.05 and 0.10 in Central Africa and 0.60 in South-East Asia. Hence, a FMI of 90 in Asia corresponds to higher environmental damage than the same value in Africa. Furthermore, FMI is relative small (below 50 percent) for all Central American countries, Colombia, Venezuela and for Thailand. In these countries, primary forests are disturbed in the majority by non-forestry activities.

5. Impact of Forest Legislation and Other Policy Measures

In this section the impact of policy measures on the utilization of tropical forest resources by the forestry sector will be analyzed. Since the forestry sector jointly uses forest areas with other sectors of the economy, forestry policies cannot be strictly confined to logging activities but have to consider other complementary or competing forms of land use, i.e., shifting cultivations, permanent agriculture, mining etc. From this it will become clear, that a bundle of coordinated measures is necessary to receive the maximum social benefit from national forest resources.

Although forest areas in tropical countries are to a large extent publicly owned, timber harvesting is in general done by private enterprises, because the public sector lacks a sufficiently developed forest administration and the financial funds for necessary investments in infrastructure and machinery. In a broader sense, policy measures related to the forestry sector include the legal order of forest and land utilization as well as economic incentives and disincentives for forestry and agriculture in any form, for example, taxes, tariffs or specific obligations.

These measures are in general directed to the potential productive uses of the forest areas, either timber harvesting or deforestation for agriculture, pasture or wood plantations. The declaration of forest reservations until recently has only been of minor interest in most of the tropical countries. Until 1980, only 3.3 percent of all tropical closed

Table 13 - Forest Reservations in Tropical Countries, 1980

	Closed broadleaved forest		Reservation/ total
	total	reservation	
	mil. ha		percent
West and Central Africa	188	8	4.1
Latin America	654	14	2.1
Asia and Oceania	292	16	5.5
Total	1134	38	3.3

Source: FAO/UNEP [1981].

forest areas had been given the status of a reservation (Table 13). However, given the poor forest administration in many tropical countries, the necessary supervision of reservations is almost impossible. This is only another indication for the low priority given to forest protection.

The main reason for that is, that the value of protected (or at least less intensively used) forest areas in terms of sustained quality of soil, water and air has not yet entered the economic calculus. This ignorance is probably due to the seeming abundance of tropical forests, which still cover large parts of the land area in many countries. Moreover, economic agents engaging in logging have been given little incentives to preserve the ecological benefits of rain forest ecosystems.

The most important regulation of the forestry sector consists of individual forest utilization contracts (concessions) for private enterprises, which are granted for fees [F. Schmithüsen, 1976]. Basic elements of these contracts are minimum cutting requirements (stem diameter), a maximum harvesting volume for the concession area and standards for the roads to be constructed by the enterprise. Many governments urge the private concessionaries to construct durable roads that can be integrated into the national road system after wood harvesting has been finalized. In some countries foreign firms are not allowed to apply for concessions. Since many domestic concessionaries lack the know-how and the capital to engage in wood harvesting themselves, they transfer short-run forest use allowances to other domestic

and foreign concessionaries, thus giving an incentive for more damaging wood harvesting. The contract period rarely exceeds ten years and quite many contracts run for only one or two years. Due to insufficient control through the authorities, these regulations, which aim on sustaining the natural regeneration potential of the forest, are frequently dismissed. This is the case especially when the contract period is relatively short which gives no incentives for larger investment in infrastructure, for careful, low-waste logging activities and reforestation. More recently, further obligations have been added, for example, minimum degrees of local processing, export bans on unprocessed roundwood or requirements for reforestation of exploited areas. These regulations can give incentives for private investment in wood manufacturing industries, if other economic conditions in the respective country, for example, tax system, access to bank credits and guaranteed property rights, are favourable. Anyway, controlling any of these contractual obligations is still a major problem.

The bases of the fees, which are charged for concessions, vary widely between countries [Gray, 1983]. In some countries there are still fees existing, which are based on the concession area (for example, in most West African countries) or on standing timber volumes (for example, in the Philippines), but they are relative unimportant compared to other charges. Nevertheless, this gives obviously an incentive for maximum timber harvesting or even clear cutting, because selective logging provides smaller revenues due to high fixed costs for the road system. An optimal fee system is based on fees charging only the volume of the trees felled, while differences in the commercial values of species should be taken into account. In addition, concessions should be granted in a competitive bidding process with previously announced minimum offers. This makes sure that the country receives the maximum revenues. It is reported that in some countries the allocation of concessions is affected by corruption and political patronage. Such concessions involve a high degree of political and commercial risk, so that the concessionaries have no incentive for long-term sustainable forest management.

The above mentioned regulations and the system of forestry charges are to be viewed in close connection with the national trade policy measures. Basically, there are three instruments which have been used frequently in developing countries to protect the national wood manufacturing industry and to attract foreign investors: export taxes or bans for unprocessed wood, tariffs on imports of wood manufactures and subsidies for domestic lumber exports. All three policies aim at the protection of the domestic wood processing industry against foreign competition. Especially, barriers for exports of unprocessed wood are meant to reserve domestic wood resources for local wood processing industry. Given such export regulation, unprocessed wood is provided to these industries at lower prices than the world market price.

The cumulated effect of all trade policy instruments is commonly measured with the indicator "effective rate of protection" (ERP), which includes both government-induced price distortions of input and output goods.[1] The ERP is calculated as the percentage change of value-added in one industry compared to a (hypothetical) free trade regime. A sectoral ERP, that lies above the average rate of the manufacturing sector, has to be interpreted as a disincentive for exports and an incentive for foreign investment in this sector (and vice versa), because the profit margin on the domestic market is higher than on foreign markets. In Table 14, this indicator is listed for wood and paper industries of selected tropical countries. The figures show, that distortions are high in all countries, but there is obviously no common pattern. Brazil, as one example, obviously protects its lumber, panels and furniture industry against foreign competitors, whereas domestic supply prices for wood pulp are below world market prices, so that trade protection for the pulp industry is not necessary. Thailand protects only its furniture industry, whereas the Philippines protect only the basic wood manufacturing through a differential tax on unprocessed timber exports. Indonesia's negative effective rate contrasting with a positive nominal rate for the panels industry probably indicates subsidies on panels exports outweighed by relative high domestic wood prices. Except Thailand, all countries are protecting their domestic paper manufacturing while unprocessed paper can be imported more liberally.

Although the large reduction of transport costs through processing[2] gives all forest-rich countries a comparative advantage for local wood

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[1] For a definition of the effective protection measure as it is used above, see Amelung and Sell [1991].

[2] Weight and volume of wood products are much lower than the roundwood equivalent necessary to produce them.

Table 14 - Effective Protection of Forestry and Wood Processing in Tropical Countries, 1978, 1980 and 1985 (a)

	Indonesia	Philippines	Thailand	Malaysia	Brazil
	1980			1978	1985
Logging	.	-21 (-19)	.	.	.
Wood manufacturing	.	.	.	.	35 (23)
Lumber		50 (0)		-1 (0)	60
Panels	-20 (19)	28 (-1)	20 (13)	42 (20)	(33)
Joinery		7 (2)		28 (20)	-2
Other wood products	45 (14)	8 (0)	52 (30)	21 (20)	(8)
Furniture	12 (15)	17 (7)	124 (52)	28 (20)	64 (52)
Pulp, paper and products	.	.	.	.	42 (14)
					pulp paper
Pulp and paper	12 (12)	34 (32)	37 (31)	18 (15)	-42 48 (-25) (13)
Paper products	73 (55)	51 (39)	27 (29)	49 (20)	95 (46)
Total manufacturing(b)	33	36	49	34	29

(a) Figures given in parentheses refer to nominal rates of implicit protection. Effective rates of protection have been calculated by using the Corden [1971] formula and rates of implicit protection. - (b) Averages refer to the manufacturing sector.

Sources: Amelung, Sell [1991]; Findlay, Garnaut [1986].

processing, many developing countries create additional incentives through trade policy measures. This has been justified with two arguments: First, industrial countries are accused to protect their own manufacturing industries through taxes on imports of wood manufactures from tropical countries, which is a barrier to their exports. In fact, there are still tariffs on wood products charging mainly plywood imports from developing countries in Asia and Latin America.[1] Second, it was claimed that a newly emerging industry needs a certain period to reach the same efficiency (in terms of labour skills or technical standards) as the established industries in more developed countries. Therefore, not only trade protection, but also a number of subsidies have been provided, for example, in Ghana, Ivory Coast and Brazil [see Repetto, Gillis, 1988, and the country studies therein].

These industrialization incentives may be regarded as successful in terms of employment and income creation, as was already shown in Section III.3. Moreover, many countries were relatively successful in attracting foreign investors. In the first place, this is true for Indonesia, but also for West Africa, where more than two-thirds of the processing capacity is due to foreign direct investment [Contreras, 1987]. Nevertheless, some disadvantages of this promotion policy became already obvious: First, processing is still inefficient in terms of raw material input, especially wood. The comparative wastage of wood in domestic manufacturing in tropical countries can probably be attributed to low labour skills and the lack of further processing of wood waste. This leads to a higher depletion of national wood resources which should also be abandoned for ecological reasons. Second, in some countries excess capacities have been built up as a consequence of the high policy-induced private rentability.

A simple lifting of all distortions and governmental regulations is, however, not a solution to the problem. Tropical forests produce a variety of ecological services (for example, sink for CO_2, production of non-wood forest products, preservation of soil quality), which can be regarded as economic goods, even though these goods cannot be sold on markets rewarding the production of these goods. In order to maintain these ecological services, a minimum of governmental regulation is needed to make sure that ecological functions enter the economic calculus. This

[1] Import tariffs on plywood are 8 percent in the USA, 10 percent in the EC and 17-20 percent in Japan [Bourke, 1988, p. 122].

could be done either in the form of contractual obligations for concessionairs or in the form of a "resources-depletion tax" levied on logging activities as well as on deforestation. The revenues of such a tax could be invested in reforestation projects or in the promotion of sustainable forms of tropical agriculture, if this receives higher priority for national development. Concession fees and taxes on unprocessed timber exports may be regarded as a substitute, but in the past, the respective revenues have not been invested in such projects.

In many cases agriculture is competing for forest areas, which presently are under utilization of forestry. Therefore, any incentive for the agricultural sector to extend its area translates into an incentive for deforestation. As a consequence, an isolated solution for the forestry sector is not realistic, given the weakness of forest administration. Any proposal for the forest resources has to include a component for shifting cultivation, i.e., uncontrolled deforestation, and policy instruments for the agricultural sector. The experience with different regulations and policy measures shows, that a coordination of instruments within the forestry industry and between forestry, wood manufacturing, agriculture and environmental policy is crucial. Elements of such a coordinated forest policy should include long-term concessions, a resources-depletion tax or an equivalent fee, a less distorted trade regime and incentives for sustained yield agriculture or agroforestry.

These considerations, however, should not be regarded as final policy conclusions, but as a starting point for more detailed country studies. Ecological conditions and economic activities in tropical forest areas are too different across tropical countries. Nevertheless, it can be concluded that an effective policy framework cannot be confined to forestry policies but has to be suited to all economic sectors involved. Moreover, such a framework should include both domestic policy measures in tropical countries as well as multilateral and bilateral programs supporting these policies.

IV. Conversion of Tropical Forest Areas into Agricultural Land

1. Agricultural Production for Markets outside the Tropical Forest Areas

Following earlier studies on the sources of deforestation, the agricultural sector is one of the main sources of deforestation. Despite the environmental damage associated with deforestation, one should not forget that for most tropical countries the agricultural sector is one of the key sectors of the economy, while land is one of the major input factors to this sector.

Table 15 yields the contribution of the agricultural sector to the national economy in tropical countries in terms of contribution to the GDP, share in total employment and export shares. In most of these countries, the agricultural sector contributes more than a fourth to the GDP of the respective tropical country. Only in some Latin American countries (Brazil, Mexico, Panama and Venezuela) this share ranks below 10 percent.

Generally, the employment shares given in the second column of the table are substantially higher than the percentage contribution to GDP. The reason is that agriculture is highly labour-intensive, thus absorbing the bulk of employment in many tropical countries. Especially in African countries agriculture accounts for more than half of the employment. Only in Suriname and Venezuela, the agricultural sector accounts for less than 20 percent of total employment.

Agricultural exports account for a high share of export earnings in tropical countries. Even in Brazil, which is highly industrialized compared to other tropical countries, more than one-fourth of total exports are due to the agricultural sector. There are a number of countries (Costa Rica, Guatemala, Honduras, Nicaragua, Paraguay, Ghana, Ivory Coast, Madagascar, Rwanda), where more than half of the export earnings have been produced in the agricultural sector. By contrast, export shares are comparatively low in oil-exporting countries (Colombia, Mexico, Venezuela, Congo, Gabon, Nigeria, Indonesia) or in countries with sizeable endowments of other mineral resources (Bolivia, Peru, Guinea, Zaire, Papua New Guinea).

Table 15 - Contribution of the Agriculture Sector to GDP, Exports and Employment in Selected Tropical Countries, 1987-1988 (percent)

	Agriculture/ GDP(a)	Agricultural employment/ total employment(b)	Agricultural exports/total exports(c)
	1988		1987-1988
Bolivia	24	43	10
Brazil	9	26	31
Colombia	19	29	45
Costa Rica	18	25	63
Dominican Republic	23	38	50
Ecuador	15	32	32
Guatemala	26	52	77
Guyana	24	23	38
Honduras	25	56	75
Mexico	9	31	7
Nicaragua	29	40	86
Panama	11	26	46
Paraguay	30	47	86
Peru	10	36	20
Suriname	11	17	17
Venezuela	6	12	0
Angola	36	71	2
Cameroon	26	63	45
Central African Republic	44	65	35
Congo	15	60	2
Gabon	11	69	1
Ghana	49	51	48
Guinea	30	76	5
Ivory Coast	44	58	73
Liberia	36	71	27
Madagascar	41	78	70
Nigeria	34	65	4
Rwanda	38	92	95
Sierra Leone	46	64	15
Zaire	31	67	18
Bangladesh	46	70	12
Burma	58	48	30
India	32	67	18
Indonesia	24	50	15
Malaysia	23	34	21
Papua New Guinea	34	69	26
Philippines	23	48	20
Sri Lanka	26	52	40
Thailand	17	66	35

(a) These shares have been derived from national accounts data and include forestry and fishing. - (b) Employment shares have been proxied by the share of economically active agricultural population in total economically active population. - (c) Agricultural exports comprise all food and agricultural raw materials (SITC categories 0, 1, 2 and 4 excluding 232, 266, 267, 27 and 28) except fish (03), beverages (11), lumber (24) and pulp (25).

Source: FAO [c, 1988]; UNCTAD [1991]; World Bank [1990a; 1991]; own calculations.

However, even in these countries the agricultural sector absorbs the bulk of the labour force.

As a result of the high level of population growth, land reserves in many developing countries have been declining [Scholz, 1988]. The growing scarcity of agricultural land has caused an expansion of agricultural land into tropical forest areas. Farmers and ranchers convert tropical forests into marginal agricultural land, even though the soil quality in tropical rain forest areas ranks below that in non-forest areas.

As already mentioned in Section II.3, there are different segments of agriculture contributing to the conversion of tropical forests into agricultural land. On the one hand, there are the small-scale non-permanent agricultural holdings comprising mainly shifting cultivators, a large part of them being settlers that have immigrated into tropical forest areas. These shifting cultivators partly belong to the subsistence sector or are integrated into local and regional markets (Section IV.3).

Beside the shifting cultivations sector, tropical deforestation is caused by permanent or sedentary agriculture. The respective producers are usually integrated into national or international markets. Basically, these market-oriented producers encompass both large plantations and small holdings. For instance, in Sawarak, where 76 percent of total area are covered with tropical rain forest, more than 95 percent of the productive agricultural land is cultivated by smallholders, while only 1 percent is due to large estates and plantations [Schätzl, Piening, 1988]. Moreover, small holdings of less than 100 ha constitute the majority of producers in the East Amazon region. Even though these producers cultivate only a fifth of the agricultural land, four-fifth of rural employment and regional food production is due to these small holdings. For this reason, the deforestation caused by this segment of agriculture cannot be attributed to large-scale holdings, monocultures or large-scale livestock production. [1]

A recent study of the present authors compiles the range of agricultural products harvested on converted tropical forest areas. The information was derived by evaluating a substantial set of map data show-

[1] Basically monocultures, plantations and large-scale livestock projects are more damaging than small-scale production and agroforestry because the former require the entire clearing of land.

ing the geographical location of main crop areas and grazing land by their respective agricultural product [Amelung, Diehl, 1991, pp. 177-183].

This evaluation has shown that the production of export crops like coffee, tobacco, oil palms, cocoa, nuts and pineapples is predominant in many tropical countries irrespective of the continent. The loss of forest land due to the establishment of crop areas varies substantially across products. While the production of some crops like groundnuts, cotton, large-scale livestock production or food crops like maize and rice require the clearing of large forest areas, some other products are harvested on areas that have to be surrounded by tropical forest areas. This applies especially to export crops that are harvested from trees and shrubs, like cocoa and oil palms. Since these plants cannot stand the declining of ground water, as it is caused by excessive deforestation, there are certain limits to deforestation [Repetto, 1989].

Apart from that, there are agricultural products that are confined to certain regions. For instance, the production of cattle is concentrated in Central and South America. In Central American countries ranching on converted tropical forest areas has a long tradition reaching back to the end of the last century. Both in Central America and in Paraguay the production of cattle is export-oriented [Browder, 1988]. By contrast, the expansion of cattle ranches into tropical forest areas in Brazil and Colombia is a relatively new phenomenon. In the Amazon region cattle ranching can be traced back to the sixties [Fearnside, 1986a]. In Brazil, most of the production is supplied to the domestic market, because ranching did not turn out to be a profitable business in the Amazonian rain forest, even though production was extensive and until recently heavily subsidized by the government [Bojö et al., 1990, pp. 147-150]. Beside cattle ranching, the production of sugar cane is predominant in Central America. The production of coca is predominant in remote tropical forest areas of Peru and Colombia. Especially in Peru, the conversion of tropical forests into coca cultivations became an important segment of agriculture, which recorded an employment of 250,000 and annual exports of US$ 1.2 billion or roughly 50 percent of the country's export earnings. Until 1990, approximately 2,000 sq km of rain forest were converted into coca plantations.[1]

[1] Data have been estimated by the USDA as reported in the Frankfurter Allgemeine Zeitung, No. 133, June 12, 1991.

In Africa, the expansion of the agricultural sector into tropical forest areas is mainly due to export crops like coffee, cocoa, pineapples and peanuts. Especially in Cameroon and Ivory Coast the doubling of the hectarage of the coffee plantations in the 1960-1980 period has contributed to the conversion of forest areas into agricultural land [Sommer et al., 1990, p. 213]. Because of locational factors, epecially the Nagana disease, livestock production is of less importance in the tropical moist forest areas of Africa.

Tree crop development seems to be more concentrated in Asian forest areas. It is estimated that in the outer islands of Indonesia estate crop plantations led to the conversion of 400 sq km p.a. at the beginning of the eighties. Due to the financial constraints faced by the government of Indonesia, this rate may have slowed down to 200 sq km since 1986 [Pearce et al., 1990, p. 103].

Since data on the structure of production in tropical forest areas are not available, it is impossible to assess, to what extent particular agricultural products have contributed to the conversion of tropical forests into agricultural land. However, Table 16 shows to what extent different segments of agricultural production have contributed to the conversion of tropical forest areas into other economic uses. This table has been calculated by evaluating data on land uses as they have been derived from the FAO Production Yearbooks. Basically, the FAO distinguishes between five kinds of land use:

- arable land
- land under permanent crops
- permanent meadows and pastures
- forest and woodland
- other land.

Arable land is defined as land under temporary crops, while double-cropped areas are counted only once. Furthermore, this category includes temporary meadows for mowing or pastures and land which lies temporarily fallow. Land under shifting cultivations is generally not included in this category unless shifting cultivators obtain legal claims and are officially acknowledged as farmers.

The land under permanent crops refers to areas cultivated with crops occupying the land for long periods and not to be replanted after each harvest, for example, cocoa, coffee, rubber, fruit trees etc. How-

Table 16 - Conversion of Tropical Forest into Various Forms of Land Use in Selected Countries, 1971-1988 (sq km) (a)

	1971-1980					
	Decline of forest area	Conversion into				Other land uses
		arable land	permanent crop area	permanent pastures	total agri-cultural land	
		(1)	(2)	(3)	(1)+(2)+(3)	
Bolivia(b)	20000	11000	470	0	11470	8530
		(55.0)	(2.4)	(0.0)	(57.4)	(42.6)
Brazil(b)	189100	77870	17440	93790	189100	0
		(41.2)	(9.2)	(49.6)	(100.0)	(0.0)
Colombia	30000	1530	50	27200	28780	1220
		(5.1)	(0.2)	(90.7)	(96.0)	(4.0)
Costa Rica	7400	0	150	6470	6620	780
		(0.0)	(2.0)	(87.4)	(89.4)	(10.6)
Dominican Republic	200	175	25	0	200	0
		(87.5)	(12.5)	(0.0)	(100.0)	(0.0)
Ecuador	23000	150	900	17160	18210	4790
		(0.7)	(3.9)	(74.6)	(79.2)	(20.8)
Guatemala	5500	1700	250	1000	2950	2550
		(30.9)	(4.5)	(18.2)	(53.6)	(46.4)
Guyana	18210	1160	0	2210	3370	14840
		(6.4)	(0.0)	(12.1)	(18.5)	(81.5)
Honduras	8830	1800	370	2100	4270	4500
		(20.4)	(4.2)	(23.8)	(48.4)	(51.6)
Mexico	59600	13120	800	0	13920	45680
		(22.0)	(1.3)	(0.0)	(23.4)	(76.6)
Nicaragua	11120	350	60	5300	5710	5410
		(3.1)	(0.5)	(47.7)	(51.3)	(48.7)
Panama	3000	30	90	1000	1120	1880
		(1.0)	(3.0)	(33.3)	(37.3)	(62.7)
Paraguay(c)	11000	3870	10	7120	11000	0
		(35.2)	(0.1)	(64.7)	(100.0)	(0.0)
Peru	25000	4700	150	0	4850	20150
		(18.8)	(0.6)	(0.0)	(19.4)	(80.6)
Surinam	500	100	10	80	190	310
		(20.0)	(2.0)	(16.0)	(38.0)	(62.0)
Venezuela	29000	2410	120	7700	10230	18770
		(8.3)	(0.4)	(26.6)	(35.3)	(64.7)
Latin America(d)	441460	120095	21095	168480	309670	131790
		(27.2)	(4.8)	(38.2)	(70.1)	(29.9)
Angola(c)	8800	400	0	0	400	8400
		(4.5)	(0.0)	(0.0)	(4.5)	(95.5)
Cameroon	10900	3800	4620	0	8420	2480
		(34.9)	(42.4)	(0.0)	(77.2)	(22.8)
Central African Republic(c)	950	875	75	0	950	0
		(92.1)	(7.9)	(0.0)	(100.0)	(0.0)

Table 16 continued

	1971-1980					
	Decline of forest area	Conversion into				Other land uses
		arable land	permanent crop area	permanent pastures	total agri-cultural land	
		(1)	(2)	(3)	(1)+(2)+(3)	
Congo	2300	110	20	0	130	2170
		(4.8)	(0.9)	(0.0)	(5.7)	(94.3)
Ghana(c)	7000	970	890	0	1860	5140
		(13.9)	(12.7)	(0.0)	(26.6)	(73.4)
Guinea(c)	8600	200	10	0	210	8390
		(2.3)	(0.1)	(0.0)	(2.5)	(97.5)
Ivory Coast(b)	59100	2500	700	0	3200	55900
		(4.2)	(1.2)	(0.0)	(5.4)	(94.6)
Madagascar	15700	4500	1800	0	6300	9400
		(28.7)	(11.5)	(0.0)	(40.2)	(59.8)
Nigeria(b)	30000	4300	550	2000	6850	23150
		(14.3)	(1.8)	(6.7)	(22.8)	(77.2)
Rwanda(b)	300	190	66	0	256	44
		(63.3)	(22.0)	(0.0)	(85.3)	(14.7)
Sierra Leone(b)	270	264	6	0	270	0
		(97.8)	(2.2)	(0.0)	(100.0)	(0.0)
Zaire(b)	32500	2560	700	0	3260	29240
		(7.8)	(2.2)	(0.0)	(10.0)	(90.0)
Africa(d)	176420	20669	9437	2000	32106	144314
		(11.7)	(5.4)	(1.1)	(18.2)	(81.8)
Bangladesh	540	200	300	0	500	40
		(37.0)	(55.6)	(0.0)	(92.6)	(7.4)
Indonesia	51800	13000	2200	0	15200	36600
		(25.1)	(4.2)	(0.0)	(29.3)	(70.7)
Laos(b)	10000	300	80	0	380	9620
		(3.0)	(0.8)	(0.0)	(3.8)	(96.2)
Malaysia	24000	800	3000	10	3810	20190
		(3.3)	(12.5)	(0.0)	(15.8)	(84.2)
Papua New Guinea	2000	40	170	60	270	1730
		(2.0)	(8.5)	(3.0)	(13.5)	(86.5)
Philippines	20430	0	9000	1970	10970	9460
		(0.0)	(44.1)	(9.6)	(53.7)	(46.3)
Sri Lanka	600	220	0	0	220	380
		(56.7)	(0.0)	(0.0)	(36.7)	(63.3)
Thailand(b)	60000	42150	2750	2000	46900	13100
		(70.2)	(4.6)	(3.3)	(78.1)	(21.9)
Vietnam	13000	3700	2050	80	5830	7170
		(28.5)	(15.8)	(0.6)	(44.9)	(55.1)
Asia(d)	182370	60410	19550	4120	84080	98290
		(33.1)	(10.7)	(2.3)	(46.1)	(53.9)
Total(d)	800250	201174	50082	174600	425856	374394
		(25.1)	(6.3)	(21.8)	(53.2)	(46.8)

Table 16 continued

	1980-1988					
	Decline of forest area	Conversion into				Other land uses
		arable land	permanent crop area	permanent pastures	total agri-cultural land	
		(1)	(2)	(3)	(1)+(2)+(3)	
Bolivia(b)	4900	200	710	0	910	3990
		(4.1)	(14.5)	(0.0)	(18.6)	(81.4)
Brazil(b)	194400	61340	8040	77720	147100	47300
		(31.6)	(4.1)	(40.0)	(75.7)	(24.3)
Colombia	24000	1370	110	20300	21780	2220
		(5.7)	(0.5)	(84.5)	(90.7)	(9.3)
Costa Rica	1900	0	90	1570	1660	240
		(0.0)	(4.7)	(82.6)	(87.3)	(12.7)
Dominican Republic	160	130	30	0	160	0
		(81.2)	(18.8)	(0.0)	(100.0)	(0.0)
Ecuador	24500	1740	300	10340	12380	12120
		(7.1)	(1.2)	(42.2)	(50.5)	(49.5)
Guatemala	6400	1100	50	800	1950	4450
		(17.2)	(0.8)	(12.5)	(30.5)	(69.5)
Guyana	na	na	na	na	na	na
		na	na	na	na	na
Honduras	5770	150	130	1300	1580	4190
		(2.6)	(2.3)	(22.5)	(27.4)	(72.6)
Mexico	43000	1500	300	0	1800	41200
		(3.5)	(0.7)	(0.0)	(4.2)	(95.8)
Nicaragua	9080	200	20	4200	4420	4660
		(2.2)	(0.2)	(46.3)	(48.7)	(51.3)
Panama	2400	50	150	800	1000	1400
		(2.1)	(6.3)	(33.3)	(41.7)	(58.3)
Paraguay(c)	50500	4600	10	45000	49810	680
		(9.5)	(0.0)	(89.1)	(98.6)	(1.4)
Peru	20000	1800	250	0	2050	17950
		(9.0)	(1.3)	(0.0)	(10.3)	(89.7)
Surinam	350	170	20	20	210	140
		(48.6)	(5.7)	(5.7)	(60.0)	(40.0)
Venezuela	23200	1200	150	4000	5350	17850
		(5.2)	(0.6)	(17.2)	(23.1)	(76.9)
Latin America(d)	410560	75770	10060	161850	247680	162880
		(18.5)	(2.5)	(39.4)	(60.3)	(39.7)
Angola(c)	7200	1000	0	0	1000	6200
		(13.9)	(0.0)	(0.0)	(13.9)	(86.1)
Cameroon	8800	1600	280	0	1880	9620
		(18.2)	(3.2)	(0.0)	(21.4)	(78.6)
Central African Republic(c)	750	550	110	0	660	90
		(73.3)	(14.7)	(0.0)	(88.0)	(12.0)
Congo	1600	90	100	0	190	1410
		(5.6)	(6.3)	(0.0)	(11.9)	(88.1)
Ghana(c)	5600	600	500	0	1100	4500
		(10.7)	(8.9)	(0.0)	(19.6)	(80.4)

Table 16 continued

	1980-1988					
	Decline of forest area	Conversion into				Other land uses
		arable land	permanent crop area	permanent pastures	total agri-cultural land	
		(1)	(2)	(3)	(1)+(2)+(3)	
Guinea(c)	7900	160	50	0	210	7690
		(2.0)	(0.6)	(0.0)	(2.6)	(97.4)
Ivory Coast(b)	40000	4700	1000	0	5700	34300
		(11.8)	(2.5)	(0.0)	(14.3)	(85.7)
Madagascar	12800	500	280	0	780	12020
		(3.9)	(2.2)	(0.0)	(6.1)	(93.9)
Nigeria(b)	24000	9500	0	900	10400	13600
		(39.6)	(0.0)	(3.8)	(43.3)	(56.7)
Rwanda(b)	230	160	60	0	220	10
		(69.6)	(26.1)	(0.0)	(95.7)	(4.3)
Sierra Leone(b)	430	350	0	0	350	80
		(81.4)	(0.0)	(0.0)	(81.4)	(18.6)
Zaire(b)	26400	1940	500	0	2440	23960
		(7.3)	(1.9)	(0.0)	(9.2)	(90.8)
Africa(d)	135710	21150	2880	900	24930	110780
		(15.6)	(2.1)	(0.6)	(18.4)	(81.6)
Bangladesh	2150	870	270	0	1140	1010
		(40.5)	(12.6)	(0.0)	(53.0)	(47.0)
Indonesia	41870	13000	1200	0	14200	27670
		(31.0)	(2.9)	(0.0)	(33.9)	(66.1)
Laos(b)	8000	200	10	0	210	7790
		(2.5)	(0.1)	(0.0)	(2.6)	(97.4)
Malaysia	19200	400	300	0	700	18500
		(2.1)	(1.6)	(0.0)	(3.7)	(96.3)
Papua New Guinea	1620	130	90	0	220	1400
		(8.1)	(5.6)	(0.0)	(13.6)	(86.4)
Philippines	17070	750	1070	2230	4050	13020
		(4.4)	(6.3)	(13.1)	(23.8)	(76.2)
Sri Lanka	230	120	0	0	120	110
		(52.2)	(0.0)	(0.0)	(52.2)	(47.8)
Thailand(b)	23820	11850	4670	1200	17720	6100
		(49.7)	(19.6)	(5.0)	(74.3)	(25.7)
Vietnam	31910	0	2200	500	2700	29210
		(0.0)	(6.9)	(1.6)	(8.5)	(91.5)
Asia(d)	145870	27320	9810	3930	41060	104810
		(18.7)	(6.7)	(2.7)	(28.1)	(71.9)
Total(d)	692140	124240	22750	166680	313670	378470
		(18.0)	(3.3)	(24.1)	(45.3)	(54.7)

(a) Figures in parentheses give the percentage share of different land uses in the conversion of tropical forest areas. - (b) More than one-third, but less than two-thirds of total forest area in 1980 are open forest formations. - (c) More than two-thirds of total forest area in 1980 are open forest formations. - (d) Regional averages refer to the sum of countries listed in the table.

Source: FAO [c]; own calculations.

ever, trees grown for timber and wood are excluded. Hence, this category includes all kinds of monocultural plantations and cash crops for export markets.

The permanent meadows and pastures refer to areas that are used permanently for forage crops and grazing for a minimum period of five years. This category comprises livestock production.

Forests and woodland include all kinds of primary and secondary forests. In general, this category refers to land under natural or planted stands of trees whether productive or not, while the data include land from which forests have been cleared but that will be reforested in the foreseeable future. For this reason, the decline of the forest area as it is reported in these statistics can only be regarded as an inadequate proxy for deforestation.

Finally, other land uses encompass land not specifically listed under the other categories, i.e., unused potentially productive land, built-on areas, wasteland, parks, roads etc. For most countries, land converted by shifting cultivators is included under this category.

In general, the reliability of these data which are compiled mainly from government statistics have to be questioned, as they cannot be as accurate as forest inventories. However, the data can show to what extent other forms of land use have increased in years, in which there was a decline of forest area.[1]

The first column of Table 16 gives the absolute decline of forest area both for the 1971-1980 and 1981-1988 periods.[2] The average annual decline of forest and woodlands as it can be calculated from these tables for the latter period ranges between the FAO estimations for 1981-1985 and Myers's estimations for 1980-1989, except for Colombia and Guyana.

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[1] The calculation of the conversion rates given in Table 16 had to be built on a number of assumptions. In cases where only the forest area decreased while all other land areas increased, the total area changes were taken as the forest conversion areas of the respective land use form. The underlying assumption is that shifts between forms of land use other than forestry can be neglected. Only in a few countries, the area of an agricultural land use form (commmonly pastures) showed a decrease. In this case, it was assumed that all other forms of land use had a share in forest conversion that was proportional to their total increase in this period.

[2] Tables 16, 17 and 18 do not contain figures for all tropical countries. For some countries (Belize, Equatorial Guinea, Gabon, Kampuchea), the FAO Production Yearbook does not report any decline of forest area, for Burma even a steady rise is reported. The provided land use data for India are extremely controversial.

The other columns show which share of the decline in forest areas can be attributed to other forms of agricultural land use. The figures in parentheses yield the percentage shares in land conversion. In general, Table 16 yields that the share of the agricultural sector in the conversion of tropical forest areas had declined in the 1981-1988 period compared to the 1971-1980 period. The reason is that agricultural land was increasingly converted to other uses or remained fallow after clearing.

Latin America shows the highest share for the agricultural sector in both periods. The major part of tropical forest conversion in the agricultural sector was due to the expansion of permanent pastures necessary for livestock production. In Brazil, the share of pastures in conversion ranks above 40 percent. Livestock production in Brazil is mainly located in the state of Mato Grosso as well as in the east and southeast of Para. It has been estimated that in 1983 cattle ranchers controlled more than 350,000 sq km, of which 140,000 sq km had already been cleared for production [Kohlhepp, 1989]. Mahar [1989] has estimated that forest conversion for pastures took place at the rate of 8,000-10,000 km p.a. in the seventies, while the lion's share was due to large landholdings in excess of 1,000 ha. These estimations are confirmed by the figures in Table 16, which shows an average annual conversion into pastures of 9,379 sq km p.a. for the 1971-1980 period and 9,715 sq km p.a. for the 1981-1988 period. The expansion of pastures into tropical forests has been promoted by fiscal incentives and land tenure regulations (Section IV.4). However, this does not allow for the conclusion that only large agricultural holdings are responsible for forest conversion. The second major source of deforestation in the Amazon forests were small farmers accounting for 11 percent of deforestation by 1983 [Repetto, 1988, p. 76].

In Africa, only a fifth of the decline of tropical forests can be attributed to the expansion of agricultural land. However, it has to be noted that the high values for other land uses include fallow land in the shifting cultivation cycle. For this reason, the share of agriculture reflects only the share of permanent agriculture. Within the agricultural sector, the arable land category is the major source of deforestation in Africa.

In tropical Asia, the category named other land uses seems to dominate the conversion of tropical land, while in the 1971-1980 period the share of agriculture and the share of other land uses was more balanced. A possible explanation for the high share of other uses is the expansion of permanent fallow land after logging and the shift towards expansion of shifting cultivations, which are not officially recorded. However, further analysis is needed to test this hypothesis.

These regional averages should not be taken as yardsticks for particular countries of that region, since differences among countries are substantial. For instance, in some countries in Latin America, for example, Brazil, Colombia, Costa Rica and Paraguay, the agricultural sector had accounted for more than 70 percent of the conversion of forest areas to other land uses in the 1981-1988 period, while in other countries like Bolivia, Mexico and Peru other land uses had been more than 80 percent. In the same vein, there are African countries, where the major part of deforestation was due to the expansion of agricultural land. This is especially the case in the Central African Republic, Rwanda and Sierra Leone. Among the Asian countries Bangladesh, Sri Lanka and Thailand show very high percentage shares of conversion into agricultural land.

A major factor behind the rapid extensification of agriculture to converted forest lands is the poor productivity of soils, which further decreases after few years of use. For instance, in Indonesia, farmers on the outer islands, where the bulk of Indonesia's tropical forest reserves are located, require substantially more land per familiy to earn the same income as in Java. For example, Sumatra as a whole requires 2.1 ha to produce the same value-added as 1 ha on Java, while Sulawesi requires 2.7 ha, Kalimantan 3.9 and Irian Jaya 10.7 [Douglass, 1987, pp. 55-57]. In the same vein, Sioli [1985, pp. 197-203] reports that the carrying capacity of tropical forest areas converted into pastures near the Belem-Brasilia highways decreased from 0.9-1.0 head of cattles on one ha of young pastures to only 0.3 after six years. In order to compensate for these losses in productivity, producers in tropical forest areas usually convert new rain forest areas.

Summing up, it can be stated that there are a number of countries in which deforestation was due to the expansion of agricultural land. In these countries, the agricultural sector contributed to deforestation,

even if the respective forests had been used for commercial logging prior to its conversion into agricultural land, since agricultural land is one possible by-product of tropical forest exploitation.

Tables 17 and 18 show the share of forest conversion into various forms of agricultural uses in the 1971-1980 (1981-1988) period in total land under production in 1988. A high (low) share indicates that a sizeable part of the agricultural land and thus the productive capacity was due to conversion of tropical forests. There are only few countries, in which more than 10 percent of the agricultural land in 1988 were due to tropical forest conversion in the eighties, i.e., Ecuador, Paraguay and Suriname. In Brazil, Costa Rica, Guatemala, Nicaragua, Malaysia and Thailand this share exceeded 5 percent. In all other countries, the expansion of agricultural land into tropical forest areas can be assumed to have only a marginal effect on the agricultural production capacity. Again, it has to be noted that these data are based on official government statistics, which do not include producers with inofficial land titles and shifting cultivations.

In Brazil, the forest conversion for livestock production reached a share of 5 percent of total pastureland. In Zaire, another tropical country with sizeable tropical forests, the growth of agricultual land due to forest conversion was comparatively moderate reaching 1 percent in the respective period. Within the agricultural sector the permanent agricultural holdings recorded the highest growth. In the same vein, Table 18 reports quite low percentage shares for African countries. As it was mentioned above, these countries face substantial conversion due to shifting agriculture which is not officially recognized as expansion of agricultural land. In general, Table 18 reveals structural differences across the three regions. In Asia, it is the permanent crops and arable land that record the highest growth rates. In Africa, it was only the growth of arable land which was substantial, while the expansion of pastures was negligible because of locational factors. Conversion due to livestock production seems to be more important for Latin American countries, especially for countries in Central America.

Even though the expansion of agricultural land into rain forests adds to the productive capacity of the agricultural sector in some countries, it should be noted that the increase of agricultural production cannot be assumed to be in the same proportion as the increase in

Table 17 - Share of Forest Conversion 1971-1980 into Agricultural Land by Various Kinds of Land Use (percent) (a)

	Forest conversion into			
	arable land	pastures	permanent cropping areas	total agri-cultural land
Bolivia	33.6	0.0	24.6	3.8
Brazil	11.7	5.5	14.5	7.6
Colombia	4.0	6.8	0.3	6.3
Costa Rica	0.0	28.0	6.2	23.3
Dominican Republic	1.6	0.0	0.7	0.6
Ecuador	0.9	34.0	9.5	23.6
Guatemala	12.3	7.2	5.2	9.1
Guyana	24.2	18.0	0.0	19.5
Honduras	11.4	8.3	17.6	9.9
Mexico	5.7	0.0	5.2	1.4
Nicaragua	3.2	10.0	3.5	8.7
Panama	0.7	7.5	6.7	5.9
Paraguay	18.4	3.5	0.9	4.8
Peru	13.8	0.0	4.6	1.6
Surinam	17.5	40.0	9.1	16.1
Venezuela	7.5	4.4	1.7	4.8
Angola	1.3	0.0	0.0	0.1
Cameroon	6.4	0.0	43.3	5.5
Central African Republic	4.6	0.0	8.7	1.9
Congo	7.6	0.0	8.3	0.1
Ghana	8.4	0.0	5.2	3.0
Guinea	3.3	0.0	0.9	0.6
Ivory Coast	10.3	0.0	5.6	4.8
Madagascar	17.6	0.0	34.7	1.7
Nigeria	1.5	1.0	2.2	1.3
Rwanda	2.3	0.0	2.3	1.7
Sierra Leone	1.6	0.0	0.4	0.7
Zaire	3.5	0.0	11.7	1.4
Bangladesh	0.2	0.0	11.0	0.5
Indonesia	8.2	0.0	4.1	4.6
Laos	3.4	0.0	38.1	2.2
Malaysia	7.7	3.7	7.8	7.8
Papua New Guinea	12.1	7.1	4.8	5.7
Philippines	0.0	16.1	26.3	11.9
Sri Lanka	2.4	0.0	0.0	0.9
Thailand	23.5	26.3	12.2	22.4
Vietnam	6.5	2.4	23.8	8.4

(a) In percent of 1988 area of the respective category.

Source: FAO [c]; own calculations.

Table 18 - Share of Forest Conversion 1981-1988 into Agricultural Land by Various Kinds of Land Use (percent) (a)

	Forest conversion into			
	arable land	pastures	permanent cropping areas	total agri-cultural land
Bolivia	0.6	0.0	37.2	0.3
Brazil	9.2	4.6	6.7	5.9
Colombia	3.6	5.0	0.7	4.8
Costa Rica	0.0	6.8	3.7	5.8
Dominican Republic	1.2	0.0	0.8	0.5
Ecuador	10.1	20.5	3.2	16.0
Guatemala	8.0	5.8	1.0	6.0
Guyana	0.0	0.0	0.0	0.0
Honduras	1.0	5.2	6.2	5.6
Mexico	0.7	0.0	1.9	0.2
Nicaragua	1.8	7.9	1.2	6.7
Panama	1.1	6.0	11.1	5.3
Paraguay	22.9	22.0	0.9	21.9
Peru	5.3	0.0	7.7	0.7
Surinam	29.8	10.0	18.2	23.9
Venezuela	3.7	2.3	2.2	2.5
Angola	3.3	0.0	0.0	0.3
Cameroon	2.7	0.0	2.6	1.2
Central African Republic	2.9	0.0	12.8	1.3
Congo	6.3	0.0	41.7	0.2
Ghana	5.2	0.0	2.9	1.7
Guinea	2.6	0.0	3.5	0.5
Ivory Coast	19.4	0.0	8.1	8.6
Madagascar	2.0	0.0	5.4	0.2
Nigeria	3.3	0.4	0.0	2.0
Rwanda	1.9	0.0	2.1	1.4
Sierra Leone	2.1	0.0	0.0	0.9
Zaire	2.7	0.0	8.3	1.1
Bangladesh	0.7	0.0	11.8	1.0
Indonesia	8.2	0.0	2.2	4.3
Laos	2.3	0.0	4.8	1.2
Malaysia	3.9	0.0	0.8	1.4
Papua New Guinea	39.4	0.0	2.5	4.7
Philippines	1.6	18.3	3.1	4.4
Sri Lanka	2.5	0.0	0.0	1.0
Thailand	6.6	15.8	20.7	8.5
Vietnam	0.0	15.2	25.6	3.9

(a) In percent of 1988 area of the respective category.

Source: As for Table 17.

productive land. This can be explained by the lower productivity in tropical forest areas. Hence, the economic importance of the expansion of agriculture into tropical forest areas, as it was to be measured in terms of the share of agricultural production in tropical forest areas in total agricultural production, cannot be properly assessed by the analysis given above, since this would imply an overestimation of the productive capacity in converted rain forest areas.

Because of a lack of data on agricultural production in tropical forest areas it is not possible to calculate the share of production in converted tropical forest areas in total agricultural production directly. For this reason, production data for tropical forest areas have to be estimated by using estimations for converted areas and the productivity of land (output/ha), as it has been estimated for converted areas in tropical forest regions. The size of the converted areas and thus of the resulting productive capacity, of course, is dependent on the period considered. There are a number of countries which were almost totally covered by tropical forests at the beginning of this century. In such countries all agricultural production is due to converted tropical forest areas, if one considers more than 30 years as the relevant observation period. Since this study aims at an analysis of more recent trends in deforestation, land converted in the last 10-15 years will be taken as a reference point for the following case studies of Brazil, Indonesia and Cameroon, while conversion prior to that will be neglected. [1]

The official land use statistics as they are given in the Production Yearbooks of the FAO do not include the extent of forest conversion due to logging activities and normal fire losses. In addition, deforestation due to spontaneous migration probably has been underestimated. For this reason, the conversion of tropical forest areas for agricultural use in Indonesia has been derived from World Bank sources, as they are given in Table 19. Accordingly, the bulk of forest conversion is due to shifting cultivators. Since a large share of these shifting cultivators is integrated into regional or even international markets, it makes sense to include the shifting cultivator segment into the analysis.

[1] The inclusion of very early forest conversion incurs a number of problems, since it has to be taken into account that a sizeable share of these converted areas has already been transformed into non-agricultural land uses, remain fallow or have experienced a substantial decline of their initial productivity. Since it is not possible to take account of these effects in our analysis, the respective periods do not exceed 15 years, even though productivity is likely to decrease even within this period.

Table 19 - Sources of Deforestation in Indonesia, 1980-1990

	Average annual deforestation (FAO)	Loss of forest area (World Bank estimate)	
	sq km		percent
Shifting cultivation	4350	50000(a)	59
Kalimantan	.	35000	41
Irian Jaya	.	3000	4
Transmigration program		9000	11
Sponsored settlement		6000	7
Secondary development		3000	4
	1650		
Spontaneous migration		10000	12
Estate crop development		2000	2
Logging	-	8000(b)	9
		(16000)(a)	19
Fire loss	-	6000(c)	7
Total	6000	85000	100

(a) Includes losses due to shifting cultivations and logging; could be attributed to either category. - (b) Forest land that has been logged prior to shifting cultivation has been excluded to avoid overlapping. - (c) The huge 1983 fire loss in East Kalimantan (about 30000 sq km) is not included.

Source: Pearce et al. [1990, p. 95]; World Bank [1990b, p. 3]; FAO/UNEP [1981]; own calculations.

In Indonesia approximately 68,000 sq km of tropical forests had been converted into agricultural land, of which 50,000 were due to shifting cultivators, 10,000 can be attributed to spontaneous migration and finally 2,000 to estate crops in the 1980-1990 period (Table 19). Secondary effects resulting from the national transmigration program (Transmigrasi) have not been included, because this kind of land use is predominantly non-agricultural land use. The land consumption of shifting cultivators has to be included, as in Indonesia a large number

of this group of farmers is integrated into markets, while some of them are engaged in the production of export crops (Section IV.2). The converted area of 68,000 sq km is very high relative to the total productive land, which was estimated to be 330,200 sq km in 1988 [FAO, c, 1989]. Since those areas in the shifting cultivation cycle which presently lie fallow are only included in the first figure, the share of actually cultivated land in Indonesia's total area under agricultural production cannot be estimated from these figures. As it has been noted above, the productivity of land in recently converted areas ranks substantially below that of cultivated areas in Java. The value-added produced in converted areas is estimated to reach only 28 percent of the value-added in non-forest areas.[1] Hence, agricultural value-added in converted tropical forest regions accounted for a maximum of 6 percent of Indonesia's total agricultural value-added in 1988.[2]

However, this should be interpreted as the maximum rate, as the averages for the value-added in tropical forest regions given above are likely to include some non-forest areas as well, while a large share of shifting cultivators are not likely to reach the average productivity in these regions. In addition, it has to be taken into account that the

[1] In order to gain the same value-added as on 1 ha on Java, which is a non-forest region, producers need 2.1 ha in Sumatra, 2.7 ha in Sulawesi, 3.9 ha in Kalimantan and 10.7 ha in the Moluccas and Irian Jaya. Irian Jaya, Kalimantan and Sumatra account for 85 percent of Indonesia's forest lands [Pearce et al., pp. 91-108]. In order to calculate an average productivity for tropical forest regions these figures of productivity were weighted with the percentage share in deforestation in the late seventies and early eighties, as it was derived from FAO/UNEP [1981]. Accordingly, Sumatra accounted for 30 percent, Kalimantan for 55 percent, Sulawesi for 10 percent and the Moluccas and Iran Jaya for 5 percent. Thus, the average area needed in the outer islands to produce the same value-added as on 1 ha of land in Java is 3.6 ha. Hence, the productivity measured in value-added per ha is only 28 percent of the productivity in non-forest areas. If one corrects the 68,000 sq km of forest-land converted into agricultural holdings in the 1980-1990 period for the lower productivity, it can be estimated that this area produces the same value-added as about 19,000 sq km of land in Java.

[2] Many market-oriented farmers in tropical forest areas, especially those that have established their holdings under government-induced settlement programs, have access to fertilizers that can help to avoid or at least delay losses of productivity due to soil erosion. As these agricultural holdings may reveal only a comparatively small differential in productivity measured in output per ha, the value-added per ha reveals more explanatory power.

productivity in tropical forest regions is likely to decrease after a few years of agricultural production. Since agriculture accounted for a fourth of Indonesia's GDP in 1988, the share of production on tropical forest areas was probably lower than 2 percent.

In Cameroon the loss of forest-land in the 1981-1988 period totalled 8,800 sq km following Table 16.[1] In the 1981-1988 period virtually all expansion of agricultural land had been facilitated by the conversion of tropical forests. Because of locational factors, livestock production did not expand into tropical forest areas. Thus, forest conversion led to an increase of arable land of 1,600 sq km and permanent cropping areas of 280 sq km. The rest is due to fallow areas in the shifting cultivation cycle, which apparently is not fully reflected in the agricultural land use categories of the FAO (Section IV.2). Since data on regional differences in agricultural value-added are not available, one has to resort to rather crude approximations of differences in land productivity. On average, the productivity in recently converted tropical forest areas can be assumed to reach 75 percent of the productivity in longstanding agricultural lands.[2] Excluding the agricultural land which is used for livestock production, the total agricultural land in Cameroon added up to 70,080 sq km in 1988 excluding land under shifting cultivation converted in the 1981-1988 period (Section IV.2). As it was mentiond above, the tropical forest lands converted for agricultural use were 1,880 sq km in the 1981-1988 period, which was 2.7 percent of Cameroon's total agricultural land in 1988 excluding permanent pastures. If one takes into account that these 1,880 sq km produce only roughly 75 percent of the output that could have been produced on non-forest lands of the same size, the estimated share of production on areas that have been con-

[1] Hence, the yearly deforestation averages 1,100 sq km. This figure which relies on official government statistics ranks between the FAO estimate for 1981-1985 and Myers's estimate for 1989 which reported 800 sq km and 2,000 sq km.

[2] According to field studies by Prinz [1987], the productivity of wet paddy and maize in the Bamendahighlands reaches 2,500 and 1,050 kg/ha p.a., respectively. Since the soils in the Western region are predominantly alluvial deposits or of volcanic origin, the productivity can be assumed to be twice as large as in other forest regions. This leads to an estimated average productivity of 75 percent, based on the assumption that 50 percent of the converted areas are located in the Centre-South and East regions.

verted in the 1978-1988 period, in total agriculture excluding livestock is 2.0 percent. Since agricultural activities accounted for 26 percent of Cameroon's GDP in 1988, it seems likely that agricultural activities due to tropical forest areas converted into agricultural land in the 1981-1988 period account for less than one percent of Cameroon's GDP in 1988. Moreover, this seems to point to the fact that the contribution of agricultural poduction on forest areas converted in the 1981-1988 period had only a marginal impact on employment and export performance of Cameroon's economy.

However, this does not include the shifting cultivation sector which plays an important role in the country's agricultural production. Moreover, this analysis involves some degree of arbitrariness, since forests that had been converted to agricultural holdings prior to 1981 are not included. Forest conversion in the 1971-1980 period, however, was comparatively high reaching 10,900 sq km, of which 4,600 sq km were due to the expansion of permanent crop areas and 3,800 sq km to the increase of arable land. Hence, in the 1971-1980 period, forest conversion into agricultural land accounted for 9.0 percent of production in 1988 using the method of estimation described above. However, these estimations do not take into account the loss of productivity caused by soil erosion and thus should be interpreted with caution.

In Brazil, it is mainly arable land and pastures that accounted for the highest shares in forest conversion for agricultural use. Conversion into agricultural land totalled 147,100 sq km in the 1981-1988 period and 189,100 sq km for the 1971-1980 period (Table 16). This is 5.9 or 7.6 percent of the total area under agricultural use in 1988. The largest share of conversion, namely 77,720 sq km in the 1981-1988 period and 93,790 sq km in the 1971-1980 period can be attributed to the expansion of permanent pastures for extensive cattle ranching. As these ranches make extensive use of agricultural land their yearly output/ha ranges between 30-50 kg/ha. By comparison, cattle ranches in Western Europe range between 600-2,500 kg/ha p.a. [EK, 1990, p. 249]. Due to this extensive use of land the average density of cattle population amounts to only 1 head of cattle/ha. Since the number of cattle in Brazil was 136.814 million in 1988, the conversion of tropical forest areas in the 1981-1988 period (1971-1980 period) accounted for approximately 5.8 (6.9) percent of total production.

However, this estimation presumes that there is no loss of productivity over time. However, productivity can only be maintained at its initial level, when ranchers make extensive use of fertilizers on the entire pasture land. This is a very strong assumption. Following FAO Production Statistics, the average productivity of Brazilian cattle ranches is only 0.79 head of cattle/ha p.a. It has been reported that the productivity of Amazonian ranches decreases from 1.0 head of cattle/ha p.a. to 0.3 head of cattle/ha p.a. in the sixth year of use. Taking account of such reductions in productivity the entire picture changes. Accordingly, the pasture land converted in the 1981-1988 (1971-1988) period had a carrying capacity of 5.247 (7.546) million head of cattle.[1] This corresponded to 3.9 (5.6) percent of the cattle inventories of 1988. However, these figures are based on official reports on area estimates of permanent pastures.[2]

Given the extensive use of land, the labour intensity of cattle ranching in the Brazilian Amazon is quite low. Kohlhepp [1987] reports that farms of an average size of 12,700 cattle need 52 workers, which corresponds one worker per 178 ha or per 244 head of cattle. Hence, the work force employed in cattle ranches that had been established on forest lands converted in the 1981-1988 (1971-1988) period was 21.5 thousand (30.9 thousand) or less than 0.1 percent of total employment in 1988.[3] Since cattle production in Brazil and especially in the Amazon

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[1] The carrying capacity of pastures in tropical forest areas has been calculated by asssuming that productivity is 1.0 head of cattle/ha p.a. in the first year and decreases to 0.8 in the second, 0.6 in the third, 0.5 in the fourth, 0.4 in the fifth, and 0.3 in the following years. This decline in productivity is in line with observations cited in Sioli [1985].

[2] In fact, Kohlhepp [1989] reports that the area covered with permanent pastures was as large as 140,000 sq km in 1983, while the total area controlled by ranches was 350,000 sq km leaving a large potential for further land conversion. Taking into account an annual average conversion of forests into pasture land of 9,715 sq km p.a. (Table 16) for the eighties, the converted pastures were as large as 188,575 sq km in 1988 which corresponds to an initial carrying capacity of 8.84 million head of cattle/ha p.a., assuming that the land had been converted in the 1971-1988 period. Accounting for the decline in productivity in that period, the share of converted areas in total production is about 6.6 percent of total production in 1988.

[3] These estimations are confirmed by Kohlhepp [1987]. Accordingly, all cattle ranch projects approved by Superintendencia de Desenvolvimento

region is predominantly inward oriented, it does not contribute to the country's foreign exchange earnings.

By contrast, the productive capacity of tropical forest areas converted into arable land and permanent cropping areas was more important compared to the total productive capacity of Brazilian agriculture. In the 1981-1988 (1971-1980) period the area converted into arable land and cropping areas was 69,380 (95,310) sq km, of which 61,340 (77,870) were converted into arable land and 8,040 (17,440) into permanent cropping areas (Table 16). Hence, the areas converted into permanent cropping areas and arable land in the 1981-1988 (1971-1980) period accounted for 8.8 (12.1) percent of the respective total productive land in Brazil in 1988, which was 785,500 sq km. As agricultural productivity in tropical forest areas reaches on average a maximum of 83.3[1] percent of the productivity outside tropical forest areas, the productive capacity of tropical forest areas converted in the 1981-1988 period (1971-1980 period) was 7.3 (10.1) percent of the respective total production in Brazil 1988. These figures should be interpreted as maximum shares, as the underlying assumption is that the rather high levels of productivity, as they can be obtained from Coy [1987], can be maintained for long periods of time. This, however, is a strong assumption, even if one takes into account that market-oriented

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da Amazonia (SUDAM) until 1983 were to create approximately 25,000 jobs.

1 Data on agricultural productivity on converted tropical forest lands have been derived from Coy [1987], who has carried out a field study in Rondonia, where the bulk of the tropical forest areas converted into permanent pastures and arable land is located. The yields on this areas were 1,504 kg/ha for rice, 1,466 for maize, 598 for beans, 16,845 for maniok, 705 for coffee and 417 for cocoa in 1983/1984. These products, which cover the bulk of agricultural production in Rondonia, are cropped on an area covering 90 percent of total arable and permanent cropping land. In order to calculate an average productivity for tropical forest areas, the yields given above were divided by the respective average yields for 1987-1989, as they can be obtained from the FAO [c, 1989]. These results show the ratio between productivity in tropical forest areas and average productivity in Brazil by various products. These product-specific ratios have been aggregated by weighting these ratios, which range between 0.74 and 0.78 for rice, maize, coffee and cocoa and between 1.33 and 1.37 for beans and manioc, with the respective percentage share in total agricultural area, as they are given in Coy [1987]. Accordingly, the average ratio between productivity, in tropical forest areas and average productivity in Brazil is 0.83.

agricultural holdings in Brazil can afford to use fertilizers to raise their productivity.

Since the share of agriculture of GDP in Brazil was as low as 9 percent in 1988 (Table 15), there is reason to assume that farming and ranching on tropical forest areas converted in the 1981-1988 (1971-1988) period accounted for less than 2 (3) percent of GDP in 1988.

As the analysis of the three countries has shown, expansion of agriculture into tropical forest areas in the eighties has not led to a substantial increase of agricultural output in these countries. The resulting increases in GDP resulting from this increase of agricultural production are comparatively low. Since it is not possible to obtain data on the product composition of agricultural production in tropical forest areas and their respective labour intensity, the economic significance of these activities in terms of their contribution to national employment and export performance cannot be assessed at this stage of the analysis. Given the rather low shares in total agricultural production and the lack of developed infrastructure services in tropical forest areas, it can be assumed that the export share of production is relatively small in tropical forest areas compared to non-forest areas. However, this does not apply for employment, as there is reason to assume that agricultural production in tropical forest areas is more labour-intensive than outside these areas. Nevertheless, given the rather low impact of forest conversion on agricultural output, the employment effects of forest conversion for agricultural production should be moderate.

2. Shifting Cultivation and Small-Scale Farming in Tropical Forest Areas

Following earlier studies on the causes of deforestation, shifting cultivation in tropical countries is one of the main causes of deforestation [Seiler, Crutzen, 1980]. It has been estimated that in the eighties 200-500 million people farm land in shifting cultivation systems [Lamprecht, 1986, p. 100]. This agricultural sub-sector encompasses a very heterogenous group of farming systems with respect to clearing method and cropping system (for example, mixed cropping versus rotation). Moreover, the length of the cropping period and its ratio to the fallow period varies widely across regions, depending on soil

characteristics and climatic conditions [for example, see Ruthenberg, 1980, Ch. 3]. In the humid tropics, the land regenerates for ten years or more (forest fallow) after one to three years of cropping. High growth rates of the rural population and the integration into regional and international markets have given incentives to shorten the fallow periods. Hence, a gradual transition to permanent cropping systems (for example, rubber, cocoa, palm oil) has taken place, especially in West Africa and continental South East Asia. In some regions, for example, in Indonesia, the higher farming intensity has led to the savannization of large areas.

As it can be obtained from Table 20, which is based on FAO estimations, more than two million of sq km of land in closed forest regions (forest fallow) are part of the shifting cultivation cycle, which is the equivalent of about one-fifth of the tropical closed forest area.[1] Every year, this area is increased by 1-2 percent on the global level with relatively high growth rates in Thailand, Nigeria, Central America, and the Andean region. In absolute terms, the largest areas of newly deforested land can be found in Indonesia, followed by Brazil, Mexico, Colombia, Ivory Coast and Nigeria.

Following the figures in the last column of Table 20, a high share of deforestation in closed forests can be attributed to shifting cultivators. For all the countries listed, the share reaches 47 percent, while there are extreme variations between individual countries. On average, the share is above 80 percent in African countries, and quite low in Latin America. For instance, in Brazil, Costa Rica, Guatemala, Honduras, Panama and Venezuela shifting cultivators contributed even less than a fourth to tropical deforestation in contrast to Bolivia, Ecuador and the Guyanas, where the share exceeded 60 percent. In Thailand and Sri Lanka, however, the share was only about 20 percent.

In Amazonia, shifting cultivators producing for their own consumption or regional markets, usually harvest rice, beans, manioc, potatoes and onions. Moreover, some of these small holdings managed by shifting cultivators in Amazonia can afford to raise pigs or cattle for milk production [Kohlhepp, 1989]. The majority of shifting cultivators in

[1] In addition, more than one million of sq km of land in humid savannah regions is concerned by shifting cultivation (bush fallow), especially in Brazil and West Africa.

Table 20 - Deforestation of Closed Forests Caused by Shifting Cultivation, 1981-1985

	Land in the shifting cultivation cycle(a), 1980	Closed forests newly deforested for shifting cultivations (annual average)(b)		
	1000 sq km	sq km	in percent of forest fallow area, 1980	in percent of total deforestation of closed forests
Belize	5.3	64	1.2	71.1
Bolivia	11.0	600	5.5	69.0
Brazil	464.2	3400	0.7	23.0
Colombia	85.0	3000	3.5	36.6
Costa Rica	1.2	60	5.0	9.2
Ecuador	23.5	2100	8.9	61.8
Guatemala	3.6	120	3.3	13.3
Guyana	2.0	20	1.0	80.0
Honduras	6.8	220	0.1	24.4
Mexico	260.0	3200	1.2	53.8
Nicaragua	13.7	380	2.8	31.4
Panama	1.2	70	5.8	19.4
Peru	53.5	1140	2.1	42.2
Suriname	2.7	20	0.7	80.0
Venezuela	106.5	260	0.2	20.8
Cameroon	49.0	760	1.6	95.0
Central African Republic	3.0	50	1.7	100.0
Congo	11.0	200	1.8	90.9
Gabon	15.0	150	1.0	100.0
Ghana	65.0	180	0.3	81.8
Guinea	16.0	300	1.9	83.3
Ivory Coast	84.0	2630	3.1	88.9
Liberia	55.0	340	0.6	73.9
Nigeria	77.5	2500	3.2	83.3
Sierra Leone	38.6	40	0.1	66.7
Zaire	78.0	1500	1.9	83.3
Bangladesh	3.2	50	1.6	62.5
Burma	181.0	950	0.5	90.5
Indonesia	134.6	4000	3.0	66.7
Kampuchea	2.0	120	6.0	48.0
Laos	50.0	800	1.4	80.0
Malaysia	48.3	1290	2.7	50.6
Sri Lanka	8.5	130	1.5	22.4
Thailand	8.0	400	5.0	16.3
Vietnam	107.5	650	0.6	100.0
Total	2075.4	31694	1.5	46.5

(a) Area of young secondary forest (forest fallow) in closed forest area. - (b) Approximated by the increase of forest fallows.

Source: FAO/UNEP [1981]; Molofsky et al. [1986]; own calculations.

the Amazon region comprise settlers from other parts of the country. In recent years tropical forest areas have been subject to considerable immigration flows, thus contributing to the destruction of tropical rain forests. There are several reasons for these migration flows, namely government-induced settlement programs, uneven distribution of agricultural land, crowding-out of small farmers on non-forest areas as a result of mechanization of agriculture as well as rising population growth in both rural and urban areas. The number of these shifting cultivators has been growing, thus leading to a growing consumption of new agricultural land.

For Brazil, the contribution of shifting cultivators is reported as 23.0 percent, while the total share of agriculture as reported in Table 16 was 75.7 percent for the 1981-1988 period. Taking account of the fact that non-agricultural sectors had been in charge of roughly 7 percent in the same period, the maximum deforestation due to unofficial shifting cultivators was about 15 percent. This is supported by a study by Fearnside [1990], who reports that traditional shifting cultivation as practiced by some indigenous people and small farmers is only a minor factor of deforestation in Brazil, while it is mainly the pioneer agriculture engaging in slash-and-burn on sizeable tropical forest areas. The latter, however, has already been included in our estimations in the preceding section.

By contrast, shifting cultivation systems in the outer islands of Indonesia are extremely diverse and are used by a very broad spectrum of farmers encompassing all of Indonesia's ethnic and language groups. They include sedentary farmers engaging in marginal shifting cultivation, spontaneous immigrants seeking land for permanent agriculture and indigenous people employed in more traditional slash-and-burn practices. These smallholder shifting cultivators grow most of Indonesia's pepper, coffee, coconuts and rubber [Dove, 1985; Pearce et al., 1990]. The number of shifting cultivators has been steadily growing which is due to three factors. First, the Transmigrasi settlement program brought a large number of farmers into tropical forest areas (Section IV.4). As many of these farmers experienced a decline of productivity on the land provided by the government, the settlers inofficially expanded into new forest areas. Second, the extent of spontaneous migration to tropical forest areas has been increasing in the wake of the transmigration

program (Section IV.3). Third, the population of indigenous people engaging in traditional shifting cultivation is growing as a result of the increase in life expectancy. In Indonesia, approximately 1 million families out of 12-13 million households on the outer islands depend primarily on shifting cultivation and farm approximately 7.3 million ha [Pearce et al., 1990, p. 101]. Given an average family size of 5 persons, the population depending on shifting cultivation was at least 5 million, which was 2.9 percent of Indonesia's total population of 172 million and 7.5 percent of the population on the outer islands in 1987, where almost 97 percent of Indonesia's tropical rain forests are located.[1] This is above the regional average for Asia, where shifting cultivators have been estimated to account for 2 percent of the total population in 1980 [Scholz, 1988]. Many of these shifting cultivation systems, particularly developed by indigenous populations, can remain sustainable unless population expands.

According to the FAO/UNEP study, in Indonesia roughly two-thirds of deforestation was due to the shifting cultivation sector (Table 20). This is confirmed by another study, which reports a share of 59 percent for the 1980-1990 period (Table 19).

In Cameroon, small farmers and shifting cultivators engage in a variety of activities namely hunting, farming and timber production. The reason is that most of the shifting cultivators in Cameroon's tropical forests are indigenous people. According to their tradition women are in charge of crop production, while men engage in the clearing of forests for agricultural use and non-agricultural activities [Prinz, 1987]. According to Ruitenbeek [1990], 34 percent of household income in West Cameroon is due to the production of cash crops, while forest products account for 29 percent, hunting and trapping for 21 percent. Forest farming occurs both from the clearing of land in the traditional bush-fallow farming manner, as well as direct gathering of forest products for both subsistence and cash.

Deforestation due to shifting cultivators in Cameroon is 95 percent following Table 20. It has to be mentioned, however, that a large share

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[1] Population data have been obtained from Pearce et al. [1990]. The average population size of 5 has been taken as a yardstick, as the average family size of the transmigration people ranges between 4 and 5 [Biro Pusat Statistik, 1987].

of these shifting cultivators seem to belong to the market-oriented sector. Table 16 reports that 77.2 percent of conversion was officially attributed to the agricultural sector in the 1971-1980 period. In the 1981-1988 period this share declined to 21.4 percent, which seems to indicate that in the 1981-1988 period shifting cultivation was not subsumed under arable land in the government statistics. Hence, the share of tropical forest areas converted in the 1981-1988 period should be carefully revised taking into account the shifting cultivation areas. Assuming an annual conversion of 760 sq km (as reported in Table 20) for the 1981-1988 period, the entire area added to the shifting cultivation cycle is 6,080 sq km. Assuming an average cultivation period of three years, the total agricultural area including shifting cultivations was 72,360 sq km in 1988 after revision. Hence, the share of tropical forest areas converted to shifting cultivations in 1981-1988 in total agricultural land in 1988 was three percent, if one disregards fallow areas. This is to say, that the productive capacity of these shifting cultivations reached about three percent of the productive capacity in 1988.

However, the estimates given in Table 20 have to be interpreted with caution. First of all, the separation of young secondary forests (forest fallow) from mature ones is rather vague in practice, especially in regions where mixed cropping systems with tree crops prevail. Moreover, even though remote sensing and satellite technology can reveal slash-and-burn parcells, as they are typical for shifting cultivators, clearing by burning is not only due to shifting cultivators but all other uses of tropical rain forests except logging. Hence, there is reason to assume that forest clearing for pastures, permanent agriculture and plantations are attributed to shifting cultivations, if the resulting increase of agricultural land is not recorded in official statistics. This, of course, leads to an overestimation of the shifting cultivators role in deforestation [Scholz, 1988, p. 211].

In addition, it has to be noted that a large share of the forest areas cleared by shifting cultivators have been degradated before by loggers or the production of infrastructure. Given the conceptual problems and the lack of data it is not possible to quantify exactly the degree of this joint use on the country level for all countries given in Table 20. As Figure 1 in Chapter III shows, there is a wide range of

overlapping with respect to forest areas that have been under use by shifting cultivators and the forestry sector in tropical countries. In Indonesia, the total loss of forests due to shifting cultivators has been estimated to be 50,000 sq km or 59 percent of total deforestation for the 1980-1990 period (Table 19). However, 8,000 sq km of this area had already been logged over. If this proportion is solely attributed to the forestry sector, the shifting cultivation sector ends up with a reduced rate of 42,000 sq km which accounts for 49 percent of total deforestation.[1]

Summing up, it can be presumed that a large part of the so-called shifting cultivation sector in Indonesia, Cameroon and Brazil is integrated into regional or even international markets and that only a minority engages in pure subsistence farming. Hence, economic policy measures impact on this agricultural subsector in nearly the same way as it has been analyzed in the preceding section for permanent agriculture.

The need for newly cleared areas in closed primary forests does not only arise from high population growth. Soil degradation due to the shortening of fallow periods and limited access of the landless to arable land are other important causes. For this reason, more attention should be paid to the introduction of sustainable high yield farming systems (for example, agroforestry systems).

3. Settlement Programs in Tropical Forest Areas

The growing scarcity of agricultural land has led to both planned and unplanned (or spontaneous) migration into tropical forest areas. Usually, land conversion due to unplanned agricultural colonization substantially exceeds the land subject to government-induced migration programs. While in many Asian countries such government programs have already

[1] Moreover, there is some indication that there is a cooperation between shifting cultivators and landlords that cannot afford to violate forestry regulations or regard the clearing of forests as an unprofitable business. In Thailand, for instance, it has been recorded that landlords offer parts of their tropical forest land to shifting cultivators, since they cannot be legally prosecuted in case of an illegal clearing of forests. As a result, shifting cultivators may clear these forests areas, while the landlord takes over the agricultural production after four years [Scholz, 1988, p. 214].

been initiated in the fifties and the sixties, for example, the "Grow More Food" campaign in India and the "Land for the Landless" program in the Philippines, the colonization of Indonesian tropical forests has not gone far yet, since both planned and unplanned migration flows have not been substantial before 1980 [Scholz, 1988]. Since it is not possible to discuss all migration programs implemented in tropical forest areas, the following assessment of these programs will be confined to Brazil, Indonesia and Malaysia, as in these countries major settlement programs have been initiated. In most African countries, migration into tropical forest areas was not government-induced in the sense that the administration planned the colonization of tropical forest areas. Migration in Africa is mostly unplanned and intra-regional [Ruitenbeek, 1990]. Hence, the rise of population pressure and deforestation in Africa's tropical rain forests cannot be attributed to governmental intervention.

Like in many tropical countries the Brazilian government considers its tropical forest areas as an important location for the relief of over-populated urban areas and as a politically more acceptable option than the reform of the traditional agricultural lands elsewhere in Brazil. Hence, the creation of public settlements along the Transamazonia highway and the gradual moving of the agricultural production frontier is seen as an alternative migration strategy to the city-ward movement of the people in the southern part of the country.

Nevertheless, Brazil's government-induced migration programs have not played a leading role in the colonization of Amazonia. The process of colonization in the Amazon region actually began in 1964 due to direct government incentives for private companies and developing the infrastructure, particularly the road network. Considerable impetus to the construction of the road network was provided by the national integration program, established in 1970, which made resources available for the construction of roads in the 1970-1975 period including the Transamazonia highway connecting Amazonia with the North-South highway. A 20 km strip on either sides of the highways was reserved for agricultural settlement projects. To carry out the settlement program, the National Institute for Colonization and Agrarian Reform (INCRA), established a network of new villages, towns and cities at predetermined locations along the highway and demarcated 100 ha farmlots nearby. Initially there was also a strategic military interest in affirming Brazilian

sovereignty over Amazonian territory. In addition to these infrastructure programs, a new strategy aiming at private capital was adopted in 1967 which was termed "Operação Amazônia". The responsible development agency, SUDAM, provided a package of attractive tax exemptions for establishments producing raw materials such as cattle meat, minerals and timber, including the respective related industries. But SUDAM continued to have little planning control, and discrepancies between planning and control became apparent [Morgan, 1988].

In the eighties, it was mainly the Polonoreste-Program which brought settlers to Rondonia and the northwestern part of Mato Grosso. This program aimed at the lower-income rural population in South and Southeast Brazil and was supported by the World Bank. Until 1985, only 44,000 families settled down in Rondonia, while 48,000 families were given either temporary or permanent land titles. Due to this small number the impact on reducing rural population pressure in the rest of Brazil has been largely superficial. The number of official settlers contrasts sharply with the total number of settlers which had averaged 150,000 p.a. during the eighties [Kohlhepp, 1989]. It has been reported that many of these pioneer settlements have already been abandoned and transformed into cattle pastures [Morgan, 1988]. It has been estimated, however, that the semi-directed and directed programs in Rondonia were responsible for 6.6 percent for the forest area altered in Legal Amazon [Binswanger, 1987].

Another form of government-induced migration is the construction of roads opening up rain forest areas for settlers. While large cooperations and landlords have enough capital to build their own roads into the forests, small farmers need to stick close to public roads for access to health, education and marketing facilities. The major part of the road system in the Brazilian Amazon was built in the 1970-1980 period. It was not only the federal government which was in charge of this policy, as the construction of state and local roads had the highest share in the expansion of the road system. On average 1 km of federal road construction was accompanied by 2 km of state and local road construction. The direct impact of road construction was relatively small, namely less than 1,000 sq km in the 1970-1985 period. However, indirect impacts on deforestation, i.e., the land conversion for agricultural use along the

roads can be considerable.[1] If the government continues to reserve 40 km along all federal roads built in the 1970-1985 period for agricultural holdings, the converted area will amount to 332,000 sq km, which is 5.8 percent of Brazil's total forest area in 1980.[2]

In Malaysia most planned settlements have been initiated by the Federal Land Development Authority (FELDA), which has been described as a state within the state [Morgan, 1988], because of its large endowment with capital and modern technical resources. FELDA's activities were fostered by the more agressive role of the government in utilizing agricultural expansion as a means of achieving both economic and social objectives. One achievement of the resettlement schemes has been that the large plantations no longer control the great part of palm oil production. From 1971 to 1975, FELDA developed 52 percent of the newly cleared land in Peninsular Malaysia. The settlement schemes involve a high degree of supervision at all stages of the programs including the creation of a system of central settlements and infrastructure. Settlers are only brought in tropical forest areas after primary or secondary forests have been cleared, the crops, mostly oil palm or rubber, have been planted, houses built, social infrastructure prepared and basic maintenance carried out. In 1981, approximately 300,000 people or 8 percent of the population had been relocated in West Malaysia [Morgan, 1988].

Likewise, colonization in Sarawak is fostered through major infrastructure programs. The so-called "integrated rural development projects" provide a framework for the expansion of agricultural land and

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1 Assuming an average strip of 50 m for federal highways and 30 m for state and local highways, the total deforestation caused by the road system of 25,000 km built in the 1970-1985 [Mahar, 1989] period adds up to 500 sq km for state and local highways and 417 for sq km for federal highways in the 1970-1980 period. Deforestation in the 1980-1985 period is predominantly caused by state and local roads accounting for 60 sq km. However, this analysis does not include private roads built by private companies. A large share of these companies can afford to construct their own link to the public road system.

2 It can be assumed that on average 1 km on each side of public roads is converted into agricultural use. This is probably a lower margin, since in the case of the Transamazonia highway a 20 km strip on each side of the road was allocated to agricultural use [Mahar, 1989]. Hence, road construction may have led to 50,000 sq km in the 1970-1985 period.

the establishment of villages and small towns in tropical forest areas. The first stage of the project, the Bintulu Miri Long Project, envisages to establish agricultural holdings for rubber and oil palms covering 14,000 sq km, of which only 770 sq km had been cleared in the 1971-1980 period and 170 sq km in the 1981-1985 period [Schätzl, Piening, 1988]. This, however, compares very low to total deforestation which was estimated to be 2,550 sq km p.a. in the 1981-1985 period [Lanly, 1982].

In the same vein, Indonesia faces increasing demographic and economic pressures to open up forest lands. Indonesia's population is not evenly distributed, as approximately 60 percent of the total population were concentrated on the so-called inner islands of Java and Bali in 1987 [Pearce et al., 1990]. Hence, the population density on these islands reached 800 and 500 people/sq km against 15 and 3 in Kalimantan and Irian Jaya. The outer islands with nearly 40 percent of the population and 97 percent of Indonesia's forests have only 5 percent of the land in sedentary agriculture, while the level of industrialization ranges by far below the national average. Consequently, extensive agricultural development continues to be the main source of additional employment in the outer islands. On top of that, the relative land abundance on the outer islands spurs both spontaneous and official migration of poor undercapitalized labour from Java and other inner islands. Both the official transmigration policy, which is known as the Transmigrasi Program and spontaneous migration have been responsible for significant migration. As Table 19 shows, the colonization of forest areas on the outer islands had become a major source of deforestation in the eighties reaching 23 percent of total deforestation, of which 7 percent was due to sponsored settlements, 4 percent accounted for secondary development associated with these planned settlement programs, while the lion's share of 12 percent can be attributed to spontaneous or unplanned migration. Hence, like in Brazil, unplanned migration accounts for a higher share than government-induced migration programs.

Since 1979, around 535,000 families have been resettled in the outer islands of Indonesia [Fasbender, Erbe, 1989], of which 366,000 were due to planned migration and 123,000 to spontaneous migration. The majority of the official migrants, namely 62.1 percent, settled down in Sumatra, while Kalimantan accounted for 19, Sulawesi for 12, Irian Jaya for 4 and

the Moluccas for 3 percent. By the end of the eighties, it is estimated that about 1 million ha have been converted to agricultural land for transmigration (Table 19). The high costs of the program (US$ 9,000/ family), the lack of suitable sites as well as the reluctance of donors to support the program has meant that transmigration was virtually stopped in 1986. However, the ending of official transmigration has not stopped spontaneous migration to the outer islands. In the wake of the Transmigrasi Program, there was a steady increase in spontaneous migration. In the 1979/1980 period 21,000 families were resettled under the Transmigrasi Program, while only 2,000 families were spontaneous settlers. As the spontaneous migration gained momentum, the number of families resettled under the government program fell behind spontaneous migration in the 1983/1984 period, when 94,000 official settlers and 123,000 spontaneous migrants were recorded [Fasbender, Erbe, 1989]. It has been estimated that spontaneous migration had converted another 1,000 sq km p.a. of forest area to agricultural production in the 1980-1990 period, which compares very high to sponsored transmigration which accounted for 900 sq km deforestation p.a. in the same period (Table 19). Recent studies suggest that there is little support and facilities for spontaneous migrants in the outer islands. Consequently, these migrants are more likely to depend on converting new areas than sponsored transmigrants [World Bank, 1986], as without instruction these settlers are unfamiliar with the outer islands, thus leading to less sustainable and more destructive shifting cultivation. Hence, increased unplanned migration to the outer islands may actually exacerbate rather than retard forest conversion.

The increasing speed of agricultural colonization in tropical forest areas has been affected by technical improvements in the agricultural sector. On the one hand, the availability of motor-driven saws has facilitated the clearing of sizeable forest areas in a short period of time. On the other hand, even small farmers can afford to rent agricultural machinery like tractors, thus increasing the land one peasant family is able to manage [Scholz, 1988].

In addition, the high population growth leading to an increased demand of agricultural land, especially in tropical forest areas has been identified as one of the crucial causes of deforestation [Allen, Barnes, 1985; Palo et al., 1987]. However, this should not lead to the conclusion

that in general high population growth must inevitably lead to an expansion into tropical forests, even if the country has no land reserves outside tropical forest areas, since agricultural products can be provided without further expansion. Basically, agricultural production can be made more productive by using improved methods of cropping and modern agricultural technology. Moreover, the productivity of land can be increased, when the unequal distribution of land in many tropical countries is changed. In many tropical countries, large landlords account for a high share of potential agricultural land. Some of these landlords can afford to underutilize that land in the sense that parts of their land is left idle, while other parts were cultivated extensively [Todaro, 1989, pp. 304-307]. If these hidden land reserves are utilized, agricultural production could increase without further expansion into forest areas. This, however, requires a land reform and a redistribution of unused land. Furthermore, the supply of food to the population can be complemented by substituting export crop production for food crop production and by allowing for imports of agricultural products.

4. The Role of Agricultural Policies and Land Tenure Systems

As the previous section has shown, government policies impact on the clearing of tropical forest areas for agricultural production. Besides settlement programs, agricultural policies provide many incentives or disincentives for individuals to start or increase production in tropical forest areas. Basically, there are two ways of discriminating in favour of producers in tropical forest areas. On the one hand, the government may provide regional incentives schemes that accrue to producers in tropical forest areas. As the soil in most tropical forest areas is of relatively poor quality this kind of discrimination against the agricultural sector outside forests may lead to an expansion of production into forest areas. On the other hand, the government can discriminate among sectors. This discrimination among sectors can favour or tax industries which strongly expand into tropical forest areas. If government regulations discriminate against these industries, their investment activities and growth prospects are likely to lose momentum both in

forest and in non-forest areas. The opposite holds true, when government policies discriminate in favour of these industries.

The first category of policy measures is subject to regional policy frameworks, as they have been partly discussed in the last section. There are several examples of discrimination among regions, for example, subsidization of settlers in tropical forest areas, as it has been discussed in the last section, or the subsidization of agriculture and manufacturing industries in the Brazilian Amazon. Until recently, enterprises in Brazil's Amazon region were given tax exemptions for both agricultural and non-agricultural profits. Over the period 1965 to 1983 direct tax credit subsidies worth US$1.4 billion were granted to 808 existing and new private investment projects, of which 35 percent went to 59 industrial wood producers (mainly saw mills) and over 42 percent to 469 livestock projects producing mainly cattle beef [Pearce et al., 1990, p. 201].

Especially a number of large-scale companies including some multinationals took advantage of this regulation and established cattle ranches in Amazonia, as the tax system created benefits even for the companies' activities outside the Amazon area. In 1983, the ranches under this tax incentive scheme covered 90,000 sq km [Kohlhepp, 1989]. However, it has to be noted that only a third of all ranches took advantage of this regulation, as the total area covered with ranches was estimated to amount to 350,000 sq km (Section IV.1). Nevertheless, these subsidized cattle projects which have an average size of 49,500 ha against 9,300 ha in non-subsidized ranches, are estimated to have caused over 26 percent of all forest cover alteration from 1972 to 1980 [Pearce et al., 1990, p. 201]. Hence, the subsidized ranch projects not only have a greater financial capacity to clear forest, but they also cover larger forest areas. Financial analysis of typical subsidized ranches reveal that without the subsidies the ranches would produce a net loss [ibid., p. 202; Repetto, 1988].

Beside these regional incentive schemes, governments tend to discriminate among sectors. This discrimination can create incentives for those sectors using tropical forest resources. There are a variety of policy instruments that can create an incentive scheme which is biased towards some sectors of the economy, namely taxes including allowances and exemptions, trade barriers, subsidies, land allocations, price

regulations, supply of preferential loans and costless infrastructure services, preferential treatment with respect to imported inputs, etc.

Though it is not possible to include all these policy instruments in some overall measures of protection, the effective rate of protection, as it is given in Table 21 for some agricultural products in selected tropical countries, yields some information on the discrimination among sectors.[1]

As the rates for Brazil and the South-East Asian countries show, the government discriminated against a number of producers of agricultural commodities. While some sectors show even negative rates of effective protection, the rates of protection were usually below the average rates of the whole economy or those of the manufacturing sector. Hence, factors of production, i.e., capital and labour, have been rather attracted by manufacturing industries which featured more profitable investment opportunities given the prevailing structure of protection.

However, not all agricultural products were discriminated compared to the manufacturing industry. In Indonesia and Thailand livestock production, slaughtering and meat production were highly protected. Since livestock production makes extensive use of agricultural land in most tropical countries, such a discrimination among agricultural products is likely to increase the demand for agricultural land and cause more deforestation than one would have expected under a neutral incentive scheme. Moreover, some foodcrops are heavily protected like rice in Zaire and Malaysia[2] as well as maize in Nigeria. These differential incentives are quite important, since farmers respond more to differentials among agricultural products than to overall discrimination against agriculture, because it is easier to shift land and other resources from one crop to another than it is to withdraw from agriculture [Askari, Cummings, 1976; Bale, Lutz, 1981].

As most developing countries discriminate against export crops, deforestation and soil erosion increases, because export crops with some exceptions as groundnuts and cotton tend to be less dangerous to soils

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1 All rates given in the table are calculated by using implicit rates of protection, which is the ratio between the domestic price of an agricultural commodity and the respective import price in the country.

2 For the case of Malaysia, see Krueger et al. [1988], where a different protection indicator is applied.

Table 21 - Effective Protection in Agriculture and Processing of Agricultural Goods in Selected Tropical Countries, 1978-1985 (a)

	Indonesia	Philippines	Thailand	Malaysia	Brazil	Nigeria	Zaire
	1980			1978	1985	1982	
Agriculture	.	3	.	29(b)	-15	.	-33(c)
Coconuts	.	-7	.	.	.	.	.
Cocoa	.	4	.	.	.	114	.
Maize	.	.	.	.	.	247	-10
Rice	.	.	.	.	-27	59	53
Manufacturing	56	36	49	34	29	.	.
Meat processing	59	14	71	20	-36	.	.
Dairy products	15	50	29	39	89	.	.
Canned fruits	33	15	-36	22	448	.	.
Palm oil	13	.	10	-75	.	-29(d)	4
Other vegetable oil	44	42	.	.	50	.	.
Flour	-2	804	148	0	46	.	.
Rice milling	-1	-2	-7	0	.	.	.
Tapioca	-1	.	-1	-1	.	1	.
Coffee	22	30	59	-11	-60	.	-68
Animal food	.	91	-11	-1	-32	.	.
Tobacco processing	66	.	.	.	-80	.	.
Rubber sheets	-11	.	-35	-13	93	34(c)	.

(a) Due to differences in national input-output codes, the product categories listed above can display differences across countries. - (b) 1973. - (c) 1981. - (d) 1970/76 average.

Source: Akrasanee, Ajanant [1986]; Amelung, Sell [1991]; Hock [1986]; Oyejide [1986]; Pangestu, Boediono [1986]; Tan [1986]; Tshibaka [1986].

than basic food crops. Moreover, many export crops, i.e., cocoa, coffee, rubber, palm oil and bananas grow on trees and bushes that provide continuous canopy cover and root structure.

Hence, it is not only the discrimination of the agricultural sector compared to the manufacturing sector that determines the level of agricultural production and thus the demand for agricultural land. In the same vein, the discrimination among agricultural products especially against those that are less land consuming, may result in an increased demand for agricultural land, thus fostering deforestation.

In Brazil, which was the country revealing the highest rates of agricultural conversion in the eighties, all agricultural products suffered from substantial discrimination except for dairy products as well as poultry and eggs, which are not large land consumers and not predominant in tropical forest areas. This raises the question whether a

reduction of this discrimination against the agricultural sector as a whole, as it has been stipulated by trade liberalization programs in many developing countries, increases the demand for agricultural land and thus the population pressure in tropical forests. In theory, a reduction of the discrimination against the agricultural sector results in increased profitability of agricultural production, thus attracting both capital and labour, which is presently engaged in the manufacturing sector or in the case of labour remains unemployed in urban areas. Basically, such an adjustment can be expected to raise the welfare of the country. Nevertheless, the demand for land will rise both in tropical forests as well as outside these areas. This may cause additional clearing of forest land.

However, this positive relationship between abolishing discrimination against agriculture and deforestation must not hold. There are several reasons for that. A reduction of discriminatory measures against agriculture may lead to higher prices (in the case of producer price limits or export taxes) or to lower input costs (in the case of import tariffs on essential inputs) for a number of agricultural products: This increase of profitability has two implications. First, this improves the income of small farmers in non-forest areas, who are no longer urged to give up their land and move into tropical forest areas, as they can afford to service their debt and keep their land. The case of Brazil shows that a large share of the migrants moving into the Amazon rain forest were actually small farmers and peasants that had been urged to give up their land in Southern Brazil [EK, 1990, pp. 248, 256-260]. Hence, it can be expected that rising producer prices lower the migration pressure in tropical forest areas.

Second, an increase of agricultural prices may cause investment increasing the productivity of land. Agricultural producers facing negative effective protection cannot afford to use more sophisticated agricultural technology and fertilizers, since the prices of their output goods are kept below the world market level, while prices for agricultural inputs may rank above the world market prices. A reduction of these government-induced discriminatory measures can help to increase agricultural productivity, thereby reducing the demand for marginal agricultural land. Nevertheless, further research is needed to analyse, whether these two effects outweigh the increased demand for forest land resulting from increasing agricultural prices.

Beside these measures, property rights regulations and land titling legislation affect the speed of conversion in tropical forests. Basically, agricultural production in tropical forest areas is characterized by low fertility soils, an abundance of land use relative to labour and few institutional constraints (i.e., land registration and titling). Under these conditions, land extensification and shifting cultivation is a rational production system.

In Brazil, it is mainly the land titling regulations which provide incentives for the expansion of agricultural land and deforestation. For example, a claimant who lives on an area of land has first preference to title for three times the area he or she has cleared. The right is obtained if the claimant has used and lived on unclaimed public land for more than five years or has squatted on private land for a sufficiently long time without being challenged by the owner. Hence, contrary to popular belief, there are no vast areas of unclaimed land available for settlement in the Amazon [Pearce et al., 1990]. Especially small farmers have difficulties in finding free land for squatting, since only corporations and large ranchers have the capital to built their own access roads into the forests. These large companies have an incentive to foster clearing in order to protect themselves against small squatters. The "first come first served" titling also ensures a rush to claim large tracts of land. [1]

The acquisition of land titles or user rights simply by cultivation is predominant in many tropical countries, for example, Malaysia (Sabah), Congo, Ivory Coast, Papua New Guinea. In some countries like Sierra Leone and Nigeria, user rights are still subject to tribal or community law. This does also apply to some regions in Cameroon, where land

[1] Moreover, the land tax can be legally reduced by a factor of up to 90 percent by converting unused forest land into more productive "use" or fallow land. Hence, a farm containing forests is taxed at a higher rate than one containing only pastures or cropland, while agriculture is virtually exempt from income tax laws [Binswanger, 1987]. Consequently the land tax system provides incentives for deforestation. The government enforced regulations prohibiting the clearing of more than 50 percent on private property. However, this regulation was circumvented through repeated sales and purchases of uncleared land. In addition, these laws provide an incentive for land acquisition in Amazonia, especially for wealthy private investors or corporations. Given high inflation rates and risky financial markets, land acquisition is an attractive alternative for portfolio investment and speculation.

tenure arrangements are informal though well-respected. [1] As far as these regulations provide only opportunities for leasing land for a given period of time, farmers have no incentives for long-term sustainable use of tropical forest land. In Thailand, the Philippines and Ghana "first come first served" regulations do not exist. Because of the deficient administrative capacity, the governments, however, cannot enforce their property rights on state-owned land and prevent spontaneous settlers from clearing forests.

Summing up, it can be conluded that in many tropical countries the creation of incentive schemes benefitting producers in tropical forest areas, i.e., government-induced migration programs and regional policy measures, have fostered the clearing of forest areas. In some tropical countries the production of food crops and livestock is highly protected. As far as these agricultural subsectors are predominant in tropical forest areas, a reduction of protection can help to reduce the agricultural expansion into forests. By contrast, the reduction of the discrimination against the agricultural sector in general must not necessarily lead to an increased demand for agricultural land and thus an increase in deforestation.

[1] This applies especially to regions without shortage of agricultural land. Given this condition, any individual from within a village can claim land through claim-staking and farm it within an area of control of that village. Outsiders wishing to farm land can do so only upon payment of some consideration to the village chief or upon marriage. The commonness of this practice has made these regions almost impervious to immigration [Ruitenbeek, 1990, p. 16].

V. Exploitation of Mineral Resources and Hydroelectricity Potentials in Tropical Forest Areas

1. The Expansion of the Mining Sector and Its Role for National Development

Another sector to which is attributed a leading role in tropical deforestation is the mining sector and hydroelectricity production. It is reasonable to discuss the impact of these two sectors on tropical deforestation in one chapter because these sectors are interlinked. The exploitation and processing of mineral sources is a highly energy-intensive process. Accordingly, the establishment of industrial plants processing mineral materials requires an extensive supply of energy, especially electricity.

In terms of economic performance, the mining industry is a key sector for a number of tropical countries. Table 22 shows that the share of mining activities in GDP ranged above 10 percent for a number of countries (Ecuador, Venezuela, Cameroon, Congo, Gabon, Guinea, Liberia, Nigeria, Zaire, Indonesia, Malaysia, Papua New Guinea). Since mining is a very capital-intensive industry, the mining sector's contribution to total employment ranged generally below 3 percent except for Guyana, Suriname and Liberia. By contrast, the mining sector ranks among the largest exporters in many tropical countries. There are a number of countries where the bulk of the export earnings is highly dependent on mining exports. In Bolivia, Peru, Suriname, Venezuela, Cameroon, Congo, Gabon, Liberia, Nigeria, Zaire and Papua New Guinea more than half of the country's total merchandise exports was produced by the mining sector.

These figures refer only to the exports of ores, while exports of intermediate products are neglected. A number of countries such as Brazil, Mexico and India have established metal processing industries such as aluminium and steel plants depending on the output of the mining industries. Table 23 shows shares of exports in production for a number of selected minerals. Hence, there are a number of countries in which the mining sector has become a major supplier of industrial inputs. In Brazil, more than 25 percent of the production of iron ore, manganese ore, copper and tin was processed by local industries. In India almost

Table 22 - Contribution of the Mining Sector to GDP, Exports and Employment in Selected Tropical Countries, 1988 (percent)

	Mining(a)/GDP	Mining employment/total employment, 1988(b)	Mining exports/merchandise exports, 1988(c)
Bolivia	10	1.7	89
Brazil	2	0.2	21
Colombia	8	0.5	26
Costa Rica	3	0.2	1
Ecuador	11	0.4 (1982)	45
Guatemala	3	0.2	3
Guyana	9	3.9 (1980)	33
Honduras	4	0.2	10
Mexico	5	2.3	38
Nicaragua	3	0.7	2
Panama	3	0.1	13
Paraguay	3	0.3	0
Peru	3	2.4	58
Suriname	9	4.6	67
Venezuela	17	1.0	90
Cameroon	16	0.1	53
Central African Republic	2	0.7 (1983)	0
Congo	17	na	72
Gabon	30	1.7 (1985)	59
Ghana	3	0.5 (1987)	32
Guinea	13	0.7 (1983)	83
Ivory Coast	3	na	3
Liberia	11	3.2 (1985)	54
Madagascar	1	na	14
Nigeria	22	0.1	88
Rwanda	1	na	9
Sierra Leone	9	1.4 (1981)	21
Zaire	20	na	64
Bangladesh	1	0.0	2
Burma	1	0.6	3
India	4	0.5 (1981)	9
Indonesia	13	0.7	49
Malaysia	15	0.6	18
Papua New Guinea	20	na	63
Philippines	4	0.7	12
Sri Lanka	3	1.1 (1986)	7
Thailand	5	0.2	3

(a) Including public services (gas, water, electricity). - (b) Economically active population. - (c) Mining exports comprise crude and refined fuels (SITC 3), minerals (27), metal ores (28) and nonferrous metals (68).

Source: ILO [various issues]; Statistisches Bundesamt [various issues]; UNCTAD [1991]; own calculations.

Table 23 - Share of Mineral Exports in Total Production, 1988 (percent)

	Bauxite	Chromite	Copper ore	Crude oil	Iron ore	Lead ore	Manganese ore	Nickel ore	Tin ore	Zinc ore
Bolivia	.	.	.	.	.	776	.	.	44.8(a)	.
Brazil	64.5(b)	.	.	.	72.1	.	62.8	.	0.0(a)	.
Mexico	.	.	31.7	50.2	.	3.7(a)	.	.	.	35(a,c)
Peru	.	.	14.4	2.7	79.6	65(a,c)	.	.	93.2	75(c)
Suriname	0.3(a)	.	.	.	.	.	.	.	.	.
Venezuela	.	.	.	50.0	67.4	.	.	.	.	.
Cameroon	.	.	.	12.9	.	.	.	.	.	.
Gabon	.	.	.	82.1	.	.	100.0	.	.	.
Guinea	81.8(a)	.	.	.	100.0	.	.	.	.	.
Liberia	.	.	.	.	95.1	.	.	.	.	.
Zaire	.	.	6.2(a)	68.3	.	.	.	.	100.0	5(a,c)
India	0.0	30(c)	.	.	64.1	.	22.4	.	.	.
Indonesia	90.0(b)	.	93.1(b)	45.6	.	.	.	42.0(a)	3.6(a)	.
Papua New Guinea	.	.	100.0	.	.	.	.	.	.	.
Philippines	.	85(c)	54.8	.	.	.	.	82.5	.	.
Thailand	.	.	.	.	.	88.3(b)	.	.	0.0(a)	0(a,c)

(a) More than 50 percent of the first stage of processing (primary metal; alumina in the case of bauxite) is exported. - (b) First stage of processing is imported, though the ore is available. - (c) Partially estimated.

Source: UNCTAD [1990]; US Bureau of Mines [1989]; own calculations.

40 percent of the iron ore produced in the country is processed by steel industries rather than being exported. In those countries, where export shares were comparatively low, the mining sector provided inputs for metal industries, which in turn have contributed to GDP and export performance of the respective countries.

On the whole, a high share of the world's mineral resources are located in countries that have sizeable closed forest areas. Table 24 shows that for 12 out of 29 minerals tropical countries had a percentage share of world reserves[1] exceeding 10 percent in 1988. More than half of the world reserves of bauxite, cobalt, niobium, tantalite and tin are located in tropical countries. However, there is not even one mineral which is only available in tropical forest countries. At the present stage of the analysis it is not possible to quantify the mineral reserves located in tropical forest areas for all tropical countries. Since this kind of analysis is quite complicated, it will be done for only three countries, namely Cameroon, Brazil and Indonesia.

As the study by Amelung and Diehl [1991] shows, a number of sizeable deposits are located in tropical forest areas in various countries. In some countries all sizeable deposits of one kind are located in tropical forest areas. This holds true for Congo (bauxite, iron, diamonds, gold, tin), Gabon (iron, chrome, diamonds, nickel, zinc), Suriname (iron, manganese, diamonds, gold), Guyana (copper, manganese, chromium, gold, nickel, zinc) and Kampuchea (molybdenum, copper, chromium, antimonium, pyrite, zirconium, bismuth). This is not very surprising, since this group of countries encompasses small nations with a forest area covering the major part of the country. If these countries plan to develop their resource base they can hardly avoid to open up a large part of their tropical forest areas for industrial development. By contrast, Brazil has not one mineral which is located in tropical forest areas only. The same does apply to the other countries with large tropical forest areas: in Indonesia only tin and lead are concentrated in tropical forest areas, while in Zaire it is the major deposits of uranium that are located in tropical forest areas only.

[1] Reserves refer to resources which are economically exploitable given the prevailing world market prices and the costs of exploitation of the respective deposit [US Bureau of Mines, 1990, p. 195]. Hence, a price increase or a less expensive exploitation method directly increases the volume of reserves.

Table 24 - Share of Mineral Reserves Located in Tropical Regions in World Reserves, 1988 (percent) (a)

	Africa (19 countries)		Asia (10 countries)		America (15 countries)		Total (44 countries)	
Antimony	.		.		11.6	(11.6)	11.6	(11.6)
Barite	.		22.3	(8.6)	5.4	(2.2)	27.7	(10.8)
Bauxite	25.7	(25.4)	4.6	(5.2)	20.1	(20.5)	50.4	(51.1)
Bismuth	.		.		22.9	(30.0)	22.9	(30.0)
Cadmium	.		.		6.5	(4.1)	6.5	(4.1)
Chromium	.		2.7	(0.9)	0.8	(0.1)	3.5	(1.0)
Cobalt(b)	41.1	(25.1)	-	(4.8)	.		41.1	(29.9)
Copper	7.4	(5.3)	3.4	(3.2)	3.4	(5.7)	14.2	(14.2)
Diamonds	15.3	(18.4)	.		0.5	(0.8)	15.8	(19.2)
Fluorspar	.		0.4	(1.2)	8.2	(7.1)	8.6	(8.3)
Gold(b)	.		.		2.2	(2.1)	2.2	(2.1)
Iron	0.8	(0.8)	5.0	(6.5)	11.6	(11.7)	17.4	(19.0)
Lead(b)	.		.		7.2	(5.8)	7.2	(5.8)
Magnesium	.		1.2	(1.3)	1.8	(1.9)	3.0	(3.2)
Manganese	6.4	(4.6)	.		3.0	(2.0)	9.4	(6.6)
Mercury	.		.		3.8	(3.8)	3.8	(3.8)
Molybdenum	.		.		4.1	(3.8)	4.1	(3.8)
Nickel	.		7.3	(21.6)	2.5	(4.6)	9.8	(26.2)
Niobium	1.8	(2.2)	.		93.6	(86.0)	95.4	(88.2)
Potash	.		.		0.3	(3.9)	0.3	(3.9)
Selenium	.		.		8.8	(9.2)	8.8	(9.2)
Silver(b)	.		.		22.1	(18.1)	22.1	(18.1)
Tantalum	14.6	(13.2)	37.5	(31.6)	4.2	(3.9)	56.3	(48.7)
Tellurium	.		.		3.5	(5.3)	3.5	(5.3)
Tin	1.0	(1.0)	48.6	(47.2)	18.5	(17.9)	68.1	(66.1)
Titanium(c)	0.7	(0.4)	12.4	(6.7)	23.7	(16.2)	36.8	(23.2)
Tungsten	.		1.8	(1.8)	2.6	(3.7)	4.4	(5.5)
Vanadium	.		.		-	(0.2)	-	(0.2)
Zinc(b)	.		.		8.9	(6.8)	8.9	(6.8)
Zirconium	.		5.8	(5.5)	2.8	(2.5)	8.6	(8.0)

(a) Measured plus indicated reserves. Reserves have been calculated on the basis of metal content. Figures in parentheses include subeconomic resources. - (b) A sizeable share of reserves was not reported on country level. - (c) Anatase, Ilmenite or Rutile.

Source: See Table A14.

As far as the geographical distribution of these major deposits over the three regions is concerned, no regional pattern can be observed [Amelung, Diehl, 1991]. A large set of metal ores, i.e., bauxite, iron, copper, manganese or gold are located in tropical forests all over the world. For instance, large deposits of bauxite are located in Brazil, Suriname, Indonesia, Malaysia, Cameroon and Congo, whereas major deposits of gold have been explored in almost every country's tropical forest area. Hence, there are not any structural characteristics by which the three major regions, namely Asia, Africa and America can be distinguished.

It has to be noted, however, that the exploration of mineral resources in tropical rain forests is technically extremely difficult because of the topographical conditions and the lack of infrastructure. As a result, there are good reasons to assume that there is a large number of unknown deposits in tropical forest areas. Most of the known deposits are located near towns, highways or rivers, where access is comparatively easy and less costly. Moreover, mining areas yield not only one mineral but rather a set of them. There are two reasons for that. First, exploration activities are easier and less costly in tropical forest areas which have already been partly developed as mining areas. Second, a number of metal ores are joint products, such as columbite (niobium) and tantalite, gold and copper, or lead and zinc. This leads to a concentration of mining activities and exploration in certain areas, while other areas remain unexplored.

Though the deposits listed in the study by Amelung and Diehl [1991] are classified as sizeable in the geological charts and infrastructure maps, only few of these deposits are sizeable relative to world reserves. Table A14 lists the percentage shares of tropical countries in the world's mineral reserves in 1988. Accordingly, there are only a few countries owning more than 10 percent of world reserves for one mineral source, namely Brazil (anatase, bauxite, iron, niobite, tin), Guinea (bauxite), India (barite, ilmenite), Indonesia (tin, nickel), Malaysia (tin), Mexico (silver), Nigeria (tantalite), Peru (bismuth), Sierra Leone (rutile), Thailand (tantalite, tin) and Zaire (cobalt, diamonds, tantalite). Following the FAO data, this list of countries comprises 68 percent of tropical forest resources in 1980 [Lanly, 1982]. Moreover, Table 24 shows that the sum of those tropical countries listed in Table A14 accounts for a sizeable share of world reserves of a number of minerals.

Despite the large number of deposits and the sizeable volume of resources located in tropical forest areas, there are only relatively few mining operations in tropical forest lands. The majority of mineral deposits in tropical forest areas have not been exploited because exploitation is not profitable. These deposits, however, can become

economic reserves, as the price of the respective mineral ore changes and infrastructure is extended into remote tropical forest areas. This seems to support the hypothesis that the development of mining industries in tropical countries may become a major source of deforestation.

A recent study by Amelung and Diehl [1991, pp. 200-203] yields a list of mines and mining areas located in tropical forests. In order to compile this list not all mines in the world have been considered, but only those listed in the Annual Mining Activity Survey of the Mining Journal Research Service [1990a]. [1]
Out of these 3,500 mines and mining areas only few are located in existing or former tropical forest areas. [2] According to Table 25, there are 93

[1] This list comprises 29 metals and minerals (gold, silver, platinum, copper, lead, zinc, tin, tantalite, mercury, aluminium, iron, chromium, manganese ore, molybdenum, niobium, nickel, antimony, titanium, vanadium, tungsten, uranium, asbestos, borax, diamonds, nitrate, phosphate, potash, pyrites and trona) and 1,249 mines producing more than 150,000 t p.a. These mines cover more than 90 percent of Western world ore output. It has to be noted, however, that there are roughly 6,000 mines producing less than this cut-off rate. This incurs some problems, since there are some tropical countries like Mexico, Bolivia, Brazil, India, Philippines, Malaysia and Thailand, where these mines represent an important part of the industry in the respective country. In addition, 1,700 coal mines as they have been derived from the Mining Journal Research Service [1989] accounting for 80 percent of Western World coal and lignite output have been considered. These lists have been updated by including major new projects and expansion programs as they have been listed in the Mining Journal Research Service [1990b; 1990c] covering roughly 550 additional mining projects.

[2] In several cases, it was not possible to determine whether the geographical location could be classified as a tropical forest area. The first one is the Kinta Valley, which is located 200 km north of Kuala Lumpur in Malaysia. Roughly 10 percent of the world's tin output comes from this valley [Schwartz, Askury, 1989]. Since this valley has already been industrialized in the fifties it was excluded. By contrast, the territory of the Bougainville and Ok Tedi mines in Papua New Guinea has been classified as tropical forest land, as vegetation maps indicate tropical forest near to these mines, while mining activities in this region are subject to major expansion programs. The Grasberg and Ertsberg mines in Irian Jaya (Indonesia) have not been classified as a tropical forest area, as they are located in a mountain region above 2,000 m. Nevertheless, it seems very likely that the infrastructure requirements, i.e., cable tramways and slurry pipelines for transport, harbour facilities 125 km away as well as a concentrating plant [Soesastro, Sudarsono, 1988] may have caused deforestation, which can be assumed to be marginal compared to annual deforestation rates, as calculated by the FAO and Myers [1989]. Finally, the Carajas

large mines or mining areas in tropical forest areas. Most of these mines are located in the Amazonian rain forest in Brazil, Indonesia, Zaire, the Philippines, Thailand, Papua New Guinea and Ghana. It has to be noted, however, that a number of mines in Ghana and Zaire are underground mines which deserve a different assessment with respect to their environmental impact. Production in underground mines and dredging requires only a very small proportion of land as an input factor, while the opposite applies for alluvial deposits and open-pit mining [Iwersen-Sioltsidis, 1988, p. 185]. As Table 25 shows, more than half of these mines are of the open-pit type, while Brazil, Papua New Guinea, the Philippines, Zaire and Indonesia account for more than two thirds of these mines. Hence, only in those countries the mining sector can be expected to account for a sizeable share in deforestation.

As mentioned above, it is not yet possible to quantify the production of these mines and the reserves of deposits located in tropical forest areas for a large number of countries. In the same vein, deforestation caused by the mining sector cannot be assessed for a number of countries. For this reason, this part of the analysis is done only for three countries, namely Cameroon, Zaire and Brazil. However, it has to be noted that though such an analysis can yield valuable insights, one should not forget that the share of most mines in national output is negligible, since the major part of the rain forests in Indonesia and Brazil have not been explored or exploited by mineral industries. Following Amelung and Diehl [1991, Ch. 5], only few deposits in tropical forest areas have been developed. This leads to the conclusion that the mineral resources located in tropical forests are still to become an input to the development of mining industries in tropical countries.

This is especially true for Cameroon where no major mining operations in tropical forest areas have been undertaken. In general, Cameroon is not well-endowed with mineral sources [BGR, 1976a], except for bauxite in the savannah area, offshore oil and gold. Gold production in Cameroon is mainly based on the exploitation of two equally sized deposits. Both of them have produced as much as 8,300 kg in the 1934-1974 period. In the recent years however, production declined to less than 10 kg p.a. Moreover, there are unexploited economic reserves of

iron ore deposit (Brazil) has been classified as a tropical forest area, though this does not apply to the entire planned mining area.

Table 25 - Number of Major Mining Areas and Mines in Tropical Forest Areas, 1990

	Dredging	Open-pit	Underground	Alluvial	Total
Brazil		10	1	5	16
Colombia		1			1
Ecuador				1	1
Guyana		3			3
Nicaragua		1	2		3
Peru	1				1
Venezuela		3			3
Ghana		2	4	3	9
Guinea		2			2
Ivory Coast		1			1
Liberia		2			2
Sierra Leone				1	1
Zaire		4	3	3	10
India		2	1		3
Indonesia		4		6	10
Malaysia		1	1	1	3
Papua New Guinea	1	7			8
Philippines		6	1		7
Sri Lanka				1	1
Thailand		4	1	3	8
Total	2	53	14	24	93

Source: Amelung, Diehl [1991, pp. 200-203].

rutile and ilmenite that have been discovered near the villages Ngambe, Mbalmayo and Akonolinya. However, these reserves are negligible compared to the country's total reserves which are concentrated in the coastal zones outside the tropical forests of the country. Summing up, it can be assumed that both direct and indirect effects of mining operations on deforestation have been negligible in the last 20 years.

By contrast, mineral resources in Indonesia's tropical forest areas are quite substantial. Data on the reserves and the production of particular locations, however, are only available from a report by BGR [1976b] for the mid-seventies. Accordingly, a large share of the oil reserves is located in tropical forest regions. The bulk of reserves is due to three oil fields in Central Sumatra, while the fields in Northwest Java and East Kalimantan are off-shore and accounted for less than 10 percent of the national reserves in 1975. Indonesia's oil reserves have been estimated to be 2,055 million t or 1.7 percent of world reserves, of

which 1,043 million t or 50.8 percent were due to the three fields in tropical forest areas, namely the Minas field (756 million t), the Duri field (242 million t) and the Bekasap field (45 million t). In 1974 these three fields combined 35.6 percent of Indonesia's oil production capacity. Despite the overwhelming economic importance of these oil fields in tropical forest areas, the direct and indirect impact of oil production on recent deforestation is probably very small. There are two reasons for that. First, large-scale exploitation on these three fields began very early in the beginning of the fifties. Second, indirect effects on deforestation are not likely to be expected, since most of the oil-processing facilities are located in coastal zones outside the tropical forest area.

Moreover, there are coal deposits of 204 million t or 6.7 percent of national reserves in 1975 located in tropical forest areas. Since production in these deposits requires underground mining and is comparatively expensive, all mines in tropical forest areas are presently out of production. In the same vein, 370 million t of iron ore deposits are located in tropical forest areas. Though this accounted for roughly 18 percent of Indonesia's total deposits and 51 percent of Indonesia's reserves, exploitation has not begun yet. In addition, Indonesia's tropical rain forest areas are reported to account for 375 million t of nickel reserves, which is 12 percent of world reserves and 71 percent of Indonesia's total reserves in 1975. Since mining operations in Sulawesi started in the early seventies, this has probably caused part of the forest loss.

Indonesia also possesses sizeable reserves of tin, of which approximately 6.7 percent were located in former tropical forest areas in 1975. Recent deforestation due to these mining activities is relatively unlikely. First, a sizeable share of these reserves is located off-shore. Second, all reserves in tropical forests are located on small islands, where large-scale mining activities can be traced back to the fourties and the fifties. Third, indirect deforestation caused by tin processing facilities can be excluded, as all plants are located outside tropical forest areas.

Indonesia's total bauxite reserves and bauxite production is located in former tropical forest areas, which have already been cleared since 1935. Production in 1975 was as much as 1.4 percent of world production and is only due to small islands, where also processing takes place. Bauxite reserves located in the tropical forest areas of Kalimantan have

not been fully explored yet. Finally, there are a few other minerals like copper, gold, silver, mercury, antimonium and bismuth which are partly located in tropical forest areas. The respective reserves and production in tropical forest areas are quite small in terms of their economic importance to the Indonesian mining sector and world mineral production.

Summing up, total land allocation for oil, mining and other major developmental projects appears relatively small compared to total land area of the outer islands where the bulk of Indonesia's primary forests is located [Pearce et al., 1990, p. 104]. In general, most of the land is allocated for exploration purposes. Significant amounts of land are used only when minerals or oil is actually found. Following the geological maps of the BGR [1976b] the oil fields located in tropical forest areas cover not more than 1,100 sq km. By comparison, annual deforestation in the 1980-1990 period was 8,600 sq km. Assuming that the total land area in the oil field will be cleared and that clearing proceeded in these oil fields at an annual average of 30 sq km a year since 1950, the direct contribution of oil production to deforestation would be 0.3 percent in terms of annual deforestation in the 1980-1990 period. This kind of calculation is questionable, since most mineral deposits under production had already been developed in the fifties. Hence, the overall impacts on deforestation are usually confined to relatively small areas, since the outer islands of Indonesia have not yet experienced a process of large-scale industrialization. Following the industrial census of 1987, approximately 83 percent of the country's medium and large-scale manufacturing is concentrated in the inner islands of Java and Bali. Another 11 percent are due to Sumatra, while all other outer islands account for 6.2 percent [Pearce et al., 1990, p. 93]. However, the concentration of extractive industries and their processing facilities in small areas have led to serious problems of pollution which can be damaging to coastal zones and forest areas. Especially the recent and rapid expansion of gold mining activities in Kalimantan has led to excessive destruction of riverbanks and swamp areas in and near important protective and conservation forests [Pearce et al., 1990, p. 104].

While in Indonesia most of the mines in tropical forest areas have been established before 1960, the exploitation of mineral deposits in the Amazon rain forest of Brazil is by comparison a rather new development which began at the end of the seventies. Table 26 shows the measured

Table 26 - Mineral Resources in Tropical Forest Areas in Brazil, 1987

	Measured resources in tropical forest areas(a)		
	1000 t	share in Brazil's total measured resources(b)	share in world-wide resources(b)
		percent	
Bauxite	246,600	29 (36)	(4.2)
Chromium	45	2 (1)	(0.0)
Copper	3,889	65 (80)	(1.6)
Diamonds	1,170(c)	11 (20)	(0.2)
Gold	19(d)	4 (4)	(0.1)
Iron	1,611,221	25 (30)	(3.0)
Kaolin	487,760	82 (83)	na
Manganese	12,057	41 (40)	(0.7)
Nickel	329	7 (11)	(0.4)
Tin	221	73 (73)	(10.8)
Zirconium	449	48 (55)	(1.0)

(a) The Brazilian term "reservas" apparently coincides with the above mentioned "resources"-concept [MME-DNPM, 1987, p. 11], whereas economic resources (reserves) are only reported in US Bureau of Mines [1990] on country level. Resources have been calculated on the basis of metal content. - (b) Figures in parentheses refer to the respective shares in measured plus indicated resources. - (c) In 1000 carate. - (d) In t.

Source: MME-DNPM [1988]; US Bureau of Mines [1990]; own estimations.

resources located in Brazil's tropical forest areas. Accordingly, the bulk of the country's resources of zirconium, tin, copper and manganese is located in tropical forest areas.

About 50 percent Brazil's zirconium resources and more than two-thirds of the tin, kaolin and copper resources were located in tropical forests, whereas the iron reserves in tropical forest areas accounted for less than one-third of Brazil's total resources in 1987.[1] Exploration for

[1] This result is quite surprising, since according to common belief a large share of the world's iron ore resources are located in the Carajas area in the Amazon rain forest. The relatively moderate share of iron ore resources in tropical rain forests can be explained by the abundance of iron ore resources outside the Brazilian rain forest. Moreover, it has to be noted that the shares calculated in Table 26 are based on measured resources of iron ore content which yield a high reliability. If one recalculates these figures on the basis of measured plus indicated resources, the respective share for iron is 40 percent

other minerals in tropical forest areas especially oil and gas have not come up with measured reserves. Some of the resources in the Brazilian Amazon are even sizeable in terms of their share in worldwide resources. The resources of bauxite[1], tin and iron constituted more than 3 percent of world resources. Nevertheless, it would be an exaggeration to consider these resources as having strategic importance for the world mineral supply. This holds also true for tin which accounts for more than 10 percent of world reserves. The resources of chromium, diamonds, nickel and gold are clearly less than 1 percent of world resources, thus, being of no importance for the world mineral supply in the medium term.

Despite an abundance of exploitable deposits, not all potential mining areas have entered production yet. As Table 27 shows, bauxite, diamonds, tin, iron, manganese and gold are produced in tropical forest areas. In 1987, more than 75 percent of Brazil's manganese and tin production and almost one-third of its iron ore production were due to establishments located in tropical rain forests. Despite relatively small resources of gold compared to Brazil's total resources, gold production in tropical forest areas is quite well developed reaching almost one-third of national output. On the whole, the metal production in Brazilian rain forests exceeded 30 percent of national production. The share in Brazil's total mineral production is significantly smaller because of the high value of Brazil's oil and natural gas production which is located outside tropical forest areas. Given this level of production in tropical forest areas, the contribution of the mining sector in tropical forest areas to Brazil's GDP can be estimated as less than 1 percent in 1987.

Brazil's mineral production in tropical forest areas records sizeable shares in worldwide production. Tin production in the Brazilian Amazon accounted roughly for one-seventh of world production in 1987, while manganese production recorded a share of more than 7 percent. Since 1987, however, mining of tin, bauxite and iron ore increased significantly.

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for 1987 [MME-DNPM, 1988]. For calculations based on estimated resources see Kohlhepp [1987, p. 56].

[1] The large bauxite deposits near the mouth of Rio Trombetas, which account for almost 50 percent of Brazil's resources (or 8 percent of world resources) have been excluded since the region was not covered with dense rain forest when mining operations started.

Table 27 - Estimated Production of Mineral Commodities in Brazil's Tropical Forest Areas, 1987

	Production in tropical forest areas		
	mil. cruzeiros	share in Brazilian production(a)	share in world production(b)
		percent	
Bauxite(c)	1222	14.1	1.4
Diamonds(c)	53	5.3	0.1
Gold	7763	32.8	1.4
Iron	13512	32.7	2.8
Kaolin	1104	44.8	na
Manganese	1909	75.7	7.4
Metals	30226	33.4	na
Tin(c)	5820	78.6	13.8
All minerals	31383	9.6	na

(a) Shares in national production have been calculated on the basis of output values as they are given in the first column of the table. - (b) Shares in world production have been calculated on the basis of quantities. - (c) In the Brazilian mining statistics production data can be obtained on state level and not for particular mines. However, there are states with rain forest areas but some mines located outside tropical forest areas. In these cases production of tropical forest mines has been estimated by assuming that the mine's share of production in total production of the respective state corresponds to the mine's share in total reserves of the respective state.

Source: As for Table 26.

The contribution of mineral production to Brazil's export performance is quite difficult to assess because of two reasons. First, there are no data on export shares on the firm or mine level. Hence, one has to assume that mines located in tropical rain forests record on average the same export shares as the national average ratio of mining exports to mining production. Accordingly, the share of exported unprocessed mineral commodities in production was 48 percent for bauxite, 72 percent for iron ore and 37 percent for manganese ore in 1987. Gold and tin ore were not exported [UNCTAD, 1990]. Hence, the share of exported minerals produced in tropical forest areas in total mineral exports was one-third for 1987, while the share in total exports was 2 percent for the same year. This high share is due to the fact that the bulk of

mineral production in tropical forest areas is iron ore exploitation (Table 27), the larger part of which is exported without processing.

Second, one should take into account that a sizeable share of the mineral commodities exploited in tropical forest areas is processed. Hence, the export share given above should be taken as a lower margin, as exports of processed mineral products are an important item in Brazil's export basket. However, at this stage of the analysis, it is not possible to calculate the share of these products that draw upon mineral resources from tropical forest areas.

While the mining sector in tropical forest areas is relatively important in terms of export sector performance, the mining activities' contribution to national employment are only marginal. As mentioned above, the mining sector and its related processing industries are relatively capital-intensive. Hence, the employment facilities created by the development of the mining sector are quite small compared to the employment effects that can be expected from the expansion of other sectors. Following the employment statistics given in MME-DNPM [1988] for 1987, employment in the mining industries in tropical forest areas was 21,940 employees or 23.4 percent of total employment in the mining industries. These employment figures cover both production of primary mineral commodities as well as the first stage of their processing. Because of the high transport costs, these processing facilities are usually located in the mining area. Hence, the direct employment effect of mineral extraction in tropical forest areas is relativly negligible, reaching 0.05 percent of Brazil's total employment in 1987. [1]

As far as the mining sector's contribution to tropical deforestation is concerned, the size of the mining areas in the Amazon region seems to point to the fact that direct deforestation due to mining operations is

[1] Yet, it has to be mentioned that these employment data do not include inofficial and small-scale gold mining activities. The number of these gold miners has been reported as 40,000 in Roraima [Treece, 1990, p. 264] and 75,000 in the Serra Pelada (Para) [Fearnside, 1990, p. 211], whereas the total number of "garimpeiros" has been estimated as 300,000-500,000 [Hecht, Cockburn, 1989]. Following these two studies, direct deforestation caused by these gold miners is only marginal, while their detrimental impact is mainly due to pollution of rivers. Moreover, there are a number of pig iron smelters and ferrous alloy plants projected for 1990 along the Carajas railway corridor in tropical rain forest areas. These establishments are to create 4,063 jobs.

comparatively small. According to MME-DNPM [1988], the size of the mining areas accounted for 5,175 sq km in the North and the Northeast of the country. This was 0.1 percent of Brazil's closed forest area in 1980 and 0.2 percent of the primary forest area in 1989. Assuming that all of this mining land was covered with tropical forests prior to 1980, the average annual clearing for mineral exploitation is 646 sq km in the 1981-1988 period. Given an average annual deforestation of 24,300 sq km, as it was estimated for the 1981-1988 period (Table 16), the mining sector's direct contribution to tropical deforestation was 2.6 percent in the eighties. [1]

The bulk of deforestation caused by the mining sector in Brazilian Amazon can be directly attributed to the development of the Carajas mining area, which is 4,290 sq km and thus by far the largest mining project that has been undertaken in tropical forest areas [Shaw, 1990, p. 91]. Even neglecting that only a part of this area was covered with tropical rain forests, the Carajas mining area amounts to a maximum of 0.1 percent of the forest area in 1980 and 0.2 percent of the primary forest area in 1989. Again, this is a relatively small amount compared to an annual rate of deforestation of 2.3 percent in 1989 and of 0.4 percent in 1980-1985.

Hence, there is reason to assume that the major part of deforestation related to mining sector development can be attributed to related industries and infrastructure requirements. It has been calculated that approximately 2,000 sq km have to be deforested in order to meet the annual charcoal requirements of the steel industries in the Carajas area [Anderson, 1990]. [2] However, these calculations have been challenged by Nitsch [1989], who took into account that the production of fuelwood per ha is actually higher than it was planned. Accordingly, the forest loss resulting from charcoal production is reduced to 400 sq km or 3 (1) percent of annual deforestation in 1981-1985 (1989). [3]

[1] Depending on the deforestation data used, the contribution of the mining sector varies between 4.7 percent in the 1981-1987 period [FAO/UNEP, 1981] and 1.2 in 1989 [Myers, 1989].

[2] This amounts to 15 percent of annual deforestation in 1980-1985 or 4 percent of deforestation in 1989.

[3] The use of charcoal for mineral processing is not uncommon in tropical countries. It has been reported that the processing of copper has led

Yet, forest clearing is due to related industries. Most of the aluminium smelters are located near Belem (in Barcarena) and São Luis. Moreover, most tin processing plants are located outside tropical forest areas. Hence, the impact of tin and bauxite processing on tropical deforestation is negligible. This does not apply to the 17 iron and steel plants located along the Carajas railroad which were planned to start operation in 1990. Following maps published by Kohlhepp [1987], approximately 800 km of this railroad have been constructed in rain forests. Assuming that these steel plants and other infrastructure services cover an average strip of 1 km on each side of this railroad, this results in a deforestation of an area as large as 1,600 sq km.

If all projects of the Grande Carajas Program, which stipulates a rapid industrialization of the region until 2010, are realized, this would cause the degradation and destruction of an area totalling 900,000 sq km [Alvers, 1989; Shaw, 1990]. Assuming that 80 percent of this area is covered with trees, the resulting deforestation and degradation would comprise 20 percent of the closed forest area in 1980 or 40 percent of primary forest in 1989. However, the majority of the projects of this program are not related to the mining sector, as they comprise agricultural projects (64 percent of approved projects) and cattle farms (19 percent of approved projects). Hence, it is questionable whether the infrastructure requirements in this planning region can be attributed to the mining sector.

Another sector, which is related to the processing of minerals, is the generation of electricity. The generation of power in tropical countries, which are highly dependent on hydropower, is generally highly land-intensive. For this reason, electricity generation is expected to be a major cause of deforestation. Since electricity generation is not directly related to the mining sector but rather to the mineral processing industry, the impact of hydropower production on deforestation will be discussed in the next section.

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to extensive harvesting of fuelwood in primary forestland in Zambia [Lewis, Berry, 1988, Ch. 11]. Accordingly, in the fifties approximately 2,500 ha of forest land had to be cleared. However, this figure ranges below 0.1 percent of the remaining forest areas at the end of the seventies.

2. Dam Construction and the Generation of Hydroelectricity

Since the processing of ore is a highly energy-intensive form of production, investment in the power sector encompasses a large share of the infrastructure requirements of the mining sector and its related industries. Most moist tropical forest areas are located in regions with large rivers bearing a high hydropower capacity.

As it can be obtained from Table 28, most tropical countries have not been in a position to utilize the bulk of their hydropower potential in 1986. Accordingly, the share of hydropower generation in the exploitable potential was below 20 percent except for Thailand and Sri Lanka. In Congo, Guyana, Madagascar, Papua New Guinea and Zaire this share ranked below 1 percent of the exploitable potential. For comparison, Japan, the USA and West Germany recorded shares reaching 65, 81 and 79 percent in 1986. In the case of Brazil, which bears the highest hydropower potential among all tropical countries, approximately 87 percent of the exploitable potential are located in Amazonia. In 1988, the utilization rate of the Amazonian hydropower resources was already comparatively high reaching 25 percent [Sommer et al., 1990]. In the same vein, 86 percent of Malaysia's hydropower potential is located in Sabah and Sarawak, both of them being regions with the highest forest cover in Malaysia.

Even though the hydropower sector is still to be developed in many tropical countries, the current importance of hydroelectricity to the economy of the tropical countries is considerable. Basically, electricity generation is an infrastructure service that does not provide a sizeable contribution to GDP and employment, once the construction of the dam is completed. For instance, the Tucurui dam which is one of the largest dams built in tropical forest areas, operates with a staff of 2,000, while 30,000 workers were employed for its construction [EK, 1990, p. 552]. Hence, employment effects resulting from dam projects can only be expected in related industries. Moreover, electricity cannot be viewed as a tradeable good given the lack of interconnected systems in most parts of the world. The supply of power and electrification is, however, believed to enhance regional development and to attract energy-intensive industries [Mehltretter, Amelung, 1986]. Despite the low utilization of their hydropower potential, the electricity generation from hydropower

Table 28 - Hydroelectric Potential and Hydropower Generation in Selected Tropical Countries, 1986

	Exploitable potential	Total hydropower generation	
		Share of potential	
	GWh		percent
Bolivia	90000	1116.0	1.24
Brazil	1194500	172052.0	14.40
Costa Rica	37000	2890.6	7.81
Guyana	63100	1.8	0.00
Venezuela	330000	31400.0	9.52
Cameroon	100000	1500.0	1.50
Congo	50000	75.0	0.15
Gabon	32500	420.0	1.29
Madagascar	32000	262.0	0.82
Senegal	200	0.0	0.00
Zaire	530000	4000.0	0.75
India	600100	52539.0	8.76
Indonesia	709000	9517.7	1.34
Malaysia	114779	5149.0	4.49
Papua New Guinea	95000	500.0	0.53
Sri Lanka	6000	2395.0	39.92
Thailand	17700	4860.2	27.46

Source: Water Power and Dam Construction Handbook [1988].

plants provides a considerable contribution to the national power supply. As Table 29 shows, the share of hydroelectricity plants in total installed capacity exceeds 20 percent for most of the tropical countries listed. The share of hydroelectricity in total power generation is even higher, since hydropower plants are used to meet the base load demand, thereby serving the needs of the industrial sector.

In order to utilize the hydropower capacity of the rain forest areas a number of large dams have been built. A list of these dams can be obtained from Amelung and Diehl [1991], which also contains large dams under planning and construction. In addition, the second part of the list includes a number of smaller dams, which have been compiled for Venezuela, Malaysia, Indonesia, Zaire, Cameroon, Colombia and Brazil. Except for Venezuela, which has built a number of smaller dams in rain forest areas, the inclusion of these smaller dams does not alter the results. There are two reasons for that. First, most of these smaller dams have been constructed in the fifties and the sixties. For this

Table 29 - Hydropower Generation in Selected Countries, 1980-1988

		Installed capacity (MW)			Electricity generation (GWh)		
		hydro	total	(1)+(2)	hydro	total	(3)+(4)
		(1)	(2)	percent	(3)	(4)	percent
Bolivia	(1984)	304	566	53.7	1195	1695	70.5
Brazil(a)	(1986)	39102	46149	84.7	193100	211800	91.2
Colombia(a)	(1983)	3539	5550	63.8	15184	23034	65.9
Costa Rica	(1984)	631	819	77.0	2975	3067	97.0
Ecuador	(1985)	741	1778	41.7	3240	4490	72.2
Guatemala(b)	(1987)	442	812	54.5	1714	1911	89.7
Guyana	(1983)	2	168	1.2	5	435	1.1
Honduras(c)	(1984)	131	273	48.1	874	1184	73.8
Mexico	(1986)	6532	21210	30.8	19900	89400	22.3
Nicaragua(a)	(1985)	100	338	29.6	256	986	26.0
Panama	(1983)	298	704	42.3	866	2239	38.7
Paraguay	(1986)	890	900	98.9	1640	1644	99.8
Peru	(1986)	2050	3575	57.3	10058	12935	77.8
Suriname	(1983)	189	415	45.5	725	1300	55.8
Venezuela	(1983)	3500	9812	35.7	17000	41700	40.8
Cameroon	(1984/85)	527	610	86.4	2319	2374	97.7
Central African Republic(a)	(1984)	20	30	66.7	65	68	95.6
Congo(a)	(1984)	120	149	80.5	251	253	99.2
Equatorial Guinea(a)	(1980-82)	1	7	14.3	2	26	7.7
Gabon	(1985)	329	na	na	668	861	77.5
Ghana	(1986)	1072	1185	90.5	3670	3749	97.9
Guinea	(1986)	47	176	26.7	165	497	33.2
Ivory Coast(a,d)	(1984/86)	885	1163	76.1	1192	2086	57.1
Liberia	(1986)	81	325	24.9	318	819	38.8
Madagascar	(1985)	45	102	44.1	258	462	55.8
Nigeria(a)	(1984)	3178	na	na	2596	9036	28.7
Rwanda	(1984)	43	46	93.5	94	96.3	97.5
Sierra Leone	(1986)	2	110	1.8	na	na	na
Zaire	(1983)	1661	1716	96.8	4150	4213	98.5
Bangladesh	(1983)	130	1087	12.0	662	3758	17.6
Burma(a,e,f)	(1987/88)	258	746	34.6	1121	2279	49.2
India(a,g)	(1986/87)	16	49	32.9	54	188	28.6
Indonesia	(1986)	1660	8470	19.6	7040	29850	23.6
Kampuchea(a)	(1984)	10	35	28.6	30	70	42.9
Malaysia (West)	(1985)	1229	3897	31.5	3300	13341	24.7
Papua New Guinea	(1982)	100	328	30.5	306	1266	24.2
Philippines	(1985)	1839	6581	27.9	7409	21018	35.3
Sri Lanka(h)	(1984/87)	542	812	66.7	2177	2707	80.4
Thailand(i)	(1982/84)	1538	5073	30.3	4081	22029	18.5

(a) Data include only public enterprises. - (b) Installed capacity refers only to public enterprises. - (c) Only "Empresa Nacional de Energia Eléctrica". - (d) Installed capacity: 1984; electricity generation: 1986. - (e) Period: April - March. - (f) Only "Electric Power Corporation". - (g) Installed capacity: position as per March 31, 1987; electricity generation: 1986/87, period: April - March. - (h) Installed capacity: 1984; electricity generation: 1987, only "Ceylon Electricity Board". - (i) Installed capacity: 1982; electricity generation: 1984.

Source: Statistisches Bundesamt [1986a; 1986b; 1987a-p; 1988a-p; 1989a-o; 1990a-f].

reason, the impact on deforestation in the seventies and eighties is relatively small. For instance, all of Zaire's dams in tropical rain forest areas have been built between 1949 and 1956. In the same vein, the only

dam which is located in Cameroon's rain forest areas was built in 1953.[1] Second, these dams have been quite small in terms of their reservoir area which can be taken as an indicator for their forest conversion. The five dams located in Zaire's rain forest areas, account for a reservoir area adding up to 19 sq km. In the same vein, Indonesia's only dam which has caused major tropical forest conversion has a maximum reservoir area of 16 sq km.

In the seventies and the eighties there was a tendency to construct fewer and larger dams which led to higher rates of land conversion than the sum of smaller dams that had been built prior to that. Despite of the small number of large dams located in tropical forest areas, the flooding of forest land was substantial, as it can be obtained from Table 30.[2] However, in relative terms, deforestation due to large dams can be regarded as negligible. Assuming that the flooded areas have a forest coverage of 100 percent, the share of flooded areas, due to dams, in the total remaining forest area in 1980 did not exceed 1 percent for all of the seven countries that have undertaken major dam projects.

While countries like Cameroon and Zaire have not performed major dam projects in tropical forest areas in the 1970-1990 period, the forest area converted into dam reservoirs in Malaysia and Indonesia ranges below 0.01 percent in terms of existing forest areas in 1980. Only in Brazil this conversion is quite high in terms of existing forest areas in 1980. The two large dam projects, which have been planned in Suriname and Sarawak (Malaysia) respectively, have been cancelled in the eighties.

In Brazil, the country with the largest number of large dam projects, the area flooded reaches only 0.2 percent. Even if one includes all dam projects which entered the planning stage, the area consumption of

[1] The related power generation is mainly supplied to the city of Douala and to an aluminium plant, which went into operation in 1957 and has a maximum capacity of 60,000 t of crude aluminium p.a.

[2] The areas of the dam reservoirs have been obtained from EK [1990], Rosa et al. [1988], Lazenby and Jones [1987] and ICOLD [1988]. For some dams it was not possible to estimate the conversion of land into dam reservoirs either because the maximum area of the reservoir was not available or a part of the reservoir is due to a natural lake or large river. In the first case, the area of the dam reservoir was estimated by taking a sixth of the dam height above the lowest formation as an average depth of the reservoir and dividing the maximum reservoir capacity by this average depth.

Table 30 - Tropical Forest Areas Converted into Major Reservoirs for Hydroelectricity Generation, 1970-1990 (a)

	Estimated area converted into reservoirs, 1970-1990		For comparison:	
	total	share in closed forest area, 1980	estimated annual rates of deforestation	
			1980(b)	1989(c)
	sq km	percent		
Brazil	7700	0.2	0.4	2.3
Colombia	22	0.0	1.8	2.3
Mexico	434	0.2	1.8	4.2
Venezuela	286	0.1	0.7	0.4
Indonesia	16	0.0	0.5	1.4
Malaysia	1	0.0	1.2	3.1

(a) This table includes also dams under construction. Dams that are in a planning stage are excluded. - (b) FAO/UNEP estimates for closed forest. - (c) Myers'sestimates for tropical moist forest.

Source: Table 3; Amelung, Diehl [1991, pp. 235-237].

hydroelectricity plants does not exceed 0.6 percent of primary forests in 1989. Nevertheless, the exploitation of hydropower may become a major source of deforestation in Brazil in the next two decades. Following the Energy Plan 2010, about 80 dams are to be built in the Amazon basin. All planned dam projects are located in tropical rain forests except for those dams that are built at the upper Araguaia-Tocantins river system. It has been estimated that the area of the dam reservoirs would total approximately 100,000 sq km [Fearnside, 1989]. This is roughly 6 percent of all remaining tropical moist forests in 1989.[1] These figures are, however, highly speculative, as it is presumed that all dams that are currently under planning will be actually constructed. Given the current low degree of capacity utilization in Amazonian power plants, it seems to be likely that eight large dams will be finalized until 2010 covering an reservoir area of 20,000 sq km [Nitsch, 1989].

[1] Since the forest coverage in the respective areas is often below 100 percent, this figure is probably too high.

The percentage share of dam construction in total deforestation is quite different across countries in the 1970-1990 period. There are only a few countries which have undertaken large dam projects in this period, namely Brazil, Malaysia, Mexico, Venezuela, and Indonesia.

Following our own estimates of deforestation in the 1971-1988 period (as they can be obtained from Table 16), the percentage contribution of dam reservoir construction to tropical deforestation yields 1.6 for Brazil, 0.04 for Malaysia, 0.4 for Mexico, 0.5 for Venezuela and 0.02 for Indonesia.[1] Since only a few countries have built large dams in tropical forests in the 1970-1990 period, the contribution of dam construction to global rain forest deforestation is approximately 8,500 sq km or 0.5 percent. (If one takes deforestation data of the FAO and Myers, this percentage rate ranges between 0.3 and 0.6.) Hence, the direct impact of dam construction on the destruction of tropical forest ecosystems is comparatively small.

The calculation of percentage shares of large dam projects in deforestation on an annual basis or for a given period of time is highly arbitrary. Annual rates of deforestation as they have been calculated by Myers [1989] and Lanly [1982] are long-term averages. Fluctuations from one year to another cannot be excluded. A part of these fluctuations may be due to large projects like dam construction. Usually the flooding or clearing of areas takes less than two years, while few large dam projects are finalized irregularly across time. If one relates the deforestation due to the dam reservoir to the average annual deforestation in the period of the dam construction, the resulting share in deforestation would definitely be an overestimate, since large dam projects

[1] If one takes the annual deforestation rates estimated by the FAO for 1980-1985 as annual average deforestation in the 1970-1990 period, the percentage contribution of dam construction is 2.8 for Brazil, 0.02 for Malaysia, 0.5 for Mexico and 1.1 for Venezuela. However, these relative shares should be regarded as maximum rates, as the FAO figures for 1981-1985 are likely to be underestimations. If one takes Myers's [1989] deforestation rates for 1981-1989 as an annual average for the 1970-1990 period, the contribution is 0.8 for Brazil, 0.01 for Malaysia, 0.3 for Mexico and 1.0 for Venezuela, while the percentage share for Indonesia is 0.01 in both estimations. It should be noted, however, that Myers's [1989] estimations are likely to give the lower margin for the hydropower sector's contribution, since annual average deforestation in the 1970-1990 period was lower than deforestation in the eighties.

are not finalized every year but rather irregularly. For purposes of comparison, Table 30 yields also the average annual rates of deforestation.

It has to be concluded that the deforestation which is directly related to large dam projects was only marginal, since the area covered with dam reservoirs was relatively small compared to total forest conversion. However, this must not apply for related industries. Moreover, the case of Brazil shows that the majority of industrial energy consumers is located in large cities or outside tropical forest areas. Nevertheless, it can be expected that in the future the availabilty of cheap electricity will attract electricity-intensive industries, especially the metal-processing sector, a part of which will also be located in tropical forest areas. These plants in turn may directly and indirectly add to future deforestation.

Although the hydropower sector is still to be developed in many developing countries, there are already some countries in which the development of the hydropower potential in tropical rain forest areas provides already a considerable contribution to national electricity generation. In 1986 large dams in tropical rain forests accounted for 9 percent of Brazil's total installed capacity. In Mexico, Colombia and Ghana this share was 17, 18 and 74 percent. Since the hydropower sector serves predominantly the base load demand by industrial users, the development of such sizeable hydropower potentials in tropical forest areas may become a major stimulus for industrial development in tropical forest areas and additional deforestation. However, this must not hold true for countries, in which the processing of minerals relies on the use of charcoal and firewood. As the clearing for energetic use of wood is much larger than the areas flooded for dam reservoirs, the use of electricity in manufacturing instead of wood and charcoal is likely to reduce deforestation.

VI. Summary and Conclusions

1. Sources of Deforestation and Forest Degradation in Tropical Countries

As the previous chapters have shown, there are a number of economic sectors using the rain forest as an economic resource, thereby depleting the rain forests. The forestry and the wood industry in tropical countries make use of the tropical wood in these forests. For the agricultural sector the tropical forest areas constitute a huge land reserve which can be utilized to expand agricultural production. In addition, there are many non-wood forest products which can be extracted without major forest disturbances. The mining sector and the related processing industries located in tropical forest areas engage in the exploitation of mineral resources and of the hydropower potential, which facilitates the generation of electricity and, hence, investment in energy-intensive industries.

For various reasons, an assessment of the percentage share of these economic activities in destruction of the rain forest ecosystem has to remain tentative. First and foremost, it is the weakness of most official data sources that stems from the lack of global forest inventories. Hence, it cannot be discriminated exactly between forest use categories (for example, virgin forest, selectively logged forest or secondary forest in the shifting cultivation cycle). Even the FAO figures for total forest area on country level were repeatedly corrected backwards due to this methodological problem. Second, official data on deforestation, which in FAO sources is a reduction of the crown cover to less than 10 percent, are only provided for closed forests and open formations. It should be kept in mind, however, that closed forests especially in West Africa and some South American countries comprise also formations other than moist evergreen. In addition, deforestation rates are in many cases the result of extrapolating scattered information on country level with population growth rates. In the case of forest degradation the estimation is even more difficult since degradation is sometimes only gradual. Finally, it is hard to blame one specific sector for deforestation, when the forest resources have been used successively or jointly by several sectors. In addition, the identification of the sectors involved is always to be enriched with hints on the complex system of incentives and disincentives that indirectly causes the forest disturbance.

Table 31 shows the estimated percentage share of various economic activities in deforestation for the three countries studied and average values for 40 tropical countries. Accordingly, the agricultural sector recorded the highest share in all tropical countries ranging between 80 and 100 percent. Within the agricultural sector the shifting cultivators accounted for the largest share of deforestation in Indonesia, Cameroon and on average for all tropical countries. The expansion of areas under shifting cultivation is not simply caused by high population growth rates, but is due to a bundle of reasons, including national settlement programs, soil degradation on land areas cultivated before and the frequent marginalization of the rural population. It has to be noted, however, that presently a large part of the shifting cultivators comprises small market-oriented farmers producing cash and export crops and not for pure subsistence needs. Hence, the separation between shifting cultivations and the pioneer front of more sedentary farming systems is in practice rather superficial. While shifting cultivators accounted for the largest share of deforestation in Indonesia and Cameroon, their respective share is relatively small in Brazil, where the major part of deforestation is due to livestock production.

By contrast, the mining industry and related processing facilities accounted for a very small share in total deforestation, as the analysis for Cameroon, Brazil and Indonesia shows. Only in Brazil, where a number of mining projects in tropical rain forests have been established in the last decade, the deforestation due to the mining industries and the respective infrastructure requirements exceeded 2 percent. In the same vein, large dam projects have not significantly added to worldwide deforestation in relative terms. Again, it was Brazil, which has recently built a number of dam reservoirs in rain forest areas. The share of these dam reservoirs in deforestation was 2 percent against an average of less than 1 percent for all major tropical countries.

The forestry sector recorded relatively low shares in terms of deforestation because in most tropical countries trees have been harvested through selective logging rather than total clearing. Selective logging does not add to deforestation following the definition given above, even though the reduction of biomass and the modification of

Table 31 - Sources of Deforestation in Tropical Countries, 1981-1990 (percent) (a)

	Brazil	Indonesia(b)	Cameroon	All major tropical countries
Forestry	2	9	0	2-10(c)
Agriculture	91	90	100	86-94
shifting cultivators(d)	15	59	79	41-49
	(23)	(67)	(95)	(47)
permanent agriculture	76	31	21	45
of which:				
pastures	40	0	0	24
permanent crops	4	3	3	3
arable land	32	28	18	18
Mining including related industries	3	0	0	1
Dam construction	2	0	0	1
Other(e)	2	1	0	2

(a) Figures refer to deforestation of closed forests in the strict sense, i.e., degradation has not been regarded. - (b) Estimates provided by Pearce et al. [1990] have been reconciled, using mainly FAO sources. - (c) The higher figure is from EK [1990], where the loss of biomass through logging activities has been estimated. - (d) Figures in parentheses are taken from FAO/UNEP [1981]. Other figures have been calculated as residual. - (e) Road construction and other industries.

Source: Anderson [1990] for the forestry sector in Brazil (see Section V.1); FAO [c] and FAO/UNEP [1981] for the agriculture sector (see Tables 16 and 20); Pearce et al. [1990] for additional information on Indonesia (see Table 19); own calculations for the mining sector (see Section V.1) and for dam construction (see Table 30).

forests through selective logging may incur serious ecological damages and economic costs. Fuelwood production is not a major factor in conversion of tropical moist forests, since predominantly open forests, shrubs and plantations are concerned. Moreover, people collecting fuelwood concentrate on broken or dry tree parts, and on logging waste. In the long run, however, the biomass reduction due to fuelwood collecting may contribute to soil degradation.

In order to take account of the damages caused by the forestry sector other measures than deforestation have to be assessed. Table 32 features two other indicators namely percentage share in biomass reduction and percentage share in forest modification. Assuming that the ecological and economic damages can be measured by the degree of biomass reduction, this percentage rate can serve as a proxy for the combined sectoral share in deforestation and forest degradation. Degradation is especially high in Indonesia, where the number of trees harvested per ha is larger than in Africa and Latin America. As Table 32 shows, the forestry's share is much higher than its share in deforestation if one accounts for forest degradation. Nevertheless, even in terms of biomass reduction the agricultural sector recorded the lion's share in forest disturbance.

An alternative measure, namely forest modification, assesses the share of various economic activities in converting virgin forests into productive closed forests or other forms of land use. Accordingly, even minor disturbances would be considered as an irreversible damage. The rationale behind this concept is the assumption that forest modification opens up the virgin forests for other economic sectors, in the sense that successive users of tropical forest resources face lower costs of investment in infrastructure. If one takes the percentage rate of forest modification as a yardstick, the forestry sector accounted for nearly all forest modification, since agriculture and other sectors rarely entered virgin forest formations, but already disturbed or modified forest areas.

However, the percentage shares in forest modification cannot be interpreted in such a way that the forestry sector accounts for the lion's share in the destruction of the tropical forest ecosystem, and that a prohibition of logging would preserve virgin forests and hinder other sectors from entering these forest areas. There are two reasons for that. First, forest modification does not measure the degree of disturbance of the rain forest ecosystem. Though forest modification certainly incurs ecological damages, it does not necessarily destroy the entire regenerative capacity of the ecosystem. This is to say that deforestation in degradated forest areas may incur more ecological damages than the degradation itself, since it is only clearing which involves a complete and almost irreversible destruction of rain forests.

Table 32 - Sectoral Share in Forest Degradation and Forest Modification, 1981-1988 (percent)

	Share in biomass reduction (degradation)				Share in forest modification			
	Brazil	Indonesia	Cameroon	Total (b)	Brazil	Indonesia	Cameroon	Total (b)
Forestry	6	44	10	10	(100)(c)	(100)(c)	98	71
Agriculture(d)	87	55	90	85	0	0	2	26
Others(d)	7	1	0	4	0	0	0	4

(a) For the definition of modification and biomass reduction (degradation), see Chapter III. - (b) Total refers to all major rain forest countries (Chapter III). - (c) Following FAO statistics, deforestation in virgin forests is 0, since clearing by agriculture and other sectors concentrates on disturbed forests. Even though some clearing occurs in virgin forests, there is reason to assume that the bulk of deforestation is due to forests that have been logged over prior to the clearing of the respective areas. - (d) These figures have been derived from Table 31 and reflect averages for the 1981-1988 period or, in the case of Indonesia, the 1980-1990 period.

Source: As for Tables 12 and 31.

Second, the opening up by the forestry sector could only be regarded as the main source of forest disturbance, if it was clear that otherwise potential users face prohibitive costs of entering virgin forests. This, however, is a strong assumption, which does not hold true for all forests and all economic sectors. Basically, mining activities, dam projects or large-scale agricultural holdings do not depend on infrastructure established by the forestry sector. Only in countries, in which the share of shifting cultivators in deforestation is very high, logging can be considered as a necessary first step of destruction by opening up forest areas. Hence, a prohibition of forestry activities cannot be considered as a general solution in the sense that deforestation would be reduced to a large extent. In this respect, further research is needed in order to find out to what extent logging actually facilitates successive economic activities.

2. The Impact of Tropical Rain Forest Resources for Economic Development in Tropical Countries

All of the resources and commodities exploited and produced in rain forests are of relatively minor importance for the world economy, since their share in world trade, world production or world reserves is comparatively low. However, a complete ban of these commodities from world markets could incur price increases and severe regional disparities during the adjustment process in the industrialized countries, since some countries heavily rely on tropical resources, as, for instance, Japan on tropical roundwood.

This does not apply to the relevance of these resources to the economies in tropical countries. All of the tropical countries can be classified as developing since they aim at an improvement of their economic welfare relative to the level prevailing in industrialized countries. Producers, consumers and governments in tropical countries regard tropical forest resources as an input for their economic development. Despite the detrimental ecological and economic impact, the exploitation of these resources may follow an economic rationale. The underlying reason is that, given the low income levels and the abundance of rain forest resources in many tropical countries, short-run goals like serving the basic needs of the population are given a higher priority than long-run goals like preserving the environmental quality.

The contribution of rain forest resources to development is commonly measured in terms of three indicators, namely the contribution of these resources to the export performance of the economy, the share of exploitation and processing of these resources in GDP as well as the employment resulting from these activities. The export performance of the respective sectors can be of major importance to many tropical countries because it affects the credibility of the country on world capital markets and increases the country's import capacity. Many tropical countries are highly dependent on imports of capital goods to enhance industrialization and development. Moreover, the share in GDP shows to which extent production in these countries depends on rain forest resources. In the same vein, the contribution of sectors using rain forest resources to total employment reveals to which extent these sectors help to lower unemployment and underemployment in tropical countries.

On the other hand, it should be accounted for the costs of exploiting or converting forest areas in terms of lost revenues from forest products and environmental degradation [Farnworth et al., 1983]. The case studies in Browder [1989] indicate that extensively harvested non-wood forest products, for example, nuts, vegetable oils, natural rubber or hunted animals may sustainably contribute a large share to rural income. Deforestation thus imposes an annual cost on the regional population in terms of income foregone. Concerning the environmental aspect, part of the detrimental consequences, for example, the degradation of watersheds and of soils, is also revealed as income foregone, since the regional revenues in agriculture decline. Other consequences are typically not monetary or not visible, for example, lower water quality or changes in regional or global climate. Although all these costs are obviously far from negligible, they have not been considered in the present study due to the weak empirical data base.

As far as the *agricultural* sector is concerned, there are a number of countries, in which the conversion of tropical forest areas adds a sizeable share to total agricultural land. In 1988, more than 5 percent of agricultural land in Indonesia, Brazil, Costa Rica, Ecuador, Guatemala, Suriname, Cameroon, Ivory Coast and Thailand consisted of tropical forest converted in the 1981-1988 period. Even though these percentage rates seem to be very small, one should not forget that only agricultural land in the 1981-1988 period has been considered. If one includes land cleared in the seventies, the percentage shares given above generally increase. For some countries, for example, Costa Rica, the Philippines and Thailand, large shares can be recorded only in the seventies.

According to our estimations for Cameroon, agricultural production on areas converted in the 1981-1988 period in Cameroon comprised approximately 3 percent of agricultural production in 1988 excluding livestock production. In Indonesia, this share was 5 percent and in Brazil 7 percent of agricultural production. Whereas in Indonesia and Cameroon livestock production in tropical forest areas plays only a minor role, in Brazil 5 percent of production in 1988 was due to pastures cleared in the 1981-1988 period. Employment effects due to these cattle ranches were negligible reaching less than 0.1 percent of national employment in 1988. In the same vein, export shares of cattle production should be negligible, since production in tropical forest areas is mainly for the domestic

market. On the whole, agricultural production on areas converted in the 1981-1988 period accounted for less than 2 percent in all three countries analyzed.

The importance of agriculture in terms of employment cannot be quantified, since a large share of the small producers are not included in government statistics. However, it can be assumed that the role of agricultural employment in tropical forest areas is greater than the percentage shares in total production given above. The reason is that the majority of agricultural holdings in tropical forest areas are small farmers and shifting cultivators using less sophisticated agricultural technologies compared to producers in non-forest areas.

The contribution of the *forestry sector* to employment and GDP cannot be estimated on a global level, since in most official data sources this sector is not separated from agriculture. However, there are a number of countries, in which the exports of this sector accounted for more than 5 percent of total export revenues in 1988. If one includes processed wood, this share exceeded 10 percent for most countries in Africa and Asia. Moreover, in 1980 the processing of wood recorded more than 10 percent of employment and more than 5 percent of value-added in the manufacturing sector for the majority of tropical countries. Hence, both in terms of employment and exports the logging and processing of wood seems to be an important industry in most tropical countries.

Compared to the respective share in deforestation or even in biomass reduction, forestry and wood processing seemingly exceeds the agricultural holdings on newly deforested land in its economic relevance. This result, however, is subject to some restrictions of our analysis. First, major components of both sectors could not be analyzed quantitatively. This applies to the shifting cultivation sector as well as to the harvesting of non-wood forest products. Second, neither agriculture nor forestry have been analyzed in terms of sustainability. This is to say, that the relative importance of forestry decreases in those regions, where the regenerative capability of the forest has been seriously affected, since the forestry revenues from this region cannot be regarded as permanent.

Despite the rich endowment with mineral resources in tropical countries and in tropical forest areas in particular, only few countries have established sizeable *mining operations* in tropical forest areas, for

example, Brazil, Guyana, Venezuela, Ghana, Zaire, Indonesia, Malaysia, Papua New Guinea, Thailand and the Philippines. Among the three countries analyzed, Indonesia and Brazil show sizeable reserves in tropical forest areas, while in Cameroon the exploitation of mineral resources is not profitable given their small resource base and poor reserves. In Indonesia, the majority of the mines located in tropical forests have started production more than 20 years ago. This does also apply to Indonesian oil fields located in rain forests. These fields account for a third of Indonesia's oil production capacity and a half of the country's reserves, thus being of major economic importance to the country. However, since recent conversion of tropical forests into mining land was extremely small even in terms of absolute area size, its respective contribution to exports, employment and GDP was negligible.

Even in Brazil, which experienced a strong expansion of mining land into rain forest areas in the recent decade, the mining sector and their related processing facilities in tropical forest areas generally accounted for negligible shares in GDP and total employment. In 1987, mining operations in rain forest areas recorded only 2 percent of GDP, while the share in national employment was less than 0.1 percent for the same year. This, however, is not surprising, since in most tropical countries the mining sector does not account for sizeable shares in total employment and GDP. By contrast, the export of mining products constitutes a sizeable share in the countries' total merchandise exports. For the case of Brazil, mining industries located in tropical forest areas accounted for 5 percent of the country's merchandise exports in 1987. In this respect, mining industries in tropical forest areas provide a significant contribution to the country's development.

The relatively low shares of mining in tropical forest areas in employment, GDP and total exports do not allow for the conclusion that mineral resources in tropical forest areas are of minor economic importance for tropical countries. First, it has to be accounted for the fact that currently only a minor part of mineral deposits in tropical forest areas is under mining, while it can be expected that the mining sector in these areas will be developed in the future. This applies especially to countries which have a large share of their mineral resources of one kind located in rain forests, for example, Indonesia, Brazil, Suriname, Guyana, Congo, Kampuchea and Laos. Second, the

above analysis has neglected all industries depending on minerals produced in mines in tropical forest areas.

In the same vein, the *hydropower potential* in tropical forest areas is currently not fully utilized. There are a number of countries in which a large part of the hydropower potential is due to rivers or basins in rain forests, for example, Brazil, Cameroon, Malaysia, Indonesia, Guyana, Gabon, Venezuela, Zaire, Papua New Guinea and Congo. In Malaysia and Brazil almost 90 percent of the hydropower potential is located in rain forests. Because of the low degree of utilization in all tropical countries, the present relevance of hydropower production for the domestic economies is only marginal. Only in Brazil, Mexico, Colombia and Ghana the share of installed hydropower capacity in tropical forest areas exceeded 9 percent of the total capacity in the eighties. Though these hydropower facilities do not significantly increase employment and GDP of the respective tropical countries, their impact on development is quite significant, since the supply of cheap energy can attract industries which depend on an assured supply of electricity. Moreover, hydroelectricity generation widens the import capacity of the tropical country, if hydropower replaces electricity generation from imported coal and fuels.

Some hypotheses should be added, which deal with questions of natural resources and development strategies, but which slightly exceed the objectives of the present study.

First, the exploitation of natural resources cannot be regarded as a sound basis of economic development, nor as a necessary precondition for rapid economic growth. A successful resource-based developed strategy comprises plans for the investment of resource revenues in domestic manufacturing industries as well as measures for the stabilization of ecological conditions. In both respects, many resource-rich countries have failed, even under more favourable conditions of the world economy than those prevailing in the eighties. On the other hand, the experience of the sixties and seventies shows, that even less developed countries with no major natural resources can start with a successful development strategy, based on human capital formation and step-wise industrialization.

Second, the world economy has put severe pressure on all less developed countries in the eighties, especially in terms of availability of

foreign capital. This must not lead to the conclusion, however, that the obligation of a country to service its foreign debt coerces the accelerated exploitation of natural resources. The large amounts of foreign debt would cause less problems, if the respective credits had been invested properly in the seventies and if policy-induced economic conditions had been kept liberal, so that the debt could now be serviced out of investment revenues. On the other hand, even with large national debt obligations there are ways of maintaining the standing on world capital markets, for example, through improvements of the conditions for foreign direct investment and credible future liberalization announcements.

Third, the role of projects financed by bilateral or multilateral development aid is ambiguous, since this category comprises large scale infrastructure projects as well as pilot projects in forestry or agriculture aiming at the development of sustainable land use systems. Nevertheless, it can be stated that all these projects are in relative terms far from being an important contribution to rainforest disturbance.

3. Assessment of Policy Measures for the Conservation of Tropical Rain Forest Ecosystems

Since it was not the objective of this study to develop policy concepts, the following policy conclusions have to remain brief and tentative. Nevertheless, there are three policy conclusions that can be derived from the above analysis:

1) The conservation of tropical forests can only be achieved by a bundle of policy measures as there are a number of sectors involved in the disturbance of rain forests, especially agriculture and forestry which are the two main causes of deforestation.
2) Special consideration should be given to an economic valuation of the ecological services of intact forests, though the value cannot always be quantified exactly. Therefore, this bundle must encompass both domestic policy measures in the respective tropical countries as well as international agreements.
3) Even a large reduction of international trade in tropical hardwood is not likely to directly reduce logging substantially, since the bulk of tropical hardwood is consumed in tropical countries, whereas the reduction of export revenues incurs losses of their economic growth potential. Moreover, deforestation may even increase, since the economic value of intact forests decreases if the cultivation of forest areas looses attention and the ecological functions are still not kept into account.

As far as the forestry sector is concerned, long-term concessions should be introduced in order to create incentives for sustainable management [Pearce et al., 1990]. Moreover, a resource use tax could be a useful policy instrument, which gives an incentive for an optimal use of wood resources. In order to enforce these policy measures, the capacity of forestry employees in tropical countries has to be improved.

These measures aiming at the forestry sector have to be supplemented by agricultural policy reforms, since agriculture is the main source of deforestation. In order to achieve an efficient use of resources, land reserves outside tropical forest areas have to be allocated to potential farmers, while special incentives for migration into tropical forest areas and production in these areas have to be reduced. Moreover, the present system of land titling in many tropical forest areas has to be improved in order to guarantee property rights, reduce extensive expansion of land and increase incentives for long-term agricultural holdings.

Most of these policy measures are costly to implement. In addition, the subsequent structural adjustment in the economy of the tropical countries is painful and hardly sustainable for some of these countries. On top of that, the governments of the tropical countries view the tropical rain forest as an input for development and may not be inclined to renounce the destructive use of tropical rain forests. Hence, even if the government follows an optimal policy from the tropical country's viewpoint, the resulting deforestation may still be too high from the perspective of industrialized countries, which derive benefits from the existence of the rain forest ecosystem. If non-tropical countries have an interest in the persistence of tropical rain forest ecosystems, reform programs have to be supported by industrialized countries and multilateral organizations in order to be politically and economically sustainable and successful. Such a payment should be regarded as a compensation for the export of environmental services rather than as development aid or a donation from one country to another.

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Most of these policy measures are costly to implement. In addition, the subsequent structural adjustment in the economy of the tropical countries is painful and hardly sustainable for some of these countries. On top of that, the governments of the tropical countries view the tropical rain forest as an input for development and may not be inclined to renounce the destructive use of tropical rain forests. Hence, even if the government follows an optimal policy from the tropical country's viewpoint, the resulting deforestation may still be too high from the perspective of industrialized countries, which derive benefits from the existence of the rain forest ecosystem. If non-tropical countries have an interest in the persistence of tropical rain forest ecosystems, reform programs have to be supported by industrialized countries and multilateral organizations in order to be politically and economically sustainable and successful. Such a payment should be regarded as a compensation for the export of environmental services rather than as development aid or a donation from one country to another.

The discussion of policy measures that are to be implemented by industrialized countries has revealed a variety of policy proposals, which cannot be discussed in detail. Basically, these approaches stipulate trade barriers against commodities produced by using tropical forest resources or require compensation payments for those tropical countries. The former, however, cannot be regarded as useful policy measures for the reasons given above.

Moreover, import barriers can be questioned on the grounds that the entire burden of adjustment is shifted to the tropical countries. As it was discussed in the preceding chapters, supply of wood and mineral sources produced in tropical forest areas can be substituted. As these resources do not account for a large share of world supply, industrial countries can import these products without major price increases. Hence, the industrialized countries would not be severely affected. The tropical countries, however, are likely to be affected by the loss of export earnings, since tropical hardwood and mineral sources exploited in tropical forest areas record relatively high shares in the exports of tropical countries. These losses of exports are likely to affect the development of the tropical countries.

The alternative solution involves the supply of financial means to those tropical countries which are prepared to implement measures for environmental protection. Such transfers are to compensate tropical countries for the reduction of economic benefits, resulting from the preservation of rain forest areas. There are various institutional arrangements under which such compensation payments can be given to tropical countries, for example, an international rain forest fund, debt-for-nature swaps, bilateral aid, internationally tradeable carbondioxide permits etc.[1] An implementation of such an international arrangement can

[1] For a discusion of these arrangements see EK [1990, pp. 802-830, 852-864] as well as Amelung [1991; 1992]. At present, it is not possible to calculate the amount of compensation payments necessary to save a sizeable share of the remaining rain forests. However, calculations have been made for the transformation of rain forest areas into protection forest. For instance, Ruitenbeek [1990] has calculated the compensation payments necessary to save the Korup Park in Cameroon. Accordingly, the conservation of these 200 sq km of rain forest would require 212,000 ECU p.a. or 1,060 ECU per sq km p.a., while the author concedes that the cost of protection for the rain forest ecosystem is comparatively high.

help to create economic incentives for the reduction of environmental degradation in tropical countries, as these countries are given the opportunity to preserve their environment without losses in terms of economic development.

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Appendix Tables

Table A1 - Production of Fuelwood and Charcoal, 1980 and 1988

	Fuelwood production		Charcoal production		Total wood production for energetic use		Total roundwood production	
	1000 m^3		1000 mt		1000 m^3			
	1980	1988	1980	1988	1980	1988	1980	1988
Angola	3441	4214	na	na	3441	4214	4331	5258
Cameroon	7973	9885	na	na	7973	9885	10167	12574
Central African Republic	2485	3055	na	na	2485	3055	3009	3449
Congo	1386	1710	1	3	1393	1728	2193	3315
Equatorial Guinea	421	447	na	na	421	447	445	607
Gabon	1766	2396	na	na	1766	2396	3113	3618
Ghana	9647	12750	384	529	11951	15924	12932	17025
Guinea	3244	3923	na	na	3244	3923	3801	4559
Ivory Coast	5906	8231	144	200	6770	9431	12139	12813
Liberia	2400	2700	263	339	3978	4734	4837	5889
Madagascar	5330	6827	na	na	5370	6827	6137	7634
Nigeria	67449	88283	1111	1455	74115	97013	81475	104881
Sierra Leone	2279	2756	6	7	2315	2798	2473	2938
Zaire	24644	31525	na	na	24644	31525	26824	34239
Belize	79	126	na	na	79	126	123	188
Bolivia	948	1178	12	15	1020	1268	1453	1417
Brazil	121746	144975	4778	5690	150414	179115	212122	245751
Colombia	10584	12520	417	495	13066	15490	16120	18163
Costa Rica	2163	2713	13	17	2241	2815	3516	3961
Ecuador	3610	3940	323	406	5548	6376	7577	9336
French Guiana	54	60	1	1	60	66	248	254
Guatemala	5797	7276	na	na	5797	7276	5956	7390
Guyana	11	13	1	1	17	19	206	228
Honduras	3801	5014	na	na	3801	5014	4913	5957
Mexico	11709	14115	105	127	12339	14877	18684	22302
Nicaragua	2288	2990	na	na	2288	2990	3168	3870
Panama	1671	1708	na	na	1671	1708	2010	2047
Paraguay	3402	4082	152	195	4314	5252	6726	8358
Peru	6104	7591	10	12	6164	7663	8152	8780
Surinam	20	2	2	3	32	20	369	202
Venezuela	578	722	na	na	578	722	1214	1464
Brunei	79	79	na	na	79	79	213	294
Burma	14431	17046	na	na	14431	17046	17383	21033
India	192397	228880	1584	1884	301901	240184	221585	264412
Indonesia	114878	133257	105	122	115508	133989	146430	173598
Kampuchea	4161	5110	na	na	4161	5110	4728	5677
Laos	2422	2921	90	108	2962	3569	3172	3878
Malaysia	4861	5847	308	370	6709	8067	35782	44431
Papua New Guinea	5390	5533	na	na	5390	5533	7142	8231
Philippines	25863	31854	2	29	25875	32028	34983	38214
Sri Lanka	7182	8154	30	8	7362	8202	8036	8882
Thailand	25900	30026	518	601	29008	33632	33738	38214
Vietnam	19444	23248	na	na	19444	23248	22530	26620
Total	729944	879682	10360	12617	792104	955384	1002174	1191951
World	1378249	1639412	17427	21330	1482808	1767393	2933730	3431072

Source: FAO [a, 1988].

Table A2 - Production and Trade of "Tropical Hardwood", 1980 and 1988 (a)

	Production		Exports				Exports/production (quantity)	
	1000 m^3		mil. US$				percent	
	1980	1988	1980	1988	1980	1988	1980	1988
Angola	750	904	na	na	na	na	na	na
Cameroon	2194	2689	743	538	113.9	74.6	33.9	20.0
Central African Republic	524	394	137	28	27.5	8.0	26.1	7.1
Congo	800	994	281	382	44.6	69.5	35.1	38.4
Equatorial Guinea	24	160	16	120	2.2	10.7	66.7	75.0
Gabon	1347	1222	1071	913	129.5	114.7	79.5	74.7
Ghana	981	1101	105	339	12.4	45.4	10.7	30.8
Guinea	557	636	na	8	na	0.8	na	1.3
Ivory Coast	5369	3382	3055	550	490.2	72.1	56.9	16.3
Liberia	859	1155	475	681	84.0	87.8	55.3	59.0
Madagascar	807	807	0	2	0.1	0.5	0.0	0.2
Mozambique	933	942	11	6	3.3	2.6	1.2	0.6
Nigeria	7360	7868	10	60	0.8	6.0	0.1	0.8
Sierra Leone	158	140	na	na	na	na	na	na
Togo	143	178	na	na	na	na	na	na
Uganda	1385	1777	na	na	na	na	na	na
Zaire	2180	2714	66	113	8.3	15.3	3.0	4.2
Belize	42	44	7	8	0.6	0.3	16.7	18.2
Bolivia	433	149	na	na	na	na	na	na
Brazil	20395	23845	7	46	1.5	3.8	0.0	0.1
Colombia	2425	2308	na	na	na	na	na	na
Costa Rica	1265	1140	0	4	0.0	1.2	0.0	0.3
Ecuador	2029	2696	na	na	na	na	na	na
French Guiana	188	188	36	5	3.3	0.3	19.1	2.7
Guatemala	52	11	na	2	na	0.2	na	18.2
Guyana	189	209	23	22	2.5	5.3	12.2	10.5
Honduras	30	39	0	0	0.1	0.1	na	na
Mexico	364	464	na	na	na	na	na	na
Nicaragua	535	535	5	na	1.5	na	0.9	na
Panama	339	339	na	3(b)	na	0.0	na	0.9
Paraguay	2412	3106	0	na	0.0	na	0.0	na
Peru	1953	1107	na	na	na	na	na	na
Surinam	337	182	26	7	2.1	0.6	7.7	3.8
Venezuela	636	742	na	na	na	na	na	na
Brunei	134	215	na	na	na	na	na	na
Burma	2952	3987	77	206	42.1	72.8	2.6	5.2
India	16396	20401	27	61	14.0	17.7(b)	0.2	0.3
Indonesia	29898	38939	14884	3	1513.5	0.3	49.8	0.0
Kampuchea	562	562	2	0	0.0	0.0	0.4	0.0
Laos	210	309	18	34	8.2	10.0	8.6	11.0
Malaysia	28448	35740	15180	20574	1205.3	1532.7	53.4	57.6
Papua New Guinea	1326	2416	642	1283	46.5	101.0	48.4	53.1
Philippines	8149	5543	1154	176	148.9	6.1	14.2	3.2
Sri Lanka	643	649	0	na	0.0	na	0.0	na
Thailand	4730	4582	1	na	0.3	na	0.0	na
Vietnam	2842	3128	na	na	na	na	na	na
Total	153824	177741	38048	26168	3903.9	2250.6	24.7	14.7

(a) The category "tropical hardwood" consists of all wood removals from broadleaved species, except pulpwood and wood for energetic use. - (b) own estimations.

Source: As for Table A1.

Table A3 - Production and Trade of Sawnwood from "Tropical Hardwood", 1980 and 1988 (a)

	Production		Exports				Exports/production (quantity)	
	1000 m^3				mil. US$		percent	
	1980	1988	1980	1988	1980	1988	1980	1988
Angola	10	5	na	na	na	na	na	na
Cameroon	380	368	83	93	21.4	21.8	21.8	16.4
Central African Republic	71	52	36	24	9.5	7.1	50.7	46.2
Congo	64	57	37	25	13.4	9.2	57.8	43.9
Equatorial Guinea	3	42	0	9	0.0	1.6	0.0	21.4
Gabon	88	106	18	1	3.5	0.1	20.5	0.9
Ghana	160	390	69	170	23.2	45.4	43.1	43.6
Liberia	43	311	43	14	11.0	4.2	100.0	4.5
Guinea	90	90	na	na	na	na	na	na
Ivory Coast	664	775	277	460	72.7	122.0	41.7	59.4
Madagascar	231	234	na	na	na	na	na	na
Mozambique	51	27	8	0	2.1	0.0	30.8	0.0
Nigeria	2782	2700	2	1	0.3	0.1	0.1	0.0
Sierra Leone	24	12	na	3	na	0.2	na	25.0
Zaire	121	121	24	20	4.0	4.2	19.8	16.5
Belize	20	9	5	6	1.2	2.1	25.0	66.7
Bolivia	216	91	91	57	19.0	18.2	42.1	62.6
Brazil	7738	9795	622	533	145.1	169.2	8.0	5.4
Colombia	900	680	11	3	2.6	0.9	1.1	0.4
Costa Rica	512	503	0	3	0.0	0.5	0.0	0.6
Ecuador	903	1278	8	15	4.1	13.7	0.9	1.2
French Guiana	19	19	1	12	0.2	1.8	5.3	63.2
Guatemala	33	na	25	12	3.8	1.4	75.8	na
Guyana	70	57	14	9	3.7	2.7	20.0	15.8
Honduras	7	2	2	na	20.2	28.4	48.0	39.8
Mexico	84	169	na	na	na	na	na	na
Nicaragua	230	127	1	1	0.0	0.1	0.4	0.8
Panama	53	45	na	na	na	na	na	na
Paraguay	649	900	285	112	52.2	20.6	43.9	12.4
Peru	602	534	16	3	3.0	1.0	2.7	0.6
Surinam	74	63	13	3	3.3	0.8	17.6	4.7
Venezuela	349	325	na	na	na	na	na	na
Brunei	60	90	0	0	0.0	0.0	0.0	0.0
Burma	421	472	118	31	68.9	14.6	28.0	6.6
India	9244	14834	2	2	0.6	0.9	0.0	0.0
Indonesia	4797	10173	1203	2983	258.1	553.8	25.1	48.2
Kampuchea	43	43	na	na	na	na	na	na
Laos	41	16	25	2	2.7	0.3	61.0	12.5
Malaysia	6234	6189	3141	4103	583.2	717.6	50.4	66.3
Papua New Guinea	133	74	45	4	9.2	0.8	33.8	5.4
Philippines	1529	1033	742	629	181.3	156.4	48.5	60.9
Sri Lanka	22	16	1	na	0.7	na	4.5	na
Thailand	1527	1024	2	93	0.4	47.1	0.1	9.1
Vietnam	410	307	na	na	na	na	na	na
Total	41651	54331	6962	9436	1520.5	1968.8	16.7	17.4

(a) The category "tropical hardwood" consists of all wood removals from broadleaved species, except pulpwood and wood for energetic use.

Source: As for Table A1.

Table A4 - Production and Trade of Wood-based Panels, 1980 and 1988

	Production		Exports				Exports/production (quantity)	
	1000 m^3				mil. US$		percent	
	1980	1988	1980	1988	1980	1988	1980	1988
Angola	6	7	na	na	na	na	na	na
Cameroon	73	67	28	22	19.4	16.3	38.4	32.8
Central African Republic	7	4	4	1	1.1	0.7	57.1	25.0
Congo	79	61	67	38	26.5	16.7	84.8	62.3
Equatorial Guinea	na	10	na	4	na	0.8	na	40.0
Gabon	192	228	61	52	29.4	16.6	31.8	22.8
Ghana	79	83	9	22	3.3	9.3	11.4	26.5
Guinea	2	2	na	na	na	na	na	na
Ivory Coast	195	266	62	98	23.1	42.0	31.8	36.8
Liberia	9	5	4	5	0.7	1.8	44.4	100.0
Madagascar	1	1	na	na	na	na	na	na
Nigeria	116	233	na	na	na	na	na	na
Sierra Leone	na	na	na	na	na	na	na	na
Zaire	40	53	26	8	9.9	3.1	65.0	15.1
Belize	na	na	na	na	na	na	na	na
Bolivia	16	8	4	1	1.5	0.8	25.0	12.5
Brazil	2482	2986	324	662	125.0	244.9	13.1	22.2
Colombia	111	113	2	9	0.5	1.8	1.8	8.0
Costa Rica	68	58	25	20	7.6	4.6	36.8	34.5
Ecuador	87	171	70	24	23.3	8.9	80.5	14.0
French Guiana	na	na	na	na	na	na	na	na
Guatemala	9	8	1	na	0.5	na	11.1	na
Guyana	na	na	na	na	na	na	na	na
Honduras	11	9	4	na	1.7	na	36.4	na
Mexico	604	802	24	15	7.4	9.8	4.0	1.9
Nicaragua	14	14	5	3	2.2	1.4	35.7	21.4
Panama	14	12	1	1	0.4	0.5	7.1	8.3
Paraguay	69	107	69(a)	37	11.9(a)	4.4	100.0	34.6
Peru	84	59	7	0	2.4	0.1	8.3	0.5(a)
Surinam	23	10	18	4	5.9	1.3	78.3	40.0
Venezuela	136	169	na	na	na	na	na	na
Brunei	na	na	na	na	na	na	na	na
Burma	12	15	na	na	na	na	na	na
India	252	442	13	17	7.2	13.2	5.2	3.8
Indonesia	1012	6614	245	6426	55.7	2135.0	24.2	97.2
Kampuchea	2	2	1	1	0.8	0.8	50.0	50.0
Laos	2	5	na	na	na	na	na	na
Malaysia	1079	1421	604	1076	152.4	306.1	56.0	75.7
Papua New Guinea	20	19	8	0	4.6	0.1	40.0	0.0
Philippines	759	540	435	321	133.3	99.5	57.3	59.4
Sri Lanka	15	10	na	na	na	na	na	na
Thailand	150	251	15	56	15.1	34.3	10.0	22.3
Vietnam	18	40	na	na	na	na	na	na
Total	7648	14905	2136	8923	672.8	2974.8	27.2	59.9
World	101115	125877	16323	25471	5160.5	8162.4	16.1	20.2

(a) Own estimations.

Source: FAO [a, 1988].

Table A5 - Production, Consumption and Direction of Trade, Industrial Roundwood, 1988

Exporter \ Importer	USA and Canada	Latin America (tropical)	Latin America (other)	USSR and East Europe	Japan	Asia and Oceania (tropical)	Asia and Oceania (other)	Scandi-navia	West Europe (excluding Scandinavia)	Africa (tropical)	Africa (other)	Produc-tion	thereof: Exports
USA and Canada	2.5 0.5 4.6				13.2 0.2 5.1		8.0 0.2 0.3	 0.1	 0.3 0.1			348.5 44.6 196.7	24.1 1.2 10.2
Latin America (tropical)												26.8 31.1 31.9	0.0 0.1(a) 0.0
Latin America (other)							1.3					5.1 3.4	1.4 0.0
USSR and East Europe					1.2 4.8		 2.3	1.3 0.9 0.2	0.1 0.7 0.5			8.9 172.1 38.3	2.7 8.9 0.8
Japan				2.2	1.8		0.5	6.8	4.5			175.4 15.1 2.5	16.1 0.0 0.0
Asia and Oceania (tropical)					11.9(a) 0.5	1.5(a)	8.5(a) 0.5 0.4					10.2 3.4 100.0 20.2 48.7	0.0 0.1 22.4(a) 1.2 0.9
Asia and Oceania (other)					9.3		0.1					27.7 69.3	0.4 9.4
Scandinavia								0.5 2.4				44.9 2.0 57.0	0.7 0.1 2.5
West Europe (excluding Scandinavia)								0.1 4.0	2.4 2.3 7.0			52.7 18.0 53.1	2.7 3.3 11.2
Africa (tropical)									3.6(a)			0.0 15.3 11.9	0.0 3.7(a) 0.5
Africa (other)												5.4 1.6 21.8	0.0 0.0 0.3
Apparent consumption	327.1 44.2 191.1	26.8 31.1 31.9	3.7 3.4 6.2	163.8 37.9 161.9	33.1 14.5 28.2	3.3 79.1 19.0	59.8 37.2 62.2	45.7 2.4 69.7	53.8 21.6 55.6	0.0 11.6 11.4	5.7 2.0 30.0	722.7 284.4 656.6	38.8 32.0 54.1
thereof: Imports	2.7 0.8 4.6	0.0 0.1 0.0	0.0 0.0 0.0	0.6 0.4 2.6	16.0 12.0 18.0	0.0 1.5 0.0	12.0 9.9 2.3	1.5 0.5 15.2	3.8 6.9 13.7	0.0 0.0 0.0	0.3 0.8 0.5	39.0 32.5 56.9	

(a) Tropical hardwood. - First figure: coniferous woodlogs in mil. m^3; second figure: non-coniferous woodlogs in mil. m^3; third figure: pulpwood (including woodchips and residues) and other industrial roundwood in mil. m^3.

Source: Based on FAO [a, 1988]; UN [1990b].

Table A6 - Production, Consumption and Direction of Trade, Sawnwood and Wood Pulp, 1988

Exporter \ Importer	USA and Canada	Latin America (tropical)	Latin America (other)	USSR and East Europe	Japan	Asia and Oceania (tropical)	Asia and Oceania (other)	Scandi-navia	West Europe (excluding Scandinavia)	Africa (tropical)	Africa (other)	Produc-tion	thereof: Exports
USA and Canada	34.0 0.9 3.9	1.0 0.6			6.4 0.6 2.3	 0.3	2.0 0.3 1.8		4.8 1.1 4.1		0.5	147.9 20.2 79.1	49.1 3.7 13.1
Latin America (tropical)	0.1 0.2(a) 0.4	0.1(a) 0.0	0.1(a)		0.2				0.1 0.3(a) 0.3			10.9 14.8(a)	0.3 0.8(a)
Latin America (other)		0.2 0.1			0.2		0.1		0.2 0.2		0.1	5.2 2.5 1.6	1.1 0.9 0.0
USSR and East Europe			0.5	2.5 0.6	0.2			0.1 0.1	5.5 0.8 0.8		0.3	1.4 106.5 19.8 15.0	0.5 10.8 1.1 1.4
Japan												26.2 3.9	0.0 0.0
Asia and Oceania (tropical)	0.1(a)				1.3(a)	0.8(a)	3.5(a)		1.8(a)			10.4 2.5 34.4(a)	0.0 0.1 7.8(a)
Asia and Oceania (other)					0.1 0.1 0.3	 0.1	0.4 0.2 0.2		0.3		0.3	1.4 27.8 14.6	0.0 0.8 1.3
Scandinavia	0.1			0.4	0.1	0.1	0.2 0.3	0.7 0.2	9.5 4.0		1.1 0.1	4.7 21.1 0.3 21.0	0.6 12.2 0.0 5.4
West Europe (excluding Scandinavia)	0.1			0.1			0.1	0.1	6.0 1.5 2.5		0.5 0.1	30.9 9.0 11.1	7.1 2.0 2.8
Africa (tropical)									0.7(a)			0.0 5.5(a)	0.0 0.8(a)
Africa (other)	0.1				0.1				0.1			0.1 2.3 0.7 1.6	0.0 0.1 0.0 0.6
Apparent consumption	133.0 18.1 70.5	11.8 14.2 5.0	2.1 1.8 1.2	98.3 18.8 15.0	33.2 5.8 13.5	2.4 27.3 1.9	30.0 17.2 6.7	9.7 0.5 15.9	50.2 13.5 20.5	0.0 4.7 0.1	4.9 1.3 1.2	378.6 124.7 151.2	81.4 17.6 25.5
thereof: Imports	34.2 1.6 4.5	1.2 0.2 0.9	0.5 0.2 0.1	2.6 0.1 1.8	7.0 1.9 3.1	0.0 0.7 0.5	3.0 3.9 2.6	0.8 0.2 0.3	26.4 6.5 12.2	0.0 0.0 0.0	2.7 0.6 0.2	78.5 15.9 25.7	

(a) Tropical hardwood. - First figure: coniferous sawnwood in mil. m^3; second figure: non-coniferous sawnwood in mil. m^3; third figure: wood pulp in mil. m^3.

Source: As for Table A5.

Table A7 - Production, Consumption and Direction of Trade, Wood-based Panels, 1988

Exporter \ Importer	USA and Canada	Latin America (tropical)	Latin America (other)	USSR and East Europe	Japan	Asia and Oceania (tropical)	Asia and Oceania (other)	Scandi-navia	West Europe (excluding Scandinavia)	Africa (tropical)	Africa (other)	Produc-tion	thereof: Exports
USA and Canada	0.25 0.21 1.78	0.06			0.03 0.05 0.07		0.04 0.15	0.01	0.19 0.80 0.35			0.75 23.48 18.45	0.60 1.14 2.64
Latin America (tropical)	0.04(a) 0.06(a) 0.10	0.07 0.05					0.02(a) 0.05(a)	0.01(a) 0.01	0.01(a) 0.19(a) 0.08		0.01(a)	0.38(a) 1.88(a) 2.39 0.01 0.10	0.09(a) 0.43(a) 0.26 0.00 0.01
Latin America (other)												0.53	0.09
USSR and East Europe	0.05 0.02	0.05 0.04		0.01 0.10 0.50			0.05	0.04	0.03 0.35 0.50		0.01	1.06 3.18 18.57 0.30 7.26	0.05 0.62 1.22 0.06 0.02
Japan												1.80	0.04
Asia and Oceania (tropical)	0.02(a) 1.00(a)	0.02			0.26(a) 1.89(a)		2.80(a)	0.02(a)	0.02(a) 1.00(a)		0.09(a)	0.75(a) 8.33(a) 0.28 0.18	0.34(a) 7.53(a) 0.05 0.04
Asia and Oceania (other)	0.30	0.01			0.13 0.10				0.33		0.01	3.87 4.15 0.04	1.60 0.23 0.03
Scandinavia	0.03			0.03 0.02			0.01	0.02 0.15	0.30			0.69 2.70	0.52 0.77
West Europe (excluding Scandinavia)	0.02			0.01				0.02 0.01 0.05	0.51 0.30 0.80 5.00			1.16 1.71 19.98	0.35 0.86 5.60
Africa (tropical)	0.02(a)			0.04					0.15(a) 0.06(a)			0.48(a) 0.44(a) 0.10	0.17(a) 0.07(a)
Africa (other)												0.11 0.20 0.57	0.01 0.02 0.02
Apparent consumption	0.68 24.34 17.95	0.33 1.55 2.24	0.02 0.24 0.45	1.11 2.74 18.02	0.68 9.21 2.08	0.41 0.83 0.25	0.38 5.77 4.41	0.05 0.41 2.25	1.54 4.96 21.74	0.31 0.39 0.10	0.13 0.55 0.39	5.23 51.14 69.51	1.74 12.81 10.93
thereof:	0.53 2.00	0.04 0.10	0.01 0.15	0.10 0.18	0.44 1.97	0.00 0.03	0.24 3.50	0.04 0.24	0.73 4.11	0.02	0.03 0.37	2.15 12.67	
Imports	2.14	0.11	0.01	0.67	0.32	0.02	0.49	0.32	7.36	0.00	0.01	11.45	

(a) Tropical hardwood. - First figure: veneer sheets in mil. m^3; second figure: plywood in mil. m^3; third figure: particleboard and fibreboard in mil. m^3.

Source: As for Table A5.

Table A8 - Production, Consumption and Direction of Trade, Wood Pulp, Paper and Paperboard, 1988

Exporter \ Importer	USA and Canada	Latin America (tropical)	Latin America (other)	USSR and East Europe	Japan	Asia and Oceania (tropical)	Asia and Oceania (other)	Scandi-navia	West Europe (excluding Scandinavia)	Africa (tropical)	Africa (other)	Produc-tion	thereof: Exports
USA and Canada	3.9 0.1 10.1	0.6 1.1			2.3 0.8	0.3 0.1	1.8 1.0		4.1 0.1 1.5		0.3	79.1 0.3 86.2	13.1 0.2 16.1
Latin America (tropical)	0.4 0.2	0.1			0.2		0.0 0.1		0.3 0.4			5.2 0.9 9.8	1.1 0.0 1.1
Latin America (other)		0.1					0.1		0.2			1.6 0.1	0.5 0.0
USSR and East Europe		0.1		0.6 1.0		0.1			0.8 0.6			1.5 15.0 0.5 17.5	0.2 1.4 0.0 2.3
Japan												10.4 0.0	0.0 0.0
Asia and Oceania (tropical)							0.2					24.6 1.4 2.1	0.6 0.0 0.0
Asia and Oceania (other)					0.3	0.1	0.2 0.1 1.5					3.9 4.7 6.6 21.3	0.3 0.6 0.1 1.7
Scandinavia	0.1 1.1	0.2		0.4 0.5	0.1 0.3	0.1 0.4	0.3 0.6	0.2 0.4	4.0 10.5	0.1	0.1 0.3	21.0 0.0 18.5	5.4 0.0 15.0
West Europe (excluding Scandinavia)	0.1 0.6			0.1 0.2			0.1 0.3	0.2	2.5 11.0	0.1	0.5	11.1 0.4 38.5	2.8 0.0 13.5
Africa (tropical)												0.1 0.0	0.0 0.0
Africa (other)	0.1 0.0				0.1		0.1		0.1 0.1			0.1 1.6 0.2 2.3	0.0 0.6 0.0 0.6
Apparent consumption	70.5 0.2 82.6	5.0 0.9 10.4	1.2 0.1 1.4	15.0 0.5 16.9	13.5 0.0 25.1	1.9 2.1 4.9	6.7 6.6 25.1	15.9 0.0 4.1	20.5 0.5 49.1	0.1 0.0 0.3	1.2 0.2 1.7	151.2 11.0 224.3	25.5 0.3 51.1
thereof:	4.5 0.1	0.9 0.0	0.1 0.0	1.4 0.0	3.1 0.0	0.5 0.0	2.6 0.1	0.3 0.0	12.2 0.1	0.0 0.0	0.2 0.0	28.7 0.4	
Imports	12.5	1.4	0.4	1.7	1.1	1.3	5.5	0.6	24.1	0.2	1.7	50.5	

First figure: wood pulp in mil. mt; second figure: other fibre pulp in mil. mt; third figure: paper and paperboard in mil. mt.

Source: As for Table A5.

Table A9 - Share of Wood Products in Total Merchandise Export Revenues, 1980 and 1988 (percent)

	Exports of industrial roundwood(a)		Exports of sawnwood(a)		Exports of wood-based panels		Exports of paper and paperboard		Total exports of wood products	
	1980	1988	1980	1988	1980	1988	1980	1988	1980	1988
Angola	na	na	na	na	na	na	na	na	na	na
Cameroon	7.9	4.6	1.5	1.3	1.3	1.0	na	na	10.7	6.9
Central African Republic	18.6	6.1	6.5	5.6	0.7	0.5	na	na	25.8	12.0
Congo	4.6	7.6(b)	1.4	1.0(b)	2.7	1.8(b)	na	na	8.7	10.4
Equatorial Guinea	12.4	35.0(b)	0.0	5.0(b)	na	2.5(b)	na	na	12.4	42.5
Gabon	6.0	9.5	0.2	0.0	1.4	1.4	na	na	7.6	10.9
Ghana	1.0	5.1	1.8	5.1(b)	0.3	1.1	na	na	3.1	11.3
Guinea	na	na	na	na	na	na	na	na	na	0.1
Ivory Coast	15.6	3.1	2.3	5.2	0.7	1.8	na	na	18.6	10.1
Liberia	14.1	30.0(b)	1.8	1.1	0.1	0.5(b)	na	na	16.0	31.6
Madagascar	0.0	0.2	na	na	na	na	na	na	0.0	0.2
Mozambique	1.2	2.5	0.7	0.0	na	0.5	na	na	1.9	3.0
Nigeria	0.0	0.0	0.0	0.0	na	na	na	na	0.0	0.0
Sierra Leone	na	na	0.0	0.0	na	na	na	na	0.0	0.0
Zaire	0.3	0.7	0.2	0.2	0.4	0.1	na	na	0.9	1.0
Belize	0.5	0.3	1.1	1.7	na	na	na	na	1.6	2.0
Bolivia	na	na	2.0	3.4	0.2	0.1	na	na	2.2	3.5
Brazil	0.0	0.0	0.7	0.5	0.6	0.7	2.6(c)	3.9(c)	3.9	5.1
Colombia	na	na	0.1	0.0	0.0	0.0	0.2	0.2	0.3	0.2
Costa Rica	0.0	0.1	0.0	0.0	0.7	0.4	1.2	1.3	1.9	1.8
Ecuador	na	na	0.2	0.6	0.9	0.4	na	na	1.1	1.0
French Guiana	13.2	0.8(b)	0.8	4.9(b)	na	na	na	na	14.0	5.7(b)
Guatemala	na	0.0	0.3	0.1	0.0	na	1.2	0.5	1.5	0.7
Guyana	0.7	2.4(b)	1.0	1.2	na	na	na	na	1.7	3.6
Honduras	0.0	0.0	0.0	na	0.2	na	0.6	na	0.8	0.0
Mexico	na	na	na	na	0.1	0.1	0.0	0.0	0.1	0.1
Nicaragua	0.6	na	0.0	0.0	0.5	0.6	na	na	0.9	0.6
Panama	na	0.0	na	na	0.1	0.0	0.2	0.1	0.3	0.1
Paraguay	0.0	na	16.8	2.2	3.9	0.5	na	na	20.7	2.7
Peru	na	na	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0
Surinam	0.4	0.1	0.6	na	1.1	na	na	na	2.1	0.1
Venezuela	na	na	na	na	na	na	na	na	na	na
Brunei	na	na	na	na	na	na	na	na	na	na
Burma	9.8	25.0(b)	16.1	5.0(b)	na	na	na	na	25.9	30.0
India	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.3	0.2
Indonesia	6.9	0.2	1.2	2.8	0.3	10.9	0.0	0.6	8.4	14.5
Kampuchea	2.6	0.1(b)	na	na	na	na	na	na	2.6	0.1
Laos	15.0(b)	17.2	5.0(b)	0.5	na	na	na	na	20.0	17.7
Malaysia	9.3	7.3	4.5	3.5	1.2	1.5	0.0	na	15.0	12.3
Papua New Guinea	4.5	6.9	0.9	0.1	0.4	0.0	na	na	5.8	7.0
Philippines	2.6	0.1	1.2	2.2	2.3	1.4	0.0	0.0	8.0	3.8
Sri Lanka	0.0	na	0.1	na	na	na	na	na	0.1	na
Thailand	0.0	na	0.0	0.3	0.2	0.2	0.1	0.3	0.3	0.8
Vietnam	na	na	na	na	na	na	na	na	na	na

(a) Tropical hardwood only. - (b) Own estimations. - (c) Including exports of wood pulp.

Source: Tables A3-A6; World Bank [1991]; own calculations.

Table A10 - Employment in Wood-related Industries, 1980

	Economically active population	thereof: agriculture	thereof: industry	Employment (sample results)				
				total manufacturing	wood and wood products		paper and paperboard	
	mil.	percent		1000		percent of total	1000	percent of total
Cameroon(a)	3.6	70	8	48	9	19	na	na
Ghana	4.4	56	18	80	17	21	1	1
Ivory Coast	3.5	65	8	67	12	18	2	3
Madagascar	4.9	81	6	39	2	5	1	3
Nigeria	32.1	68	12	295	20	7	2	1
Bolivia	1.7	46	20	43	4	9	0	0
Brazil	44.2	31	27	3800	406	11	106	3
Colombia	8.0	34	24	508	13	3	11	2
Ecuador	2.4	39	20	122	10	8	3	2
Mexico	22.2	37	29	1768	144	8	31	2
Panama	0.7	32	18	30	2	6	1	3
Peru	5.4	40	18	273	17	6	7	3
Venezuela	4.9	16	28	409	22	5	15	4
India	265.3	70	13	6801	79	1	125	2
Indonesia	56.3	57	13	963	65	7	12	1
Malaysia(b)	5.3	42	19	557	84	15	7	1
Papua New Guinea	1.5	76	10	20	6	30	0	0
Philippines	17.5	52	16	1053	111	11	21	2
Sri Lanka	5.5	53	14	162	7	4	7	4
Thailand(c)	25.7	68(d)	11(d)	994	69	7	12	1

(a) 1979. - (b) 1981. - (c) 1982. - (d) Own estimations.

Source: ILO [1986]; UN [1986].

Table A11 - Contribution of Woold-related Industries to GDP, 1980

	GDP at factor costs	thereof: agriculture	thereof: industry (a)	Value-added (sample results) (b)				
				total manu-facturing	wood and wood products		paper and paperboard	
	mil. US$	percent		mil. US$		percent of total	mil. US$	percent of total
Ghana	15028	58	12 (8)	1004	62	6	3	4
Ivory Coast	8482	33	20 (11)	1092	88	8	37	3
Madagascar	3265	36	18 (12)	206	4	2	4	2
Nigeria	99564	26	42 (9)	6419	160	2	5	0
Bolivia	2750	19	35 (15)	379	10	3	0	0
Brazil	215660	11	41 (31)	72857	3123	4	2258	3
Colombia	30049	22	28 (19)	7131	85	1	227	3
Ecuador	10756	12	38 (18)	1355	69	5	42	3
Mexico	178217	8	33 (22)	42826	1696	4	1174	3
Panama	3291	10	21 (10)	na	16	na	20	na
Peru	18621	10	42 (20)	4966	121	2	156	3
Venezuela	67555	5	46 (16)	na	256	na	355	na
India	154918	38	26 (18)	13042	81	1	295	2
Indonesia	67429	24	42 (13)	3394	246	7	51	2
Malaysia(c)	21208	21	37 (20)	4020	376	9	41	1
Papua New Guinea	2385	33	27 (10)	280	60	21	2	1
Philippines	31816	26	37 (24)	5839	322	6	190	3
Sri Lanka	3766	28	30 (18)	301	6	2	8	3
Thailand(d)	31870	19	32 (21)	11374	187	2	96	1

(a) Share of manufacturing in parantheses. - (b) For many countries, value-added is only given at market prices (purchasers' values). - (c) 1981. - (d) 1982.

Source: World Bank [1991]; UN [1986].

Table A12 - Price Relations for Selected Wood Products, 1970-1988 (a)

	African non-coni-ferous logs to		Asian non-coniferous sawnwood to			Asian plywood to	
	coniferous logs USA	non-coni-ferous logs Europe	European non-coni-ferous sawnwood	European coniferous sawnwood	Canadian coniferous sawnwood	North American plywood	European plywood
1970	1.192	0.861	0.783	1.102	1.543	0.952	0.663
1971	1.231	0.941	0.684	1.000	1.300	0.992	0.635
1972	1.393	1.000	0.663	1.073	1.180	0.845	0.609
1973	1.167	1.086	0.824	1.304	1.537	1.105	0.685
1974	1.339	1.129	0.638	0.888	1.708	0.873	0.520
1975	1.155	0.985	0.618	0.944	1.672	0.776	0.542
1976	1.283	1.027	0.857	1.026	1.686	0.761	0.524
1977	1.179	0.888	0.681	0.947	1.632	0.864	0.490
1978	1.222	0.815	0.636	0.978	1.494	0.905	0.522
1979	1.137	0.850	0.716	1.193	1.846	1.053	0.574
1980	1.495	1.100	0.679	1.116	2.208	1.119	0.509
1981	1.366	1.144	0.632	1.065	1.978	1.253	0.535
1982	1.193	0.990	0.626	1.221	2.036	0.870	0.517
1983	1.343	0.969	0.713	1.388	2.000	0.795	0.532
1984	1.155	0.976	0.830	1.313	2.023	0.883	0.508
1985	1.348	1.094	0.744	1.339	1.930	0.986	0.612
1986	1.648	1.125	0.718	1.281	2.361	0.757	0.447
1987	1.355	0.943	0.599	1.119	1.790	0.881	0.481
1988	1.360	1.259	0.616	1.139	1.841	1.018	0.528

(a) Price relations are calculated as quotient of export unit values (US$/$m^3$) of the respective product categories.

Source: FAO [a, 1981; 1988]; own calculations.

Table A13 - Structure of Wood Consumption in the EC, 1970-1986

	Coniferous	Non-coniferous (tropical)	Non-coniferous (other)	Non-coniferous tropical(a)	Non-coniferous tropical(b)
	mil. m^3			percent	
	Apparent consumption of logs				
1970	32948	5987	19361	23.6	10.3
1971	33035	6163	18132	25.4	10.9
1972	32951	6850	17924	27.6	11.9
1973	39375	7908	19309	29.1	11.9
1974	34848	5999	18395	24.6	10.1
1975	29146	4713	16813	21.9	9.3
1976	34286	6136	16864	26.7	10.7
1977	34739	5754	18565	23.7	9.7
1978	36958	4916	18869	20.7	8.1
1979	37391	5281	18279	22.4	8.7
1980	37149	5355	18994	22.0	8.7
1981	35029	4072	18149	18.3	7.1
1982	36053	3791	16500	18.7	6.7
1983	36339	3714	16437	18.4	6.6
1984	37378	3633	16747	17.8	6.3
1985	36707	3350	16884	16.6	5.9
1986	37338	3252	17391	15.8	5.6
	Apparent consumption of sawnwood				
1970	40601	1325	10832	10.9	2.5
1971	40427	1256	11068	10.2	2.3
1972	42621	1446	11525	11.1	2.5
1973	46660	2387	12203	16.4	3.8
1974	40707	1560	10690	12.7	2.9
1975	32727	1639	9150	15.2	3.7
1976	40039	2629	10615	19.9	4.9
1977	39286	2415	10944	18.1	4.6
1978	40419	2550	11083	18.7	4.5
1979	44415	3279	11550	22.1	5.5
1980	42613	2718	11215	19.5	4.7
1981	38012	2134	10056	17.5	4.2
1982	38617	2281	9904	18.7	4.4
1983	40145	2617	9198	22.1	5.0
1984	39234	2304	9593	19.4	4.5
1985	38153	2372	9392	20.2	4.7
1986	41161	2661	9153	22.5	5.0

(a) Share in total non-coniferous. - (b) Share in total.

Source: UN-ECE/FAO [1988]; own calculation.

Table A14 - Mineral Reserves Located in Tropical Countries, 1988 (a)

Mineral	Important reserves (percent)
Antimony	Bolivia (7.3), Mexico (4.3)
Barite	India (18.1), Thailand (4.2), Mexico (4.2), Peru (1.2)
Bauxite	Guinea (25.7), Brazil (12.8), India (4.6), Guyana (3.2), Suriname (2.6), Venezuela (1.5), Cameroon (.)
Bismuth	Peru (12.3), Mexico (5.6), Bolivia (5.0)
Cadmium	Mexico (6.5)
Chromium(b)	Philippines (1.4), India (1.3), Brazil (0.8)
Cobalt	Zaire (41.1)
Copper	Zaire (7.4), Peru (3.4), Philippines (3.4)
Diamonds	Zaire (15.3), Brazil (0.5)
Fluorspar(b)	Mexico (8.2), Thailand (0.4)
Gold	Brazil (2.2), Philippines (.), Mexico (.)
Iron ore	Brazil (9.8), India (5.0), Venezuela (1.8), Liberia (0.8)
Lead	Mexico (4.3), Peru (2.9)
Lithium	Bolivia (.), Zaire (.), Brazil (.)
Magnesite	Brazil (1.8), India (1.2)
Manganese	Gabon (6.4), Brazil (2.6), Mexico (0.4)
Mercury	Mexico (3.8)
Molybdenum	Peru (2.5), Mexico (1.6)
Nickel	Indonesia (6.5), Brazil (1.4), Colombia (1.1), Philippines (0.8)
Potash	Brazil (0.3)
Selenium	Mexico (5.0), Peru (3.8)
Silver	Mexico (13.2), Peru (8.9)
Tantalum	Thailand (33.3), Nigeria (14.6), Zaire (8.3), Brazil (4.2), Malaysia (4.2)
Tellurium	Peru (3.5)
Thorium	India (32.1), Brazil (1.8)
Tin	Malaysia (25.9), Indonesia (15.9), Brazil (15.2), Thailand (6.3), Bolivia (3.3), Nigeria (0.5), Zaire (0.5)
Titanium(c)	Brazil (23.7), India (12.4), Sierra Leone (0.7)
Tungsten	Bolivia (1.8), Thailand (1.2), Brazil (0.8), Burma (0.6)
Uranium	Brazil (.), India (.)
Vanadium	Brazil (.)
Zinc	Peru (4.8), Mexico (4.1)
Zirconium	India (5.8), Brazil (2.8)

(a) Measured plus indicated reserves. Shares have been calculated on the basis of metal content (except where noted). - (b) Gross weight. - (c) Anatase, ilmenite or rutile.

Source: US Bureau of Mines [1990].

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