Chapter 5

Energy and the Environment in Developing Countries

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Introduction and Summary

Many developing countries are experiencing significant environmental degradation. In rural areas, population pressure and low agricultural productivities are among the factors forcing people into marginal and ecologically fragile lands. Woodlands are being cleared for cropland and pastures and are being commercially logged. The use of biomass for fuel or fodder places further demands on woodlands and grasslands, particularly in arid regions with high population densities. Farming, ranching, logging, and the use of biomass fuels are all necessary if the people dependent on these resources are to survive. But these various pressures can also have negative impacts: destruction of tropical forests and biodiversity; desertification; soil erosion and increased downstream flooding and siltation; and air pollution-local, regional, and global.

In many urban areas of developing countries, rapid population growth, inadequate infrastructure, and economic and industrial growth with minimal or inadequately enforced environmental controls have led to high levels of pollution. Levels of sulfur dioxide, particulate, ground-level ozone, and nitrogen oxides often exceed those in industrialized countries. Major sources include electricity generation, transportation, and industrial production. Greater use of fossil fuels in the modern, primarily urban, sector can also lead to environmental degradation and pollution in the rural areas where these fuels are extracted from the ground and transported to the cities, and where hydroelectric facilities are sited.

Many have viewed environmental costs--degradation and pollution of the natural resource base-as the price that must be paid in order to develop economically.[1] Increasingly, however, others argue that environmental protection and economic development are tightly interconnected and mutually supportive.[2] The landless peasants who migrate to fragile watersheds in order to feed their families, for example, clear land that is highly susceptible to erosion. This can lead to serious soil loss and downstream flooding and siltation-ultimately reducing the productivity of their land as well as that of land downstream. In turn, this can exacerbate their , and others' poverty. This may be particularly significant in developing countries because their economies are so heavily dependent on agriculture. For the 2.8 billion people in the lowest income countries, agriculture accounted for fully 31 percent of gross domestic product (GDP) in 1987 and an even greater portion of employment.[3] Economic analyses that include environmental impacts are improving knowledge of this interdependency and may assist policymakers in more wisely making these tradeoffs.

Energy production and use contribute to environmental degradation in developing countries. Other contributing factors include population growth, inequitable land tenure, unsustainable agricultural and forestry practices, industrialization, and government policies. In order to understand the role of energy in overall environmental degradation, it is therefore necessary to include these other factors in the analysis.

Energy, used wisely, might also potentially provide several important environmental benefits in developing countries. Greater energy inputs into agriculture in the form of tractive power, fertilizer, and irrigation, for example, can substantially improve agricultural productivities where soils and climates are appropriate, and might help slow the expansion of agricultural lands necessary to feed a burgeoning population. (At the same time, however, modern agriculture might also cause environmental damage: by overuse of pesticides, herbicides, and fertilizers; by waterlogging and salinizing irrigated

[1] Clem Tisdell, "Sustainable Development: Differing Perspectives of Ecologists and Economists, and Relevance to LDCs," *World Development*, vol. *16, No. 3, 1988*, pp. *373-384.*

[2] World Commission on Environment and Development, *Our Common Future (New* York, NY: Oxford University Press, 1987).

[3] World Bank, *World Development Report 1989* (New York, NY: Oxford University Press, 1989), indicator tables 1 and 3.

Table 5-l-Causes and Consequences of Environmental Degradation in Rural Areas

Consequences	Direct cause	Underlying cause
Deforestation Loss of biodiversity Soil erosion Flooding	Shifting agriculture Permanent agriculture Permanent pasture	Population growth Poverty Lack of land tenure Low-level agriculture inputs Mechanization of agriculture and/or the consolidation of agricultural lands
	Commercial logging	Destructive logging, lack of forest management and protection, poor reforestation Increased access to forests along logging roads for farmers and ranchers
	Commercial agriculture, ranching	Production for export markets Fiscal policies and legislation, in part to promote exports of primary products due to need for foreign exchange to service debt. Inappropriate economic valuations of natural resources and biodiversity
	Use of Biomass Fuels	Inefficient use of fuelwood; overcutting of fuelwood resources
	Use of forest biomass for fodder	Shortages and lack of alternative sources of fodder
Desertification	Agricultural expansion onto fragile lands Overgrazing Burning of grasslands	Population growth Poverty Lack of land tenure Low-level agriculture and/or the consolidation of agriculture lands
	Use of biomass fuels	Inefficient use of fuelwood; overcutting of fuelwood resources
	Climate change	Various; not well understood
Air pollution	Use of biomass fuels Slash and burn agriculture Burning of grasslands	Lack of access to higher quality fuels and stoves Population growth Poverty Lack of land tenure Low-level agricultural inputs
Salinization and water-logging of irrigated lands	Poor planning and management Inadequate investment in infrastructure	Cheap or free water contributing to inefficiency

SOURCE: Office of Technology Assessment, 1990.

lands; and by use of these techniques under inappropriate soil and climatic conditions).[4]

Energy-efficient technologies may offer the potential of simultaneously reducing the total cost of delivering energy services and cutting pollution. New industrial processes may increase productivity and lower costs while reducing hazardous wastes. Much research and development work remains to be done to bring many of these innovations to fruition. A later report from this OTA study will examine the extent to which improved technologies for energy production and use can contribute to economic development and environmental protection; under what circumstances energy technology innovations might ease the difficult tradeoffs between economic growth and the environment; and policy issues associated with accelerating the introduction of improved energy technologies that minimize environmental degradation.

This chapter traces the causes and consequences of environmental degradation in developing countries, beginning in rural areas and following them through to urban areas, modern industry, and the use of fossil fuels. This organization has several advantages over the more conventional cataloging of environmental problems by their impacts on land, water, and air. First, it helps capture the dynamic causes of environmental degradation in developing

[4]U.S. Congress, Office of Technology Assessment *Enhancing Agriculture in Africa: A Role for U.S. Development Assistance,* OTA-F-356 (Washington, DC: U.S. *Government* Printing *mice,* September 1988). *Some* note, however, that even steep or acid-infertile lands can be productive over long periods as shown by the centuries of terraced rice farming in Asia or continuous sugar-cane cropping in the Dominican Republic. SeRicardo Radulovich, ''A View on Tropical Deforestation,'' *Nature,* vol. 346, July 19, 1990, p. 214.

countries in the various contexts of the rural struggle for survival by the landless peasant, or of the urban effort to develop modern industry in an economy that has limited capital, technology, and skilled human resources. Second, it highlights the differences in the causes and consequences of environmental degradation between rural and urban areas. Third, it helps illustrate some of the complex linkages between these environmental problems that make effective responses so difficult. If economic needs are to be met while simultaneously maintaining environmental quality, these dynamics and complex interconnections must be understood and responded to appropriately.

The Rural Sector

Many developing countries are suffering significant environmental degradation in rural areas, including: rapid devegetation/deforestation and the loss of irreplaceable biodiversity; desertification; erosion of crop and pastureland; watershed degradation, siltation of downstream waterways, downstream flooding, and other impacts on water quality and supplies; and local and regional air pollution. In turn, these environmental impacts may damage or destroy farm and range land and force more people into watersheds and other ecologically fragile lands--potentially creating a vicious cycle of degradation. Clearing and burning woodlands and grasslands for agriculture or pasture also contribute to the global increase in atmospheric greenhouse gases.

The principal direct causes of these forms of environmental degradation are shifting cultivation, conversion of forest lands to permanent pasture and agriculture, commercial logging, overgrazing, inappropriate management of irrigated land, and the use of biomass for fuel. These factors are often interconnected. Commercial logging of closed tropical forests, for example, opens new areas with roads and partial clearings, which enables settlers to follow, converting forests to pasture and cropland.

Underlying these causes are factors such as: population growth; poverty; the lack of access to modern energy-intensive inputs for agriculture (mechanical traction, irrigation, fertilizers, etc.); the lack of secure land tenure for many people; and government pricing, tax, and other policies that may encourage misuse of natural resources. These causes and consequences are listed in table 5-1.

The extent and rate of environmental degradation are difficult to quantify accurately under the best of circumstances, even when reliable data are available. As it is, estimates vary widely on the basis of the underlying definitions of what constitutes ecological vulnerability or degradation; the methodologies used for the analysis; and the assumptions used to go from local measures of degradation to global extrapolations.

The depiction of environmental degradation also depends on what measure is used for comparison. Local degradation may be severe and rapid. Irrespective of the hardship this places on people in the immediate region and the need for local responses, it does not necessarily translate into corresponding problems at the regional or global scale. There is considerable variation in form and degree of environmental degradation from one region to another. Consequently, an attempt is made below to place estimates of the rate of local environmental degradation into the global context.

Causes of Environmental Degradation

Agriculture

As the populations of developing countries grow, the demands on the land for food, fuel, and fodder increase accordingly. Farmers then face three basic choices: they can 'mine' the land—taking more out of it than they put in-until the land is exhausted; they can migrate to new lands; or they can increase the level of (capital-, energy-, and labor-intensive) agricultural inputs-mechanical traction, fertilizer, and irrigation—into the land in order to raise yields. These might also include higher inputs of information and management as might be the case for intercropping, agroforestry, integrated crop-livestock, or other sophisticated agricultural systems.[5]

Mining the Land—"Mining" the land usually takes the form of shortened fallow periods-leaving inadequate time for the natural regeneration of soil-as population pressures mount. It is obviously a temporary solution, but one often resorted to by those without access to the modern agricultural

[5] U.S. Congress, Office of Technology Assessment, *Enhancing Agriculture in Africa: A Role for U.S. Development Assistance,* OTA-F-356 (Washington, DC: Government Printing Office, September 1988).

inputs needed to raise crop yields.[6] Declining yields from such "mining" are seen in a number of local and regional areas, particularly in Africa.[7]

Migration-Many people migrate to new lands or to urban areas. In addition to population pressures or soil exhaustion, factors forcing people to migrate from long-established farming areas to new lands include the low productivity of traditional agriculture; inequities in land tenure for many subsistence farmers; drought or other disasters; and, in some areas, mechanization of agriculture and/or consolidation of agricultural lands. In many cases, currently farmed areas have been subdivided among successive generations to the point that the landholdings for those who remain are, or will soon become, marginal. In Rwanda, for example, the average smallholder had 1.2 hectares in 1984 and, by tradition, would divide it equally among his average of four sons—leaving them 0.3 hectares each. If the same trend continues, the following generation will have less than 0.1 hectare each.[8] Estimates of the number of landless or near-landless (with too little land to subsist) in developing countries range as high as 1 billion people, most of them in Asia.[9]

Wage-paying jobs are scarce for those who are forced to migrate. Land-anywhere they can get it—for subsistence agriculture and fuelwood is often their only means of survival. Increasingly, however, available lands are remote, only marginally productive, or ecologically fragile--on upland regions that are easily eroded when groundcover is removed, on arid or semi-arid lands, or in forested areas of high biological diversity (but which may have poor soils). As many as 370 million people in developing countries may live in rural areas that are ecologically vulnerable.[10] To generate good yields on a sustainable basis on these lands often requires larger inputs of labor and/or capital and technology than the lands left behind-inputs to which these people seldom have access.[11] This maybe particularly true in newly opened areas where infrastructure (including access to extension efforts) is especially weak. The immigrants into these areas may be unfamiliar with the different agricultural techniques appropriate (sustainable) to these new lands and resources.

In many regions, shifting agriculture is initially practiced by those who migrate.[12] (Sing agriculture is also practiced traditionally by "long-term" residents in many areas and is a sustainable form of agriculture if fallow periods are sufficiently long.) Shifting agriculture begins with forest-fallow systems in which small patches of land are cleared and cultivated for a few years and then left fallow for as long as two to three decades (see ch. 3). This remains an important form of agriculture in west Africa, southeast Asian hill communities, parts of South America,[13] and elsewhere.[14] This form of shifting—or slash and burn-agriculture is believed by many to be the most important cause of secondary[15] forest destruction and to be roughly comparable to commercial logging in its impact on primary forest (table 5-2).[16] Shifting cultivation consumes enormous amounts of biomass energy in the process of clearing the forest.[17]

Modern Agriculture-Those farmers with access to good soils and water resources and modern agricultural inputs can increase the yields of their croplands. Modern agricultural practices in develop-

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6 Poor soil quality or inadequate water resources *may also* be significant constraints on raising crop yields even with high levels Of agricultural inputs.

7 U.S. Congress, Office of Technology Assessment op. cit., footnote 5, pp. 63 ff.; United Nations Food and Agriculture Organization, *African Agriculture: The Next 25 Years, Annex* II, *"The* Land Resource Base" (Rome, Italy: United Nations, 1986).

8 United Nations Population Fund, "The State of World Population 1990," New York, 1990.

9 H. Jeffrey *Leonard, Environment and the Poor: Development Strategies for a Common Agenda (New* Brunswick, NJ: Transaction Books, 1989).

10 Ibid.

11 U.S. Congress, Office of Technology Assessment, op. cit., footnote 5.

12 Alternatively those who migrate may continue their previous pattern of agriculture—often permanent agriculture--rather than adopting shifting agriculture techniques as traditional in the new area.

13 Norman Myers, *Deforestation Rates in Tropical Forests and Their Climatic Implications* (London: Friends of the Earth Limited, 1989).

14 U.S. Congress, Office of Technology Assessment, *Changing By Degrees: Steps To Reduce Greenhouse Gases,* forthcoming.

15 Secondary forest is that which has been logged in the past and then allowed to regrow, or has otherwise been significantly affected by human activity.

16 See also Julia C. Allen and Douglas F. Barnes, "The Causes of Deforestation in Developing Countries," *Annals of the Association of American Geographers,* vol. *75, No. 2, 1985,* pp. 163-184.

17 Kirk R. Smith, "The Biofuel Transition," *Pacific and Asian Journal of Energy,* 1987, pp. 13-32; Terry Rambo, "Human Ecology Research on Tropical Agroecosystems in Southeast Asia," *Singapore Journal of Tropical Geography,* vol. 3, No. 1, 1982. Some of the biomass ash generated serves as nutrients for the crops subsequently planted.

Table 5-2—Estimates of Land Use Changes in Closed and Open Tropical Forests, circa 1980 (million hectares per year)

	Closed forest					Open forest			
	Seiler and Crutzen		Food and Agricultural Organization	Lanly	Myers	Seiler and Crutzen		Food and Agricultural Organization	Lanly
Land use change	Low	High				Low	High		
Primary forest to:									
Shifting cultivation	2.6	3.6	3.2	3.4	1.9	—	—	1.2	1.7
Permanent pasture	1.6	1.4	1.1	2.5	0.6	1.7	2.1	0.8	1.3
Permanent agriculture	0.3	2.2	1.1	2.3	0.0	0.2	3.0	0.7	0.8
Logged forest	—	–	4.6	3.7	4.5	—	—	—	—
Logged forest to:									
Permanent pasture	—	—	1.1	—	0.6	—	—	—	—
Permanent agriculture	—	—	1.0	—	3.9	—	—	—	—
Secondary forest to:	14.9	40.0	18.5	22.0	3.4	6.9	21.9	11.4	18.6
Shifting cultivation									
Permanent pasture	0.5	1.5	0.1	—	3.3	1.0	1.0	—	—
Permanent agriculture	0.6	0.8	0.1	—	6.8	0.2	1.4	—	—

NOTE: The data in this table maybe significantly inaccurate. The table is presented here only to provide a general indication of the rates and causes of deforestation. The Food and Agricultural Organization (FAO) and Lanly data are essentially the same (Lanly is the principal author of the FAO study), based primarily on official government statistics, and maybe underestimates of the rate of deforestation. A more recent review by Myers, for example, indicates substantially higher rates.[1] The UNFAO currently has underway a more detailed study that may resolve some of these large discrepancies.

[1] Norman Myers, *Deforestation Rates in Tropical Forests and Their Climatic Implications* (London: Friends of the Earth, December 1989).

SOURCE: R.P. Detwiler and Charles A.S. Hall, "Tropical Forests and the Global Carbon Cycle," *Science, vol.* 239, Jan. 1, 1988, pp. 42-47, citing Seiler and Crutzen, Food and Agricultural Organization, Lanly, and Myers.

ing countries use, to varying degrees, improved plant species, synthetic fertilizers, pesticides and herbicides, irrigation, and mechanized operations to generate higher crop yields. These require high levels of capital and energy inputs.

Modern agriculture has, with mixed success, provided environmental, social, and economic benefits. It has moderated cropland expansion into ecologically fragile or particularly valuable lands through technological advance (the green revolution) and energy inputs in the form of fertilizer, irrigation, and mechanical operations. Over the 20-year period from 1965 to 1985, cropped areas increased by only 14 percent, 35 percent, and 4 percent in Africa, South America, and Asia while their populations increased by roughly 75 percent, 60 percent, and 50 percent respectively (table 5-3). Modern agriculture has also raised the personal incomes of many farmers; and it has contributed to national economic growth in many countries, especially in Asia.

Modern agriculture has also had serious shortcomings. It has increased economic inequities between those farmers who have sufficient land and access to capital and other inputs necessary for high-yield agriculture and those farmers who do not have such resources, and it has displaced laborers in many cases. It has caused environmental damage through the misuse of fertilizers, pesticides, and herbicides. Inadequate investment and poor management have led to waterlogging and salinization of valuable irrigated lands. Finally, modern agricultural techniques require dramatic increases in commercial energy use.[18] Concern over environmental impacts and high dependence on purchased inputs has led to considerable interest in farming systems that depend more on resources internal to the farming system and less on external purchases. These agricultural and agroforestry systems tend to be very information and management-intensive.[19]

Irrigated Lands—Irrigation is an important element in modern agriculture. It frees the farmer from dependence on irregular rains and raises yields, allowing double- and even triple-cropping. Some 160 million hectares of land in developing countries are irrigated. In Asia alone, 100 million hectares are irrigated, and this land produces roughly 60 percent of the region's food on just 45 percent of its cropped area.[20] In India, more than 6 million electric and 3 million diesel pump sets have been deployed (see ch. 3), consuming nearly 2,000 GWh of electricity and 3 million tons of diesel fuel in 1985.[21]

Inadequate investment and poor management have resulted in various degrees of salinization and/or waterlogging of irrigated lands in many countries. For example, by one estimate 75 percent of Pakistan's irrigated land suffers salinization and/or waterlogging, with corresponding reductions in crop yields.[22] Some 20 million hectares-roughly half--of India's irrigated croplands have sufficient salt buildup to reduce productivity; another 7 million hectares of land in India now lie unused due to excessive salt.[23] (Similar problems afflict the United States, where 20 to 25 percent of the 20 million hectares of irrigated lands are affected by salinization.[24]) Reclamation is possible through improvements in canals and other infrastructure to reduce leakage and by providing drainage from the fields, but it is expensive.

The technology to prevent or minimize salinization and waterlogging has been available since the

[18] Note that the energy intensity of shifting—or slash and burn-cultivation may be significantly higher than commercial agriculture when the energy consumed by burning off the standing biomass is taken into account. However, commercial fuels are little used, if at all, in shifting agriculture.

[19] Advisory Committee on the Sahel, *Agroforestry in the West African Sahel*, Board on Science and Technology for International Development National Research Council (Washington DC: National Academy Press, 1983, 1984); U.S. Congress, Office of Technology Assessment, op. cit., footnote 5; Clive A. Edwards et al., *Sustainable Agricultural Systems* (Ankeny, Iowa: Soil and Water Conservation Society, 1990); Robert Winterbottom and Peter T. Hazlewood, "Agroforestry and Sustainable Development: Making The Connection," *AMBIO*, vol. 16, No. 2-3, 1987, pp. 1(W11O; C. Okail and J.E. Sumberg, "Sheep and Goats, Men and Women: Household Relations and Small Ruminant Production in Southwest Nigeria," *Understanding Africa's Rural Households and Farming Systems*, Joyce Lewinger Moock (cd.) (Boulder, CO: Westview Press, 1986).

[20] Montague Yudelman, "Sustainable and Equitable Development in Irrigated Environments," *Environment and the Poor: Development Strategies for a Common Agenda*, Jeffrey Leonard (cd.) (New Brunswick, NJ: Transaction Books, 1989).

[21] Ashok Desai, "Energy Balances for India, 1985-86," contractor report prepared for the Office of Technology Assessment, 1990. This is equivalent to 125,000 GJ.

[22] Yudelman, op. cit., footnote 20. Total cmp areas from World Resources Institute, *World Resources 1990-91* (New York, NY: Oxford University Press, 1990). For other estimates, see C.E. Whitman et al. (eds.), *Rainfed Agriculture in the Near East Region*, proceedings of the workshop at Amman Jordan, Jan. 18-23, 1986, USDA and USAID, p. 92.

[23] Yudelman, op. cit., footnote 20. Total crop areas from *World Resources 1990 -91*,' op. Cit., footnote 22.

[24] World Resources Institute, *World Resources 1987* (New York, NY: Basic Books, 1987), p. 280.

Table 5-3-Changes in Land Area Uses

Region	Total area (million hectares)	Population density, 1989 (people per thousand ha)	Cropland area: 1985-87 percent of total land area	Cropland area: 1964-66 to 1983-85 percent change in cropland	Permanent pasture: 1985-87 percent of total land area	Permanent pasture: 1964-66 to 1983-85 percent change in pasture	Forest/woodlands: 1985-87 percent of total land area	Forest/woodlands: 1964-66 to 1983-85 percent change in forest	Other land: 1985-87 percent of total land area	Other land: 1964-66 to 1983-85 percent change in other uses
Africa	2,965	212	6.2	14.0	26.7	–0.5	23.2	-8.6	43.9	3.6
N. America	2,139	197	12.8	7.7	17.2	–2.4	32.0	-5.9	38.0	1.5
S. America	1,753	166	8.0	35.2	27.0	9.4	51.6	-7.3	13.4	-1.4
Asia	2,679	1,139	16.8	4.2	25.3	-3.0	20.2	-4.6	37.7	-0.7
Europe	473	1,050	29.6	–5.0	17.8	-4.9	33.2	7.1	19.4	3.9

SOURCE: World Resources Institute, *World Resources 1988-89 (New York, NY:* Basic Books, 19SS) table 16.1; World Resources institute, *Work/ Resources 1990-91 (New* York, *NY: Oxford* University Press, 1990), table 17.1.

1950's, yet designers frequently fail to incorporate these improvements in their projects. Many factors contribute to this failure. One factor may be that designers tend to be overly optimistic in their initial appraisals: they assume that waterlogging and salinization will not occur for 20 to 30 years, and that drainage systems and other capital-intensive improvements will not be necessary before then. This lowers the apparent costs of their projects and may improve the chances that the projects will be approved.[25]

Pasture-The opening up of lands for pasture is a significant cause of deforestation (table 5-2) particularly in Central and South America where grazing lands have increased by more than 9 percent during the past 20 years (table 5-3).

Overgrazing may also play a significant role in the desertification of semi-arid regions.[26] Overgrazing and trampling can quickly destroy the grass layer. Without the protection of ground cover, topsoil can be washed or blown away, lowering fertility. In some areas, the full force of rain on the soil can bring clay particles to the surface and cause surface hardening and sealing that seeds cannot penetrate.[27] The end result of such processes can be desertification.[28]

Herders burn grasslands to encourage new growth; numerous studies have shown this new growth to be particularly good forage for their herds.[29] More generally, repeated burning is believed to help create and maintain much of the world's savannah and grassland.[30] Such brushfires in the African grasslands may burn as much as 2 billion tons of biomass annually, cause volatilization of organic nitrogen and sulfur, and allow excessive leaching of other valuable nutrients.[31] This maybe particularly damaging in much of the Sahel, where growth is already strongly limited by the lack of nutrients.[32] Thus, brushfires help the herder feed his animals in the near term but, in the longer term, lower soil fertility, and kill brush and trees that hold the soils and pull nutrients up from deep in the ground.[33] Brush and grassland fires may also be significant contributors to regional air pollution and may contribute modestly to the global increase in greenhouse gases.[34]

More stable supplies of forage might reduce the need of herders to maintain large numbers of animals in order to ensure the survival of a few through periods of drought. Higher quality forage (higher protein content) would reduce the need to burn grasslands. Inputs of capital- and energy-intensive fertilizer, increased supplies of water, and mechanical harvesting of the forage (or even grain crops) when its protein content is at a maximum-as is common in industrial countries-might aid in achieving both of these goals.

Commercial Logging--Commercial logging impacts perhaps 3 to 5 million hectares of primary tropical forest annually (table 5-2). In many areas, only the highest grade logs are removed from the forest. But for every tree removed, roughly 5 to 10 other trees are destroyed.[35] Commercial logging also develops roads that allow settlers access to forested regions, where they can clear the forests for farms or ranches.

Biomass Fuels—Biomass-wood, crop residues, and animal dung-is the primary fuel for people in

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[25]Yudelman, op. cit., footnote 20.

[26]William H. Schlesinger et al., "Biological Feedbacks in Global Desertification," Science, vol. 247, Mar. 2, 1990, pp. 1043-1048.

[27]National Research Council, Board On science and Technology in Development, *Agro Forestry in the West African Sahel* (Washington, DC: National Academy of Sciences, 1983); Georges Novikoff and Mohamed Skouri, "Balancing Development and Conservation in Pre-Saharan Tunisia," *AMBIO*, vol. 10, Nos. 2-3, 1981, pp. 135-141.

[28]United Nations Food and Agricultural Organization, African *Agriculture: The Next 25 Years*, Annex II, "The Land Resource Base," Op. Cit., footnote 7.

[29]J. Dirck Stryker, "Technology, Human Pressure, and Ecology in the Arid and Semi-Arid Tropics," in H. Jeffrey Leonard (cd.), op. cit., footnote 9.

[30]Carl Sagan, Owen B. Toon, and James B. Pollack, "Anthropogenic Albedo Changes and the Earth's Climate," *Science*, vol. 206, 1979, pp. 1363-1368; Daniel Finn, "Land Use and Abuse in the East African Region," *AMBIO*, vol. 12, No. 6, 1983, pp. 296-301; DJ. Pratt and M.D. Gwynne (eds.), *Rangeland Management and Ecology in East Africa (Huntington NY:* Robert E. Kreiger Publishing Co., 1977).

[31]National Research Council, Board on Science and Technology in Development, *Environmental Change in the West African Sahel* (Washington, DC: National Academy of Sciences, 1983); World Resources Institute, *World Resources 1990-91 (New* York, NY: Oxford University Press, 1990).

[32]H. Breman and C.T. deWit, "Rangeland Productivity and Exploitation in the Sahel," *Science*, vol. 221, 1983, pp. 1341-1347.

[33]Stryker, op. cit., footnote 29.

[34]World Resources Institute, World Resources 1990-91 (New York, NY: Oxford University Press, 1990).

[35]Fred Pearce, "Hit and Run in Sarawak," *New Scientist*, May 12, 1990, *pp.* 46-49.

rural areas, and in many regions it is also important for the urban poor (see ch. 3). Until recently, it was widely believed that many developing countries were on the verge of being transformed into treeless deserts or mountain wastelands due to the demand for fuelwood. These predictions were largely based on the "gap" model, which assumed a freed per-capita demand for fuelwood and a growing population while at the same time the forest base was declining due to agricultural expansion and over-cutting of the forest.[36]

In more recent studies, however, it has been found that the use of fuelwood is highly elastic according to its availability and the labor required to collect it or, if traded, its price. When fuelwood is difficult to obtain by foraging, people quickly resort to lower quality wood, agricultural residues, or dung. More generally, rural subsistence farmers cause relatively little damage to forests, as they usually take only deadwood or small limbs. They do not have the tools to cut down large trees. Much of the wood they collect is from hedgerows or other sources near their farms. In Kenya, for example, trees outside the forest supply half the fuelwood demand.[37] And in West Java, one study found that three-fourths of all the fuel collected came from within family courtyards and gardens, and two-thirds of this fuel was branches and twigs .38

In contrast to rural foragers, commercialized fuelwood and charcoal operations to supply urban households, commercial facilities and industrial operations often cut whole trees and can damage or destroy forested areas. The impact of commercial demands for fuelwood are limited, however, as users will switch to fossil fuels when fuelwood becomes scarce and prices climb (ch. 3).[39] The extent of the damage to the forest resulting from commercialized fuel demand will then depend on the distance between the user and the forest, the size of the forest, the size of the demand, the rate of regrowth, and other factors. The use of biomass for fuel is not usually a principal cause of deforestation. It does, however, add additional pressure on forest resources. In arid or semi-arid regions, where forest growth is slow and there is a high population density or a concentrated urban demand for fuelwood, such as the African Sahel, the use of biomass fuels can contribute significantly to local deforestation.[40] Similarly, the use of biomass fuels can lead to local deforestation in some cases where there is a concentrated commercial or industrial demand.

Environmental Impacts

The environmental impacts of agriculture, ranching, lumbering, and the use of biomass for fuel include deforestation, desertification, soil erosion, flooding, pesticide and fertilizer runoff from cropland, and air pollution from biomass fuels.

Deforestation[41]

The forests of the developing world provide a number of resources and benefits, including food, fuel, fodder, fiber, timber, and medicines. Forests are a vital ecological resource, protecting soils, maintaining diverse plant and animal life, regulating the flow of water, and playing an important role in the global carbon cycle. Forests may also strongly influence regional climates.[42] The loss of tropical forests not only threatens to deprive the world of valuable resources on which it currently depends, but also to foreclose opportunities to discover new

[36] Gerald Foley, "DiscussionPaper on Demand Management,'' proceedings of the ESMAP Eastern and Southern Africa Household Energy Planning Seminar, Harare Zimbabwe, Feb. 1-5, 1988, UNDP/World Bank Energy Sector Management Assistance Program, Activity Completion Report No. 085/88.

[37] Phil O'Keefe, "Fuel for the People: Fuelwood in the Third World,'' *AMBIO*, vo1. 12, 1983, pp. 21-26.

[38] M. Hadi Soesastro, ''Policy Analysis of Rural Household Energy Needs in West Java,'' *Rural* Energy to *Meet Development Needs: Asian Village Approaches,* M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds.) (Boulder, CO: WestView Press, 1984), p. 114.

[39] Douglas F. Barnes, ''Understanding Fuelwood Prices in Developing Nations," draft, Household EnergyUnit, Industry and EnergyDepartment, World Bank, Washington DC, Oct. 31, 1989.

[40] Douglas F. Barnes, World Bank, "Population Growth, Wood Fuels, and Resource problems in Sub-Saharan Africa," Industry and Energy Department Working Paper No. 26, March 1990; R. Moss and W. Morgan, *Fuelwood and Rural Energy Production and Supply in the Humid Tropics* (Dublin, Ireland: Tycooly International Publishing Ltd., 1981); Finn, op. cit., footnote 30; Dennis Anderson and Robert Fishwick, World Bank, "Fuelwood Consumption and Deforestation in African Countries," World Bank Staff Working Paper, No. 704, 1984.

[41] For detailed reviews of deforestation and policy responses to it, see: U.S. Congress, Office of Technology Assessment, *Changing By Degrees: Steps To Reduce Greenhouse Gases,* forthcoming; U.S. Congress, Office of Technology Assessment, *Technologies to Sustain Tropical Forest Resources, OTA-F-214* (Springfield, VA: National Technical Information Service, March 1984); and Robert Winterbottom, "Taking Stock: The Tropical Forestry Action Plan After Five Years," World Resources Institute, Washington, DC, June 1990.

[42] J. Shukla, C. Nobre, and P. Sellers, "Amazon Deforestation and Climate Change," *Science,* vol. *247, Mar. 16,* 1990, pp. 1322-1325.

potential sources of wealth and scientific knowledge. On the other hand, tropical forests offer an economic opportunity that the poor in developing countries wish to seize as quickly as possible.[43] Governments may also want to colonize forest lands in order to establish more clearly their legal claim to national territory.

The rate of global deforestation-from all causes--is highly uncertain, with estimated rates in the early 1980s ranging from roughly 0.5 percent[44] to 1.8 percent[45] annually. These rates appear to be accelerating due to increasing population and other pressures noted above.

The UNFAO 1990 Forest Resources Assessment **estimates the current annual** global deforestation rate as 1.2 percent-double their estimate for 1980.[46] Forested areas and deforestation rates vary widely between countries. Indonesia and Brazil have huge areas of closed forests (100 and 350 million hectares, respectively) and annual rates of deforestation of perhaps 0.4 to 1.4 percent and 0.5 to 2.3 percent, respectively. Aggregate figures, however, tend to obscure severe deforestation occurring in certain regions. Ivory Coast, for example, has just 16 million hectares of forest remaining, and suffers an annual deforestation rate variously estimated between 6.5 and 15.6 percent. A number of other countries lie between these extremes, with forested areas of 5 to 50 million hectares and deforestation rates variously estimated in the range of 2 to 8 percent annually .47 At these rates, their closed forests could disappear in a few decades.

Desertification

Desertification can result from a variety of factors, depending on the region, including long-term climate trends, overgrazing, poor farming practices, and deforestation.[48] Although anecdotal evidence indicates that drylands in many regions are becoming decertified at an increasing rate, there is little reliable data to support the case. The "Global Assessment of Soil Degradation," initiated in late 1987 by the United Nations Environmental Program and the International Soil Reference and Information Centre in the Netherlands, should provide some of these data.

Impacts of Deforestation and Desertification

Among the potential impacts of deforestation and desertification are soil erosion and degradation, fuelwood and fodder shortages, increased flooding, microclimatic changes, and loss of biodiversity.[49]

Soils—Little soil is lost from forests or grasslands. When vegetation is removed, massive amounts of soil can be washed away as rainwater flows across the surface. Measurements in Tanzania indicated that up to half the rainfall was lost as runoff from bare fallow (3.5° slope), carrying with it some 70 tons of soil per hectare.[50] Similar impacts have been noted elsewhere.[51] With no shading, soil temperatures rise dramatically and can greatly reduce the vital biological activity in the soil.[52] Loss of tree cover also allows higher average wind velocities (and soil erosion) and, combined with the reduced soil moisture content, can lower crop yields.[53]

43Ricardo Radulovich, "A View on Tropical Deforestation," *Nature, vol. 346,* July 19, 1990, p. 214.

44Jean-Paul Lanly, "Tropical Forest Resources, « Forestry Paper No. 30, United Nations Food and Agriculture Organization, Rome 1982.

45Myers, op. Cit., footnote 13-

‘'’World Deforestation Increases at Quicker Rate Than Expected," *MultinationalEnvironmental Outlook,* Aug. 21, 1990, p. 134.

47Myers, op. cit., footnote 13, p. ²* ⁴0

48G. Novikoff, '~ Desertification by Overgrazing,'' *AMBIO*, vol. 12, No. 2, 1983, pp. 102-105; H.F. Lamprey and Hussein Yussuf, ''Pastoralism and Desert Encroachment in Northern Kenya,'' *AMBIO*, vol. 10, Nos. 2-3,1981, pp. 131-134; National *Research Council, Environmental Change in the West African Sahel,* op. cit., footnote 31; D. Anderson, and R. Fishwick, "Fuelwood Consumption and Deforestation in African Countries," World Bank, Staff Working Paper No. 704, 1984; Schlesinger et al., op. cit., footnote 26.

49Kuswata Kartawinata et al., ''The Impact of Man of a Tropical Forest in Indonesia,'' *AMBIO*, vol.10, Nos. 2-3,1981, pp. 115-1 19; Lester R. Brown, "World Population Growth, Soil Erosion, and Food Security," *Science, vol. 214, 1981,* pp. 995-1002; Alain Grainger, *Desertification* (London: Earthscan, 1984), p. 94.

50Phil O'Keefe, ''The Causes, Consequences and Remedies of Soil Erosion in Kenya,'' *AMBIO*, vo1. 12, No. 6, 1983, pp. 302-305.

51U.S. Congress, Office of Technology Assessment, op. cit., footnote 41; Finn, op. cit., footnote 30; *Eneas Salati* and Peter B. *Vose*, "Depletion of Tropical Rainforests;" *AMBIO*, vol. 12, No. 2, 1983, pp. 67-71, Vaclav Smil, "Deforestation in China," *AMBIO*, vol. 12, No. 5, 1983, pp. 226-231; Nigel J.H. Smith, "Colonization Lessons from a Tropical Forest,'' *Science, vol. 214, 1981,* pp. 755-761; A.H. Gentry and J. Lopez-Parodi, "Deforestation and Increased Flooding of the Upper Amazon,'' *Science,* vol. 210, 1980, p. 1354.

52Salati and Vose, op. cit., footnote 51; Henri Dosso, Jean Louis Guillaumet, and Malcolm Hadley. ''Land Use Problems in a Tropical Forest,'' *AMBIO*, vol. 10, No. 2-3, 1981.

53Dennis Anderson, "Declining Tree Stocks in African Countries," *World Development,* vol. 14, No. 7, 1986, pp. 853-863.

Fuel and Fodder—As forests and grasslands disappear, rural people are increasingly forced to rely on agricultural residues and dung for their cooking and heating needs, and on crop residues for animal fodder. The failure to return organic materials to the soil can have significant environmental impacts, even if these impacts are longer term and more subtle than is sometimes suggested. People in many areas already divert organic residues to other uses, often with little apparent near-term effect on yields. For example, crop residues such as millet or sorghum stalks tend to be poor fertilizers and are difficult to recycle; they are often burned in the fields to prevent them from harboring crop pests. Similarly, dung quickly loses its nitrogen and much of its effectiveness as a fertilizer when left lying in the sun, as is comrnon.[54] In areas with poor soils and/or high rainfalls that quickly leach nutrients out, however, crop yields may drop quickly if residues are not returned to the soil.

In the longer term, the loss of organic material can reduce the productivity of even the highest quality soils. Organic matter in soils provides important nutrients needed by plants; it helps the soil bind important minerals-e. g., magnesium, calcium, and potassium-that would otherwise be leached away; it buffers the acidity of the soil; and it improves water retention and other physical characteristics.[55]

Wafer—When the natural water regulation system provided by forests and grasslands is removed, stream flows tend to become more erratic, with reduced flows during dry seasons and worse floods in the wet season. This can interfere with agriculture, fishing, and darns and can threaten inhabitants.

Table 5-4-Sedimentation Rates of Some Reservoirs in India

Reservoir	Lifetime (years) Planned	Revised
Bhakra	88	47
Maithon	246	24
Hirakund	100	35
Ram Ganga	185	48

SOURCE: Kunwar Jalees, "Loss of Productive Soil in India," *International Journal of Environmental Studies, vol. 24,1985, pp. 245-250.*

Eroded soils choke downstream waterways and reservoirs, reducing their ability to handle the increased volumes of water running directly off the watersheds.[56] Over the past 10 years, the area annually flooded in India has increased by 18 percent.[57] Some observers attribute this increased flooding to the clearing of regional forests. Flood and erosion damage due to the clearing of India's forests has been estimated at $20 billion for the period from roughly 1960 to 1980, including loss of topsoil, loss of property to floods, and shortened reservoir lifetimes (table 5-4).[58] Other estimates place the direct costs of repairing flood damage in India at more than $250 million per year.[59]

Climate—In some regions, a significant portion of the rainfall is generated from moisture pumped back into the atmosphere by vegetation. Removal of this vegetation may then contribute to climatic change in the region.[60] The surface reflectance is changed and may likewise affect climate.[61] To the extent that the local climate changes due to the loss of vegetation, it may become more difficult to reverse the process and restore grasslands and

54G.C. Aggarwal, "Judicious Use of Dung in The Third World," *Energy,* vol. 14, No. 6,1989, PP. 349-352.

55Geoffrey Barnard and Lars Kristoferson, *Agricultural Residues as Fuel in The Third World* (London: Earthscan, 1985.

56Erik p. Eckholm, *Losing Ground: Environmental Stress and World Food Prospects (New* York, NY: W.W. Norton& Co., 1976).

57U.S. Congress, Office of Technology Assessment, op. cit., footnote41.

58Ibid. A more general review of this problem in India is given in The State *ofIndia'sEnvironment 1984-84; The SecondCitizen'sReport* (New Delhi: Center for Science and Environment).

59John Spears, "Preserving Watershed Environment.s," *UNASYLVA*, vol. 34, *No. 137, 1982,* pp. *10-14.*

60Sagan et al., op. cit., footnote 30; J. Shukla and Y. Mintz. "Influence of Land-Surface Evapotranspiration on the Earth's Climate," *Science*, vol. 215, 1982, pp. 1498-1501.

61Robert S. Kandel, *Mechanisms Governing the Climate of the Sahel: A Survey ofRecent Modelling and Observational Studies,* OECD/CILSS/Club du Sahel, Report Sahel D(84)252, October 1984. See also Sagan et al., op. cit., footnote 30, estimates ofalbedo changes are given in Gregory Morris, "Environmental Impacts of Bioenergy Development,'' *Biomass Energy Systems: Building Blocks for Sustainable Agriculture,* Jan. 29-Feb. 1, 1985, Airlie House, Airlie, VA, The Rockefeller Brothers Fund and World Resources Institute,Washington, DC.

forests to something approaching their original form and extent.[62]

Biodiversity[63]--Plants in tropical rain forests have evolved a particularly rich array of potentially useful chemicals, yet fewer than 1 percent of all tropical plant species have so far been screened for biochemical of use to man.[64] A number of valuable medical products have already been developed from tropical plants, including highly effective drugs for leukemia and hypertension, muscle relaxants, and others.[65] Many other aesthetic, scientific, and commercial benefits may be realized from tropical forest products. Tropical deforestation and the loss of species would foreclose many of these opportunities.[66]

Although they have received much less attention, plants in arid and semi-arid regions similarly offer many potential benefits. These areas harbor a number of wild relatives to our basic crops-beans, potatoes, wheats, barleys, millets, sorghums, and many others—and are sources for genetic resistance to drought, heat, pests, and disease. The diverse genetic resources of wild varieties can be an important input into the higher yielding but genetically narrow varieties used in intensive agriculture. Many valuable genetic strains and species may beat risk in these arid and semi-arid regions.[67]

Deforestation can result in a direct conflict between the survival of species and the livelihoods of people who exploit the land. Such a conflict recently erupted in the United States over the endangered northern spotted owl.[68] There are similar conflicts in many developing countries. Tropical rain forests contain at least half and perhaps as many as 90 percent or more of the species found on earth, yet cover just 7 percent of the total land area. No one knows precisely the share of species held by tropical rain forests, because fewer than 2 million species have been officially classified out of a total number that is variously estimated to range from less than 5 to more than 50 million.[69] Many countries are taking steps to protect their biodiversity, and a few are realizing some success. Protection of the brow-antlered deer in northeast India, for example, is helping it make a comeback from near extinction.[70]

There are concerns in developing countries, however, that the costs of conserving biodiversity—in jobs and/or access to land and resources for the poor, security enforcement, administration, and the mistrust generated as governments deny their own people access to much-needed resources-will be born by the developing countries, but the benefits will be largely captured by commercial interests in industrialized countries.[71]

Air Pollution

The burning of biomass generates large amounts of air pollution in developing countries. Food is typically cooked over an open fire or a poorly vented stove-exposing women and children, as well as other members of the family, to high levels of toxic smoke (ch. 3). Similarly, in colder climates, homes in rural areas are often heated by open fires, further increasing exposures to toxic smoke.[72] One impact of this indoor air pollution is exacerbation of one of the most deadly classes of infectious illness, acute respiratory infections in children.

The use of biomass for fuel, clearing forest land for agriculture, and burning grasslands to generate

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[62] J. Shukla, C. Nobre, P. Sellers, "AmazonDeforestation and Climate Change" *Science*, vol. *247, Mar. 16, 1990,* pp. 1322-1325. H. Schlesinger et al., op. cit., footnote 26.

[63] For a complete review of this complex issue, see U.S. Congress, Office of Technology Assessment, *Technology to Maintain Biological Diversity*, OTA-F-330 (Springfield, VA: National Technical Information Service, March 1987).

[64] Neil A. Belson, ' 'Tropical Deforestation and the Response of the United States Congress,'' *Georgetown International Environmental Law Review, vol. 2,* Fall 1989; U.S. Congress, Office of Technology Assessment, op. cit., footnote 41.

[65] U.S. Congress, Office of Technology Assessment, op. cit., footnote 41.

[66] Edward O. Wilson, ''Threats t. Biodiversity,'' Scientific American, September 1989, pp. 108-116; Walter V. Reid and Kenton R. Miller, *Keeping Options Alive: The Scientific Basis for Conserving Biodiversity* (Washington, *DC:* World Resources Institute, October 1989).

[67] Gary Nabhan, ''How Are Tropical Deforestation and Desertification Affecting Plant Genetic Resources, "Annals *ofEarth,* vol. *4, No.* 1, pp. 21-22, 1986; Paul Raeburn, "Seeds of Despair," *Issues in Science and Technology,* Winter 1989-90, pp. 71-76.

[68] Library of Congress, Congressional Research Service, ''Economic Impacts of Protecting the Northern Spotted Owl," 90-74 ENR, Mar. 5, 1990.

[69] Robert M. May, "How Many Species Are There on Earth,'' *Science,* Sept. 16, 1988, pp. 1441-1449.

[70] Sanjoy Hazarika, "A Deer Comes Back From the Brink in India," New *York Times,* July 31, 1990.

[71] Ricardo Radulovich, ''A View on Tropical Deforestation,'' *Nature*, vol. 346, July 19, 1990, p. 214.

[72] Kirk R. Smith, *Biofuels, Ai, Pollution, and Health: A Global Review* (New York, NY: Plenum Press, 1987).

fresh forage for livestock all generate large amounts of smoke that contributes to regional air pollution. These activities also pump greenhouse gases into the atmosphere, potentially contributing to global climate change.[73] This is discussed in much more detail in the forthcoming OTA report, *Changing By Degrees: Steps To Reduce Greenhouse Gases.*

The Urban Sector

Causes of Environmental Degradation

Urban areas of developing countries are growing rapidly, in large part due to migration from rural areas. For the low-income countries, urban population jumped from 17 percent of total population in 1965 to 30 percent in 1987. In 1960, there were 59 cities with more than 500,000 persons in developing countries; by 1980 that number had grown to 165 cities.[74] In the early 1990's, cities in developing countries will need to absorb more than 100 million additional people annually.[75] This trend has important implications for both energy use and energy-related environmental impacts.

Urbanization and modernization can provide many desirable benefits-improved standards of living, increased opportunities for education and employment, and greater insulation from the vagaries of drought endured by those in rural areas. (They also reduce pressures on some aspects of the rural environment.) They also have costs, including potential damage to the environment.

Urbanization changes the consumption patterns of goods and energy-related services (ch. 3). Households make a transition from biomass to commercial fuels for cooking and other domestic services. Demand for consumer goods, notably electric appliances, increases. The economic base changes from agriculture and small rural industry to larger manufacturing and services, with a corresponding change in the demand for commercial energy. The need for public and personal transport grows as employment shifts from agriculture or rural industry located within walking distance of residences to large industry and commerce located further away. The high concentration of people requires the transport of food, fuel, and other materials from long distances, as well as effective management of wastes. These changes have significant impacts on energy use and on the environment.

Residential/Commercial Sector

The transition from biomass to clean commercial fuels such as liquefied petroleum gas (LPG) and electricity for residential cooking generally reduces the total amount of air pollution emitted and largely shifts that which is emitted from the household to distant refineries and electricity generation plants (ch. 3).[76] In some countries, however, clean commercial fuels are not widely available or remain too expensive. China, for example, uses about one-third of its coal in residences, of which nearly half is used for cooking (app. 3-A). Due in part to heavy residential coal use, some northern Chinese cities, such as Beijing and Tianjin, have very high sulfur dioxide concentrations.

Lights, refrigerators, air conditioners, and other electrical appliances in the residential/commercial sector provide highly desirable services and are penetrating urban areas much more rapidly than rural areas (ch. 3). These appliances consume large amounts of electricity, however, the generation of which can cause significant environmental damage if not properly controlled. Refrigerators and air conditioners also use chlorofluorocarbons (CFCs), which have already damaged the earth's protective ozone layer and are potent greenhouse gases.

Industrial Sector

Industry provides many goods that contribute to our material comfort and well-being. Industry can damage the environment through a variety of activities, however, if they are mismanaged or inadequately controlled. These include: placing heavy demands on natural resources as feedstocks or other inputs; intensively using electricity for mechanical drive and other needs; burning fossil fuels

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[73] R.P. Detwiler and Charles A.S. Hall, "Tropical Forests and the Global Carbon Cycle," *Science*, vol. 239, Jan. 1, 1988, pp. 42-47; Richard A. Houghton, "The Future Role of Tropical Forests in Affecting the Carbon Dioxide Concentration of the Atmosphere," *AMBIO*, vol. 19, No. 4, July 1990, pp. 204-209.

[74] World Bank, World *Development Report* 1989 (New York, NY: Oxford University Press, 1989).

[75] *World Development Report 1990*, op. cit.; Indicator Tables 1 and 31. The urban population—41 percent of the developing country total of 3.95 billion people-1.6 billion people and is growing at 6.9 percent annually.

[76] This refers to carbon monoxide, particulates, sulfur dioxide, nitrogen oxides, and other such chemical species. It does not refer to carbon dioxide, which may be increased by the use of nonbiomass fuels but not by biomass if the biomass is being produced on a sustainable basis.

for process heat; and generating hazardous wastes that may be discharged into landfills, water systems, or the air. Each industry has a different mix of these activities, and each activity has a different set of environmental impacts, depending on the use of environmental controls and other means of mitigation.

Industrial pollution can pose a particularly severe health hazard in developing countries when industries are established near existing residential areas, or when residential areas buildup around them. This has led to tragedies such as Bhopal, as well as serious systemic pollution such as found in Cubatao, Brazil, in the 1970's and early 1980's.[77] Often, the lowest income people are most seriously affected. This can lead to the situation in which the poor face all of their traditional risks to health-infectious disease, hunger and malnutrition, air pollution from biomass fuels-and at the same time face even greater than normal modem risks-such as exposure to hazardous wastes and toxic air pollutants.[78]

Transportation Sector

The transportation sector is the largest contributor to air pollution in many cities. For example, in Indian cities, gasoline-fueled vehicles—mostly two and three wheelers—are responsible for 85 percent of carbon monoxide and 35 to 65 percent of hydrocarbons in the air from fossil fuels.[79] Diesel vehicles—buses and trucks-are responsible for over 90 percent of nitrogen oxide (NO_x) emissions in urban India.[80] Use of emission control devices and engine modifications have significantly reduced exhaust emissions on newer vehicles in the United States, but these pollution controls are usually not standard on vehicles in developing countries. Runoff from roads also contributes to water pollution.

In each of these sectors, there are often difficult tradeoffs between longer term environmental imacts and immediate financial costs to consumers. Many developing countries also have shortages of skilled technical manpower to implement mitigation efforts. The extent to which technological innovations or other advances might ease these tradeoffs will be examined in a later report of this OTA study.

Environmental Impacts

Air

Air quality in many of the developing world's cities is poor, and has been deteriorating. The United Nations Environment Program (UNEP) estimates that up to one-half of the world's urban population, including residents of many industrialized countries, live in areas with marginal or unacceptable levels of sulfur dioxide (SO_2) in the air. Concentrations of SO_2 (see figure 5-1) and concentrations of total suspended particulate (see figure 5-2) in major cities in the developing world are considerably above World Health Organization guidelines. Photochemical smog has become a recurrent seasonal problem in many large tropical and subtropical cities.

The sources of these pollutants vary. Coal-used for electricity generation, industrial power and process heat, and domestic heating and cooking (China)--primarily emits sulfur dioxide, particulate, and nitrogen oxides. The combustion of oil or gas in stationary sources, such as electric generating units, emits many of the same pollutants-nitrogen oxides, hydrocarbons, particulate, and sulfur dioxide--but in much different proportions.[81] Nitrogen oxide, a major ingredient of urban smog, is the most harmful pollutant released on a large scale when electricity is generated from oil or gas. Mobile sources--cars, trucks, two and three wheelers, and buses-release large amounts of carbon monoxide, NO=, hydrocarbons, and particulate and are typically the largest source of these pollutants in urban areas. These mobile sources are also major contributors of lead pollution due to the use of lead as an octane booster in gasoline. Burning fossil fuels unavoidably generates carbon dioxide, the most important greenhouse gas. These pollutants (except carbon dioxide (CO_2)) can damage crops, forests, and structures and can aggravate human health problems.

77 World *Resources Institute, World Resources 1990-91 (New* York, NY: Oxford University Press, 1990), p. 41.

78 In the more general case, there is a shift in the types of risk that people are exposed to from the traditional to the modem. See Kirk R. Smith, "The *Risk* Transition," *International Environmental Affairs*, vol. *2, No. 3, in* press.

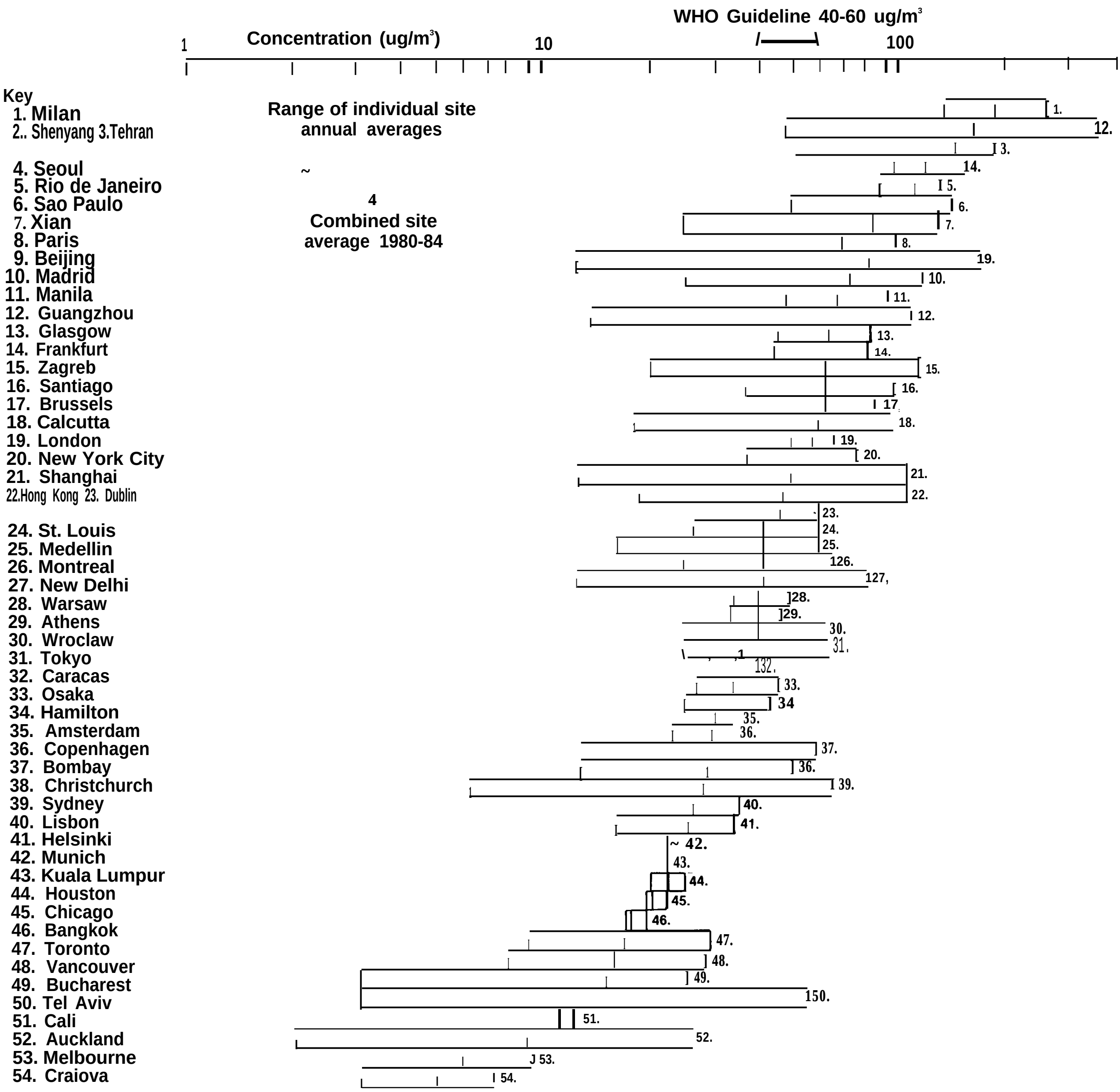
79 Tata Energy Research Institute, *TERI Energy Data Directory and Yearbook 1988 (New* Delhi, *India: 1989),* p. *250.*

80 Ibid.

81 Mitre Corp., "Health and Environmental Effects of Oil and Gas Technologies: Research Needs," report to the Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies, July 1981.

Figure 5-1-Sulfur Dioxide Levels in Selected Cities, 1980-84

Shown is the range of annual values at individual sites and the composite 5-year average for the city.

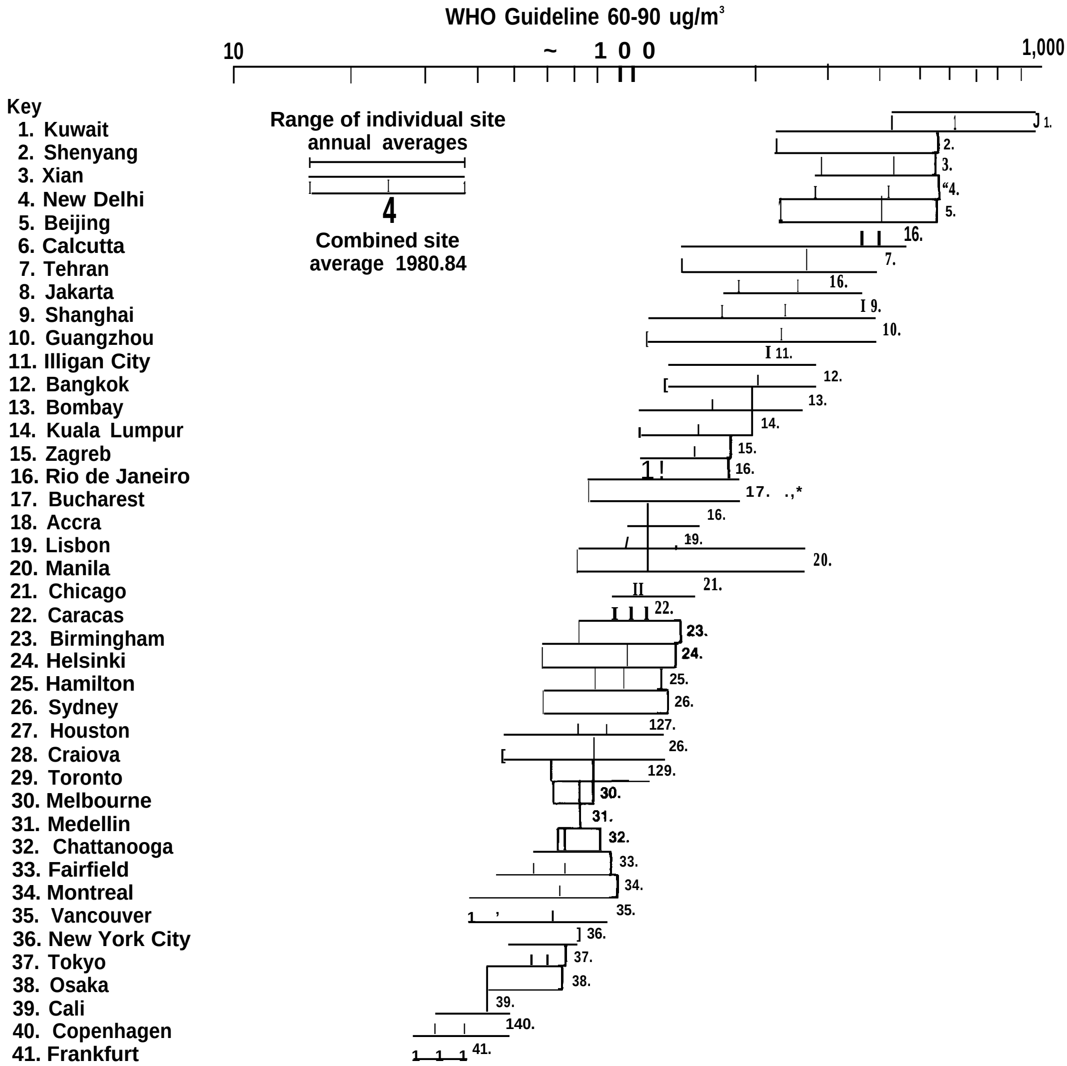


a Note logarithmic scale.

SOURCE: World Health Organization and United Nations Environment Programme, *Global Pollution and Health* (London: Yale University Press, 1987), figure 2, p. 5. (Logarithmic scale.)

Figure 5-2-Suspended Particulate Matter Levels in Selected Cities, 1980-84

Shown is the range of annual values at individual sites and the composite 5-year average for the city.



a Note **logarithmic scale.**

SOURCE: World Health Organization and United Nations Environment Programme, *Global Pollution and Health* (London: Yale University Press, 1987), figure 3, p. 6. (Logarithmic scale.)

Efforts to reduce emissions from coal burning usually involve removing harmful material from exhaust gases after combustion. Pollution controls, such as electrostatic precipitators or baghouses to control particulate, capture pollutants from exhaust gases, but they create solid wastes in the process. Flue gas desulfurization (FGD) equipment ("scrubbers") controls sulfur emissions by capturing the sulfur in the form of liquid sludges. Electrostatic precipitators are widely used in the developing world, but FGD systems are not common.[82] This may be due in part to the high costs of such systems. One study in India found that the addition of an FGD system would add about 15 percent to the cost of

[82] International Development and Energy Associates, Inc., "Clean Coal Technologies for Developing Countries," contractor report prepared for the Mice of Technology Assessment, May 1990, p. 25.

electricity .[83] Perhaps as significant is that Indian and Chinese coals have relatively low sulfur contents—typically 0.5 to 2.0 percent compared to 3 to 6 percent for Eastern European and some U.S. Coals.[84]

Adoption of more effective pollution control technologies already common in the industrialized world and improvements in energy efficiencies might significantly improve air quality in many cities of the developing world.

Water

The primary urban water pollution problem is the discharge of untreated or minimally treated human waste into water systems (this is also a significant problem in rural areas). As of the mid-1980's, only about half the developing world's urban population had adequate sewage facilities, and perhaps three-fourths had access to safe "drinking water. This situation contributes to the growth and spread of pathogenic viruses, bacteria, and protozoa and is directly or indirectly responsible for perhaps three-fourths of all illness and 80 percent of all child deaths.[85]

Industrial wastes also contribute significantly to water pollution in some areas. These range from agricultural industry wastes to heavy metals (mercury, cadmium, lead, and chromium) and chlorinated hydrocarbons-to name only a few. These pollutants can have serious impacts on water resources all the way downstream to the ocean. Many coastal areas are also being affected.[86] A recent study found that World Health Organization (WHO) standards for heavy metals-cadmium, lead, and mercury-were exceeded in one-third to three-fourths of the fish and shellfish samples taken from Jakarta Bay, Indonesia.[87] Mitigation strategies that might be applied include treatment of industrial effluents and reduction of the generation of hazardous materials themselves through improvements in manufacturing processes.[88]

Land

The major causes of soil pollution in urban areas are the disposal of solid wastes and the deposition of air pollutants such as SO_2 and particulate. The focus here is on solid wastes. Low-income countries generate much less urban refuse (around 0.5 kg per capita per day) than industrial countries (0.7 to 1.8 kg per capita per day).[89] In large cities, however, even modest per-capita levels can lead to large amounts of waste generation. Mexico City is estimated to generate 11,000 tons a day. Most of this waste originates from households, largely in the form of vegetable and putrescible materials. There is also a significant component of hazardous wastes (containing chemicals, heavy metals, and/or radioactive wastes) from industries.

In the developing countries, current procedures for disposing of such wastes are inadequate. Much household garbage is not collected at all, but left to decompose. Hazardous wastes may be dumped on uncontrolled municipal landfills. Only a small part of total wastes are disposed of in an environmentally safe reamer. Nonetheless, costs of even inadequate disposal can amount to as much as 30 percent of municipal budgets.[90]

Energy could, however, play a part in solving these problems. Urban waste can be used as feedstock for cogeneration plants. Process changes in energy-intensive industries such as steel, cement, and fertilizer may well, by economizing on the use of all materials, also reduce hazardous wastes.

[83] 1bid., p. 25.

[84] Ibid., pp. 7, 8, 27.

[85] World Resources Institute, World Resources 1990-91 (New York, NY: Oxford University Press, 1990); World Resources Institute, "Development and Pollution in the Third World,'' Tokyo Conference on the Global Environment and Human Response, Sept. 11-14, 1989; World Health Organization *The International Drinking Water Supply and Sanitation Decade* (Geneva: United Nations, 1986); World Health Organization and United Nations Environment Programme, *Global Pollution and Health (New* Haven, *CT: Yale* University Press, 1987).

[86] United Nations Environment Programme, "The State of the Marine Environment," 1990.

[87] World Resources Institute, "Development and Pollution in the Third World,'' op. cit., footnote 85.

[88] U.S. Congress, Office of Technology Assessment, *Serious Reduction of Hazardous Waste For Pollution Prevention and Industrial Efficiency*, OTA-ITE-317 (Washington, DC: U.S. Government PrintingOffice, September 1986). U.S. Congress, Office of Technology Assessment, *From Pollution to Prevention: A Progress Report on Waste Reduction,* OTA-ITE-347 (Washington, DC: U.S. Government Printing Office, June 1987).

[89] Sandra J. Cointreau, *Environmental Management of Urban Solid Wastes in Developing Countries: A Project Guide*, quoted in "Development and Pollution in the Third World,'' prepared by The World Resources Institute for the Tokyo Conference on the Global Environment and Human Response, Sept. 11-14, 1989 (Washington, DC: World Resources Institute, July 1989).

[90] World Resources Institute, *World Resources 1988-89 (New* York, NY: Basic Books, Inc., 1988), p. 46.

Energy Production and Conversion

Energy plays a critical role in fueling the transition from a traditional to a modern society and thus aiding economic and social development. In turn, this energy is extracted from rural areas-either as fossil fuels or renewable energy-and can have significant impacts on the rural economy and environment. Energy thus provides an important two-way linkage between rural and urban areas.

Used wisely, energy can provide environmental benefits; if misused it can also exact substantial environmental costs to the land, water, and air. The many social, economic, and environmental benefits have been reviewed in the preceding chapters; the environmental costs of extracting and transporting the major energy resources used in developing countries today--coal, oil, gas, hydroelectricity, and biomass-are briefly reviewed below.

Coal

Coal has significant environmental effects throughout the fuel cycle.[91] The environmental effects of coal mining depend on the techniques used. Mining methods are selected according to the depth of the coal, the thickness of the seams, and the availability of capital and equipment. In surface mining, topsoil and overburden are removed to expose the coal. The mining process can disturb surface lands and waters, and may also contaminate or disturb underground aquifers. Increased erosion, downstream siltation, and water contamination can follow if excavated material is not properly managed during mining. Soil productivity and water resources can be degraded if lands are not reclaimed adequately. The most severe impacts associated with underground mining are surface subsidence over mined-out areas, disruption of aquifers, and contamination of water by acid drainage. Additionally, dust and emissions from coal mining, preparation, and transport or related equipment can contribute to local air pollution.[92]

Oil and Gas

Oil and gas production have similar environmental impacts. During exploration and production, the major environmental concerns onshore include land disturbances, aquifer contamination, leaks and spills, and disposal of liquid and solid wastes. For offshore operations, concerns include the impacts of operations on fisheries and marine habitats, leaks and spills, and waste disposal.

Large spills of oil or petroleum products, which occasionally occur during production, storage, or transportation, are perhaps the most dramatic environmental threat associated with oil production. Small leaks and spills are much more common, however, and may have a greater overall impact on the environment. Oil spills can poison fish and aquatic animal and plant life. Additionally, sediments can trap oil, creating a long-term source of pollution. The well-publicized Alaskan oil spill of 1989 revealed the difficulties inherent in cleaning up large oil spills in difficult ocean environments.[93] Developing countries have had their share of oil spills too. The June 1979 blowout of the IXTOC 1 production well in the Mexican Caribbean was the largest oil spill to date.[94] It released an estimated 139 to 428 million gallons of crude oil into surrounding waters, as much as 40 times the amount spilled by the Exxon Valdez. Natural gas leaks pose little toxic threat to plants and animals but can explode or cause fires. The primary constituent of natural gas—methane--is also a potent greenhouse gas.

Petroleum refining generates hazardous liquid and solid wastes, as well as air emissions. These facilities have pollution control requirements similar to many other large industrial and chemical plants, but leaks of toxic compounds occur nevertheless.

Hydroelectricity

The major environmental impacts of large hydropower production projects result from the initial construction of the hydropower facilities, filling the reservoirs, and changing river flows. This is in

[91] U.S. Congress, Office of Technology Assessment, *The Direct Use of Coal*, OTA-E-86 (Springfield, VA: National Technical Information Service, April 1979), p. 186.

[92] Ibid.

[93] For a discussion of the technologies related to ocean spill cleanup, see U.S. Congress, Office of Technology Assessment, *Coping With An Oiled Sea: An Analysis of Oil Spill Response Technologies, OTA-BP-O-63* (Washington, DC: U.S. Government Printing Office, March 1990).

[94] Ibid. Many of the large spills listed in the OTA background paper occurred in or near developing countries.

contrast with other energy sources, for which major impacts are spread over the entire fuel cycle.

Large dam construction often requires the clearing of lands for access routes and sometimes for removal of construction material, with resulting soil degradation and erosion. Filling the reservoir can flood large tracts of land, uprooting people and leading to loss of forests, wildlife habitat, and species diversity. For example the Akosombo reservoir on the Volta in Ghana, with a land requirement of 8,730 km^2, approaches the size of such small countries as Lebanon or Cyprus.[95] Some currently proposed very large dam projects would inundate highly populated valleys and require large-scale resettlement of local residents.

The Three Gorges Dam project under consideration for the Yangtze river in China would be the world's largest hydroelectric project, generating the equivalent of approximately one-fifth the hydroelectricity currently produced in all of China each year, as well as providing flood control. Debate over this project has continued for six decades because it would entail the resettlement of approximately 1 million people; because it would deface one of China's most famous natural sites, and because critics believe that power could be provided more cheaply with smaller thermal and hydroelectric plants or through conservation.[96]

Dams disrupt the natural flow of rivers. Changed flows can erode riverbeds, alter flood patterns, harm aquatic ecosystems, and interrupt the spawning and migratory patterns of fish and other species. The introduction of a new lake can affect water tables and groundwater flows and interfere with the necessary flow of nutrients, and may induce microclimatic changes in humidity, cloud cover, and rainfall. In addition, if the vegetation is not cleared from the reservoir area before flooding, rotting organic matter releases significant amounts of $C0_2$ and methane, two potent greenhouse gases.

Hydropower facilities, in turn, are vulnerable to environmental degradation. Heavier than expected siltation of reservoirs from deforested and/or degraded lands upstream can reduce the lifespan of hydroelectric projects (see table 5-4).[97] The Hirakud reservoir in India, for example, was expected to be productive for about 110 years, but now has an estimated productive lifetime of 35 years.[98] In Costa Rica, excess sedimentation from soil eroded from steep slopes planted with coffee trees over the past 20 years has caused estimated losses of $133 million to $274 million at the Cachi hydroelectric station.[99]

Dams and the irrigation schemes dependent on these dams have also contributed to increased incidence of debilitating diseases, such as schistosomiasis.[100] Smaller hydroelectric systems and better management may minimize some of the above adverse consequences.

Biomass

Biomass fuels, which are critical to the rural and poor urban sectors of developing countries (chs. 2, 3, and 4), can have a variety of environmental impacts. These are discussed above and are closely intertwined with deforestation, desertification, and rural air quality. A later report from this study will examine the environmental effects of biomass use in detail, particularly in the context of producing clean biomass fuels (e.g., ethanol) and using them to fuel modern equipment.

Nuclear Energy

Nuclear energy currently makes little contribution to the overall energy requirements of developing countries. Seven developing countries produce uranium: South Africa, Niger, Gabon, India, Argentina, Brazil, and Pakistan.[101] Eight developing countries had operating commercial reactors as of late 1989 and several more had commercial reactors under

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[95]R.S. Panday (cd.), *Man-made Lakes and Human Health* (Paramari*bo:* University of Suriname, 1979).

[96]Robert Delfs, "wealth and Woe: The Long Struggle to Harness the Waters," *Far Eastern Economic Review*, vol. 147, Mar. 15, 1990, pp. 22-23; She@ WuDunn, "In China, Dam's Delay Spares a Valley for Now," *New York Times*, Apr. 18, 1989, p. C1.

[97]U.S. Congress, Office of Technology Assessment, op. Cit., footnote 41, p. 43.

[98]Ibid., p. 43.

[99]David Dudenhoefer, "Forest Crisis Nears," *The Tiw Times*, vol. 34, Feb. 16, 1990.

[100]United Nations Food and Agricultural Organization, op. cit., footnote 7, p. 69.

[101]United Nations, *Energy Statistics Yearbook, 1986* (New York, NY: 1988).

construction (ch. 4). A total of 28 developing countries had research reactors as of late 1988.[102]

The conventional nuclear fuel cycle includes uranium mining and processing, fuel fabrication, electricity generation, and radioactive waste disposal. Each of these steps has the potential to release varying amounts of toxic and/or radioactive materials to the environment. Releases usually take the form of small leakages but have, on rare occasion, also resulted in catastrophes such as Chernobyl. On the other hand, the nuclear power option releases little carbon dioxide or other greenhouse gases to the atmosphere, nor does it emit much sulfur dioxide, nitrogen oxides, or other air pollutants.[103] These tradeoffs pose difficult environmental choices.

Solar, Wind, and Other Renewable Energy

Solar energy can be used to heat water or dry crops, or can be turned directly into electricity by photovoltaic cells. Winds can be harnessed for pumping water or generating electricity. Though holding great promise for the provision of decentralized forms of energy for remote areas, as yet these sources provide only small amounts of energy for developing countries.

Geothermal energy, though still a very small part of total energy supply in developing countries, is being used in several Latin American and Asian developing countries and in Kenya. The environmental problems associated with geothermal energy production are highly dependent on the geochemical characteristics of each specific site and the extent to which good environmental practice is followed. Potential adverse environmental impacts include the release of gases (particularly CO_2), contamination of local aquifers by saline (and sometimes toxic) geothermal fluids into groundwater, subsidence of land overlying wells from which geothermal fluids have been extracted, and the generation of high-temperature liquid effluents containing metals and dissolved solids. With existing economically proven technologies and good management, however, these potentially adverse impacts can be kept under control.

Greenhouse Gases and Global Climate Change

The environmental impacts described above are largely limited to the individual countries concerned. Some activities-notably, the combustion of fossil fuels and deforestation-can have a wider impact, including impacts on the global climate. An international panel of scientific experts of the Intergovernmental Panel on Climate Change (IPCC)[104] recently concluded that: "emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. These increases will enhance the natural greenhouse effect, resulting, on average, in an additional warming of the Earth's surface. "105 Under the IPCC "Business as Usual" scenario, emissions of carbon dioxide are projected to grow from approximately 7 billion metric tonnes of carbon in 1985 to 11-15 billion metric tomes in 2025.[106] Methane emissions are projected to increase from 300 million metric tonnes in 1985 to 500 million metric tonnes by 2025. Based on current models and with these trends in greenhouse gas emissions continuing, scientists predict that global mean temperature will increase at a rate of about 0.3 'C per decade during the next century, a rate higher than that seen over the past 10,000 years.[107]

102World *Resources Institute, World Resources 1990-1991 (New* York, NY: Oxford University Press, 1990). Installed capacities are inadequate indicators by themselves, as capacity factors for nuclear, thermal, and hydroelectric plants vary considerably. Installed capacities and capacity factors can be found in World Bank, "Summary Data Sheets of 1987 Power and Commercial Energy Statistics for 100 Developing Countries," Industry and Energy Department Working Paper Energy Series No. 23, March 1990.

103Some carbon dioxide may be released during minin g, transport, or other operations by fossil-fueled equipment, and some maybe released in fabricating the construction materials-particularly cement.

104The Intergovernmental Panel on Climate Change (IPCC) is an international task force created by the World Meteorological Organization and the United Nations Environment Program. Initiated in 1987, this body focuses on analyzing current information available on climate change issues and devising strategies to address climate change.

105Intergovernmental Panel on Climate Change, ''Policymakers' Summary of the Scientific Assessment of Climate Change: Report to IPCC From Working Group I," June 1990, p. i.

106Intergovernmental Panel on Climate Change, Working Group III (Response Strategies Working Group), ''Policymakers' Summary of the Formulation of Response Strategies: Report Prepared for WCC," June 1990, p. iii.

107IPCC Working Group I, op. cit., footnote 105, p. ii.

More than half of the warming has been attributed to carbon dioxide. Atmospheric concentrations of carbon dioxide have increased by about 25 percent since preindustrial times. This rise is largely due to carbon dioxide emissions from the burning of fossil fuels and from deforestation.

In 1985, according to estimates for the IPCC Working Group III, developing countries contributed about one-quarter (26 percent) of annual global energy sector CO_2 emissions;[108] three-fourths came from the industrialized market countries and the centrally planned European countries (including the U.S.S.R.). By 2025, with expanding populations and rapidly increasing energy use, developing countries are projected to produce roughly 44 percent of global energy sector CO_2 emissions.

While the CO_2 emissions from the energy sector are fairly well known, there are large uncertainties about the contribution of emissions from deforestation and other land use changes. This makes it difficult to calculate with confidence the developing country share of both total annual and cumulative emissions for CO_2 and other gases. Estimates of the CO_2 emissions from tropical deforestation differ by a factor of four.[109] By various estimates, deforestation could be the source of between roughly 7 to 35 percent of total annual CO_2 emissions. Developing countries are also responsible for at least half of the global anthropogenic generation of two other important greenhouse gases, methane and nitrogen oxides.

In addition to increases in mean global temperature, other effects expected to occur with global warming would include increases in sea level[110] and shifts in regional temperature, wind, rainfall, and storm patterns. These, in turn, would submerge some low-lying coastal areas and wetlands, threaten buildings and other structures in these areas, and increase the salinity of coastal aquifers and estuaries. Such changes could disrupt human communities and aquatic and terrestrial ecosystems and affect food production and water availability.[111] A number of developing countries may be especially vulnerable to these effects.[112] No one, however, can yet predict the timing, severity, or extent of the potential impacts with certainty.

The IPCC scientists also noted that climate models suggest that controlling emissions can slow global warming, perhaps from 0.3 to 0.1 ‘C per decade. Emission control strategies that countries could consider today include improved energy efficiency and cleaner energy sources-strategies that may also have economic benefits. The expansion of forested areas, improved livestock waste management, altered use and formulation of fertilizers, and improved management of landfills and wastewater treatment might also reduce or offset emissions.

Achieving meaningful reductions in emissions will require unprecedented levels of international cooperation and must include developing countries. In addition to the technological challenges for the energy, agriculture, and industrial sectors, governments of the industrial and developing countries face challenges in improving and expanding institutional mechanisms for technology transfer to developing countries for providing vital energy services while limiting emissions. These issues are discussed in the forthcoming OTA report *Changing By Degrees: Steps To Reduce Greenhouse Gases.*

Government Policies

Responses to the deteriorating quality of the environment in developing countries show a mixed picture. On the one hand, progress is being made in setting up the government apparatus of environmental control, and concern and activity at the

108IPCC Working Group III, op. cit., footnote 106, p. 10, table 2.

109IPCC, ‘‘Policymaker’s summary of the Formulation of Response Strategies: ReporPrepared for IPCC by Working Group III,” June 1990, p. 5. Estimates of CO_2 emissions from deforestation and land use changes (including wood fuel) were 0.6 to 2.PtC in 1980 according to a report prepared for the IPCC Working Group 1. ‘‘Scientific Assessment of Climate Change: Peer Reviewed Assessment for WG1 Plenary Meeting, May 1990,” Apr. 30, 1990, p. 1-9. More recent evidence from selected countries would indicate deforestation rates now are higher than they werin 1980. Estimates of $C0_2$ emissions in 1987 were 5.7 +0.5 PtC from fossil fuel burning and total emissions were of 7 +1.1 PtC.

110The IPCC working group predicted an average rate of global mean sea level rise of about 6 cm per decade over the next century,20 cm by 2030, and 65 cm by the end of the century with significant regional variations. This increase is primarily due to thermal expansion of theoceans and melting of some land ice.

111Intergovernmental Panel on Climate Change, ‘Policymakers’ Summary of the Potential Impacts of Climate Change: Report from Working Group II to the IPCC,’’ May 1990, p. 8.

112J.D. Milliman et rd., “Environmental and Economic Implications of Rising Sea Level and Subsiding Deltas: The Nile and Bengal Examples,” *AMBIO*, vol. 18, 1989, pp. 340-345.

grassroots level is rising rapidly. On the other hand, implementation of environmental policies is frequently difficult to achieve, and progress is sometimes impeded by unintended environmental impacts of other policies.

The past two decades have seen considerable environmental policymaking activity in the developing world, including the establishment of national environmental agencies and organizations[113] and the adoption of laws and practices designed to prevent environmental pollution and degradation or to protect unique natural environments and wildlife. All in all, more than 100 developing countries now have governmental bodies whose responsibilities include environmental protection.[114] However, only a limited number of countries[115] have established independent environmental agencies in their central governments. Most have increased their environmental oversight capabilities by creating or expanding sections or offices within environment-related government departments such as agriculture, energy, fisheries, forestry, irrigation, natural resources, or tourism.

The larger developing nations with traditions of extensive government policymaking and implementation and a relatively advanced domestic research base have formulated and adopted a variety of environmental protection laws and standards, including the requirement of environmental impact statements for large projects. Developing countries with detailed nationwide air and water quality standards or with regulations specifying the levels of permissible pesticide residues in food are still, however, in the minority. Those that do have such regulations have usually based their legislation on the standards in force in the industrialized nations; consequently, their specifications-at least on paper —are usually as strict as and sometimes even stricter than, those of the industrial countries, although implementation may lag.[116]

Some developing countries have shown a significant commitment to protecting the environment. China's most polluted coal-burning cities have mean sulfur dioxide levels between 100 and 300 ug/m^3, about the same as in British cities prior to the introduction of Britain's Clean Air Act in the early 1950's. China, with levels of income much lower than the United Kingdom in the early 1950's, has already begun to respond to the problem by introducing cleaner urban fuels and outfitting coal-fired plants with effective particulate controls[117].

Environmental concerns in developing countries have not been limited to domestic issues. Developing countries have also participated in international environmental protection treaties. Most of the developing countries belong to the World Heritage, Endangered Species, and Law of the Sea conventions. Nine developing countries, including Mexico, Egypt, Morocco, and Venezuela, have already signed the Montreal protocol for protection of the ozone layer.

Many developing countries have also experienced an increase in grassroots environmentalism in addition to this official activity. In Ecuador, Colombia, Guatemala, and Brazil movements organized by citizen groups have led to the banning of toxic pesticides and the initiation of major urban cleanups.[118] Indigenous nongovernmental organizations (NGOs) have increasingly involved themselves in environmentally oriented efforts. More than 600 Brazilian and Indonesian NGOs currently are working on environmental issues, as are several thousand groups in India.[119]

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113 Jeffrey H. Leonard and David Morell, ''Emergence of Environmental Concern in Developing Countries: Apolitical Perspective,'' *Stanford Journal of International Law*, Issue 2, Summer 1981.

114 Barbara J. Lausche, World Bank, ''Environment and Natural Resources Management Institutions in Developing Countries,' background paper, draft, Oct. 10, 1989.

115 Bermuda, Burkina Faso, Gabon, India, Kenya, Oman, Papua New Guinea, Senegal, Singapore, Trinidad and Tobago, Venezuela, and Zaire.

116 The Chinese daily average standard for ambient sulfur dioxide is stricter in each of the three classes (natural unpolluted areas, urban residential locations, and industrial districts) than the U.S. values; maximum nitrogen oxide levels permissible in residential areas are equivalent to the Japanese standard; and the maximum carbon monoxide levels allowed at any time are much lower than the l-hour averages in West Germany or the United States. T.A. Siddiqi and C.X. Zhang, "Ambient Air Quality Standard in China,'' *Environmental Management*, vol. 8, 1984, pp. 473-479.

117 Vaclav Smil, "Environment in Developing Countries," contractor report prepared for the Office of Technology Assessment, June 1990.

118 World Resources Institute, ''Development and Pollution in the Third World,'' paper prepared for the Tokyo Conference on the Global Environment and Human Response, Sept. 11-14, 1989, July 1989, p. 33.

119 Ibid.

Despite these achievements, major problems remain. A fundamental constraint on environmental policymaking in all but a handful of developing countries is the absence of systematic, integrated data on the current state of environmental pollution and degradation. While there is sometimes a great deal of site-specific information connected with particular projects, virtually all the developing countries lack spatially representative networks for monitoring land, water, and air quality or accurately measuring the rates of deforestation or changes in agricultural land and soil quality. China and India, however, have accumulated a fairly extensive information base through the combined activities of various government departments and university-based researchers.

The implementation and monitoring of environmental policies and standards are also difficult. In most countries, the budgets of the environmental agencies are a small fraction of their minimum needs, and staffing is inadequate. Enforcement is often lax; prosecutions are often costly, uncertain, and slow; and the punishments actually meted out may be inadequate deterrents.[120]

Environmental protection is also sometimes impeded-in both developing and industrialized countries-by government policies intended to promote economic growth, generate employment, service foreign debts, or meet other important national needs. In Brazil, for example, a variety of government policies have encouraged rapid development—and thus rapid deforestation-of the Amazon. These include tax exemptions, tax credits, subsidies of rural credit, and land acquisition laws (squatter rights).[121] These inducements have inadvertently encouraged a number of activities that would not be economical in the absence of direct or indirect government supports. For example, the implicit government subsidy for ranching alone during the period 1975 to 1986 has been estimated by the World Bank at more than $1 billion.[122] The Brazilian government has recently begun to reverse many of these policies as awareness of their costs and environmental impacts has grown.

Similarly, commercial logging has also been encouraged by many governments through low royalties and fees, reduced export taxes, and other tax breaks for timber companies and other domestic wood products industries.[123]

Tax credits, investment subsidies, and other fiscal supports may be necessary and justified to encourage needed development, and such policies are widely used in developing and industrialized countries. The value of depletable natural resources and the costs of environmental degradation, however, are often not properly accounted for by these financial instruments. For this reason, many economists advocate policies that more accurately include these costs than has sometimes been done in the past. With proper valuation of the natural resources, environmental impacts, and other costs and benefits, such investments might be made more wisely.[124]

Government policies in some industrialized nations may also inadvertently affect the environment in developing countries. In 1988, the European Community, the United States, and Japan provided subsidies to their agricultural sectors totaling $97.5 billion, $67.2 billion, and $57.8 billion respectively—a total of $222.5 billion.[125] This is nearly one-third of

120 Critiques of government enforcement of environmental laws in developing countries can be found in: R. Abracosa, and L. Ortolano, 1987, Environmental impact assessment in the Philippines: 1977-1985. *Environmental Impact Assessment Review,* vol. 7, pp. 293-310. C.M. Abraham and A. Rosencranz, 1986, "An Evaluation of Pollution Control Legislation in India," *Columbia Journal of Environmental Law*, vol. 11, 1986, pp. 101-1 18; H. Haeruman, "Conservation in Indonesia," *AMBIO*, vol. 17, 1988, pp. 218-222; A.D. Johns, Economic Development and Wildlife Conservation in Brazilian Amazonia," *AMBIO*, vol. 17, 1988, pp. 302-306; J. Mayda, "Environmental Legislation in Developing Countries: Some Parameters and Constraints," *Ecology Law Quarterly,* vol. 12, 1985, pp. 997-1 024; K. Ramakris hna, "The Emergence of Environmental Law in the Developing Countries, a Case Study of India," *Ecology Law Quarterly,* vol. 12, 1985, pp. 907-935; A.S. Tolentino, "Legislative Response to Marine Threats in the ASEAN Subregion," *AMBIO*, vol. 17, 1988, pp. 238-242.

121 The government suspended provisions that made clearing for ranches profitable and penalized owners of unimproved lands, but ranches are still attractive as a speculative hedge against inflation. See U.S. Congress, Office of Technology Assessment, op. cit., footnote 14; Climate Institute, "Climate News Around the Globe,' *Climate Alert*, vol. *2, No. 3,* Fall 1989, p. 8; S.B. Hecht, "The Sacred Cow in the Green Hell: Livestock and Forest Conversion in the Brazilian Amazon," *The Ecologist,* vol. 19, No. 6, November/December 1989, pp. 229-234.

122 Hans P. Binswanger, World Bank, "Fiscal and Legal Incentives With Environmental Effects on the Brazilian Amazon," Agricultural and Rural Development Department, Operational Policy Staff, May 1987; N. Myers, *Deforestation Rates in Tropical Forests and Their Climatic Implications* (London: Friends of the Earth Limited, 1989).

123 Robert Repetto, "Deforestation in the Tropics,' *Scientific American, vol. 262, No. 4,* April 1990, pp. 36-42.

124 Robert Repetto et al., *Wasting Assets: Natural Resources in the National Income Accounts* (Washington, *DC:* World Resources Institute, June 1989).

125 Stuart Auerbach, "Statement Aimed at Farm Subsidies Impasse, " *Washington Post,* July 12, 1990, p. A9.

the GDP of the 2.8 billion people who live in low-income developing countries, and it is comparable to the GDP of their entire agricultural sector.[126] Some of these subsidies may tend to hold agricultural prices down in developing countries as well as limiting their export opportunities.[127] If this occurs and reduces developing countries' earnings for their agricultural output, they may have less incentive and ability to invest in agricultural research and development or infrastructure to achieve higher yields and quality. As noted above, low agricultural productiveties (together with inequitable land tenure, etc.) contribute to the expansion of croplands into ecologically fragile areas. Similarly, import tariffs to protect domestic timber industries in industrial countries may encourage inefficient harvesting in tropical forests because the full market value of the resources cannot be obtained.[128]

However well-intentioned, the development policies of bilateral development agencies and multilateral development banks have also sometimes directly contributed to environmental degradation due to their emphasis on large projects--transportation infrastructures, hydroelectric facilities, and industrial complexes.[129] Development agencies are, however, becoming more sensitive to these environmental concerns.[130] The role of development agencies in promoting the adoption of more environmentally sound energy technologies will be examined in a later report of this OTA study.

126 World Bank, *World Development Report 1989* (Washington, DC: 1989), indicator tables 1 and 3. Note that this does not include the 1 billion people in middle-income developing countries who had a 1987 GDP of nearly $2 trillion.

127 Vernon O. Roningen and Praveen M. Dixit, *Economic Implications of Agricultural Policy Reforms in Industrial Market Economies* (Washington, DC: U.S. Department of Agriculture, Economic Research Service, 1989).

128 U.S. Congress, Office of Technology Assessment, Op. cit., footnote 14.

129 U.S. Congress, Office of Technology Assessment, op. cit., footnote 14; Bruce M. Rich, "The Multilateral Development Banks, Environmental Policy, and the United States," *Ecology Law Quarterly, vol.* 12, No. 4, 1985; P. Aufderheideand B.Rich, "EnvironmentalR eform and the Multinational Banks," *World Policy Journal,* Spring 1988, pp. 301-321; W. Reid, "Sustainable Development: Lessons From Success," *Environment,* vol. 31, No. 4, May 1989, pp. 7-35,

130 See, f.ore-p.i.e., World Bank, "A Review of the Treatment of Environmental Aspects of B@ Energy projects," Industry and Energy Department Working Paper, Energy Series Paper No. 24, March 1990.