II STATUS OF THE NATURAL RESOURCE BASE

The use of natural resources by humans, influenced by policy and governing institutions, can affect both the quality and quantity of these resources, which in turn will affect agricultural sustainability. Although the following investigation discusses each resource separately, the effects of agricultural activities on these resources often interact and overlap. For instance, salinization may result from mismanagement of water resources, but its impact is on land resources. Forests encompass a large number of resources including water, land, and living organisms. Deforestation increases the land available for agriculture, but reduces biodiversity and water quality, and may increase flooding and sedimentation.

LAND AND SOIL RESOURCES

The term "land" as used in this section refers to arable land or land cultivated with crops. It also includes land left fallow or used for pasture for less than five years (Engelman and LeRoy, 1995). The debate on land resources revolves around the technicalities of estimating the extent of their degradation.

Land Availability

The area of land per capita in Asia at present is lower than that in the Americas and Australia. Further, the proportion of soil highly suitable for cultivation in Asia is less than 4 percent, while in Latin America it is 12 percent and in Africa, 15 percent (Lohani, 1998).

Land suitability for agriculture depends on physical and chemical characteristics, but access and population determine whether land can be economically brought into agricultural production. Given that Asia has the highest population density of the five inhabited continents, pressure on land in this region is immense.

The area of arable land per capita reflects the population pressure on the land, and is an indicator of land stress (Table II.1). In 1992, arable land per head in Asia averaged 0.3 ha, which is considerably lower than the average of 1.6 ha for all other developing countries (Lohani, 1998). A critical threshold level is estimated to be 0.07 ha per capita (Smil, 1987, cited in Engelman and Leroy, 1995). This benchmark is derived from

Table II.1: Arable Land Scarcity Index (ha per capita) in Asia

	Year		
	1961	**1990**	**2025**
East Asia			
China, People's Rep. of	0.16	0.08	0.06
Japan	0.06	0.04	0.04
Korea, Rep. of	0.08	0.05	0.04
Southeast Asia			
Cambodia	0.43	0.35	0.16
Indonesia	0.18	0.12	0.08
Lao PDR	0.38	0.20	0.09
Malaysia	0.49	0.27	0.15
Myanmar	0.47	0.27	0.13
Philippines	0.24	0.13	0.08
Thailand	0.43	0.41	0.31
Viet Nam	0.17	0.10	0.05
South Asia			
Afghanistan	0.71	0.54	0.18
Bangladesh	0.17	0.09	0.05
India	0.36	0.20	0.12
Nepal	0.19	0.14	0.07
Pakistan	0.34	0.17	0.07
Sri Lanka	0.16	0.11	0.08

Source: Engelman and LeRoy (1995).

the area of arable land that would be able to feed a population sustainably, on a vegetarian diet basis, without the assistance of agrochemicals. A closed system with mixed cropping, crop recycling, and utilization of animal and human waste for maintaining soil fertility was assumed.

On the basis of a medium population projection estimated by the United Nations, Engelman and Leroy (1995) calculated the arable land scarcity index for 125 nations with populations of more than one million for 1960,1990, and 2025 (Table II.1). Japan dropped below the critical threshold in the early 1960s, followed by the Republic of Korea in 1990. By 2025, many Asian nations including PRC, Indonesia, Philippines, and Viet Nam will have dropped below the benchmark. The arable land scarcity index for Asia for 2025 is 0.12, substantially above the threshold level. By 2025, the Asian country with the most arable land per capita will be Thailand (0.31).

Land has always been a major constraint in agricultural production and was a major instigator of the green revolution. However, land availability is not the only factor that determines sustainability. The PRC has been able to feed its burgeoning population on a nonvegetarian basis despite the fact that land availability has fallen below the threshold level and that only 9.7 percent of the total land is arable (APO, 1998). In Viet Nam, where agricultural land per capita is amongst the lowest in Asia (0.10 ha in 1990), institutional reform has fueled a dramatic increase in output and enabled Viet Nam to become a major rice exporter.

Land Degradation

With proper care and management, land resources are renewable. However, under continuous degradation, the land could ultimately become nonproductive. Degradation may be the result of erosion, nutrient depletion, and/or physical and chemical contamination. Estimates of the quantity of land eroded each year range from 25 billion t (Pimentel et al., 1995) to 75 billion t (FAO, 1992, cited in Engelman and Leroy, 1995); most serious studies tend to confirm the lower estimates.

Experience worldwide, particularly in Africa, suggests that water and wind erosion accounts for the bulk of land degradation: 56 percent from water erosion, 28 percent from wind erosion, 12 percent from chemical degradation, and 4 percent from physical degradation (Oldeman, Hakkeling and Sombroek, 1991, cited in Crosson, 1994).

In nonirrigated areas, 85 percent of total erosion is brought about mainly by the effect of wind or water (Oldeman, 1992). On grazing land, degradation is often a result of overexploitation of public land, a process widely known as the “tragedy of the commons” (Hardin, 1968). In irrigated areas, chemical degradation results from mismanagement, high precipitation rate, soil type, topography, and population pressure. Global estimates by Dregne and Chou (1992, cited in Crosson, 1994) of land degradation suggest that its severity is greater in rangelands than in irrigated and rainfed croplands.

According to many estimates, agricultural land in Asia is extensively degraded, but the quoted data are not consistent. It was estimated in an FAO study (FAO, 1995a, p. 46) that of the 747 million ha of Asian cropland, 440 million ha (59 percent) have been degraded by water erosion, 222 million ha (30 percent) by wind erosion, 73 million ha (10 percent) by chemicals and 12 million ha (1 percent) by physical degradation. The “World Map of the Status of Human-Induced Soil Degradation”, widely cited by the United Nations Environment Programme, the United Nations Development Programme, and the World Resources Institute, among others (Oldeman et al., 1990), indicates that 200 million ha of Asia’s cropland and 200 million ha of rangeland have been degraded.

A more recent estimate of “human-induced” degradation (UNEP, 1997) shows 350 million ha as having been affected by topsoil loss, another 180 million ha by fertility decline, and 44 million ha by salinization. The most recent estimate (ADB, 1997a) indicates that 130 million ha of Asia’s cropland have been salinized by poor irrigation practices, and 63 million ha of rainfed land and 16 million ha of irrigated land have been lost through desertification. This report has been summarized in a more recent paper (Crasswell, 1998): "the Asian Development Bank (ADB, 1997a) estimates that during the past 30 years one third of the agricultural land in Asia has been degraded".

A number of authors have questioned the accuracy of these estimates (Alexandratos, 1995; Crosson, 1995), which include the Global Land Assessment of Degradation. Crosson (1994) commented that most studies are based on "informed" opinions. Considering that enormous efforts have been made to rehabilitate watersheds, in India for example (Kerr et al., 1998), priority should be given to funding for scientific studies to enable a consensus on the extent of the degradation to be reached among international scientists.

At the national level, opinions on the extent of degradation also diverge and the examples quoted by opposing groups are not exactly comparable. Those who have raised concerns about the land degradation problem have pointed out that the amount of topsoil removed by runoff annually in India is around 25 billion t (Repetto, 1994, p.37). Nutrient depletion by loss of this topsoil is estimated to be equivalent to the total quantity of chemicals used over the entire country. Repetto (ibid.) further claimed that the loss in soil fertility has offset the yield improvement impact of the agricultural technology packages of India's 44 specialized research institutions in 26 States. Crosson (1994), citing a study by Bronger and Bruhn (1988, p. 688), argued that water erosion on the "red soils" that span over 700,000 km^2 (40 percent) of India's agricultural land, removes about 2.5 cm of topsoil per 100 years, which suggests that the impact under traditional agriculture was quite low. Both Repetto and Crosson did agree on one point: the cost of restoring land would be massive.

Outside India, erosion from the Loess Plateau in the PRC is often cited as an extreme example of soil erosion. Forty years of experience in soil conservation in this plateau have shown that effective control of sedimentation in the Yellow River requires integrated measures and that the process is costly and time consuming (Chen, 1992). In Southeast Asia, Indonesia, Lao PDR, Philippines, and Viet Nam tend to face more serious erosion problems because of their particular combinations of rainfall and topography.

While knowledge of the extent of degradation is useful for attracting the attention of policymakers worldwide, it would be more useful to know a) the relationship between degradation and yield loss, or the cost of degradation; b) the cost of stopping degradation; and c) the cost of rehabilitating the natural resources. Unfortunately, the answers to these questions are even more sketchy and uncertain. Studies are often based on very local conditions and are related to specific practices. Yield losses also vary from location to location. Moreover, the time frames over which these losses occur are not given, making it difficult to estimate the cost of erosion. If soils have become as degraded as the above estimates have intended to demonstrate, how can Asia's enormous food production, that feeds billions, be explained?

Among the few rigorous studies on the impact of soil erosion on yields is a study in the USA indicating that the effect of erosion-induced loss of soil productivity on corn and soybean yield there was very small and that the effect on wheat yields was negligible (Crosson, 1995). Soil erosion has caused yield losses of about 4 percent during the past 100 years. Based on the studies of both Dregne and Chou (1992) and Oldeman et al. (1990), Crosson (1995) concluded that the gain in food production from restoring land, or from attempting to reduce soil nutrient depletion, is negligible.

Studies concerning the effects of yield losses from erosion in Asia have been site-, crop- and practice-specific and cannot be generalized. Long-term studies conducted in the PRC from the 1930s to the 1980s, and in Indonesia from the 1940s to the 1990s, which combined soil surveys and input variables, revealed that over the period studied, soil organic matter and nitrogen had declined but total phosphorus and potassium had increased (Lindert, 1996a). Salinity and acidity had not shown worsening trends. In the PRC, the long-term effects of soil on yields showed that depletion of soil organic matter and total nitrogen in the Huang, Huai, Hai, and Chang Jiang plains could be reversed easily by using a quick-release fertilizer. The overall output depends on soil properties, and these had not shown depletion symptoms since the 1930s. In the southern PRC, acidity was even reduced between the 1930s and 1950s. In Indonesia, a significant drop in organic matter content was observed in various types of cultivation, including tree crops, dry-land, field crops, and fallow, although the level of both potassium and phosphorus increased. Acidity levels were reduced over time on dry land, although less reduction was found for rice.

It is important to note that much of the land defined as degraded actually contributes marginally to total crop production. For Asia, the picture becomes clearer when the problem of degradation is assessed separately for the more and the less productive croplands.

The more productive lands that have largely contributed to agricultural growth since 1960, i.e. irrigated land and rainfed areas with reliable rainfall and good soil, have yet to demonstrate effects of degradation. The regionwide yields (per ha) of rice, wheat, and maize have shown steady linear increases (R^2 = 0.96–0.98) for almost 40 years. It has been claimed that intensification of the rice cropping system has brought about environmental degradation, such as a reduction in soil quality and fertility. However, while soil analyses over the past 15 years in Karnal in Haryana, India, indicate a significant decline in soil nutrient levels (Mehta, 1990, cited in Chand and Haque, 1997), a major decline in yield levels has not yet been detected. There is indeed land degradation caused by intensive monocropping, but this can be solved by good soil and crop management, as discussed later.

Much of Asia's land degradation is in the less favorable areas, which contribute less to total production relative to their total area than do more favorable croplands (e.g. for rice, the uplands and unfavorable rainfed lowlands account for only 18 percent of the region's production and cover 42 percent of its area). Losses in production due to land degradation in these less favorable environments are not likely to be very large in terms of total output when compared with national and regional totals. Degraded lands are, however, generally in the most poverty-stricken areas in each country (e.g. the erosion-prone uplands / highlands in most countries from Nepal to Indonesia; the salt-affected areas of India, Pakistan, and Central Asia; the dry lands in the northeastern PRC and Central Asia, and the Loess Plateau in the PRC). In such areas, the losses in crop productivity due to land degradation would mean loss of a significant portion of income for the poorer, if not the poorest segments of the economy.

Success stories from India and Sri Lanka have been highlighted recently by the Technical Advisory Committee of the CGIAR (TAC, 1997), and have illustrated that sustainable growth in crop production on degraded land is possible. These cases have, however, also shown that very different sets of technological and institutional innovations are required.

In many instances, the net erosion loss could be much less than that observed onsite. Unless the eroded soil causes siltation in water resources, a loss from one production region could be a gain elsewhere. River deltas all over the world are manifestations of this gain. Moreover, the silt-laden water of the Yellow River, for example, could also be used to reclaim desert land (Fullen and Mitchell, 1994).

Diversification from food crops into higher-value crops could take more land out of food crops than land degradation. This phenomenon is spreading rapidly in the southwestern and southern parts of the PRC, the Chao Phraya Delta in Thailand, and the Red River Delta in Viet Nam. It is not a major threat because as the supply of basic food crops falls, prices will rise and land will again be brought back into basic food crop production. Price increases will harm the poor, and the issue then becomes how to guarantee nutrition and provide food security for the poor. Public policies designed for poverty alleviation are necessary.

FOREST RESOURCES

The role and value of forests have undergone more dramatic changes than have those of any other natural resources. Forests were previously valued mainly for timber and as land reserves for agriculture. Sustainability issues have significantly changed the concept of the value of forests. Today, they are valued not only as a source of land, timber, and other forest products, but also for their ecological and social functions, e.g. regulation of stream flows, soil and water conservation, microclimate regulation, carbon sequestration, tourism, recreation, and as a store of future wealth in the form of biodiversity. Forests are increasingly viewed as important sources of available and untapped genetic resources.

The multiplicity of forest resources and their uses has led to substantial conflicts both at the policy and grass-roots level. Forests are viewed by the State in terms of potential development projects and by farmers as potential farmland. NGOs, environmentalists, water users, and urban residents are demanding that forests be protected. While the debate related to land resource degradation is mainly scientific, issues related to forests are more complicated and have greater social ramifications because decisions concerning forests may have an impact on the livelihoods of the millions of persons residing in and around them.

Status of Asian Forests

About one quarter of the world's total land is presently forested (FAO, 1997a). In Asia, the proportion is only about 17 percent. The total forest area in Asia in 1995 was estimated at 499 million ha (FAO, 1997a). The Asian region also has the lowest ratio of forestland per capita (0.1 ha), much less than the world 's average of 0.6 ha. Mongolia, which is one of the least forested countries measured in terms of forest area to total land area, has the highest forest area per capita (4 ha) in Asia.

The proportion of forest in total land area is highest in the most and the least developed countries (Table II.2), e.g. Republic of Korea (77 percent), Japan (67 percent), Bhutan (59 percent), and Cambodia (58 percent). As a subregion, Southeast Asia contains the largest area of natural forests in Asia.

Changes in Forest Cover

The world's forested area decreased at the rate of 0.3 percent (or 11.3 million ha) per year during 1991–1995. There was a marked contrast in deforestation rates between developed and developing regions. In developed regions such as Europe and North America (Canada and USA), the forested areas increased at an annual rate of 0.1–0.3 percent (0.4–0.6 million ha) during 1991–1995. Conversely, the deforested areas of the developing tropical regions ranged between one and five million ha. The annual rate of forest decrease was 0.7 percent for tropical Asia (3,328,000 ha), 0.7 percent for tropical Africa (3,695,000 ha), 1.2 percent for Central America and Mexico (959,000 ha), and 0.6 percent for tropical South America (4,655,000 ha) (FAO, 1997a, Annex 3, Table 3, p. 186-189).

In Asia, the annual rate of deforestation is highest in Southeast Asia, at about 1.3 percent or 2.9 million ha, and lowest in East Asia, 0.1–0.2 percent per year. In contrast, the forested areas in Central Asia increased markedly during this period (Table II.3). The countries where the annual rate of deforestation in 1991–1995 was faster than that in 1981–1990, or with annual deforestation rates greater than 2 percent are Afghanistan, Cambodia, Kazakhstan, Malaysia, Pakistan, Philippines, Thailand, and Uzbekistan. It should be noted that most of these countries do not have high population pressure.

The causes of deforestation are complex and numerous. A typical pattern in the humid tropics generally starts with unsustainable logging, which helps clear the forest for slash-and-burn agriculture or provides easier access for commercial agriculture. Weak administration and corruption have rendered demarcation, monitoring, and enforcement ineffective, and

Table II.2: Forest Resources in Selected Asian Economies, 1995

	Land Area (ha'000)	Population (million)	Forest Area 1995 (ha'000)				
			Total	(% land)	ha/cap.	Natural Forest	Plantation
East Asia							
China, People's Rep. of	932,641	1,221.5	133,323	14.3	0.1	99,523	33,800
Japan	37,652	125.2	25,146	66.8	0.2	25,146	nc
Korea, Rep. of	9,873	45.0	7,626	77.2	0.2	6,226	1,400
Mongolia	156,650	2.4	9,406	6.0	3.9	9,406	0
Southeast Asia							
Cambodia	17,652	10.3	9,830	55.7	1.0	9,823	7
Indonesia	181,157	197.6	109,791	60.6	0.6	103,666	6,125
Lao PDR	23,080	4.9	12,435	53.9	2.5	12,431	4
Malaysia	32,855	20.1	15,471	47.1	0.8	15,371	100
Myanmar	65,755	46.5	27,151	41.3	0.6	26,875	276
Philippines	29,817	67.6	6,766	22.7	0.1	6,563	203
Thailand	51,089	58.8	11,630	22.8	0.2	11,101	529
Viet Nam	32,549	74.5	9,117	28.0	0.1	7,647	1,470
South Asia							
Afghanistan	65,209	20.1	1,398	2.1	0.1	1,390	8
Bangladesh	13,017	120.4	1,010	7.8	nc	700	310
Bhutan	4,700	1.6	2,756	58.6	1.7	2,748	8
India	297,319	935.7	65,005	21.9	0.1	50,385	14,620
Maldives	30	0.3					
Nepal	13,680	21.9	4,822	35.2	0.2	4,766	56
Pakistan	77,088	140.5	1,748	2.3		1,580	168
Sri Lanka	6,463	18.4	1,796	27.8	0.1	1,657	139
Central Asia							
Kazakhstan	267,073	16.5	10,504	3.9	0.6	nc	nc
Kyrgyz Republic	19,180	4.5	730	3.8	0.2	nc	nc
Tajikistan	14,060	5.8	410	2.9	0.1	nc	nc
Turkmenistan	46,993	4.5	3,754	8.0	0.9	nc	nc
Uzbekistan	41,424	22.8	9,119	22.0	0.4	nc	nc

nc = data not classified.

Source: Modified from FAO (1997a).

Table II.3: Changes in Forest Cover in Selected Asian Economies, 1980–1995

	Forest Area (ha'000)			Annual Change (ha'000)		Annual Change (%)	
	1980	1990	1995	1981–1990	1991–1995	1981–1990	1991–1995
East Asia							
China, People's Rep. of	137,756	133,756	133,323	-400	-87	-0.3	-0.1
Japan	25,262	25,212	25,146	-5	-13	0.0	-0.1
Korea, Rep. of	7,701	7,691	7,626	-1	-13	0.0	-0.2
Mongolia	9,406	9,406	9,406	0	0	0.0	0.0
Southeast Asia							
Cambodia	11,959	10,649	9,830	-131	-164	-1.1	-1.5
Indonesia	127,333	115,213	109,791	-1,212	-1,084	-1.0	-0.9
Lao DPR	14,467	13,177	12,435	-129	-148	-0.9	-1.1
Malaysia	21,432	17,472	15,471	-396	-400	-1.8	-2.3
Myanmar	33,098	29,088	27,151	-401	-387	-1.2	-1.3
Philippines	11,238	8,078	6,766	-316	-262	-2.8	-3.2
Thailand	18,427	13,277	11,630	-515	-329	-2.8	-2.5
Viet Nam	11,163	9,793	9,117	-137	-135	-1.2	-1.4
South Asia							
Afghanistan	1,990	1,990	1,398	0	-118	0.0	-5.9
Bangladesh	1,434	1,054	1,010	-38	-9	-2.6	-0.9
Bhutan	2,963	2,803	2,756	-16	-9	-0.5	-0.3
India	68,359	64,969	65,005	-339	7	-0.5	0.0
Nepal	5,636	5,096	4,822	-54	-55	-1.0	-1.1
Pakistan	2,793	2,023	1,748	-77	-55	-2.8	-2.7
Sri Lanka	2,167	1,897	1,796	-27	-20	-1.2	-1.1
Central Asia							
Kazakhstan		9,540	10,504		193		2.0
Kyrgyz Rep.		730	730		0		0.0
Tajikistan		410	410		0		0.0
Turkmenistan		3,754	3,754		0		0.0
Uzbekistan		7,989	9,119		226		2.8

Source: modified from FAO (1995b, 1997a).

public forestland is turned by the powerful into private domains (Box II.1). The existence and contribution of farmers' settlements in the forests are often ignored, and recently in some countries serious and violent conflicts between forest communities and the State have become frequent. Improved infrastructure and health services, reduced death rates, and improved living conditions encourage an increase in population through both natural growth and migration. In areas where the scenery is favorable, economic booms may induce conversion of forestland into tourist resorts or large-scale plantations.

Deforestation accelerates soil erosion because runoff increases, leading to increased sedimentation. Unsustainable logging and the conversion of forests into cropland, e.g. coffee, rubber, and banana in the northern Mekong Delta and Nambo region of Viet Nam, have been major causes of erosion and consequentially of sedimentation. Forest cover decreased from 70 percent of the total area in the 1940s to less than 30 percent in the 1990s, an annual reduction rate of 1.6 percent (Crooks, 1995).

Excessive siltation in reservoirs is reported in India, where actual siltation rates in 12 major dams exceeded the designed siltation capacity by a factor of two, and thus considerably shortened the useful life of the dams (Repetto, 1994). In Viet Nam, the most cited case is the Hua Binh Dam; heavy sedimentation threatened to reduce its useful life. The problem led the Government to build an upstream dam to reduce the sediment load (Mie Xie, 1996).

Biodiversity

Forest resources include plant and animal ecosystems as well as physical assets such as land and water. Plant and animal biodiversity is generally greatest in tropical forests.

Diversity is a fundamental characteristic of sustainability. The wild-growing relatives of crop species protect crop varieties against extinction from pest or disease outbreak. Apart from their use in direct consumption, wild plants and animals are

Box II.1 Poverty, Power, and Public Resources

A study of forest use in Thailand during the economic boom revealed an interesting pattern of forest usage by the elite (Anan and Mingsarn, 1996). Starting in 1981, the Thai economy grew at double-digit rates consecutively for three years, creating high expectations for the country's future. In a country where loans are made on the basis of collateral rather than financial feasibility of a project, the demand for land for collateral increased rapidly, driving the price of titled land to great heights.

The highlands, which are mostly fragile ecosystems, are much coveted as they can be used as sites for tourist resorts or for tourism-cum-agriculture projects. In addition, returns from subtemperate agriculture and highland agriculture are artificially high owing to government protection from imported agricultural produce. The lucrative returns from both lowlands and highlands have encouraged encroachment on forests in fragile ecosystems by the urban elite.

The urban elite would not have been able to locate suitable or scenic upland and highland sites on their own. The purchase of this forestland has been possible due to the flow of information between local leaders, who are vote collectors for national politicians, and their supporters, who are wealthy businesspersons. Another important condition that has made encroachments and purchases worthwhile is the ability to convert public land into private land through the abuse of administrative power, a situation that encouraged national and local politicians to join hands in converting forestland. Poor enforcement of forest laws also allowed rich people with less influence to pay for the de facto usufruct rights given to the early encroachers.

A previous Thai Government allocated forestland on the assumption that the de facto owners of these public lands were the landless. That Government was toppled when it was found that some of the land grantees were the richest people in the province. Policies based on the assumption that only the poor use forests are destined to fail. The various forest resources are

(continued next page)

(Box II.1 continued)

extracted by people of varying income and power. Different policy instruments are needed in order to deal with these different groups. For the powerful elite, increased public awareness and "people power" have proven, at least in Thailand, able to counter the abuse of power and to topple a government known to be involved in forestland scandals. Tax instruments are needed to deal with wealthy land seekers while for the poor, who encroach on forests out of necessity, the need is for policy instruments that protect the environment and include poverty alleviation as a joint objective. Similarly, policies aimed at poverty reduction need to recognize environmental constraints in order to achieve sustainable development.

important sources of scientific information. Genetic information from some of these resources may reveal properties that increase the immunity of crop varieties to certain diseases. For example, genes from a wild rice species from India provide immunity in cultivated rice to four types of disease (Bryant, 1998). Desirable properties can be synthesized and need not be directly extracted from the materials.

Currently, knowledge of potential uses of the genetic information stored in forest resources is negligible. Considering flowering plants alone, less than 10 percent of the known 250,000 species have been scientifically studied. With forests the size of Cambodia disappearing every year (Reid, 1993), the world's options for a better future are definitely at stake.

Six Asian countries, PRC, India, Indonesia, Malaysia, Philippines, and Viet Nam are among the 20 "mega-diversity" centers of the world (Paine, Byron, and Poffenberger, 1997). Animal and plant species in these six countries account for almost 60 percent of total world species.

Despite its relatively small proportion of forestland, the PRC is ranked as eighth in the world in terms of biodiversity, and first in the northern hemisphere. The country is endowed with 32,800 plant species and 104,500 animal species. Some 200 species of plants have disappeared, while a further 5,000 are endangered (Yin Runsheng, 1997). Indonesia, which has only 1.7 percent of the world's land area, accounts for 17 percent of all plant and animal species or more than the known species of the whole of Africa (State Ministry of Environment and KONPHALINDO, 1995).

The threat to biodiversity is often not from agriculture, but is related to the lack of or inappropriate management. A recent study has shown that in some countries where biodiversity is relatively great, such as India, Indonesia, Malaysia, Myanmar, and Viet Nam, the level of protection is not very strong. Often this is simply the result of the perception that where biodiversity is strong there is less need for protection (Paine, Byron, and Poffenberger, 1997).

Although wild genetic resources are potentially important to maintain varietal diversity, conservation is often costly even in the natural habitat. For major food crops, an international system exists within the CGIAR for conserving plant genetic materials. It is argued that the germplasm of major food crops is reasonably protected under this system although greater efforts could be made to collect wild species (Hawkes, 1985; Crosson and Anderson, 1985, cited in Crosson, 1994). While the genetic variation in landraces is well protected in seed banks, most of the accessions provide little information and have not been not evaluated in germination tests (McNeely et al., 1990). Crosson (1992) concluded that since the viability of the seed bank depends on the viability of the CGIAR system, which is constantly financially insecure, the threat to compiling and maintaining knowledge on genetic resources is probably bigger than the threat to the natural resource base itself.

There have been several attempts to value biodiversity loss in Asia. In the 42-km^2 Yom basin, Thailand, the loss in genetic value of the teak forests that are to be removed to make way for a reservoir is estimated at $60 million. The realizable annual ecological benefits of the mangroves of Bantuni Bay, Indonesia, are valued at $1,500 per km^2, while those of tropical forests are estimated at $3,000 per km^2 (Ruitenbeek, 1990, cited in Bann, 1998).

It should be noted that the biodiversity loss that will affect agriculture, especially food security, is more related to diversity within species of major staples than to biodiversity in general, although genetic engineering will make cross-species gene transfers more feasible (Evenson, 1996). Therefore, options for managing international gene pools are mostly limited to gene banks and habitat protection; there are a greater number of options for financing habitat protection.

Protected Areas

Many countries attempt to protect biodiversity using protected area regimes. A protected area is "an area of land or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (McNeely, Harrison, and Dingwall, 1994). There are six categories of protected areas, related to the different objectives of their establishment. Since 1970, State acquisition of protected areas has increased markedly. Countries with the highest proportion of protected land areas are Bhutan (21 percent), Cambodia (16 percent), Thailand (13 percent), and Indonesia (10 percent) (Table II.4). Except for Indonesia, the Asian countries designated as mega-centers of biodiversity tend to have relatively low ratios of protected area to total land area.

An important feature of protected areas in Asia is that they are not areas of pure wilderness, and they are occasionally inhabited by indigenous communities that have traditionally relied on forest resources for livelihood. Often the modern legal instruments used by the State to claim protected areas have neglected the rights of traditional users, depriving local communities of their usual sources of sustenance, and resulting in bitter and at times violent conflicts between the State and local communities.

Table II.4: National and International Protected Areas in Asia, 1997

	Land Area (ha'000)	National Protected Areas IUCN Class I–V			International Protected Areas Biosphere Res.		World Heritage		Wetland	
		No.	(ha'000)	%	No.	(ha'000)	No.	(ha'000)	No.	(ha'000)
Asia	**2,442,538**	**1,490**	**143,367**	**5.9**	**36**	**10,994**	**21**	**1,853**	**44**	**2,738**
East Asia	**1,142,245**	**409**	**79,483**	**7.0**	**20**	**8,166**	**8**	**252**	**18**	**672**
China, People's Rep. of	932,641	265	59,807	6.4	12	2,514	6	224	7	588
Japan	37,652	65	2,550	6.8	4	116	2	28	10	84
Korea, Dem. People's Rep. of	5,400	19	315	2.6	1	132	0	0	0	
Korea, Rep. of	9,902	25	682	6.9	0		0	0	0	
Mongolia	156,650	35	16,129	10.3	2	5,367	0	0	0	
Southeast Asia	**433,996**	**423**	**31,163**	**7.2**	**11**	**2,682**	**5**	**1,103**	**5**	**299**
Cambodia	17,652	20	2,863	16.2	0		0	0	0	
Indonesia	181,157	170	17,509	9.7	6	1,482	2	298	2	243
Lao PDR	23,080				0		0	0	0	
Malaysia	32,855	50	1,483	4.5	0		0	0	1	38
Myanmar	65,797	2	173	0.3	0		0	0	0	
Philippines	29,817	17	1,453	4.9	2	1,174	1	33	1	6
Singapore	61	1	3	4.4	0		0	0	0	
Thailand	51,089	112	6,688	13.1	3	26	1	622	0	
Viet Nam	32,549	52	994	3.1	0		1	150	1	12
South Asia	477,506	504	21,279	4.5	3	40	8	498	17	339
Afghanistan	65,209	6	218	0.3	0		0	0	0	
Bangladesh	13,017	9	98	0.8	0		0	0	1	60
Bhutan	4,700	9	998	21.2	0		0	0	0	
India	297,319	344	14,273	4.8	0		5	281	6	193
Maldives	30									
Nepal	13,680	12	1,112	7.8	0		2	208	1	18
Pakistan	77,088	55	3,721	4.8	1	31	0	0	8	62
Sri Lanka	6,463	69	859	13.3	2	9	1	9	1	6
Central Asia	388,730	153	11,439	2.9	2	106	0	0	4	1,428
Kazakhstan	267,073	70	7,337	2.7	0		0	0	2	609
Kyrgyz Republic	19,180	31	688	3.6	1	71	0	0	1	630
Uzbekistan	14,060	12	850	2.1	0		0	0	0	
Tajikistan	46,993	18	587	4.2	0		0	0	0	
Turkmenistan	41,424	22	1,977	4.2	1	35	0	0	1	189

Source: WRI (1997).

Note: The protected area management systems are as follows.

IUCN has six categories (McNeely, Harrison, and Dingwall, 1994): I Strict Nature Reserve / Wilderness Areas; II National Parks–protected areas managed mainly for ecosystem conservation and recreation; III Nature Monuments–protected areas managed mainly for conservation of specific features; IV Habitat / Species Management Areas–protected areas managed mainly for conservation through management intervention; V Protected Landscapes / Seascapes–protected areas managed mainly for landscape / seascape conservation and recreation; VI (not used in Table) Managed Resources Protected Areas–protected areas managed mainly for sustainable use of natural ecosystems.

National protection systems: all protected areas including all those as classified by IUCN (I-V), as totally protected areas IUCN (I-III) and partially protected areas IUCN (IV-V).

Biosphere reserves: representative terrestrial and coastal environments that have been internationally recognized under UNESCO's Man and Biosphere Programme.

World Heritage sites: areas of outstanding universal value, or with both natural and cultural values.

Wetlands of international importance: areas declared and recognized by the Convention on Wetlands of International Importance (Ramsar, Iran, 1971). There are 44 sites in Asia.

Laws covering protected areas are more stringent than forestry laws; consequently protected areas have become legal mechanisms used by the State for protecting public lands (as opposed to biodiversity) from encroachment. Most protected areas are established on an ad hoc rather than a scientific basis. The overexpansion of areas under protection renders that protection infeasible, and when this is coupled with poor human resource development in conservation, the result is often a "paper park", an area protected by law in theory but not in practice.

During the 1990s, State acquisition of protected areas has slowed down. This is partly because for some countries, there are no more areas suitable for protected status. Social conflicts on land rights with local communities have also slowed the process of designation. The cost of protection is also relatively high in Southeast Asia where natural forests are dwindling more rapidly. The annual cost of protection per km^2 in Southeast Asia is $509, compared with $175 and $359 in South Asia and East Asia, respectively (Paine, Byron, and Poffenberger, 1997). The average staff to area ratio also varies considerably from 26 and 29 per 1,000 km^2 in East Asia and Southeast Asia, respectively, to 81 in South Asia; the worldwide average is 25 staff per 1,000 km^2.

Most protected areas contain scenic beauty and ample opportunities exist to finance protection through tourism, for example by charging appropriate entrance fees. There is a broad range of alternative financing options for protected areas, including debt-for-nature swaps, bioprospecting, conservation funds, and nondevelopment rights (Reid et al.,1993; Mingsarn et al., 1995).

WATER RESOURCES

Unlike land, where the debate focuses on technical estimates of the size of the problem, there is general agreement that water will be increasingly diverted from agriculture to other, high-value uses. Controversies related to water center around how this can be done in an efficient and equitable manner, for example by minimizing the impact of large-scale water resource development projects on local communities and the environment, and the appropriate pricing of water without undue political consequences.

Although water is a renewable resource, the maximum amount that can be used during each season is fixed according to the geography and climate of each location. The water situation in a given area can be roughly assessed by a water availability indicator: the amount of annually renewable water per capita. The renewable water supply includes both internally produced surface water and groundwater and river flow from external sources. A threshold level for water scarcity of 1,000 persons per one flow unit (1 million cubic meters (m^3) per year), equivalent to 1,000 m^3 per capita per year, has been proposed (Falkenmark, Lundqvist, and Widstrand, 1989). A country can be described as facing a water stress situation if the water supply is between 1,000 and 1,700 m^3 per capita (Fig. II.1). Below a

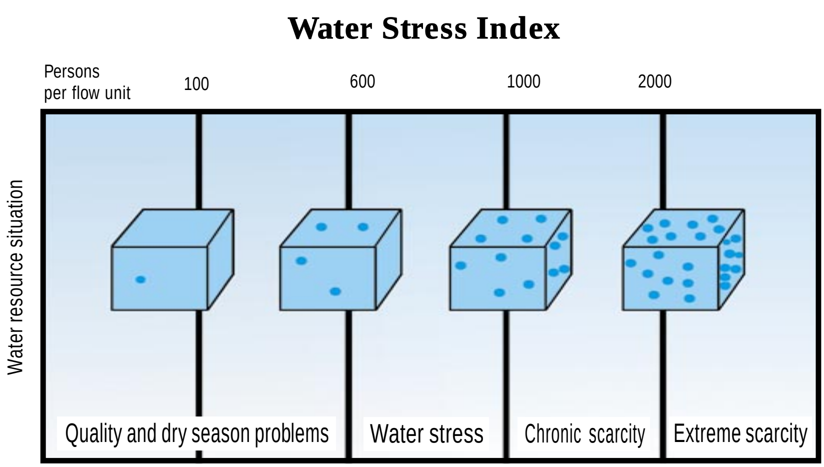

Figure II.1: The water stress index, a measure of water scarcity

Note: 1 flow unit = 1 million cubic meters per year

Source: Adapted from Falkenmark, M. 1991 The Ven Te Chow Memorial Lecture. *Water International* 16 (4): 229-240.

level of 1,000 m^3 per capita, the population faces extreme water scarcity (Table II.5). The estimated annual minimum water requirement for basic needs ranges from 400 to 2,000 m^3 per capita (Rosegrant and Ringler, 1998).

Population increase is a major cause of water stress. The per capita availability of water in Asia is the lowest among all

Table II.5: Water Resources in Asia

	Annual Internal Renewable Water Resources[a]		Annual River Flows From External Sources	Annual Withdrawals			
	Total (km^3)	1998 per capita (m^3)	(km^3)	Volume (km^3)	Proportion of Water Resource: Internal sources only (%)	Proportion of Water Resource: Including external sources (%)	Per Capita (m^3)
East Asia							
China, People's Rep. of	2,800.00	2,231.00	0.00	460.00	16.43	16.43	461.00
Japan	547.00	4,344.00	0.00	90.80	16.60	16.60	735.00
Korea, Rep. of	66.12	1,434.00		27.60	41.74	41.74	632.00
Mongolia	24.60	9,375.00		0.55	2.25	2.24	271.00
Southeast Asia							
Cambodia	88.10	8,195.00	410.00	0.52	0.59	0.10	66.00
Indonesia	2,530.00	12,251.00	0.00	16.59	0.66	0.66	96.00
Lao PDR	270.00	50,392.00		0.99	0.37	0.37	259.00
Malaysia	456.00	21,259.00		9.42	2.07	2.07	768.00
Myanmar	1,082.00	22,719.00		3.96	0.37	0.37	101.00
Philippines	323.00	4,476.00	0.00	29.50	9.13	9.13	686.00
Singapore	0.60	172.00	0.00	0.19	31.67	31.67	84.00
Thailand	110.00	1,845.00	69.00	31.90	29	17.82	602.00
Viet Nam	376.00	4,827.00		28.90	7.69	7.69	416.00
South Asia							
Afghanistan	55.00	2,354.00	10.00	25.85	47.00	39.77	1,825.00
Bangladesh	1,357.00	10,940.00	1,000.00	22.50	1.66	0.95	217.00
Bhutan	95.00	49,557.00		0.02	0.02	0.02	13.00
India	1,850.00	1,896.00	235.00	380.00	20.54	18.23	612.00
Nepal	170.00	7,338.00		2.68	1.58	1.58	154.00
Pakistan	248.00	1,678.00	170.30	155.60	62.74	37.20	1,269.00
Sri Lanka	43.20	2,341.00	0.00	6.30	14.58	14.58	503.00
Central Asia							
Kazakhstan	75.42	4,484.00	34.20	33.67	44.64	30.72	2,002.00
Uzbekistan	16.34	704.00	34.10	58.05	355.26	115.09	2,501.00
Tajikistan	66.30	11,171.00	50.30	11.87	17.90	10.18	2,001.00
Turkmenistan	1.00	232.00	70.00	23.78	2,378.00	33.49	5,723.00

0 = zero or less than half of the unit measured.

[a] Annual internal renewable water excludes river flows from other countries.

[b] Water withdrawal includes all water used for irrigation, industry, and agriculture (including watering of animals). It is not the same as water consumption.

Source: WRI (1998).

the continents (ADB, 1998); the water availability indicator dropped from 9,600 m^3 in 1950 to 3,240 m^3 in 1992 (WRI, 1994, Table 22). In rapidly growing countries, the competition for water between agriculture and other uses is likely to increase. Projections of water demand to the year 2025 reveal a switch in the demand pattern to more nonfarm uses. The growth in nonfarm use is particularly strong in PRC, India, and Southeast Asia (Rosegrant and Ringler, 1997).

On the basis of this indicator, Singapore, Turkmenistan, and Uzbekistan face extreme water scarcity conditions. However, the indicator roughly indicates overall supply only. Care must be taken when it is used to compare countries with different climatic conditions. In tropical countries, evaporative loss is much higher than in temperate countries, and the same level of precipitation may imply a very different water situation. In addition, the distribution of rainfall over the year and the length of the rainy season also make a difference in the water situation given the same level of availability. Further, the extent and severity of water pollution need to be considered.

The above supply-side indicator is more useful for guiding water management strategies when used in combination with a water withdrawal indicator (sometimes referred to as the United Nations indicator) which indicates the proportion of available water used (Table II.5). Water management problems are relatively easy to deal with if the withdrawal indicator is below 10 percent of availability (Falkenmark, Lundqvist, and Widstrand, 1989). Above 20 percent, water management becomes a major concern. At relatively high levels of water utilization, as the gap between availability and use further declines, water management strategies have to include storage enlargement, rationing, and conservation. In this case, water has to be withdrawn from outside sources. Countries with utilization rates above 40 percent are considered to be experiencing high levels of water stress. Under this indicator (Table II.5), Afghanistan, Central Asia, and the Republic of Korea appear to have major water problems. In Central Asia, the withdrawal ratio is very high in Kazakhstan, Uzbekistan, and Turkmenistan. This is mainly the result of faulty irrigation systems with canals that lose most of their water on the way to target areas. If external water sources are excluded, Thailand and India would be in relatively vulnerable water positions.

In Asia, Southeast Asia tends to be most abundantly endowed with water and the level of utilization is low, except for Singapore (Table II.5). The major problems in the deltas are drainage and eutrophication, due to the relatively humid climate. In fact, in the Mekong and Irrawaddy deltas, efficient water management and drainage systems have higher priority than large-scale water infrastructure projects.

The water availability and withdrawal indicators can be misleading when water is very unevenly distributed within a country. For example, in the PRC, water is most plentiful in the southeast where arable land is scarce. Water availability is low in the northern region above the Yangtze River basin where agriculture is intensive. While much of the surface water (80 percent) is from the Yangtze and other basins in the south, most of the cropland (63 percent) is north of the Yangtze (Brown, 1995). In addition, water can be unevenly distributed between seasons. Bangladesh and Viet Nam encounter both long periods of flooding and dry season shortages.

Also, the water availability and withdrawal indicators do not take future uses into account. The International Water Management Institute (IWMI) (Seckler et al., 1998) has attempted to provide an indicator that reflects water requirements in 2025, based on data in 118 countries. Two scenarios, business as usual and with more effective irrigation, are given. Countries were ranked into five groups according to two criteria: the percentage increase in water withdrawal between 1990 and 2025, and the extent of withdrawals in the year 2025. Group 1 consists of countries that are water scarce according to both criteria. Countries in group 2 need to develop water resources fully in order to meet increased requirements in 2025. The third group comprises countries that would need to develop 25–100 percent, 48 percent on average, of their water. Groups 4 and 5 consist of countries that have adequate water supplies, and for group 5, future requirements tend to decrease.

The IWMI model does not deal with changes in the crop and industrial mix.

Under the business-as-usual scenario, the projected increases in water withdrawals in Asian countries range from 40 to 135 percent. Under the second scenario, which assumes substantial improvements in irrigation, only two Asian countries, Singapore and Pakistan, were included in group 1. None were included in group 2. Cambodia, Indonesia, Malaysia, Myanmar, and Nepal were included in group 3, and the Philippines and Viet Nam were in group 4. Surprisingly, the Republic of Korea and Thailand, both of which are under water stress according to the United Nations indicator, and are emerging as countries facing severe or increasing water resource management problems, were ranked in group 5. The IWMI study treated the PRC and India separately, but if the same criteria were applied, the PRC would have been placed in group 5 and India in group 4.

At first glance, the IWMI indicator seems to provide a picture that conflicts with conventional indicators. However, this indicator is a projection to a future situation (year 2025), while the two indicators mentioned earlier reflect the existing situation. The IWMI projections assume increased irrigation effectiveness from around 43 percent on average currently to 60 percent in 2025. In the case of Thailand, the IWMI prediction tends to overstate the water situation because it uses the unrevised World Resources Institute data from 1990 on annual internal renewable resources, which are 69 percent greater than the revised figures for 1998. Also, the Thai projection is very sensitive to the assumption of increased irrigation efficiency because it has a very high proportion of water use for irrigation relative to other economic sectors than is the case in most other countries. Moreover, the IWMI indicator cannot properly reflect the water situation in the PRC where water is abundant where it is less needed. However, the IWMI prediction is a good illustration of the gains to be derived from improving irrigation effectiveness. According to IWMI, if Thailand can improve its irrigation efficiency by 100 percent, i.e., from 31 to 60 percent between 1990 and 2025, a substantial volume of water will be liberated from agricultural use. Total withdrawals in 2025 would then be lower than in 1990 by 11 percent without the need for new, major water resource development projects.

Pollution may make water unfit for higher-value uses. For example, pollution is emerging as a constraint to the expansion of Chinese inland fisheries. Another example is shrimp aquaculture, where shifting cultivation practices are dictated by the need for water of suitable quality in order to avoid overstocking and disease contagion.

Underground water is an important and reliable source of water for irrigation in many Asian countries. Bangladesh, Pakistan, and India all rely on groundwater for more than 30 percent of their total water resources. Recently, these resources have been placed under threat from overpumping. In India, where half the irrigation area is under pumping irrigation, groundwater is now a very valuable resource for agriculture. It is estimated that groundwater is used in 75–80 percent of Indian irrigation. Overexploitation of groundwater for rice and wheat cultivation has caused the water table to drop by 30–40 cm annually in the Gangetic Plain, and especially in Ludhaina, Paltana, and Sangur in Punjab, and Karnal in Haryana (Chand and Haque, 1997).

Overpumping across millions of hectares of the coastal areas of Gujarat and Tamil Nadu has caused seawater seepage into the aquifer (Repetto, 1994). A similar phenomenon is observed in the southern coastal areas of Viet Nam, leading to the abandonment of groundwater extraction works in the area. Open-access regimes have encouraged excessive water pumping and have lowered the water table substantially in Gujarat, Rajasthan, Punjab, and Karnataka (Moench, 1994). The water table dropped by 30 m in a few decades in Tamil Nadu (Falkenmark and Widstrand, 1992).

As stated earlier, water availability is considered to be an increasing constraint in the PRC. Prior to 1970, irrigation water there came from the development of surface sources. Since 1970, groundwater has been increasingly tapped, resulting in falling water tables, especially in Hebei Province, where the groundwater table dropped 70 m in the Cangzhou area over a period of 10 years (Zhang and Zhang, 1995). In the northern region of the PRC, where reliance is placed on groundwater because the distribution of surface water is uneven, more than 70 percent of the extractable groundwater has been utilized (Zhang and Zhang, 1995).

To ensure the sustainable development of groundwater resources, knowledge of the characteristics of the aquifers and their natural recharge rates is important. It is particularly important for Bangladesh, India, and Pakistan where private-sector investments in tube-well irrigation have proliferated, and in Thailand where the conjunctive use of surface water and groundwater is gaining in importance.

Like other natural resources, water has multiple uses and therefore many stakeholders. In certain instances, the situation is further complicated when water resources are shared by a number of countries. The various uses can be potential sources for conflict because water extracted for one consumptive use may deprive other uses, e.g. water absorbed by plants will not be available for household uses such as drinking or washing. Differences in the timing of water use may also generate conflicts between consumptive and nonconsumptive uses, e.g. hydropower and navigation. Throughout Asia, conflicts about water are growing as the demand for water increases in every economic sector.

In the past, such conflicts arose mainly from competition for water for alternative economic uses, such as between upstream and downstream users, between economic sectors, and between rural and urban uses. Traditionally, water projects have often been designed to divert water resources from their natural state for uses that bring increased economic benefits. Recently, concern over the diversion of water from its natural environmental uses to economic uses has been heightened. Environmental groups in Asia, which are growing in number, knowledge, and experience, are demanding greater public participation and more environmentally friendly approaches in the planning, decision making, implementation, and management of water resource development projects.

In the next decade, water resource management will become a major challenge for large countries with big water deficits, such as the PRC and India, as well as Thailand where rice is a major foreign-exchange earner. By 2010, water availability per capita per year from the major tributaries (except the Ping and Nan rivers) in the Chao Phraya Basin, which is the rice bowl of Thailand, will be below 1,500 m^3. Therefore, improvements to water institutions and the efficiency of the irrigation system are imperative.

AQUATIC RESOURCE SYSTEMS AND FISHERIES RESOURCES

Fisheries and aquatic resources and the consequences of their degradation have received little publicity, unlike biodiversity and forest resources. The lack of public awareness of the status of aquatic resources stems from the fact that their degradation is concealed under water and is not evident, either visually or via satellite monitoring. Moreover, because research and data collection in this sector are difficult and costly, the growth of scientific knowledge of aquatic resources has lagged behind that for the food crop, livestock, and forest sectors (ICLARM, 1999).

ICLARM has divided aquatic resource systems into 1) ponds; 2) reservoirs and lakes; 3) streams, rivers, and floodplains; 4) coastal waters including estuaries and lagoons; 5) coral reefs; 6) soft bottom continental shelves (i.e. shelves up to 200 m in depth); 7) upwelling shelves; and 8) open oceans. The total economic value of the ecological services rendered by these aquatic resources systems is estimated at $21 trillion (ICLARM, 1999). In Asia, areas with upwelling, a process through which nutrients from lower layers of the sea are brought to the surface, are small and occur mainly around the northwestern Indian Ocean and parts of Indonesia. Thus, upwelling shelves, and also open oceans, will not be emphasized here as they are only remotely related to rural Asia.

Asia has about 29 million ha of natural lakes and 5.5 million ha of reservoirs (ICLARM, 1999). There are also vast areas of wetlands. For example, 18 percent of the Ganges and 9 percent of the Mekong basins are wetlands. In Cambodia, Tonle Sap, the largest inland lake in the lower Mekong sub-basin, and its flood plains and adjoining river systems, can be considered the subregional hub for aquatic diversity. Although fishery stock assessments for this very important area are grossly inadequate, at least 215 species have been recorded in the catch (Royal Government of Cambodia, 1998). The productivity of Tonle Sap fisheries is estimated at 65 kg/ha/year, more than five times that of most other tropical freshwater bodies, which average around 12kg/ha/year. The annual catch from Tonle Sap has always exceeded that from Cambodia's marine fisheries, accounting for 50 to 70 percent of the total national catch. For example, the lake's annual catches from 1993 to 1995 ranged between 60,000 and 72,000 t, compared with around 30,000 t from marine fisheries over the same period.

The lower Mekong sub-basin is the habitat of at least 1,200 different species of fish, of which 400 species are economically important to local communities (MRC, 1997). The annual catch for the four countries it covers is estimated at 815,000 to 940,000 t (van Zalinge, 1998). Catches of two large migratory fish species, the giant Mekong catfish *(Pangasianodon gigas)*, and the giant Mekong barb *(Catlocarpio siamensis)*, have declined drastically. Similar trends are forecast for medium-sized fish. The Irrawaddy dolphin is being threatened by a tourism project near the Li Pi Falls. Multipurpose dams built in Thailand, Lao PDR, and Cambodia have blocked fish migration and disturbed spawning areas.

Coastal waters, including estuaries, lagoons, and mangroves, have higher productivity than offshore or freshwater systems (ICLARM, 1999). The ecological services provided by estuaries (mainly in nutrient recycling and food production) are estimated to be worth as much as $22,000 per ha per year (Constanza et al., 1977, cited in ICLARM, 1999). Mangroves provide shoreline protection from storms, winds, and waves; serve as nutrient filters, sediment sinks, energy sources, and habitats for a large number of species of marine and terrestrial flora and fauna; and are important to the livelihoods of small-scale fishers. In sheltered tropical coasts, the high productivity of mangroves is believed to contribute to marine ecosystems via nutrient transportation as well as through their nursery and habitat functions. It is estimated that the global value of ecosystem services provided by mangroves totals $9,900 per ha per year, and more than four fifths of this value comes from their services of waste treatment and disturbance regulation (ibid.).

In recent decades, mangroves have been rapidly destroyed to provide land for human settlements, ports and other infrastructure development, charcoal, and space for aquaculture. In the Philippines, a substantial proportion of the mangrove area has been converted into fishponds to raise milkfish. In Thailand, intensive shrimp farming spread rapidly during the 1980s and used about 30 percent of the country's mangrove areas, although they are not suitable for shrimp farming. However, due to the high returns in shrimp aquaculture, profit can be made after only a few years of operation, and it was relatively easy to set up farms in mangroves owing to a lack of property rights and weak enforcement of forest laws.

Coastal and inland aquatic resources are now seriously threatened by land-based pollution. In the PRC, important species such as sea cucumbers and scallops have become extinct in traditional fishing grounds (ADB, 1995b). Mudflats that are seriously polluted have become unfit habitats for molluscs. Red tides and oil and industrial pollution are causing greater and increasingly frequent damage to coastal resources.

Other lesser known coastal resources are also under threat. For example, seagrass beds that serve as feeding areas for fish have been disturbed to the point where their species diversity has deteriorated. The value of these coastal resources to the community provides the greatest impetus for their conservation. In a recent study, a damage schedule measuring the relative importance of various resources was conducted for Bon Don Bay and Pak Phanang Bay, Thailand. For Ban Don Bay, the rankings, from most to least important, consisted of damage to mangroves, mudflats, shellfish breeding grounds, and fish breeding grounds. For Pak Phanang Bay, the rankings consisted of damage to sandy beaches, mangroves, seagrass beds, and coral reefs (Ratana, 1998).

Coral reefs in good condition yield 20 t or more of fish per 100 ha per year, and an average yield is estimated at 8 t/km^2 (ICLARM, 1999). Reef areas produce, inter alia, aquarium species and valuable live fish, mainly for East Asian markets and especially for restaurants in Hong Kong, China. The economic benefits from coral reefs are estimated at $375 billion per year (Bryant et al., 1998).

The biodiversity of coral reefs compared with other marine resource systems is likened to that of tropical rain forests in comparison with other forests. The range of species richness is from more than 2,000 species in the Indo-Pacific area to 200 species in the Atlantic. At present, about four fifths of all coral reefs are at risk and over half (56 percent) are at high risk levels (Bryant et al., 1998). Major threats to coral reefs are from overexploitation (36 percent), coastal development (30 percent), land-based pollution and soil erosion (22 percent), and marine pollution (22 percent). Southeast Asia contains about 30 percent of the world's coral reefs. Most of the areas with high species richness and high risk are (in order) in the Philippines, Indonesia, and Japan. In fact, all coral reefs in the Philippines are assessed to be at risk while in Indonesia about 80 percent are at risk.

Attempts are being made to protect aquatic resource systems through the establishment of Marine Protected Areas (MPAs), which number about 382 in Asia, excluding the Pacific, constituting about 29 percent of all subtidal MPAs in the world's 18 marine regions. The East Asian seas have MPAs in every biogeographic zone. Most of them are relatively small, and are threatened by various human activities. The management of these MPAs is constrained by inadequate funding and technical resources, shortages of trained staff and management information, inadequate commitment to law enforcement, the unsustainable use and overexploitation of resources, overlapping mandates, and a lack of coordination. Thus, despite the severity of the problems, relatively little protection has been accomplished.

Asia's marine areas vary greatly in their physical and environmental conditions, from mostly tropical in South and Southeast Asia, to subtropical to temperate and subpolar in East Asia (Devaraj and Vivekanandan, 1997). They cover areas of continuous and seasonal upwelling along the northwestern Indian Ocean, highly productive continental shelves along southwestern India, the South China Sea, the western Bering Sea, the area southeast of the Kamchatka Peninsula, and the Gulf of Thailand (part of the Sundaic platform), and thousands of islands with oceanic or near-oceanic features, such as Indonesia and the Philippines. When catches are expressed in terms of landings per unit shelf area, tropical oceans show the lowest levels of overall productivity. This is a reflection of the natural constraints imposed by a small supply of nutrients (FAO, 1997a).

The greatest diversity of fish species is found in the warm waters of the tropics, particularly the shallow inshore seas of the Indian Ocean and the western central Pacific Ocean. For example, there are 1,694 species of fish that reportedly inhabit Chinese waters. Of these, only 289 species are found in the temperate waters of the Bohai and Yellow seas, with the remaining 1,405 species being found in the tropical and subtropical waters of the East and South China seas (ADB, 1995b). In the temperate and subpolar areas in the northeast, the fishing industry is dominated by only a few species of fish. In warmer tropical waters, a great many species are fished. This is reflected in the wide variety of fishing gear and equipment used in these areas, and in the fact that most often there are many miscellaneous species caught at the same time as the targeted species.

Considerable uncertainties exist regarding the true potential of the oceans to supply fish, mainly due to a lack of data and incomplete stock assessments. This is particularly true in developing regions, but is also in part due to incomplete knowledge of fishery dynamics, prey-predator relationships, and environmental impact (e.g. the El Niño-Southern Oscillation phenomenon). Each of these may cause fluctuations in fish yields, making it difficult to estimate fishery potential.

However, even allowing for these uncertainties, there is growing evidence that the world's fishery resources in the major fishing grounds are being overexploited. Estimates of trophic levels for some 220 fish and invertebrate species or groups that are commonly landed (Pauly et al., 1998) have shown that there has been an increasing trend towards "fishing down the marine food web", possibly with severe implications for the marine ecosystem, especially prey-predator relationships. Fishing that removes the top carnivores in a food web may in the short term lead to higher production, because preyed-upon species would increase in the absence of their predators. In the long run, however, this practice could lead to widespread fishery collapses (ibid.). For example, the absence of a certain predator may increase the population of nonutilized competing predators (e.g., jellyfish in the Black Sea).

The lack of adequate stock assessments of common commercial fish species and the presence of large numbers of miscellaneous species in catches combine to make it very difficult to estimate the population size of any one species. This is a problem common to most fisheries throughout the world. Nevertheless, the traditional belief that the possibility of fishing a species to extinction was a remote one is now being challenged. The World Conservation Union (IUCN), for example, has listed over 100 marine species on its Red List of endangered species, including some tunas, sharks, and more than 30 species of seahorse (GRAIN, 1997).

The pressures from overfishing are particularly intense on larger fish species, which tend to have lower fertility levels and longer life spans, and are also usually commercially important species, e.g. the majority of groundfish, and tunas and other large pelagics. The smaller fish species tend to have high fertility levels and shorter life spans, and can therefore replenish their numbers relatively quickly, or are less intensively fished because of their lower commercial value. Recently, however, with the depletion of the stocks of the larger species and an increase in the demand for fishmeal for the animal feed industry, the smaller species are being fished more intensively.

In the Gulf of Thailand, the species composition of catches by trawlers has been changing away from long-lived and high-value species towards short-lived species of lesser value (Suraphol, 1997). An increasing proportion of catches from commercial fishing vessels consists of trash fish used for reduction. Similar trends of nonselective fishing are also becoming evident elsewhere, such as in India. Fishing effort continues to be high due to the need to make fishing operations cost effective and to make loan payments (Gopakumar, 1997). Fleet retirement is a costly option, both to governments and to fishers.

Major threats to the sustainability of fisheries and aquatic resources systems include mismanagement, and the lack of institutions that can ensure optimal exploitation and deal with multiple-use conflicts. For example, excess nutrients from pond aquaculture are discharged into the environment instead of being used to fertilize crops, and saltwater is brought into freshwater areas for shrimp farming. Cyanide and dynamite fishing in Philippine and Indonesian reefs continues to place the world's most productive reefs at risk. Heavy tourism and land and marine pollution exacerbate the situation. Dam construction disturbs the migratory pattern of fish. Soil erosion from deforestation and upland agriculture destroys coral reefs. Urban and industrial pollution creates costs for aquaculture that go uncompensated. Competition for resources between commercial and small-scale fishers often leads to mob protests and sometimes to violence. It is evident that governing institutions are under extreme stress and the current sectoral management approach, in which one agency is in charge of one resource without taking into account the interrelationships of resources in the same ecosystem, needs to be substantially reformed.