J. ENVIRONMENTAL SYSTEMS, Vol. 15(2), 1985-86

DEFORESTATION IN DEVELOPING COUNTRIES

B. BOWONDER
Centre for Energy, Environment and Technology
Administrative Staff College of India
Hyderabad, India

ABSTRACT

Degradation of forest quality is one of the most serious environmental problems facing the world today [1-3]. Developed countries' forest ecosystems [4] are affected severely because of air pollution and acid precipitation. The damage of forests in Germany is reported to be severe [5]. Approximately 25 percent of the forests are affected – *damaged* (loss of 20% to 50% leaves or needles) or *severely damaged* (loss of over 50% leaves). The deforestation in developing countries is mainly due to poverty and underdevelopment [6]. Such deforestation is a very critical problem and eludes easy solution since it is intricately linked to underdevelopment, poverty and other complex socio-economic factors. This article analyzes the problem of deforestation in developing countries and suggests possible solutions for arresting deforestation.

Rates of deforestation in developing countries have been increasing and causing concern among international agencies and environmentally alert organizations all over the world [7-14]. Deforestation has been identified as the greatest tragedy that the Third World has to face during this century [15-17]. In the normal course extraction of renewable resources does not cause any concern. In the case of renewable resources, whenever the rate of extraction exceeds the rate of renewability, there is a reduction in the capital stock. In the case of forests the problem can be stated as follows:

1. the rate of extraction of forest resources has been going up; and
2. the efforts aimed at increasing the rate of annual incremental growth (rate of renewability) is of a far lesser magnitude (compared to the rate of extraction).

doi: 10.2190/FJDP-VRU8-F78E-FHWE
http://baywood.com

A recent study by United Nations Environment Programme and Food and Agricultural Organization shows that seventy-six developing countries deforest jointly 11.3 million ha of forests every year whereas the rate of tree planting in these countries is depressingly low, about 0.52 million ha every year [1]. Myers has estimated that the rate of clearance of tropical moist forest alone is 6.5 million hectare per year [18]. In an ideal system, the rate of deforestation should equal the rate of afforestation so forest areas are maintained. To cite an example, in the case of Malaysia, 5,56,572 ha of forests were cleared between 1972 and 1978 whereas during the same period only 5058 ha were afforestated [19]. It is estimated that by the year 2000, the world population will be 6.4 billion and wood availability per capita would have come down to 40 cubic meters from the current level of 76 cubic meters per year [20].

Reported rates of deforestation in selected developing countries is given in Table 1, which highlights the seriousness of the problem [21-45].

WOOD EXTRACTION

The rate of extraction of wood has been increasing in developing countries because of the increase in population as can be seen in Tables 2 and 3. But, on the other hand, because of the need for maintaining a minimum level of food production there has always been pressure to deforest, since forests do not have any major lobby to support them in the legislature or in administrative circles. For example, of the four million hectares of land that was deforested in India between 1951 and 1976, about 70 percent has been for agricultural operations [35]. In a number of developing countries, growth of wood extraction and population growth are of the order of 3 percent [6]. The cause for concern arises from the fact that population growth is likely to stabilize only in forty to fifty years and by then the forests would have virtually vanished in some of these countries.

Figure 1 shows countries where intensity of wood extraction (extraction per hectare of forest area) is high and forest area per capita is low (countries in Class I). In these countries, intensity of extraction has to be reduced and forest areas have to be increased. The major countries under category I are Sierraleone, Haiti, Rwanda, Kenya, Libya, South Korea, El Salvador, and Pakistan. Figure 2 shows four classes of countries with different rates of wood usage and wood extraction. Class C countries have high intensity of wood extraction in existing forests as well as high rates of wood usage by the population. In such cases, the strategy may be:

1. to reduce intensity of wood extraction in existing forests; and
2. to provide other renewable sources of energy to decrease wood usage per capita.

Table 1. Rates of Deforestation

Country	*Rates of Deforestation*	*Reference*
Bangladesh	10,000 ha annually	21
	8,000 ha annually	22
Bolivia	187,000 ha annually between 1962 and 1975	23
	250,000 ha in 1978	24
Brazil	170 million ha between 1950 and 1978	23
	Forest area reduced from 520 million ha to 350 million ha	13
	11.25 million ha cleared between 1966 and 1978	25
Burma	95,000 ha annually during 1976-80	22
Colombia	900,000 ha annually	23
	25.2 million ha between 1966 and 1977	26
Ethiopia	200,000 ha annually	27, 28, 29
Ghana	45,000 ha annually	30
	Forest area reduced from 7.94 to 2.00 million ha	13
Guatemala	60,000 ha annually	31
Haiti	Forest area reduced from 55% to 9% between 1950 and 1979	32, 33
India	4.0 million ha till 1978	34
	3.6 million ha between 1953 and 1974	35
	106,000 ha annually during 1970-73	23
	147,000 ha annually during 1976-80	22
Indonesia	550,000 ha annually during 1976-80	22
	400,000 ha annually	23, 26
Ivory Coast	500,000 ha annually	16
	10 million ha between 1956 and 1966	28, 29
Lao PDR	125,000 ha annually during 1976-80	22
Madagascar	150,000 ha annually	29
Malaysia	275,000 ha annually between 1957 and 1977	19
	Forest cover reduced from 74 to 55%	26
	200,000 ha per year	23, 36
	230,000 ha annually between 1976-80	22
Mexico	80,000 ha annually	23

Table 1. (Cont'd.)

Country	*Rates of Deforestation*	*Reference*
Nepal	2.7 million ha between 1964 and 1975	37
	Forest cover decreased from 57 to 23% between 1947 and 1980	36
	400,000 ha annually	38
	84,000 ha annually during 1976-80	22
Paraguay	Forest cover reduced from 64 to 37% between 1945 and 1976	13
Peru	18.1 million ha between 1961 and 1978	39
Philippines	Forest cover decreased from 44 to 33%	13
	4.25 million ha deforested between 1965-71	26
	80,000 ha annually	40
	101,000 ha annually during 1976-80	22
Vietnam	65,000 ha annually during 1976-80	22
All Developing Countries	7.3 - 12.0 - 20.0 million ha per annum	14
	18 to 20 million ha per annum	42
	11.3 million ha annually	1
	Between 1975 and 2000 about 75 million ha	43
Developing Countries in Asia	4 million ha annually	44
	2 million ha annually	45
Developing Countries in Africa	2 million ha annually	44
	3.7 million ha annually	26
	4.0 million ha annually	29
Developing Countries in Latin America	5 to 10 million ha annually	44
	5.6 million ha in 5 years	27

Countries coming under this category are Haiti, Rwanda, Kenya, Sierraleone, Vietnam, Benin, Indonesia, Ivory Coast, Malawi, South Korea, Mali, Nigeria, Bhutan, Liberia, Cameroon, Malaysia, Tanzania, Costa Rica, and Guatemala. Forest degradation is severe in class I (Figure 1) and class C (Figure 2) since in most of these locations the wood extraction rate exceeds 5 m^3 per hectare per year which is the average forest productivity.

Table 2. Trend of Fuelwood Extraction

Country	*Extraction in 1968 ('000 cubic mtrs)*	*Extraction in 1979 ('000 cubic mtrs)*
Afghanistan	4,934	6,553
Angola	5,580	7,282
Argentina	5,687	6,580
Bangladesh	7,106	9,464
Brazil	123,974	169,937
Burma	17,730	23,046
Chad	5,564	7,050
China	124,040	150,568
Colombia	29,837	38,813
Ethiopia	17,129	22,385
India	152,608	201,416
Indonesia	98,957	129,438
Kenya	16,795	25,210
Korea	52,938	64,723
Mali	21,523	28,357
Nigeria	66,136	89,155
Pakistan	12,716	17,790
Philippines	17,840	25,289
Sudan	24,009	31,941
Tanzania	23,782	32,855
Thailand	23,373	32,216
Turkey	27,604	34,035
Vietnam	47,451	60,389
Total For All Developing Countries	1,111,337	1,454,933

FUELWOOD USE

Fuelwood extraction has been a basic reason for deforestation with extraction satisfying a basic need. Fuelwood extraction is more than one cubic meter per capita in countries such as [6] : Mali, Bhutan, Cameroon, Sierraleone, Liberia, Tanzania, Sudan, Malawi, Kenya, Chad, Honduras, South Korea, Guatemala, Colombia, Paraguagy, Central African Republic, Angola, Mozambique, and

Table 3. Fuelwood Extraction

	Million m^3		Growth Rate
	1970	1981	Per Annum (%)
World	1351	1678	1.99
Africa	294	394	2.74
North America	51	63	1.94
South America	192	254	2.58
Asia	652	817	2.07
Oceania	5.8	8.7	3.75

Source: World Energy Statistics 1981, United Nations, New York.

Nigeria. Incidentally, all of these are countries with low per capita income (less than US $1000) [46]. With the exception of Nigeria, all of these countries are oil importing countries. Low per capita income, coupled with the fact that they have poor oil resources, will continue to make these countries dependent on fuelwood. In most of the low income, developing countries, more than 80 percent of the wood extracted is used as fuelwood. This, coupled with the fact that actual usage is also high, points to the fact that these low income countries will find it difficult to reverse this trend. Many countries in category I (Figure 1) and class C (Figure 2) are low income developing countries (countries that are underlined in Figure 1 and Figure 2), as well as oil importing developing countries (except Indonesia and Nigeria). Hence, in the near future low income developing countries using wood will not be able to reverse the rates of wood usage (mainly fuelwood) by switching over to fossil fuels. This can be considered as a reason for irreversibility of risk of deforestation [6, 47, 48]. This is supported by the trends observed, namely:

1. Fuelwood extraction per capita is high in developing countries (one cubic meter per capita corresponds to 750 kilogram fuelwood per capita per year) and the fuelwood usage is more than 96 percent of the total wood extraction in countries such as Rwanda, Mali, Somalia, Tanzania, and Uganda.
2. Fuelwood usage has been increasing during the last decade in a majority of the developing countries. Table 2 gives a selected list of countries and the trend of fuelwood extraction. As can be seen, the fuelwood use has been going up in highly populated areas of Asia (China, India, Pakistan, Philippines, Indonesia, Burma, and Thailand) and population is unlikely to stabilize in these areas in the next fifty years. Table 3 shows the fuelwood extraction by major regions of the world. The growth rates of extraction in Asia, Oceania, Africa and South America are much higher than the world average.

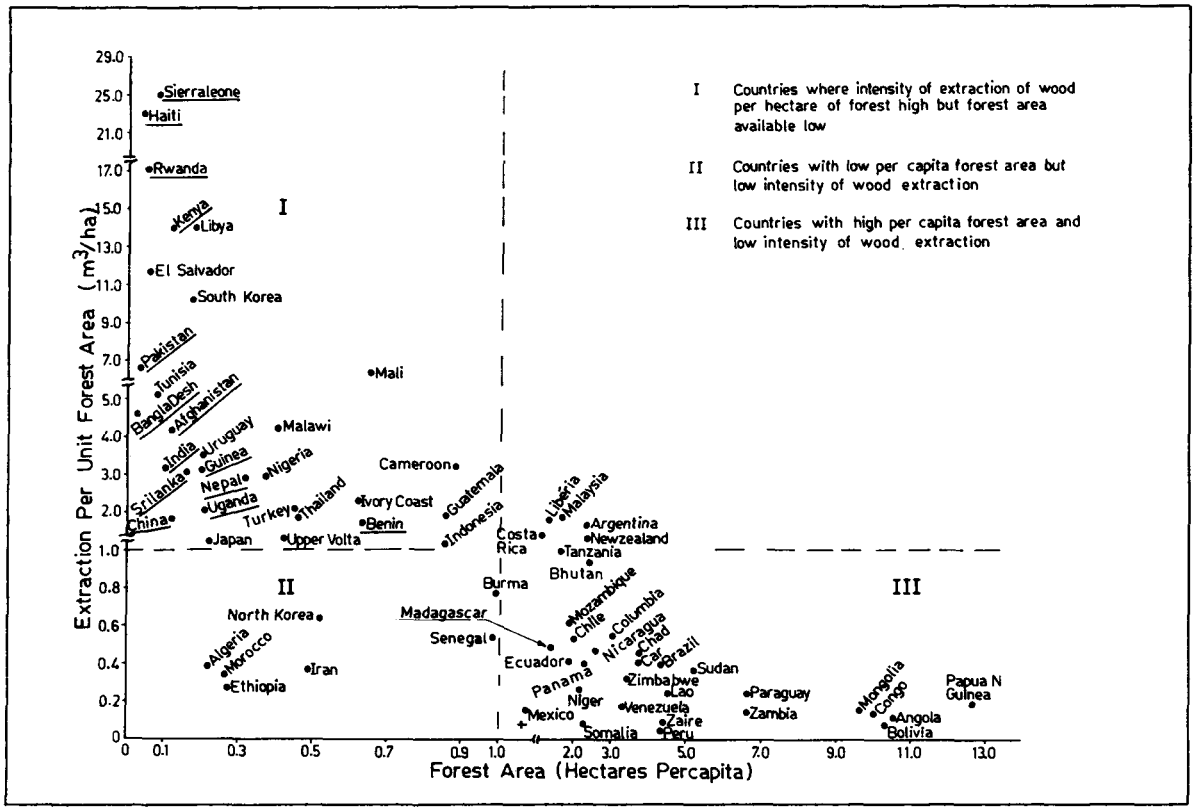

Figure 1. Forest extraction.

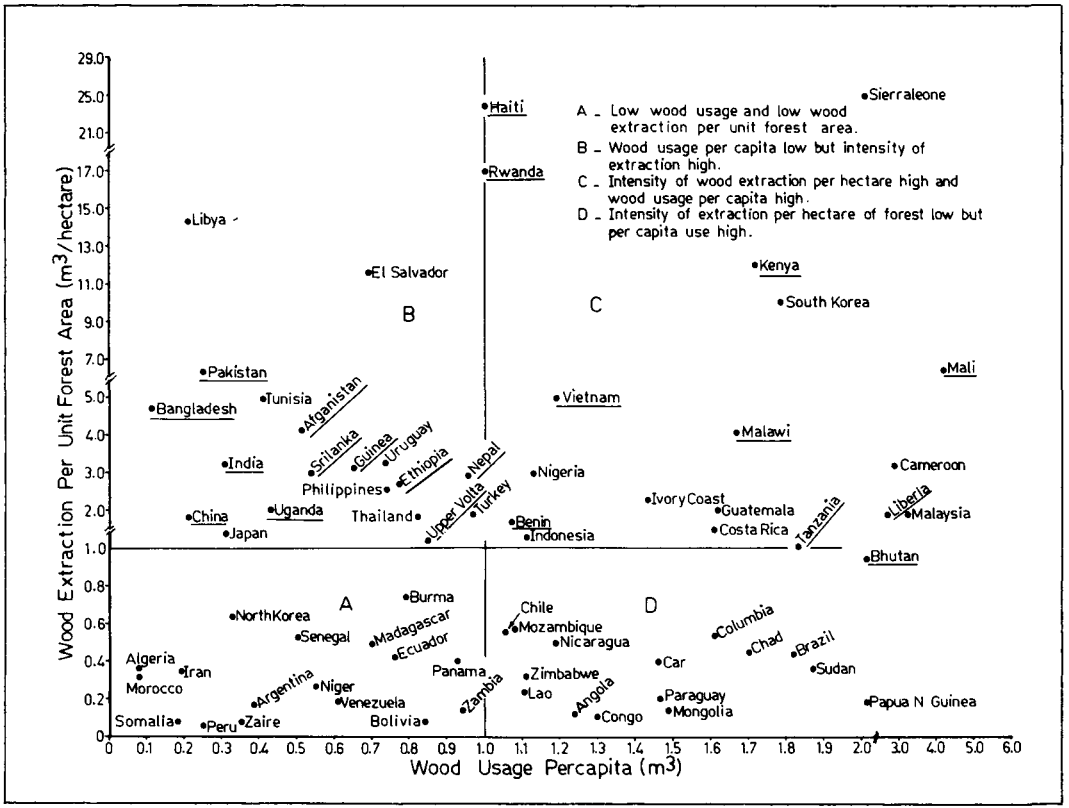

Figure 2. Wood usage.

In other words, deforestation is a consequence of low per capita income, non-availability of fossil fuels, high population density, and poverty; hence it is intricately linked to socio-economic process.

POOR FOREST MANAGEMENT SYSTEMS

Another major reason for the severe depletion of forest resources is the poor forest management systems in developing countries. Even if the rate of deforestation is high, it can be offset by good management systems which can stimulate forest regeneration.

Pricing is the most dependable long term variable for control in forest management, but it is the most neglected aspect in developing countries [6, 35, 49]. Low price for forest produce has a number of consequences, namely:

1. it inhibits the development of alternative materials or substitutes for wood (such as plastics, steel, aluminum);
2. it seriously affects the financial viability and autonomy of the forest sector since the low prices make forest organizations financially week; and
3. low prices for forest products act as a disincentive for new investments into this sector.

For example, in India about 150 million tons of wood are extracted and used. At market prices (US $40 per ton), the cost will be 6×10^9 US $ per annum. But, investments into the forest sector per annum during 1980-85 in India have been as low as 0.4×10^9 US $ per annum. It has been also reported that only 4 percent of the forest revenue collected is reinvested for afforestation programs even by the Forest Department, the remaining going to expenses on buildings, transportation, etc. [49]. In other words, developing countries have to examine critically the pricing policy since a rational pricing policy can stimulate forest regeneration and reduce wastages and inefficient uses.

Forestry education and forest management are also weak areas in developing countries. UNESCO/UNEP have identified awareness, training, education, and research as critical areas in forestry development [2]. Sasson has shown that interdisciplinarity which is needed for forest research is almost non-existent in developing countries [50]. UNESCO has initiated the Man and Biosphere program [51] and UNEP has published a report on State of Environment 1972-1982 – these can increase the awareness among bureaucracies. But very little has been done to increase awareness about ecosystem concepts and the need for environmental conservation among political leaders. Development of forestry education and training of foresters also has to be implemented. Forestry training has been neglected even in a large country like India. The field of forest services has not been able to attract the best talent and, further, forestry research is an area which has been neglected.

It has been shown that the forestry yield in developing countries can be increased three times the present value by merely improving management practices [35]. Educating the farmers would be a positive step. Existing agricultural extension personnel are unable to inculcate forestry information to the farmers. In forest areas, a new service for extension education of farmers regarding forestry has to be started.

CATTLE GRAZING

Cattle grazing in forests has been a major reason for degradation of forest quality and reduction of diversity of species in tropical forests [6, 35, 52, 53]. In the Sahel region, creation of desert increased greatly because of a combination of factors – poverty, overgrazing, overexploitation of land, lack of development of grazing lands, fuelwood extraction, and erosion [54, 55]. The land area of India is about one-sixth of the entire land area of the world [35], but 20 percent of the world's cattle population and 50 percent of its buffalo population are also in India. The problem in developing countries is the lack of pasture development and integrated livestock development programs [56]. A large number of cattle are left in the forests and because of cattle grazing, all small species and small seedlings are consumed by the grazing animals. Cattle grazing along with deforestation reduces the genetic diversity considerably. The germ plasm loss is an irretrievable and irreversible loss to humanity.

Tropical moist forests is one ecosystem that has been subjected to maximum disturbance. This ecosystem has about two-fifths to one-half of the world's total species [18, 26, 42], although they comprise a small area of the globe. It has been reported that tropical moist forests are forests which are being more rapidly disrupted than any other type. Selective logging of forests results in loss and degradation of genetic material leaving only undesirable smaller and genetically inferior individuals and it leads to genetic erosion. Indonesia has been a country where tropical moist forests have been decimated for timber exports [26]. Most of the tropical forests are nutrient-poor [57]. When nutrient-poor forests are disturbed, the nutrients are irretrievably lost. In the tropical forests of Amazonia, nutrient-poor ecosystems have evolved highly effective mechanisms for recycling nutrients [58]. Human activities destroy the series of delicate ecological links between soil, nutrients, water, and forests since nutrient conserving mechanisms are very fragile here. Most of the changes that take place as a result of simultaneous logging and cattle grazing cause irreversible genetic erosion of a large number of species. Forest clearing combined with cattle grazing removes all the seedlings, thus increasing the irreversibility stemming from soil erosion, that follow deforestation.

The major issue is that cattle population is increasing whereas land availability is decreasing, but the land holding sizes are small and hence separate pasture development is not possible. In other words, the cattle grazing in forests is likely

to increase. For example, in India areas closed to cattle have increased but the number of cattle grazing in forests have increased, indicating that degradation of forest quality is increasing in the case of open forests.

ILLEGAL ENCROACHMENTS AND EXTRACTION

Illegal encroachments and shifting cultivation are other major reasons for deforestation [59, 60]. Here again, conversion of forests to agricultural lands has been the main reason for degradation of forest quality. This is basically a socio-economic problem since population pressure hastens the conversion process.

It has been reported that of the total wood extracted, about 70 percent is illegally cut in the case of Sri Lanka [6] and 50 percent in the case of the Philippines [23]. In India also, illegal fuelwood extraction has been a serious problem. Although no estimates are available on the magnitude of illegally extracted fuelwood [35], indications are that illegal or unrecorded extraction is of the order of 90 percent. The consumption of fuelwood per annum in India is about 150 million tons (this is in addition to agricultural residues and wastes) as estimated by Planning Commission, but the recorded extraction of fuelwood from forests is as low as 15 million tons. In Haiti, forest cover declined from 55 percent to 9 percent between 1950 and 1979 because of illegal extraction. Illegal extraction will continue as long as fuelwood shortages exist. In a recent study, FAO has indicated that 101 million people are affected by acute fuelwood shortages in developing countries of Asia, Latin America, and Africa, and about 999 million people of this region face some degree of fuelwood shortage. These numbers are likely to become 356 million and 2770 million by the year 2000. The shortage of fuelwood has enormous impact on availability of employment of women. Women and children have to walk long distances collecting fuelwood thereby reducing time for productive employment-oriented activities.

Illegal encroachments have been a serious problem and in a number of countries illegal encroachments have been regularized because of political pressures. Political bosses are not concerned with the seemingly long-term consequences of deforestation [59] compared to short-term profits, winning of elections, increasing food production, etc. In other words, shifting cultivation, illegal fuelwood extraction, and illegal encroachments and conversion of forest lands are consequences of poverty and intricately linked to the socio-economic structure and development process. On the one hand there is reduction in forest areas whereas on the other hand there has been a tendency in developing countries to export wood in larger amounts to generate foreign exchange through export earnings [61]. Table 4 shows how hardwood exports have increased from 3.3 million cubic meters to 47.3 million cubic meters without major afforestation programs. Also, 95 percent of wood export originates in

Table 4. Share of Countries in Hardwood Export

	Percent of World Export Volume						
	1950	*1955*	*1960*	*1965*	*1970*	*1975*	*1979*
Malaysia	5	9	17	13	23	23	34
Indonesia	4	–	1	1	20	34	41
Philippines	28	34	29	32	25	13	3
Africa	27	'37	36	27	18	14	10
South America	–	1	22	2	1	–	–
Total of All Developing Countries	70	83	86	93	95	94	95
Actual Quantity in Million Cubic Meters	3.3	6.6	12.3	21.2	38.7	36.3	47.3

Source: Reference [61].

developing countries (Table 4). Rigid regulations and policies alone cannot arrest deforestation. Forest quality will improve only by

1. increasing biomass availability;
2. stimulating the productivity of forests; and
3. increasing efficiency of biomass utilization systems in rural areas, along with improved management of forest areas, rigid control of illegal extraction, and a systematic program for afforestation.

LOWER PRODUCTIVITY

Low productivity of forests, poor pricing of forest products, and investments in the forest sector act as a vicious circle. Low productivity attracts very little investment into the forest sector and, because of poor investments, productivity is low. Low productivity coupled with higher rates of extraction causes deterioration of forest quality. For example, in India forest productivity is as low as 0.33 tons per hectare compared to the average productivity of 3.0 tons per hectare in the United States [35]. The average productivity of forests varies from 1 to 3 tons per hectare or 1.66 to 5 m^3 per hectare whereas extraction in a number of countries exceeds this range (Figures 1 and 2) [62]. The ideal condition of extraction of forests which will not affect forest quality will be a state in which forest extraction per annum is less than the annual incremental growth. In many developing countries already the annual extraction per unit area of forests is high and since forest area is not increasing, annual extraction per hectare of forests is going up. Figure 3 gives the names of countries where

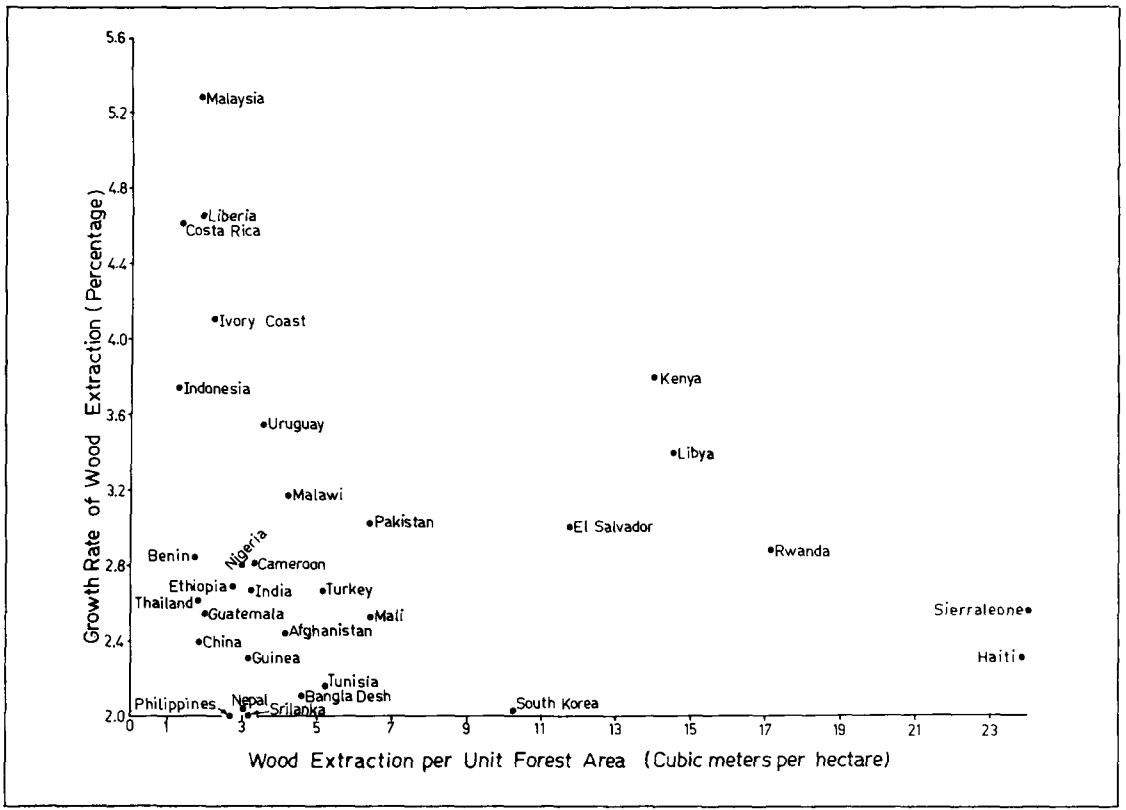

Figure 3. Countries with high rate of wood extraction.

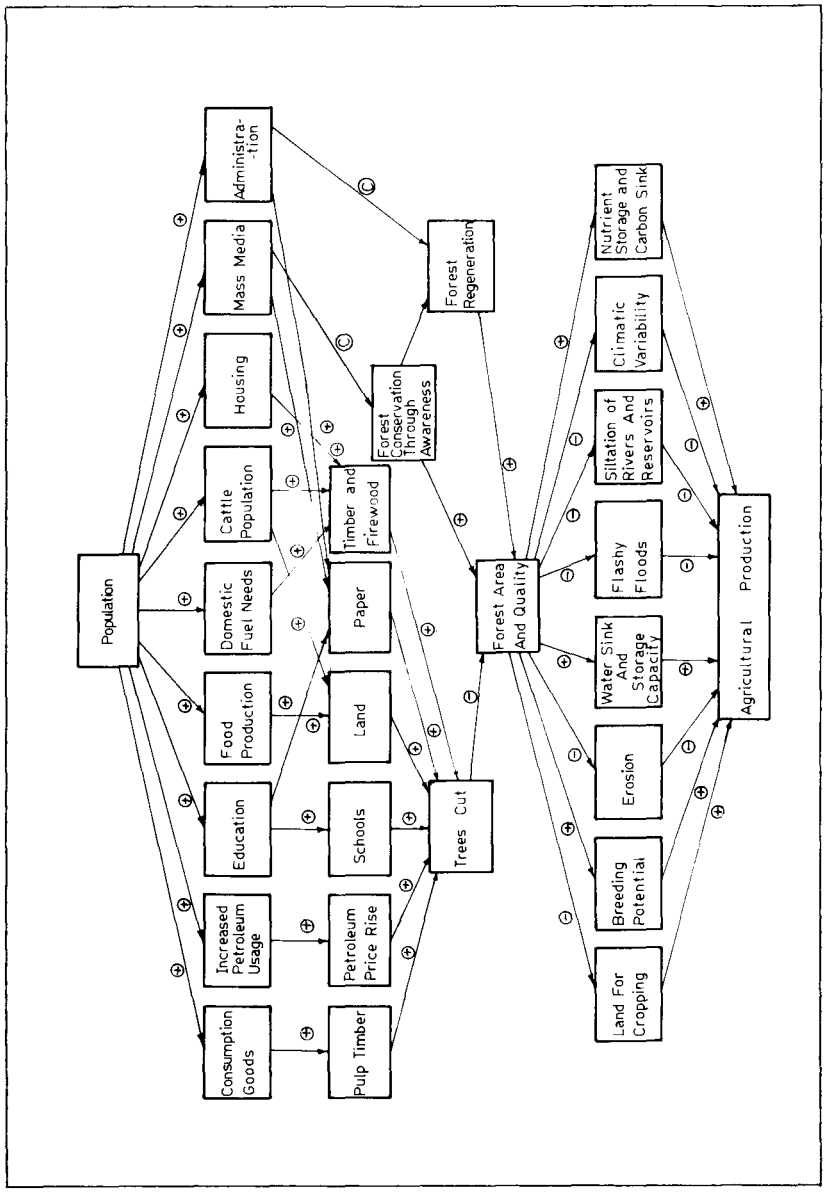

Figure 4. Population, forests, and food production.

fuelwood extraction per unit area of forest are high as well as countries with high growth rate of wood extraction. In these countries the problem of deforestation can be reversed by a combination of strategies such as:

1. increasing the forest area at the same rate at which forest extraction is growing;
2. increasing forest productivity at a rate higher than that of the rate of increase of forest extraction; and
3. reducing the growth rate of demand of forest products.

All these steps will involve considerable public and private investments, political and administrative commitment, educating farmers, distribution of seeds and seedlings, changing the pricing system and other intensive measures.

CLEARFELLING OF FORESTS

Clear felling of forests has been a feature in many developing countries. Cocoa plantations and coffee plantations have been developed on forest lands after clear felling mainly to generate export earnings [6]. Rich forests have also been clear felled for export in Indonesia, Madagascar, Kenya, and Brazil [52]. Clear felling irreversibly reduces the genetic diversity and causes severe losses of species. The rate of extinction has now reached a point such that every day one species is irretrievably lost from the face of the earth [42], and by the year 2000 about one million species will have vanished for ever. Considering that the total number of current species is somewhere between 5 to 10 million, this loss will be a severe one. Governments have to initiate action to stop conversion of forests into plantations. Waste land may be converted into plantations but not forest lands. A large number of studies conducted all over the globe indicate that clear felling has been a major reason for extinction of species. Land use changes should be examined from the point of view of environmental impact.

DEFORESTATION AS A SEVERE ENVIRONMENTAL RISK

Deforestation is a severe environmental risk in developing countries. Population growth, deforestation and agricultural production are very closely linked [47, 65]. Figure 4 shows that increases in population will increase the demand for wood in terms of pulp, timber, plywood, fuelwood, paper, etc. All of the major economic activities given at the second level (consumption goods, increased petroleum usage, education, food production, domestic fuel needs, grazing, housing, mass media, and administration) will induce demand for forest produce and all of them will aggravate deforestation (shown by + sign) as given in Figure 4. Only two factors can improve forest quality, forest generation, and forest conservation. When there are only two activities that can improve forest

quality, whereas there are nine activities closely related to satisfaction of basic human needs (which lead to deforestation) with no clear substitutes; the rate of regeneration should be such that it can compensate for the reduction in forest area. This has not been the actual condition prevailing.

The risks emanating from deforestation are (see Figure 4):

1. loss of area cleared for agriculture;
2. loss of germplasm, breeding material, and extinction of species;
3. soil erosion;
4. reduction in the ability to store water;
5. inability to control flash floods;
6. situation of rivers and reservoirs;
7. possible climatic variability;
8. reduction in the carbon sink since forests fix carbon dioxide; and
9. reduction in the nitrogen in forest soil.

These will certainly affect the long term agricultural productivity adversely. The risk is severe because of the following reasons [47, 66, 67]:

1. many of the consequences of deforestation are irreversible;
2. the risk is caused by activities aimed at satisfying basic human needs, hence reversing the causes will be difficult (uncontrollable);
3. effects of deforestation cannot be precisely predicted and managed once the effects are manifest;
4. reversal of deforestation will be difficult since it involves a large number of subjects residing in the developing countries where social communication is poor; and
5. deforestation is intricately linked to poverty, socio-economic structure, illiteracy, etc.

Under these conditions, arresting deforestation will be a very difficult task. The largest tragedy of this century for humanity as a whole, will be irreversible destruction of tropical forests. The most serious issue is that except for some international agencies (USAID, UNESCO, UNEP, and FAO) and some technical individuals, the politicians and bureaucrats of the third world have not really understood the severe crisis awaiting humanity. Forests are the most precious of global commons (common pool resource of humanity) [68], and every effort should be made if future generations are to have the benefit of this. Otherwise, future generations will face severe irreversible changes.

ENERGY PLANNING AND FOREST DEVELOPMENT

Deforestation in developing countries is very closely interlinked with socio-economic problems and poverty of rural population. Piecemeal solutions are not going to be helpful for reducing deforestation because of the nature and

magnitude of the problem. Current system of energy planning and forest development are not people-oriented and energy planning must be situated within a context of rejuvenated development planning [69]. The entire energy planning and forest development apparatus should be restructured along more integrative and democractic lines. As has been shown, energy planning along these lines will be highly political since without clarifying long-term energy development goals, fuelwood planning programs, forest development plans, and land use patterns, energy planning cannot be undertaken.

Current development plans of most of the developing countries have neglected renewable fuels such as fuelwood, agricultural residues, and animal wastes. Most development plans lack an integrated approach to energy. Planners in developing countries continue to base projects on weak foundations – dividing the energy sector into traditional and modern areas when in fact it should be treated as a whole. For example, Indian Five Year Development plans do not consider the fuelwood requirements explicitly, although out of the 150 million tons of wood extracted, 135 million tons are used as fuelwood. In other words, the planning process should not be through a "top down" approach but through a "bottom up" approach involving the local community and their real physical needs.

To this end, integrated energy plans must be prepared without artificially dividing energy into modern and traditional aspects. Energy planning has been oriented only towards electricity, coal, and petroleum and this bias has to go if forests are to be saved. Energy planning has a very close bearing on land use policy. The fuelwood crisis has a large impact on land utilization and management of the forest resource. The challenge is the delimiting and maintaining of adequate areas under forest both to insure the protection of soil and water resources and to provide the forest product needs of a country including maximum output of food and fibre [2, 3]. All these facts clearly indicate the need for improving energy and resource planning capabilities in developing countries. Considering energy needs in the form of compartments such as Departments of Forests, coal, petroleum, electricity, agriculture, etc. in government should be replaced by an integrated energy planning approach covering all fuels and all needs.

MANAGERIAL IMPERATIVES

The forest sector should be considered as a core sector and development programs should aim at satisfying the minimum fuelwood needs of rural population. Development plans should aim at increased expenditure levels in the forest sector. More public and private investments should be attracted through tax concessions and other incentives. Efforts should be made to improve forest product pricing. Subsidies in the forest sector have been one major reason for the low economic efficiency of the sector. Pricing should be based on marginal

opportunity cost, i.e., equivalent to the cost of other fuels on the basis of thermal equivalency. Wood prices should be based on heat content rather than extraction cost – wood may be priced higher than coal considering that coal burning requires pollution control systems.

Deforestation cannot be reversed by piecemeal solutions. A large number of policy interventions are necessary which must be complementary in nature. The objective of these interventions should be to reduce the gap between annual incremental growth of forests and annual extraction, so that there will be a sustainable yield on a regular basis for years to come. In other words, the interventions will be a package of incentives for stimulating forest productivity and investments into that sector and discouragement for misuse and overuse of forest resources, such as:

1. stimulation of agro-forestry and social forestry through financial loans and tax incentives;
2. user industries (such as paper industries) must be made to generate their own resources;
3. increase the price of forest products so that it will stimulate development of alternative materials and reduce overuse, misuse and wastage of timber;
4. environmental impact assessment should be made statutory for forest based industries so that raw material availability will be assessed well in advance and before starting industries;
5. increased investments in the forest sector by both public and private agencies;
6. rigid monitoring of land use changes and penal provisions;
7. increase public awareness and farmer education regarding forestry;
8. development of infrastructure for the generation and production of forest species, seeds, and seedlings;
9. multilateral agencies such as World Bank, USAID, SIDA, etc. should earmark part of their project expenses for afforestation in the case of irrigation projects;
10. development of social forestry through voluntary agencies and rural public participation;
11. incentives for organizations involved in forest regeneration and afforestation;
12. extensive public awareness programs through mass media to arrest deforestation;
13. development of a forest germ plasma bank to conserve forest resources;
14. modernization of forest resource assessment and development of forest management and service systems; and
15. countries which import forest products should be made to invest in the form of joint ventures in the exporting country for the development of forest resources.

CONCLUSIONS

Though considerable work has been done on deforestation, very little concerted action is underway to protect forests from degradation. In many developing countries deforestation has already caused irreversible changes and the process is likely to become irreversible if no corrective action is initiated. Detailed forest development plans have to be initiated with constant monitoring, review and evaluation of implemented programs. Extension education in forestry has received no attention. Forestry training for developing silviculture technology also has been a neglected activity. A complete assessment of forest resources in relation to population growth, agriculture, industry, housing, and cattle development has to be carried out by each developing country to identify strategies for saving the remaining forests from extinction.

ACKNOWLEDGMENTS

The author would like to thank the Department of Environment, Government of India, and Mr. J. A. Kalyanakvishnan, Secretary of the Department for providing a research grant to undertake this study. The author would also like to thank Mr. M. Narasimham, Principal, ASCI for the organizational support extended for completing this research work.

REFERENCES

1. M. Hadley and J. P. Lanly, Tropical Forest Ecosystems, *Nature and Resources, 19:*1, pp. 2-18, 1983.
2. United Nations Environment Programme, *World Environment 1972-1982,* Tycooly, Dublin, 1982.
3. E. El Hinnawi and M. H. Hashmi, *Global Environmental Issues,* Tycooly, Dublin, 1982.
4. W. H. Smith, *Air Pollution and Forests,* Springer-Verlag, New York, 1981.
5. G. H. Tomlinson, Air Pollutants and Forest Decline, *Environmental Science and Technology, 17,* pp. 246A-256A, 1983.
6. B. Bowonder, Forest Depletion, *Resource Policy, 9,* pp. 206-224, 1983.
7. V. Smil, Deforestation in China, *AMBIO, 12,* pp. 226-231, 1983.
8. E. Brunig, Tropical Rain Forest, *AMBIO, 6,* pp. 187-191, 1977.
9. T. M. Pasca, Concerning Wood Energy, *Unasylva, 33:*131, pp. 2-3, 1981.
10. H. J. Steinlin, Monitoring the World's Tropical Forests, *Unasylva, 34:*137, pp. 2-8, 1982.
11. A. E. Lugo and S. Brown, Tropical Forest Ecosystem and the Human Factor, *Unasylva, 33:*133, pp. 45-47, 1981.
12. E. Silati and P. B. Vose, Depletion of Tropical Rain Forest, *AMBIO, 12:*2, pp. 67-71, 1983.
13. United States Agency for International Development, *Environmental and Natural Resource Management in Developing Countries, Vol. 1,* Department of State, Washington, D.C., pp. 34-35, 1979.

14. Department of State, *World's Tropical Forests, Publication 9117,* U. S. Government Printing Office, Washington, D.C., 1980.
15. UNEP/UNESCO/FAO, *Tropical Forest Ecosystems,* UNESCO, Paris, 1979.
16. IUCN/UNEP/WWF, *World Conservation Strategy,* International Union of Conservation of Nature, Gland, 1980.
17. J. J. Talbot, The Fate of Tropical Forests, *Science and Public Policy, 6:*3, pp. 185-188, 1979.
18. N. Myers, Tropical Moist Forests, *Forest Ecology and Management, 6,* pp. 59-79, 1983.
19. C. J. Barrow, Development in Peninsular Malaysia, *Third World Planning Review, 2,* pp. 5-25, 1980.
20. Department of State, *Tropical Deforestation,* U. S. Department of State and U. S. Agency for International Development, Washington, D.C., 1978.
21. Library of Congress, *Draft Environmental Report on Bangladesh,* Department of State, Washington, D.C., 1979.
22. United Nations Environment Programme, *Resources of Development,* UNEP, Bangkok, 1981.
23. G. O. Barney, "Entering the Twenty First Century: The Global 2000," Report to the President, Council on Environmental Quality, Washington, D.C., 1980.
24. Library of Congress, "Draft Environmental Report on Bolivia," Department of State, Washington, D.C., 1979.
25. S. H. Davies, *Victims of a Miracle,* Cambridge University Press, Cambridge, England, 1977.
26. N. Myers, *Conversion of Tropical Moist Forest,* National Academy of Sciences, Washington, D.C., pp. 168-176, 1980.
27. G. D. Fox, *Forestry in Developing Countries,* National Technical Information Service, PB-212726, Springfield, Illinois, 1972.
28. R. B. Ford, Putting the Problems in Context, *Africa Report, 23,* pp. 4-7, 1978.
29. T. Synnot, *Monitoring Tropical Forests, Report-5,* Monitoring and Assessment Research Centre, London, 1977.
30. Library of Congress, *Draft Environmental Report on Ghana,* Department of State, Washington, D.C., 1979.
31. ———, *Draft Environmental Report on Guatemala,* Department of State, Washington, D.C., 1979.
32. ———, *Draft Report on Haiti,* Department of State, Washington, D.C., 1979.
33. I. Walter and J. L. Ugelow, Environmental Policies in Developing Countries, *AMBIO, 8,* pp. 102-109, 1979.
34. Library of Congress, *Draft Environmental Report on India,* Department of State, Washington, D.C., 1979.
35. B. Bowonder, Deforestation in India, *Journal of Environmental Studies, 18,* pp. 223-236, 1982.
36. M. K. Ranjitsingh, Forest Destruction in Asia and South Pacific, *AMBIO, 8,* pp. 192-201, 1979.
37. P. C. Mohan, Not Seeing the Wood for Trees in Nepal, *Ideas and Action, 139,* pp. 6-11, 1981.

38. K. P. Pandey and U. Dixit, Nepal: Himalayan Dilemma, *India Today, 7:*4, pp. 86-87, 1982.
39. Library of Congress, *Draft Environmental Report on Peru,* Department of State, Washington, D.C., 1979.
40. _____, *Draft Environmental Report on Philippines,* Department of State, Washington, D.C., 1979.
41. _____, *Draft Environmental Report on Thailand,* Department of State, Washington, D.C., 1979.
42. N. Myers, The Tropical Forest Issue, in *Progress in Resource Management and Environmental Planning Vol. 4,* T. O'Riordan and R. K. Turner (eds.), Wiley, Chichester, pp. 1-28, 1983.
43. J. P. Lanly, Present and Future of Natural Forest and Plantation Areas in the Tropics, *Unasylva, 31:*123, pp. 12-20, 1979.
44. Food and Agricultural Organization, Forestry for Local Community Development, *Forestry Paper 7,* FAO, Rome, pp. 7-8, 1979.
45. J. Giono, The Man Who Planted Trees, *Development Forum, 10:*5, pp. 8-9, 1982.
46. World Bank, *World Development Report 1983,* World Bank, Washington, D.C., 1983.
47. B. Bowonder, Environemntal Risk in Developing Countries with Special Reference to India, in *Progress in Resource Management and Environmental Planning Vol. 4,* T. O'Riordan and R. K. Turner (eds.), Wiley, Chichester, pp. 57-89, 1983.
48. _____, Catastrophe Theory and Environmental Management, *Science and Public Policy, 11,* pp. 94-99, 1984.
49. _____, Management of Forest Resources in India, *Public Administration and Development, 3,* pp. 373-381, 1983.
50. A. Sasson, Education and Environment, *Nature and Resources, 14:*1, pp. 13-16, 1979.
51. F. D. Castri, M. Hadley, and J. Damlamian, Man and Biosphere, *AMBIO, 10:*2-3, pp. 52-57, 1981.
52. R. B. Nigh and J. D. Nations, Tropical Rain Forests, *Bulletin of Atomic Scientists, 36:*3, pp. 12-19, 1980.
53. B. R. Dewalt, The Cattle Are Eating the Forest, *Bulletin of Atomic Scientists, 39:*1, pp. 18-23, 1983.
54. R. W. Kates, Drought in the Sahel, *Mazingira, 5:*2, pp. 72-83, 1981.
55. M. H. Glandz, *The Politics of Natural Disaster, The Case of Sahel Drought,* Praeger, New York, 1976.
56. UNESCO/UNEP/FAO, *Tropical Grazing Land Ecosystems,* UNESCO, Paris, 1979.
57. C. F. Jordan and R. Herrera, Tropical Rain Forests, *Nature and Resources, 16:*2, pp. 7-13, 1981.
58. R. Herrera, C. F. Jordan, E. Medina, and H. Klinge, How Human Activities Disturb the Nutrient Cycles of a Tropical Rain Forest in Amazonia, *AMBIO, 10:*2-3, pp. 109-114, 1981.
59. E. Eckholm, *Losing Ground,* Norton, New York, 1976.
60. L. R. Brown, *Twenty Nine Days,* Norton, New York, 1979.

61. R. Kumar, World Tropical Wood Trade, *Resource Policy, 8:*3, pp. 177-192, 1982.
62. D. O. Hall, G. W. Barnard, and P. A. Moss, *Biomass for Energy in the Developing Countries,* Pergamon Press, Oxford, 1982.
63. N. Myers, *Sinking Ark,* Pergamon, Oxford, 1979.
64. P. R. Ehrlich, Variety Is the Key to Life, *Technology Review, 82:*5, pp. 2-12, 1980.
65. B. Bowonder, Forests and Development, *Mazingira, 5:*2, pp. 62-71, 1981.
66. ———, Environmental Risk Assessment Issues in The Third World, *Technological Forecasting and Social Change, 19,* pp. 99-127, 1981.
67. ———, Issues in Environmental Risk Assessment, *Journal of Environmental Systems, 10:*4, pp. 305-331, 1980.
68. Soedjatmoko, Managing the Global Commons, *Environmentalist, 2,* pp. 213-216, 1982.
69. R. Hosier, P. O. Keefe, B. Wisner, D. Weiner, and D. Shakow, Energy Planning in Developing Countries, *AMBIO, 11,* pp. 180-187, 1982.

Direct reprint requests to:

B. Bowonder
Center for Energy, Environment and Technology
Administrative Staff College of India
Bella Vista, Hyderabad 500049 India