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Historic Land Use and Carbon Estimates for South and Southeast Asia 1880–1980

J. F. Richards · E. P. Flint

R. C. Daniels, editor

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Oak Ridge National Laboratory

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ORNL/CDIAC-61
NDP-46

HISTORIC LAND USE AND CARBON ESTIMATES FOR SOUTH AND SOUTHEAST ASIA: 1880-1980

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ABSTRACT

Richards, J.F. and E.P. Flint. 1993. Historic Land Use and Carbon Estimates for South and Southeast Asia: 1880–1980. ORNL/CDIAC-61, NDP-46, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 404 pp.

This document describes the contents of a digital data base containing estimates of land use change and the carbon content of vegetation for South and Southeast Asia for the years 1880, 1920, 1950, 1970, and 1980. These data were originally collected for climate modelers, so they could reduce the uncertainty associated with the magnitude and time course of historical land use change and of carbon release. For this data base, South and Southeast Asia is defined as encompassing nearly 8×10^6 km^2 of the earth's land surface and includes the countries of India, Sri Lanka, Bangladesh, Myanmar (Burma), Thailand, Laos, Kampuchea (Cambodia), Vietnam, Malaysia, Brunei, Singapore, Indonesia, and the Philippines.

The most important change in land use over the 100 year period was the conversion of 107×10^6 ha of forest/woodland to categories with lower biomass. Land thus transformed accounted for 13.5% of the total area of the study region. The estimated total carbon content of live vegetation in South and Southeast Asia has dropped progressively, from 59×10^9 Mg in 1880 to 27×10^9 Mg in 1980. Throughout the study period, the carbon stock in forests was greater than the carbon content in all other categories combined, although its share of the total declined progressively from 81% in 1880 to 73% in 1980.

The data base itself was developed in Lotus 1-2-3™ using a sequential bookkeeping model. The source data were obtained at the local and regional level for each country from official agricultural and economic statistics (e.g., the United Nations Food and Agriculture Organization); from historical geographic and demographic texts, reports, and articles; and from any other available source. Because of boundary changes through time and disparities between the validity, availability, and scale of the data for each country, the data were aggregated into 94 ecological zones. The resulting data base contains land use and carbon information for 94 ecological zones and national totals for 13 countries.

These data are available as a Numeric Data Package (NDP) from the Carbon Dioxide Information Analysis Center. The NDP consists of this document and a set of data files consisting of ninety Lotus 1-2-3™ files, three ARC/INFO™ export files, and five flat ASCII data files (provided to extend the use of the data to non-Lotus 1-2-3™ and non-ARC/INFO™ users). The documentation contains information on the methods used in calculating each variable, detailed descriptions of file contents and formats, and a discussion of the sources, restrictions, and limitations of the data. The data files are available on a variety of media and through the INTERNET. The ARC/INFO™ files contain digitized outlines of each nation and zone within the data base. Also provided are FORTRAN and SAS™ retrieval programs for use with the flat ASCII data files and a descriptive file that explains the contents and format of each data file.

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PART 1
INFORMATION ABOUT THE DATA PACKAGE

1. NAME OF THE NUMERIC DATA PACKAGE

HISTORIC LAND USE AND CARBON ESTIMATES FOR SOUTH AND SOUTHEAST ASIA: 1880-1980

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3. KEYWORDS

Agricultural expansion, biomass, carbon release, climate change, deforestation, environmental history, land use change, livestock, population, wetland clearance, Bangladesh, Brunei, India, Indonesia, Kampuchea (Cambodia), Laos, Malaysia, Myanmar (Burma), Philippines, Singapore, Sri Lanka, Thailand, Vietnam.

4. BACKGROUND INFORMATION

The irreversible nature of human induced climate change and the possible adverse impacts these changes may have on the Earth's ecological and economic systems make the task of developing an all-inclusive general circulation model (GCM) with predictive capabilities essential if we are to develop mitigation strategies for the future. Currently, GCMs estimate that an increase of 1.5 to 4.2°C in the average global surface air temperature will occur with a doubling (from preindustrial levels) of the concentration of greenhouse gases in the atmosphere (Dale et al. 1991). Based on extrapolations from currently available atmospheric CO_2 concentration data (Keeling and Whorf 1991), this doubling is expected to occur by the year 2160.

To more accurately predict the effects of long-term increases in the number and concentration of greenhouse gases on climate, GCMs will be required to predict the timing and magnitude of past and future increases in atmospheric CO_2 concentrations, as well as the concentration of methane, nitrous oxide, water vapor, and a host of anthropogenic gases, based on an understanding of all the major processes leading to the release (sources) or storage (sinks) of these gases over time.

The development of a GCM that can predict regional trends in climate will be problematic until a well-documented understanding of the past, present, and possible future usage of fossil fuels and land is achieved. Such an understanding is only possible with the concerted effort of many investigators from a diverse set of disciplines. The perspectives of ecologists, biologists, historians, geographers, foresters, mathematicians, physicists, and others are needed if a multifaceted examination of the causes and consequences of land use change and human population growth on the world's climate is to be obtained.

Reductions in the amount of carbon stored in terrestrial ecosystems are partially responsible for the increase in the concentration of atmospheric CO_2 that has occurred since 1850 (Bacastow and Keeling 1981, WMO 1981, Woodwell et al. 1978, Bolin 1978). For example, terrestrial vegetation is estimated to have contained over 900 Pg of carbon before any land clearing occurred on Earth (Olson et al. 1985). In 1982 Olson and Watts estimated the amount of carbon sequestered in vegetation to be about 560 Pg. The decline in the amount of carbon sequestered in vegetation has been associated with the rapid increase in human population that began during the industrial revolution (Woodwell and Houghton 1977). This population growth created demands for food and forest products that could only be fulfilled through the clearing and conversion of large tracts of forest to agricultural and other uses. This land use conversion impacted the concentration of atmospheric CO_2, because forests originally contained about 90% of the carbon stored in terrestrial vegetation (Dale et al. 1991).

Land use data and carbon estimates for South and Southeast Asia were collected and analyzed by John F. Richards and Elizabeth P. Flint (Department of History, Duke University, Durham, North Carolina) between 1983–1993. This data base was collected to help reduce the uncertainty associated with the release of carbon into the atmosphere caused by land use change. Results and conclusions drawn by the researchers using these data are described in detail in *Effects of Land-use Change on Atmospheric CO_2 Concentrations: South and Southeast Asia as a Case Study*, published by Springer-Verlag in 1993 (Dale 1993). Discussion of earlier results may be found in Richards et al. (1983, 1985) and Flint and Richards (1991).

Their research was supported by a series of contracts and grants from the U.S. Department of Energy (presently under the direction of program manager Roger C. Dahlman). All funding was part of a long-term, multidisciplinary research initiative to examine the impacts of land-use change in tropical regions of the world on global atmospheric CO_2 concentrations. The contracts and grants that supported the construction of this data base include the following: Department of Energy, Office of Basic Energy Sciences, subcontract 19X-43361C under contract DE-AC05-84OR21400 to Oak Ridge National Laboratory (1983–1988); Department of Energy, Office of Energy Research, subcontract 19X-SB828C under contract DE-AC05-84OR21400 to Oak Ridge National Laboratory (1988–1990); Department of Energy, Office of Energy Research, Basic Energy Sciences, Carbon Dioxide Research grant DE-FG05-90ER61082 (1990–1991); Department of Energy, Office of Health and Environmental Research, Environmental Sciences Division, Global Carbon Cycle Research Program grant DE-FG05-90ER61082 (1991–1994). Additional long-term support was provided by the Smithsonian Institute, Office of Fellowships and Grants, Foreign Currency Program (1984–1992; program manager Francine Berkowitz).

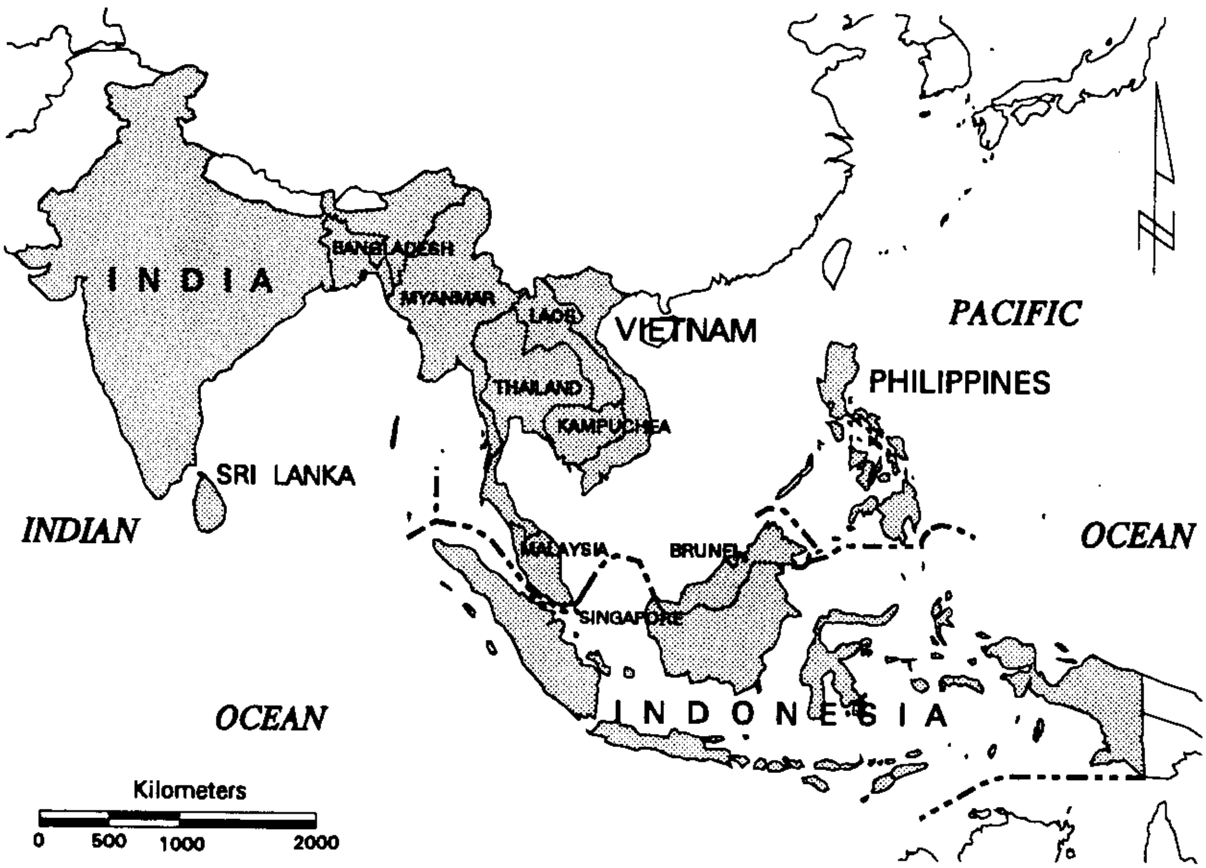

Figure 1. **Map of South and Southeast Asia identifying the 13 countries with data in this data base**

5. APPLICATIONS FOR THE DATA

This data base contains a historical record of the conversion of land from natural or partially modified vegetation (high biomass) to agricultural or other low biomass activities (e.g., pasture) for South and Southeast Asia in the years 1880, 1920, 1950, 1970, and 1980. For purposes of this Numeric Data Package (NDP), South and Southeast Asia covers 7.9×10^6 km^2 of the world's surface and includes the countries of India, Sri Lanka, Bangladesh, Myanmar (Burma), Thailand, Laos, Kampuchea (Cambodia), Vietnam, Malaysia, Brunei, Singapore, Indonesia, and the Philippines (Figure 1). The data base also includes information on human and livestock populations in each country and ecological zone for the bench mark years mentioned above. [A ecological zone is defined as an area consisting of one or more adjacent political units (e.g., districts) that have been grouped together based on socio-ecological similarities.] Thus, these data may be used by demographers, historians, geographers, or other researchers interested in the relationship between land cover change, land degradation, and anthropogenic activities.

6. COMPILATION OF THE DATA BASE

The data base itself was developed in Lotus 1-2-3™ using a sequential bookkeeping model; the source data were obtained at national, regional, and local scales for each country. Two general bodies of information were used to obtain bounds on the vegetation change component in relation to known carbon dioxide sources and sinks. The primary sources of information were historical and geographical documents from colonial records, accounts of economic and trade activities, national yearbooks, and descriptive materials of forests and their conversion, as well as the more recent statistics of the International Institute of Agriculture (IIA) in Rome and the United Nations Food and Agriculture Organization (FAO). The second body of background information was obtained from a review of research dealing with the field sampling of plant mass and the calculation of the carbon content of several different vegetation types (e.g., Brown and Lugo 1989, Negi et al. 1988). These carbon studies were used to estimate the mean carbon content per ha for the general land use classes used in this data base. Uncertainties in these values remain, but an important advantage of this approach is the possibility of modeling the differences that would result from alternative assumptions on the carbon content of a given land cover class. As additional/better data become available, the "average" carbon content of each vegetation type used herein may change. In that case, the new values may be applied to the land use data to obtain new carbon estimates.

The primary sources of uncertainty in this data base are (1) the decade-by-decade decline in biomass in live vegetation (i.e., land cover change) has not been well documented and (2) the average per ha carbon content of each ecosystem, used in predicting the total carbon content of vegetation, varies between studies. Boundary changes through time and disparities between the validity, availability, and scale of the data for each country has also introduced error into this data base. It was these data limitations that made it necessary to aggregate the available information from national administrative units into 94 ecological zones, where an ecological zone is defined as an area consisting of one or more contiguous political units (e.g., districts) that have been grouped together based on socio-ecological similarities. The names and locations of these zones are listed in Table 1 and are shown in Figure 2a through 2f. The zone identification numbers shown in Table 1 are used in all data files (ARC/INFO™, Lotus 1-2-3™, and flat ASCII) as the primary sort and identification key.

Table 1. **Listing of the 94 ecological zones contained within South and Southeast Asia.**

Country Ecological zone	Area (10^6 ha)	Country code	Zone code	Zone ID
BANGLADESH	14.797	1	0	100
Chittagong Hill Tracts	1.319	1	1	101
Eastern Coast (Noakhali, Chittagong Districts)	1.396	1	2	102
Meghna Districts (Dacca Division and Sylhet District)	4.441	1	3	103
Sundarbans (Khulna, Kushtia, Patuakhali Districts)	2.362	1	4	104
Western Districts (Rajshahi Division, Kushtia and Jessore Districts)	5.279	1	5	105
BRUNEI (entire nation)	0.577	2	0	200
Total	0.577	2	1	201
INDIA	319.700	3	0	300
Andaman and Nicobar Islands	0.825	3	1	301
Andhra Pradesh	27.507	3	2	302
Arunachal Pradesh	8.374	3	3	303
Assam	7.844	3	4	304
Bihar	17.388	3	5	305
Delhi	0.148	3	6	306
Gujarat + Dadra/Nagar Haveli	19.652	3	7	307
Haryana + Chandigarh	4.433	3	8	308
Himachal Pradesh	5.567	3	9	309
Jammu + Kashmir	13.197	3	10	310
Karnataka	19.179	3	11	311
Kerala	3.886	3	12	312
Lakshadweep Islands	0.003	3	13	313
Madhya Pradesh	44.345	3	14	314
Maharashtra + Goa/Daman/Diu	31.150	3	15	315
Manipur	2.233	3	16	316
Meghalaya	2.243	3	17	317
Mizoram	2.108	3	18	318
Nagaland	1.658	3	19	319
Orissa	15.571	3	20	320
Punjab	5.036	3	21	321
Rajasthan	34.224	3	22	322
Sikkim	0.710	3	23	323
Tamil Nadu + Pondichery	13.055	3	24	324
Tripura	1.049	3	25	325
Uttar Pradesh	29.441	3	26	326
West Bengal	8.875	3	27	327
INDONESIA	192.724	4	0	400
Aceh (Daerah Istimewa Acewh)	5.539	4	1	401
North Sumatra (Sumatera Utara)	7.079	4	2	402
West Sumatra (Sumatera Barat)	4.978	4	3	403
Riau	9.456	4	4	404
Jambi	4.492	4	5	405
South Sumatra (Sumatera Selatan)	10.369	4	6	406
Bengkulu + Lampung	5.448	4	7	407

Table 1. (Continued)

Country Ecological zone	Area (10^6 ha)	Country code	Zone code	Zone ID
INDONESIA (Continued)				
West Java [Jawa Barat + Jakarta (D.K.I. Jakarta)]	4.689	4	8	408
Central Java [Jawa Tengah + Yogyakarta (D.K.I. Yogyakarta)]	3.738	4	9	409
East Java (Jawa Timur)	5.109	4	10	410
Bali	0.563	4	11	411
West Nusa Tenggara (Nusa Tenggara Barat)	2.018	4	12	412
East Nusa Tenggara (Nusa Tenggara Timur)	4.988	4	13	413
East Timor (Timur Timur)	1.487	4	14	414
West Kalimantan (Kalimantan Barat)	14.676	4	15	415
Central Kalimantan (Kalimantan Tengah)	15.260	4	16	416
East Kalimantan (Kalimantan Timur)	20.244	4	17	417
South Kalimantan (Kalimantan Selatan)	3.766	4	18	418
North + Central Sulawesi (Sulawesi Utara + Sulawesi Tengah)	8.819	4	19	419
South + Southeast Sulawesi (Sulawesi Selatan + Sulawesi Tenggara)	10.021	4	20	420
Maluku (former Moluccas)	7.787	4	21	421
Irian Jaya (former Dutch New Guinea)	42.198	4	22	422
KAMPUCHEA (CAMBODIA)	18.100	5	0	500
Northwestern Region (Battambang, Siem Reap, Kampong Thum, Pursat, Kampong Chnang, Preah Vihear)	8.005	5	1	501
Northeastern Region (Stung Treng, Ratanakiri, Kratie, Mondokiri, Kompong Cham)	6.213	5	2	502
Southeast Lowlands (Phnom Penh, Kandal, Prey Veng, Svay Rieng, Takeo)	1.557	5	3	503
Southwest Highlands (Kampong Speu, Kampot, Kaoh Kong)	2.328	5	4	504
LAOS (Lao People's Democratic Republic)	23.680	6	0	600
Northwestern Laos (Louang Namtha, Oudamxay, Phong Saly)	2.870	6	1	601
Louang Phrabang + Xaignabouri	5.560	6	2	602
Central Laos (Vientiane, Xiangkhouang, Houaphan)	5.640	6	3	603
Annamite Chain (Khammouan + Savannakhet + Saravan + Attapu)	8.160	6	4	604
Champasak	1.450	6	5	605
MALAYSIA	33.024	7	0	700
Western Peninsular Malaysia [Includes these states: Perlis, Kedah, Pulau Pinang (= Penang + Seberang Prai); Perak, Selangor, Federal Territory, Negeri Sembilan, Melaka]	4.875	7	1	701
Eastern Peninsular Malaysia (Includes these states: Kelantan, Terengganu, and Pahang)	6.395	7	2	702
Johor (Includes the state of: Johor)	1.914	7	3	703
Western Sarawak [Includes the following divisions: 1st (Pertama) and 2nd (Kedua) Divisions through 1986. Divisional boundaries revised in 1987, formed 3 new divisions from two: Kuching (modified 1st), Samarahan (8th), and Sri Aman (modified 2nd)]	1.918	7	4	704

Table 1. (Continued)

Country Ecological zone	Area (10^6 ha)	Country code	Zone code	Zone ID
MALAYSIA (Continued)				
Central Sarawak [Includes the following divisions: 3rd Division (before 1972/73), then subdivided into 3rd (Ketiga), 6th (Keenam) & 7th (Ketujuh) Divisions. These divisions were renamed in 1987 as follows: 3rd (Ketiga) = Sibu; 6th (Keenam) = Sarikei; 7th (Ketujuh) = Kapit]	5.854	7	5	705
Eastern Sarawak [4th (Keempat) and 5th (Kelima) Divisions through 1986. In Aug. 1986 the 4th (Keempat) Division was subdivided into 2 new divisions: Miri (modified 4th) and Bintulu (9th). In Aug. 1986 the 5th (Kelima) Division was renamed as Limbang.]	4.673	7	6	706
Sabah [Total state]	7.394	7	7	707
MYANMAR (BURMA)	67.657	8	0	800
Chin + Arakan (Rakhine) States	7.280	8	1	801
Northern Myanmar (Kachin State, Sagaing Division)	18.367	8	2	802
Dry Zone (Magwe + Mandalay Divisions)	8.184	8	3	803
Shan, Karen, + Kayah States	19.791	8	4	804
Delta (Irrawaddy + Pegu + Rangoon Divisions)	8.471	8	5	805
Peninsular (Mon State, Tenasserim Division)	5.564	8	6	806
PHILIPPINES	30.000	9	0	900
Luzon (Regions 1, 2, 3, 5 and portions of Region 4, includes Luzon, Mindoro, Masbate)	12.650	9	1	901
Palawan (The rest of Region 4, includes Palawan)	1.490	9	2	902
Visayas (Regions 6, 7, and 8, includes Panay, Negros, Cebu, Bohol, Leyte, Samar)	5.661	9	3	903
Mindanao (Regions 9, 10, 11, and 12, includes Northern, Southern, Eastern, & Western Mindanao)	10.200	9	4	904
SINGAPORE (entire nation)	0.062	10	0	1000
Total	0.062	10	1	1001
SRI LANKA	6.561	11	0	1100
Wet Zone [Western Provinces (Gampaha, Kalutara, Colombo Districts) Central Provinces (Matale, Kandy, Nuwara Eliya Districts) Sabaragamuwa Provinces (Kegalla, Ratnapura Districts) + Galle, Matara, and Badulla Districts]	2.012	11	1	1101
Dry Zone [Northwestern Provinces (Kurunegala, Puttalam Districts), Northern Provinces (Jaffna, Mullaitivu, Mannar, Vavuniya Districts), North Central Provinces (Anuradhapura, Polonnaruva Districts), Eastern Provinces (Trincomalee, Batticaloa, Amparai Districts) + Monaragala and Hambantota Districts]	4.549	11	2	1102

Table 1. (Continued)

Country Ecological zone	Area (10^6 ha)	Country code	Zone code	Zone ID
THAILAND	51.311	12	0	1200
Northern Region	16.964	12	1	1201
Northeastern Region	16.885	12	2	1202
Central Plain	10.390	12	3	1203
Southern Region	7.072	12	4	1204
VIETNAM	33.169	13	0	1300
Northwest Highlands (Lai Chau, Son La, Hoang Lien Son, Ha Tuyen, Bac Thai, Cao Bang)	8.312	13	1	1301
Tonkin Delta (Vinh Phu, Ha Son Banh, Hanoi, Ha Bac, Hai Hung, Ha Nam Ninh, Thai Binh, Haiphong, Quang Ninh)	3.260	13	2	1302
North Central Coast (Thanh Hoa, Nghe Tinh, Binh Tri Thien, Quang Nam/Da Nang)	6.395	13	3	1303
Central Highlands (Gia Lai-Cong Tum, Dac Lac, Lam Dong)	5.535	13	4	1304
South Central Coast (Nghia Binh, Phu Khanh, Thuan Hai)	3.510	13	5	1305
Mekong Delta (Ho Chi Minh City, Song Be, Dong Nai, Tay Ninh, Long An, Tien Giang, Ben Tre, Cuu Long, Dong Thap, An Giang, Hau Giang, Kien Giang, Minh Hai)	6.157	13	6	1306

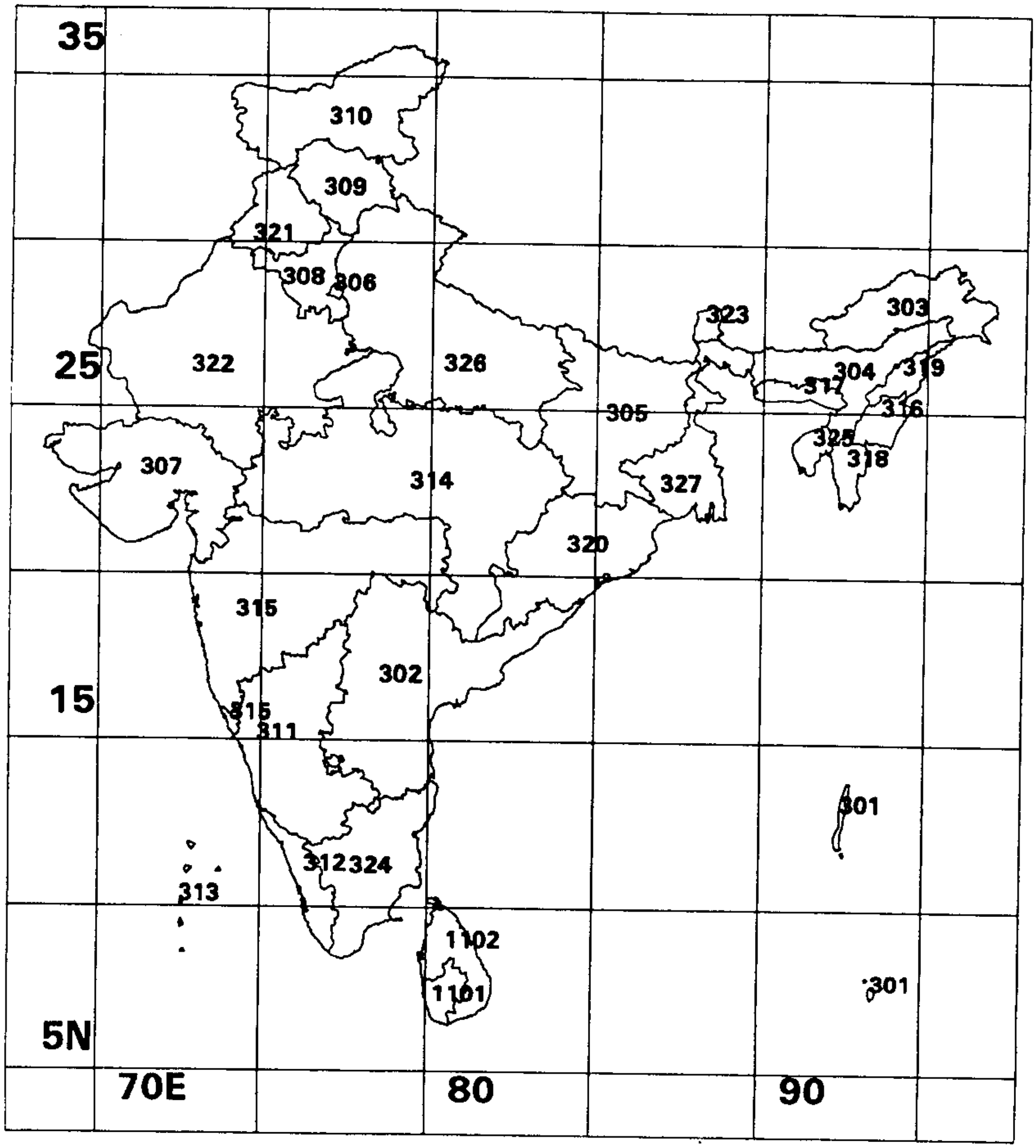

Figure 2a. Map of the identification numbers of the ecological zones contained within India and Sri Lanka.

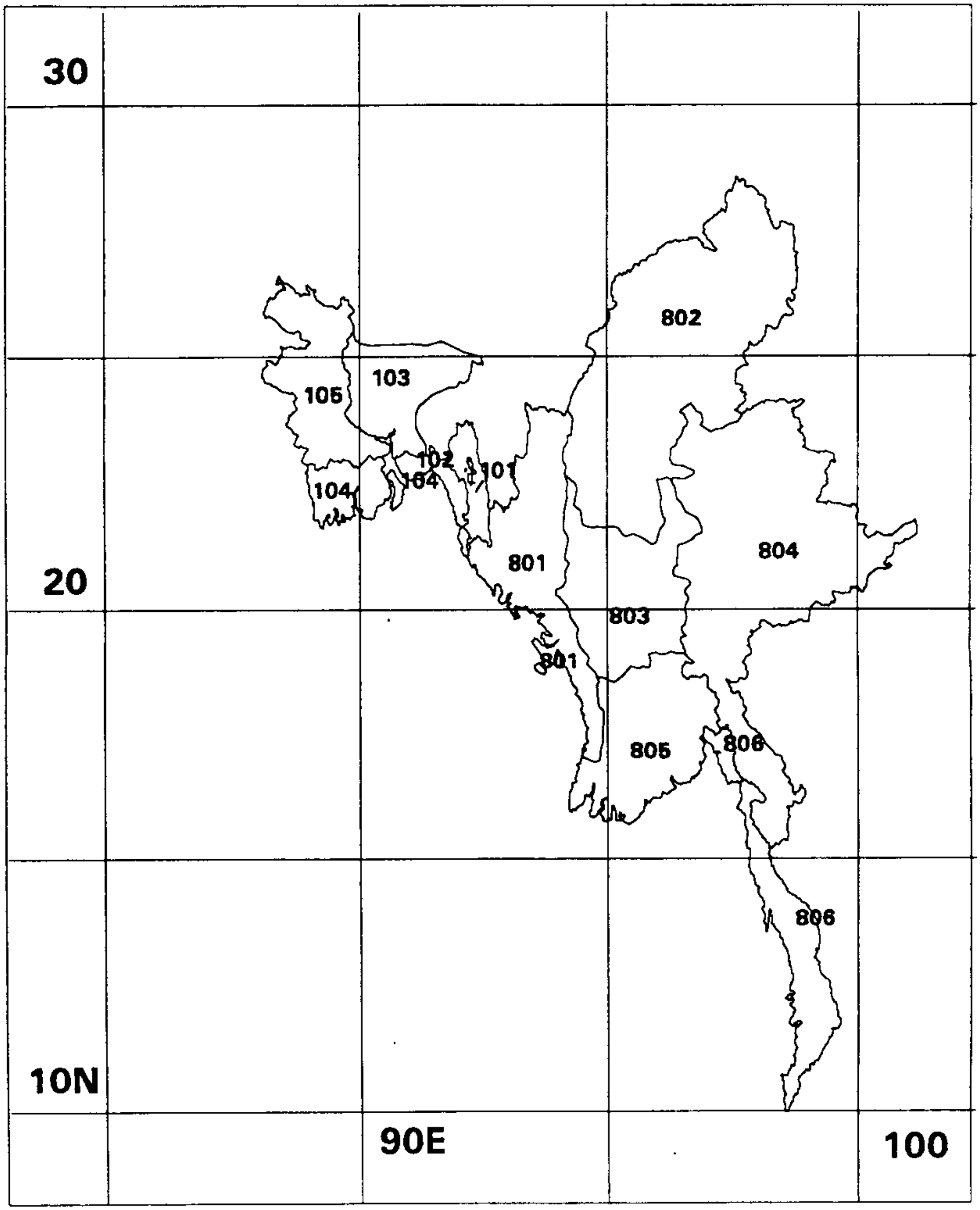

Figure 2b. Map of the identification numbers of the ecological zones contained within Bangladesh and Myanmar (Burma).

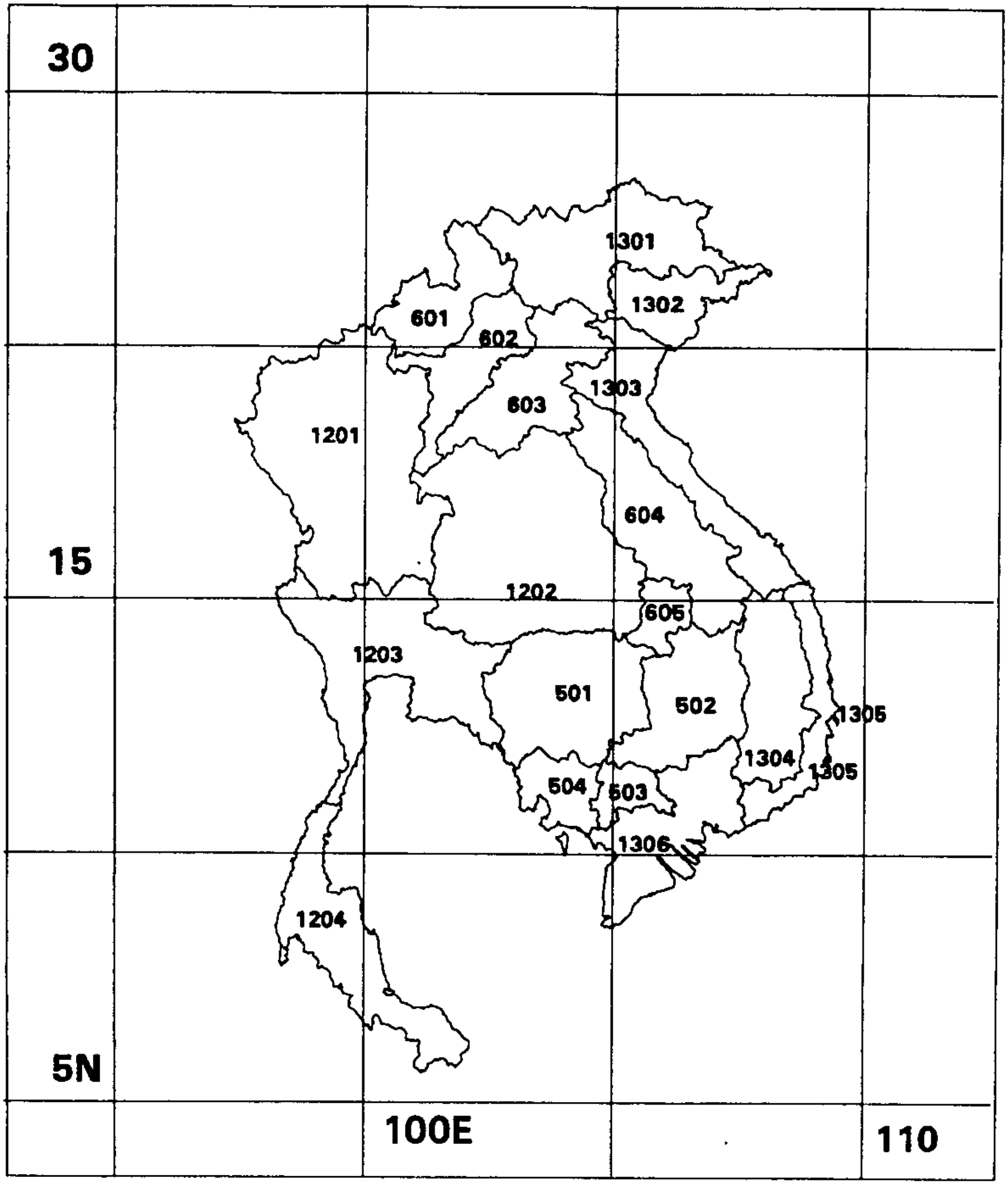

Figure 2c. Map of the identification numbers of the ecological zones contained within Thailand, Cambodia, Laos, and Vietnam.

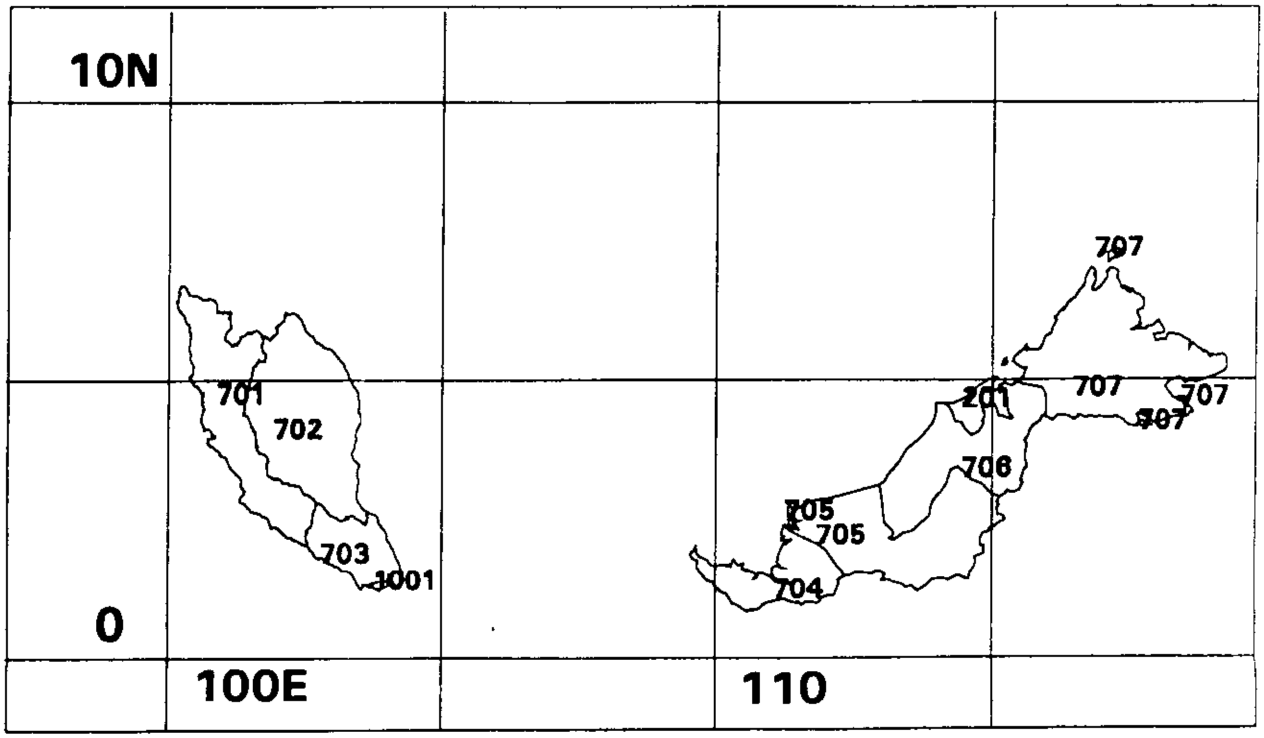

Figure 2d. Map of the identification numbers of the ecological zones contained within Malaysia, Singapore, and Brunei.

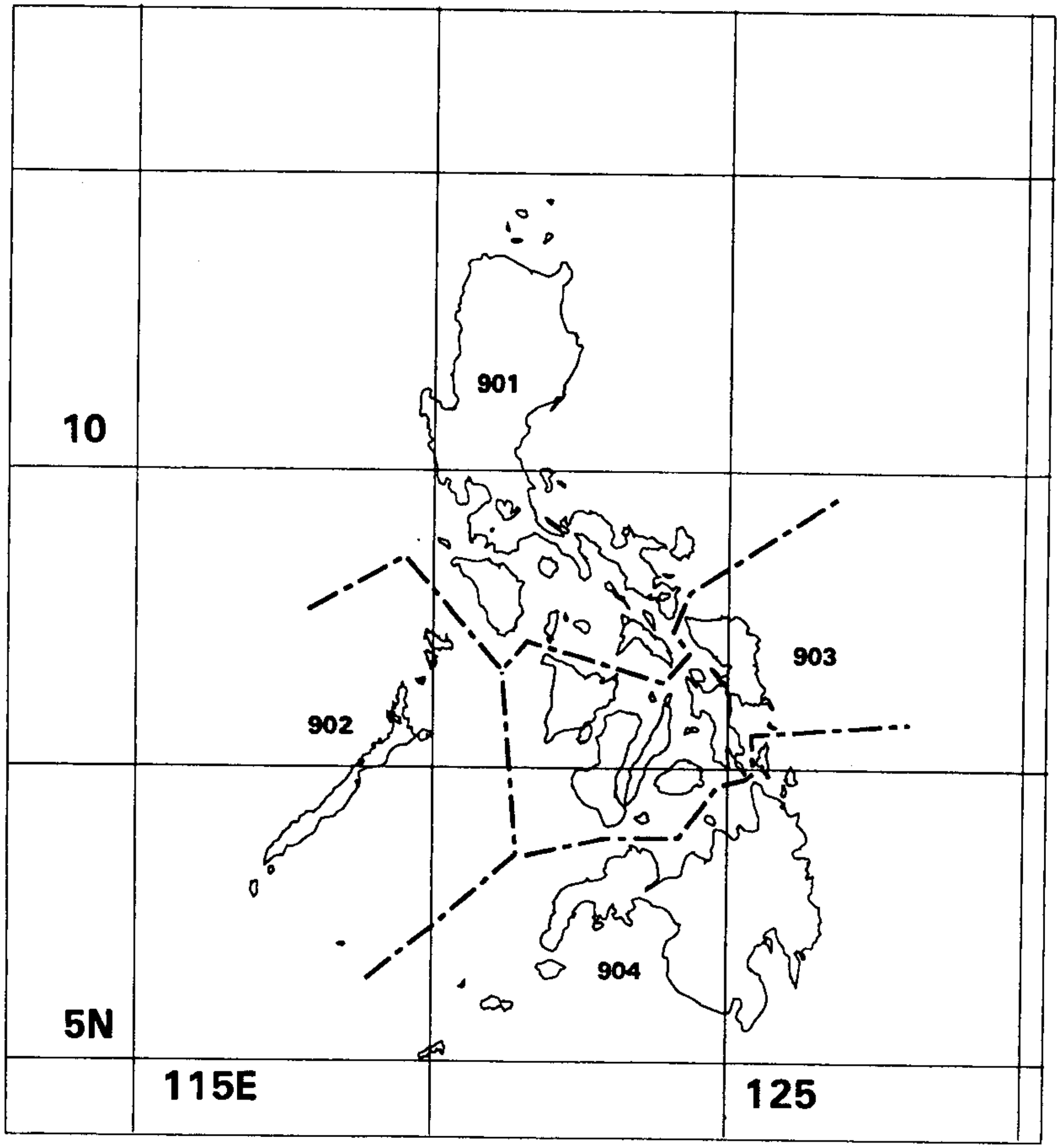

Figure 2e. Map of the identification numbers of the ecological zones contained within the Philippines.

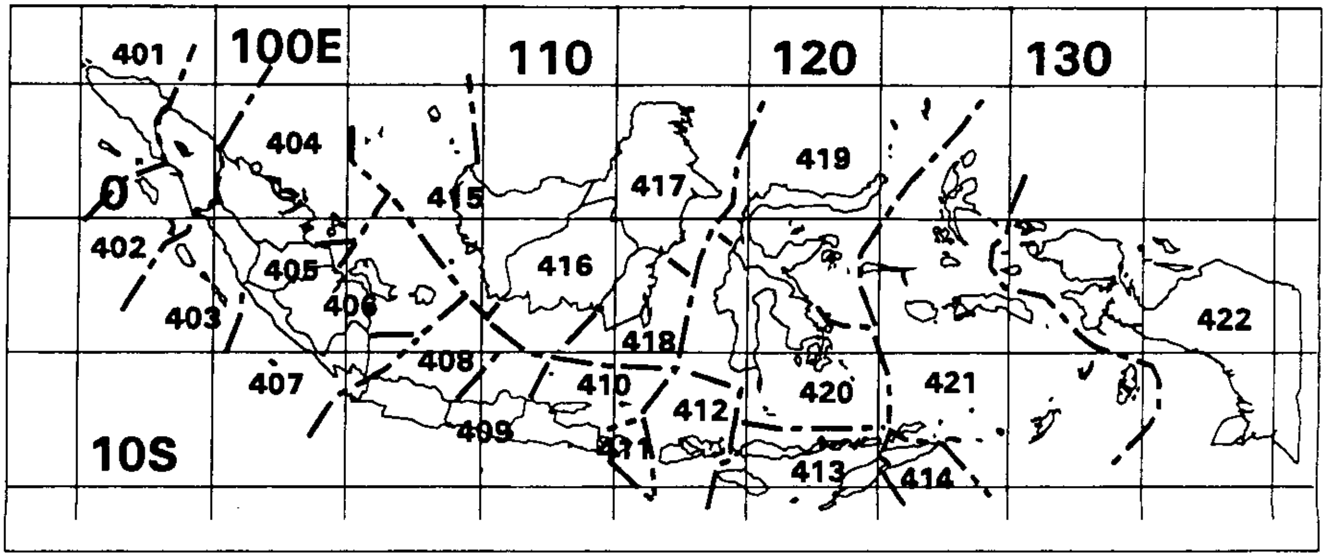

Figure 2f. Map of the identification numbers of the ecological zones contained within Indonesia.

7. REGIONAL GEOGRAPHY AND CLIMATE

A dominant feature in the climate of South and Southeast Asia is the Asiatic monsoon, which is characterized by a strong seasonal variation in the direction of summer and winter winds. In continental South and Southeast Asia moisture-laden southwesterly winds prevail in summer, causing up to 88% of the year's total precipitation to fall between June and September. Precipitation in Insular Southeast Asia, particularly near the Equator, is modified by the Intertropical Convergence Zone and, as a result, has less seasonal variation (Yoshino 1984).

The topography of the study region varies from coastal lowlands to interior mountain peaks exceeding 6000 m. This varying topography, when combined with variations in wind direction, introduces significant variability in the annual distribution of precipitation within the region. Areas with high annual precipitation (>1500 mm) show a tendency toward more even distributions of rainfall. Unlike precipitation, temperatures in South and Southeast Asia generally do not limit plant growth (FAO 1980). Mean annual temperatures range from 22 to 28°C over most of the study region (Ramdas 1974, Oldeman and Frere 1982) with a temperature regime that grades from tropical to subtropical as latitudes increase. Elevation exerts a similar influence on temperature, with mean maxima and minima decreasing by about 0.6°C per 100 m increase in elevation.

The amplitude of diurnal and seasonal temperatures varies with latitude and distance from the ocean (Donner 1987). In the more northerly and continental portions of the study area, seasonal variations in mean temperature of 13°C or more can occur (Ramdas 1974). In areas with higher elevations, alpine-type climates occur. In contrast, the climate of Insular Southeast Asia is characterized by seasonal variations in temperature of only 1 to 3°C (Oldeman and Frere 1982).

Variations in precipitation, temperature, topography, elevation, and soil types within the region encourage a wide range of natural vegetation types. The lowland vegetation of South and Southeast Asia includes large areas of wetland forest (tidal, peat swamp, and freshwater swamp), tropical humid forest, tropical moist-to-dry deciduous forest, and some tropical thorn forest. Higher elevations in northerly latitudes support wet-to-dry subtropical or temperate mountain forest types, including both broad-leafed and coniferous associations, in addition, sites at higher elevations support a variety of subalpine and alpine vegetation.

7.1 LAND USE RECORDS

Most of South and Southeast Asia was under the political control of the European colonial powers by 1880. This control was weakened during World War II and ended shortly there after when India, Bangladesh, Sri Lanka, Myanmar (Burma), Brunei, Singapore, and Malaysia (all part of the British Empire) were granted independence. Indonesia gained independence in 1949 from the Netherlands (East Timor, a colony of Portugal, was annexed by Indonesia in 1976); and Vietnam, Kampuchea (Cambodia), and Laos were ruled by France as Indochina (Forest 1980). Spain ruled the Philippines until the United States succeeded them at the end of the Spanish-American War in 1901. Not all of the territories in these countries were directly governed, as colonial powers tended to concentrate their attention on densely populated and productive lowlands. Less accessible upland territories were often administered by semiautonomous local rulers. Thailand escaped colonization by the European powers altogether, although it was forced to transfer sovereignty of some contested coastal territories to both Britain and France.

Colonial governments tended to rely on direct or indirect taxation of agricultural land as a major source of income (Blyn 1966, Randhawa 1983, Reynolds 1927, Chai 1964, Jackson 1968, Lee 1965, Furnivall 1944, Osborne 1969, Boomgaard 1990). The government of British India, for example, taxed agricultural land annually at a rate proportional to its economic productivity (Asthana and Srivastava 1965). British India conducted extensive cadastral surveys and maintained long-term land use records for most of the area under its direct control (Bansil 1984). Some of the semi-independent South Asian states also recorded agricultural information for revenue purposes (e.g., Chaudhuri 1903). In much of British India, the colonial government revised its land revenue assessments every few decades. After resurveying land and recording changes in revenue obligations and details of land tenure, the local administration issued extensive settlement reports[1] (usually at the subdistrict or district level) that contained detailed land use statistics plus information on local physiography, soils, vegetation, agriculture, and forestry. This information was used to explain and justify the proposed land tax structures that were included in these reports (e.g., Jack 1915).

The authors of settlement reports often contributed to the district gazetteer. This compendium of geographical, historical, economic, and ethnographic information was prepared according to a provincially standardized format and periodically updated. Gazetteers published for larger political units (Provinces) were compilations of the district gazetteers. The central colonial government of India summarized the entire body of gazetteer data in the 26-volume *Imperial Gazetteer of India* (India 1907-1909), a major source of statistical and descriptive information for the turn of the century. The completeness of these land use records varied with the directness of British colonial control (Heath 1951). Generally, the most comprehensive statistics were generated in densely populated and agriculturally productive regions. The same tendency was carried to an extreme by the governments of the Netherlands East Indies and French Indochina. For example, in Indonesia the Dutch kept excellent records for Java, home to at least 70% of the colony's people and almost all of its irrigated rice cultivation, whereas little attention was paid to crop production in the remaining 93% of the country until the 1920s (Boomgaard 1990). Similarly, the French maintained excellent land records in Cochin-China, Tonkin, and Annam but documented Laos and Cambodia with less precision (Henry 1932).

Taxation of agricultural land was less important to the Thai monarchy than to adjacent colonial governments (Ingram 1971), but its relative contribution to national revenue was sufficient to provide incentive for the annual compilation of agricultural statistics starting in 1905 (Wilson 1983).

With the end of World War II and the gradual end of colonial rule in South and Southeast Asia, the newly independent countries of this region tended to maintain the same statistical and land use classification systems as used by the colonial powers. In addition, the goal of national economic development and central planning, encouraged by multinational agencies such as the FAO, inspired several national efforts at data compilation. New states were urged by international organizations to obtain detailed land use surveys by contracting with private North American and European companies. The resulting aerial and cadastral

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[1]In the Presidency of Bengal (roughly equivalent to modern Bangladesh, West Bengal, Bihar, and part of Assam), a permanent assessment had been established late in the 18th century and periodic settlement reports were not issued. However, "final" settlement reports were issued for most districts in the late 19th and early 20th centuries.

surveys, such as that carried out by Hunting Survey Corporation in 1961 for Sri Lanka, were invaluable in compiling this data base (Hunting Survey Corp. Ltd. 1962).

By 1880 ownership of most forest lands in the study region were vested in the state, whether that government was the direct creation of the British, French, Spanish, or Dutch, a semiautonomous protectorate, or an independent entity such as Siam [Conservator of Forests (Siam) 1904, Cubitt 1920, Dutch East Indies 1902, 1923, Forest Research Institute (India) 1961]. An outcome of the state ownership of forests was that each government hired professional foresters to manage and survey its forests for the stated purpose of maximizing the long-term yield of timber and other renewable resources (Brandis 1897, Ribbentrop 1900, Menon 1976, Samapuddhi 1966, Kumar 1986, Feeny 1988, Boomgaard 1988, Kummer 1991). The first forests surveyed were those that contained significant quantities of merchantable timber that were immediately accessible. The quality of forestry data improved throughout the century as developments in technology and transportation increased the number of commercially exploitable species, the amount of accessible forest, and the quantity of timber that could be removed (Gaertner et al. 1963).

The rapid population growth experienced within South and Southeast Asia created a demand for food and increased export income. This population pressure mandated the continued clearing of forests. These demands conflicted with the new countries' long-term goal of self-sufficiency that mandated the conservation of forest resources. Moreover, forest preservation was a prerequisite for the proper management of watersheds to reduce soil erosion and downstream flooding (Richards et al. 1985, Kumar 1986, Boomgaard 1988). To resolve the conflicts over these issues, national governments needed reliable surveys and assessments of the quantity and quality of forest lands. Economic and political interests thus provided a strong incentive for the collection of information on the extent and condition of the forests in all but the most inaccessible territories. Professionally qualified forest officers began to carry out these tasks and to develop methods for reporting the condition of forests under their care.

Geographically specific information on population numbers and distribution (of both humans and livestock) is critical to the understanding of trends in land use. The obvious political utility of such information provided an incentive for officials to conduct population and agricultural censuses. As in the case of forest and agricultural statistics, the first areas of South and Southeast Asia to have censuses were the densely populated agricultural lowlands in each country (Jahdav et al. 1972, Wilson 1983, Boomgaard 1990). The coverage and accuracy of the census data improved as the various states consolidated political control over their territories. Both primary and secondary references on the demographic history of each country have been consulted in the construction of this data base (e.g., Sungsawan 1985, Jones 1953, 1962a, 1962b, 1966). Censuses of livestock in the study region were initiated considerably later than those of population [e.g., India (Republic) 1954, 1972]; because of this, most of the livestock data prior to 1950 were obtained from secondary data sources. The secondary sources were consulted to obtain estimates of the number and type of livestock within each ecological zone. The livestock data were collected for this data base because livestock information provides an important indicator of the amount of vegetation degradation to be expected within the forests and wetlands of each ecological zone. *Livestock are defined for this NDP as including any four-footed domesticated stock animal (e.g., cattle, water buffalo, pigs, goats, sheep, and equines).*

When analyzed and compared with other data sources, it is possible to use the official data discussed above to estimate long-term land use changes and population and livestock compositions. Admittedly, historical data contain errors of omission due to incomplete coverage in the early years of data collection. This is especially true in areas under shifting cultivation or areas of less-formalized administrative jurisdiction. Definitions of land use categories changed abruptly, often with only cryptic notice in the published compilations, to reflect changing official concerns and policies. Official biases, corruption, and ignorance also skewed reporting of land use data, with overly optimistic reports from forestry departments often inflating the areas reported under canopied forest. (This implies that the quality of the statistical data has very little to do with the age of the information, but is directly related to the priorities of the political regime in power at the time of data collection.)

When these biases are understood within the changing context of time and place, the official data series reveal long-term trends in land use; some have been published in an unbroken format as far back as the 1880s (Bansil 1984). In general, government agencies throughout the region engaged in an ongoing effort to improve the quality of their reported data because each nation was deeply interested in enumerating productive assets, especially land under crops or in forest. Systematic cadastral surveys based on trigonometric grids were routinely used by many of the colonial states in South and Southeast Asia as taxation revenues often rested on such information. Thus, the technical means for obtaining and displaying land use data improved over time as the newly created countries, anxious to be seen as modern states, became leaders in compiling and disseminating land use and population information.

Maps of vegetation and land cover that document actual vegetative cover and land use for several areas (e.g., Kuchler 1968, Gaussen et al. 1971, Whitmore 1984, Laumonier et al. 1983, 1986a, 1986b) were extremely helpful in interpreting tabular data. Two reports on tropical forest resources (FAO 1976, 1981) used a common format to summarize contemporary forest areas for each country in the study region. These reports were partly based on information gathered using remote sensing technology. Similar sources published for individual countries have also been employed in the creation of this data base (e.g., Wong 1969, 1973, 1979, World Bank 1977).

The profusion of descriptive and quantitative sources permitted cross-checks and adjustments to the official land use data. Over the course of time, scientists and academically trained government officials have carried out hundreds of studies relating to land use and population in the region. These books, articles, reports, and case studies were utilized in deriving (where necessary) and cross-checking the land use, population, and livestock information contained from official data sources. The primary data sources utilized in the creation of this data base are listed in Section 12.2. Though too numerous to cite here, the secondary data sources are partially referenced in Hall et al. (1988) and Flint and Richards (1989). These two documents [available from the Carbon Dioxide Information Analysis Center (CDIAC)] contain geographically indexed bibliographies with references to over 5,000 published botanical, agricultural, ecological, geographical, and historical studies of the region.

7.2 LAND USE CATEGORIES

Land use statistics were gathered from the available published compilations of official data at various scales (colony, country, state, district, province, or other administrative unit), and preliminary compilations were made using each nation's original classification system. As these systems were structured to meet political rather than ecological needs, their categories do not necessarily reflect the actual vegetation cover or carbon content (biomass) of a given area. Furthermore, the official statistics available for the various geographical entities in South and Southeast Asia are not directly comparable with each other, nor with land use classifications used in other parts of the world. Therefore, a set of eight carbon-based land use classes were developed, and the land use data were converted from their original classifications into this system. The eight carbon-based land use categories are defined as follows:

(1) *Net cultivated area*, is subdivided into two subcategories: land planted in temporary crops (annuals such as rice) and land planted in permanent crops (perennials such as rubber).

(2) *Settled/built-up area*, includes all land under settlements, roads, railways, mines, etc.

(3) *Forest/woodland*, includes all forms of continuous natural dry land forests or timber plantations with 40% or greater crown closure. To increase the accuracy of carbon estimates, information was compiled on the area of land in the major forest types within each zone (e.g., tropical moist forest, tropical dry forest, temperate broad-leafed forest, and coniferous forest).

(4) *Interrupted woods*, includes vegetation with an arboreal component with a crown closure below 40%. To increase the accuracy of carbon estimates, information was compiled on the area of land in several subcategories (e.g., thorn woodland, degraded or scrub forest, tree savanna, and vegetation types with biomass significantly lower than that of closed forest.) This class is similar, but not identical to, the category of the same name used by Olson et al. (1983).

(5) *Grass/shrub complex*, includes grasslands, forb communities, and shrub land.

(6) *Barren/sparsely vegetated*, includes tundra, desert, semidesert scrub land, and all non-vegetated lands.

(7) *Wetlands*, includes all lands subject to inundation by either fresh or salt water and has been divided into two subcategories: nonforested and forested wetland.

(8) *Surface water*, comprises areas permanently under water (including land in reservoirs).

Although these eight land use classes are called land use categories, this classification system is really a hybrid of land use, land cover, and vegetation terminology. In view of the extent of human impact on the region, this approach is acceptable because the so-called "natural vegetation" of the region is currently restricted to land that has been consciously allocated to conservation, forestry, and rangeland or has a potential productivity so low that there is no economic incentive to modify its vegetation cover.

7.3 ORGANIZATION OF LAND USE DATA INTO SPREADSHEETS

This land use data base is based on information taken from subnational administrative units and aggregated upward to the ecological zone and national level. The fact that substantial boundary changes occurred at virtually every level of political organization during the century covered has necessitated compromise in the choice of the spatial unit to use for this data base. In the largest country, India, basic data were obtained at the third administrative level down to the district. The same approach was used in Bangladesh and Sri Lanka. In Malaysia data were collected at the level of the state (in Peninsular Malaysia and Sabah) and the division (in Sarawak), whereas data were gathered at the division and state level for Myanmar (Burma). In Indonesia and the Philippines data were obtained at the province level. The scarcity of pre-1920 data for Thailand dictated the use of the four traditional geographic regions as units of data collection, whereas in Vietnam, Kampuchea (Cambodia), and Laos (formally Indochina) data was initially obtained at the province level. For the two smallest countries, Singapore and Brunei, data were collected at the national level only.

The large size variation between administrative units and the differences in nomenclature for the various units in each country led to the designation of a neutral term for our basic spatial unit of analysis. Data from contiguous administrative units were combined, as necessary, to create 94 "ecological zones" in 13 countries. The administrative units combined into a single ecological zone contain similar vegetation types and topography and are subject to comparable climatic regimes.

The time series of land use data presented in this NDP consists of the total area in each land use category in each ecological zone for the years 1880, 1920, 1950, 1970, and 1980. In developing this series, the data consulted have not been limited to sources covering only these dates. Information from intervening years was used to extrapolate missing data values and for error checking.

To estimate the area in each land use category at successive points in time a multistep sequence of Lotus spreadsheets were used. Flint and Richards (1991) described this process in detail for data generated by the colonial government of British India and the nations that inherited and continued its system of land records (a reprint of Flint and Richards 1991 is provided in Appendix E). Variants of this procedure were developed to deal with differences in the structure of land use data in countries where the format of official statistics were different from that used by the Indian revenue bureaucracy. Common to all versions is the use of the sequential multistep procedure depicted in Figure 3.

Step 1 involved the collection and preliminary processing of data for a single administrative unit, where the name (i.e., province, state, or district) and size of the unit varied by country. The form of the spreadsheet used for this step depended on the number and kind of land use categories found in the official records. Because of the large number of these files and the wide variation in file layout and file size imposed by dissimilar official terminology, these spreadsheets are not distributed with this data base.

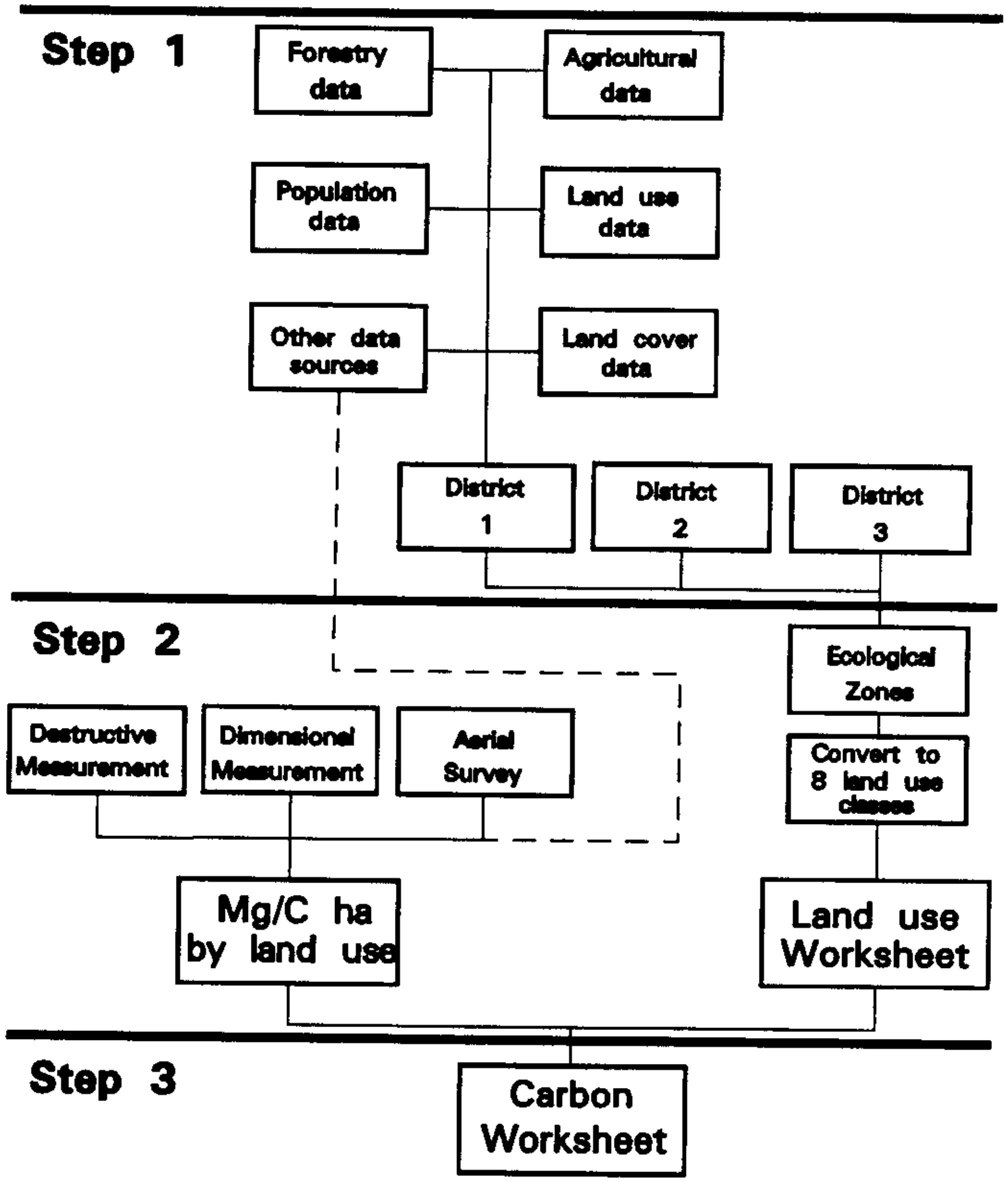

Figure 3. Flow chart summarizing the construction and aggregation of the spreadsheets used to calculate the land use and carbon data for a single ecological zone.

Spreadsheets generated during Step 1 contained rows designating with each land use category (according to the official terminology used by the particular country under study) and columns headed by the years of available data. The rows directly beneath the land use data were reserved for data on human and livestock populations for the years 1880—1980. Wherever possible, data drawn from statistical publications was entered directly into the Step 1 spreadsheets. The area in the target year is entered directly from the source for each land use category, except in categories dealing with temporarily cropped and fallow land. In cases where an annual series of areas (in each land use class) were available, the mean value for several years bracketing the target date were calculated instead of relying on a single value. Use of the mean value reduced the possibility of introducing distortion into the time series by depending on data from a single year. When data were missing from official statistical compilations, data were obtained from other sources. For a listing of the primary data sources, sorted alphabetical by country, see Section 12.2.

Once all the data were entered, algorithms contained within the spreadsheets converted areas into metric units and adjusted for small boundary changes. (Large boundary changes were evaluated on a case-by-case basis and may have entailed the simultaneous restructuring of two or three Step 1 spreadsheets.) The output of each Step 1 spreadsheet was a time series of data in which the entire area of an administrative unit was allocated to the appropriate official land use categories for each date in the analysis. When the administrative unit treated in Step 1 was congruent with a single ecological zone, this output was entered directly into a Step 2 spreadsheet. For regions composed of more than one administrative unit, the areas for all units in the ecological zone, in each category, and for each date, were summed to produced a composite spreadsheet, which became the input into Step 2.

The Step 2 spreadsheet translated land use data for a single ecological zone from the official categories (which may vary by country and date) of the Step 1 spreadsheets into the uniformly applicable carbon-based system of land use classes described in Section 7.1. This conversion process required informed evaluation of the reliability and quality of the official statistics that were used in Step 1. Critical to the successful completion of Step 2 was an understanding of the limitations of the original official data. To assist the user in this regard, a set of 75 Lotus 1-2-3™ spreadsheets are included with this NDP. These spreadsheets describe the assumptions used in each country and zone when converting the original data into the eight uniform land use classes. Appendix D provides a short description of each of these files. Due to the highly varied format and subjective nature of these spreadsheets, they have not been quality assured by CDIAC and are provided in the same form as they were received in from the primary investigators. As such, any questions regarding the contents of these Lotus 1-2-3™ files should be directed to the primary investigators.

When creating the land use spreadsheets for each ecological zone, it was necessary to keep in mind the caveat that official land use records, for a variety of political and economic reasons, may misrepresent actual vegetative cover. For example, in India the legal definition of forest is not congruent with any generally accepted botanical or ecological definition of the term, as all areas officially identified as "forest lands" under any section of the Indian Forest Act are included in official land use statistics under the category of forest, even if an area is not covered by trees (Vohra 1985; see also Lal 1989, Bansil 1984). Similar considerations hold for Bangladesh (Rashid 1977). For this reason the land area of each official category was allocated to the eight carbon-based land cover classes only after consulting a multi-disciplinary bibliography of corroborative material. [Primary data sources utilized in the creation of this data base are listed in Section 12.2. Secondary data sources are referenced in Hall et al. (1988), Flint and Richards (1989, 1993), and Richards and Flint (1993).]

The Step 2 spreadsheets structured the allocation procedure by assigning percentages of the total area in each official land use category to each of the eight carbon-based land use classes. Allocation percentages were entered into the Step 2 spreadsheets to simplify the review and revision of estimated values when new data became available. These percentages were multiplied by the summed official areas for the entire ecological zone to generate the estimated total area in each carbon-based land use category for each time period. Zone spreadsheets (i.e., the Step 2 spreadsheets distributed with this NDP) were then aggregated to obtain area totals for the each country.

All Step 2 spreadsheets are identical in structure and format across all zones, time periods, and countries, thus permitting the intercomparison of land use change over time. Printouts of the Step 2 spreadsheet for each country (aggregations of the zone spreadsheets in each country) are contained within Appendix A.

Table 2. **Total area in each land use class and population and livestock numbers for the 13 countries in South and Southeast Asia (i.e., India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Kampuchea, Vietnam, Malaysia, Brunei, Singapore, Indonesia, and the Philippines).**

Land use class	1880	1920	1950	1970	1980
NET CULTIVATED AREA	124,754	148,968	178,037	213,470	232,616
Temporary crops	117,229	137,432	161,867	192,023	205,243
Permanent crops	7,569	11,590	16,244	21,485	27,271
SETTLED/BUILT-UP	4,789	6,140	9,022	12,973	16,251
FOREST/WOODLAND	317,266	293,454	264,532	233,623	210,346
INTERRUPTED WOODS	109,594	102,273	99,680	99,578	95,596
WETLANDS	53,626	48,045	42,701	38,528	34,258
Forested wetlands	44,925	40,257	36,039	32,568	29,071
Nonforested wetlands	8,700	7,788	6,662	5,960	5,187
GRASS/SHRUB COMPLEXES	123,195	135,304	141,543	139,639	147,841
BARREN/SPARSELY VEGETATED	41,080	40,215	38,975	36,536	37,366
SURFACE WATER	17,121	17,027	16,936	17,107	17,151
TOTAL LAND AREA	791,425	791,425	791,425	791,425	791,425
TOTAL FOREST COVER	473,193	437,390	401,584	367,337	336,676
TOTAL POPULATION	310,487	396,121	584,040	900,641	1,128,373
TOTAL LIVESTOCK	223,498	273,279	359,782	470,452	511,519

Note: Areas are in 10^3 ha.
Note: Populations are in thousands.

7.4 CHANGES IN LAND USE

Changes in the area of land in each carbon-based land use class for the entire study region in 1880, 1920, 1950, 1970, and 1980 are summarized in Table 2. As mentioned previously, the most important change in land use is deforestation --the conversion of 107 $\times 10^6$ ha of land classified as forest in 1880 to categories bearing vegetation of lower biomass by 1980. Land thus transformed accounted for 13.5% of the total area of the study region. Reduction in wetlands, althought proportionately more severe than that in forests, amounted to only 2.4% of the total area of the study region. Most lands classified as wetlands, especially in Southeast Asia, originally contained forest rather than herbaceous vegetation (Whitmore 1984, Kumar 1986, Williams 1965, Champion 1936, Arhabirama et al. 1988, Davis 1964). Accordingly, the loss of area in the wetlands class can be seen as a special case of deforestation. Overall, over 123 $\times 10^6$ ha of land in the forested/woodland and forested wetland classes have been converted to one of the low-biomass categories (e.g., grassland) by 1980.

8. CARBON STOCK IN LIVE VEGETATION

The Step 2 spreadsheets contain historical land use data for 94 ecological zones and 13 countries in South and Southeast Asia. When compiling the land use data for each zone, the dominant type of forest and agricultural use was determined. Information was compiled from all available studies of patch, landscape, and ecosystem level biomass (e.g., Dagar 1987, Gupta and Mishra 1978, Brown and Lugo 1984) pertinent to the zone. Together with population density data for humans and livestock at each date, this information was used to estimate the amount of carbon per ha of live vegetation within each land use class at each point in time. By multiplying the average carbon values estimated for each land use type for each ecological zone by the amount of land within each land use class, the total amount of carbon stored within live vegetation in each zone and land use class was calculated for the Step 3 (carbon) spreadsheets (see Figure 3).

This section describes the processes used to derive the carbon estimates for each ecological zone within South and Southeast Asia. These data have been used to estimate the net change in the amount of carbon sequestered in vegetation over time, but they are particularly useful as input to geographically referenced global carbon models that link human activities to biological and geochemical processes. The following subsections describe the methods and equations used to determine the carbon pool for each land cover class (8), for each country (13), and each ecological zone (94).

8.1 ESTIMATING CHANGES IN CARBON

The equation used to calculate the total amount of carbon sequestered in live vegetation for each ecological zone for 1880, 1920, 1950, 1970, and 1980 is as follows:

$$TCS_i = \sum_{j=1}^{N} L_{ji} A_{ji} \qquad (1)$$

where the total carbon stock of vegetation at time i (TCS_i) is calculated based on L_{ji}, which is the total carbon (above- and below-ground) in vegetation type j at time i, A_{ji} is the area in vegetation of type j at time i, and N is the total number of land use categories within the zone. If $TCS_{i+1} < TCS_i$, then the difference between the two values represents the amount of carbon lost from live vegetation during the interval (i+1) - i. Otherwise, the difference represents the amount of carbon sequestered by vegetation during the given interval.

This equation utilized data from the land use spreadsheets to obtain estimates carbon content for each land use category. It permitted the estimation of the relative importance of changing land use on the amount of carbon sequestered in vegetation through the use of several equations. The output of these equations was used to produce the Step 3 spreadsheets which contain carbon estimates for each ecological zone and country. The equations standardized the methods used in obtaining estimates of the total carbon content of live vegetation per ha (CPH) in each land use category, for each date.

It is important to note that the equations used in the creation of the carbon estimates cannot provide a detailed time course of carbon release or partition carbon into different decay pools. However, their structure does permit an evaluation of the relative importance of biomass as a carbon reservoir in each land use category. Ultimately, the carbon estimates are dependent on biomass estimates that were derived using a variety of methods by several different investigators. These methods are discussed below.

The first of these methods estimated biomass based on dimensional measurements taken during forest inventories. Methods for estimating total above-ground biomass (TAGB) from information contained in stand or stock tables constructed during forest inventories have been applied to about 22×10^6 ha of tropical forests in the study area (Brown et al. 1991). Species-variable multipliers were applied to measurements of commercially useful standing timber to determine the total volume, or biomass, of the forests being inventoried. In the inventories utilized by Brown et al. (1991), TAGB for tropical moist forests (n=206) ranged from below 50 Mg C/ha to over 500 Mg C/ha, with a mean value of 225 Mg C/ha. In tropical dry forests TAGB ranged from 50 Mg C/ha to 200 Mg C/ha, with a mean of 82 Mg C/ha.

Based on data and methodology of Brown et al. (1991, 1992) and Gillespie et al. (1992), Iverson et al. (1993) developed a map of the maximum potential forest biomass (i.e., climax vegetation undisturbed by anthropogenic activities) for South and mainland Southeast Asia. This map was used to estimate the maximum potential above-ground biomass for all portions of the study region covered by the map (including peninsular Malaysia). For those locations not covered by the Iverson et al. biomass map, the methods described below were used (as appropriate) to derive an estimate of TAGB.

The second method for determining the biomass of live vegetation is based on the use of aerial surveys of forest cover (Tiwari and Singh 1987). Estimates of TAGB based on air photos and survey data have been made for forests in Himalayan Uttar Pradesh, India (Tiwari et al. 1985). Tiwari et al. (1985) mapped five crown cover classes for several forest types and then selected test sites that were representative of all combinations of forest type and crown cover. At each test site, the girths of trees greater than 10 cm was recorded for all species and ground-based measurements of the crown cover were taken. This information was used to construct an empirically based regression model that related TAGB, basal cover, and crown cover for several tree species. By applying these equations to composite air photos it is possible to estimate TAGB for a given tree stand.

The third method, direct biomass measurement, requires the destructive harvest of natural forest vegetation. Biomass estimates obtained by this method are available for India, Thailand, Kampuchea, Malaysia, and Indonesia. Estimates of TAGB range from less than 35

Mg C/ha for severely degraded tropical dry forests to almost 700 Mg C/ha in relatively undisturbed tropical rain forests. TAGB tends to increase with mean annual precipitation within the 0.5 to 2 m/yr range.

Biomass data obtained by this method must be treated with caution, because most of the destructive studies were conducted in or near major educational or forestry institutions (implying that the samples were taken from protected refuges) and the number of trees actually harvested in each study was relatively small. This is important because sample size has been shown to affect the accuracy of tropical forest biomass estimates (Negi et al. 1988). Nevertheless, the collective body of destructive-harvest research is an essential guide to the potential range of TAGB per ha as it provides information on the expansion factor that must be used to convert TAGB to an estimate of total below-ground and above-ground carbon for a given land cover class.

The fourth, or last method, is designed to be utilized in areas with nonwoody vegetation. In this method all above ground vegetation for a plot of land (usually less than 1 ha) is harvested, dried, and weighed to determine the TAGB for the given plant species or community. This technique, when used on bamboo stands, has found TAGB's of 41, 179, and 154 Mg C/ha for Myanmar bamboo in dry, moist, and wet locations, respectively, and TAGB of 272 Mg C/ha in a 15-year old plantation of *Dendrocalamus strictus* in Utter Pradesh, India (Seth et al. 1963). In studies conducted in Thailand, by Ogawa et al. (1961), a TAGB of 104 Mg C/ha was reported for a riverside thicket of *Arundo donax*, and Ruangpranit (1981) found a TAGB biomass of only 2.7 Mg C/ha for *Arundinaria pusilla*.

Most biomass measurements of nonwoody vegetation are for grasslands. In South and Southeast Asia, grass and shrub biomass has been found to vary seasonally, with peak values for above-ground biomass in the study area ranging from 0.1 in the dry season to 40 Mg C/ha in the wet. Peak total biomass for grass/shrub vegetation for South and Southeast Asia can reach 45 Mg C/ha, with the proportion allocated to below-ground biomass ranging from almost nil to 95%. Root system biomass in grassland is affected by the proportion of annual and perennial species; the amplitude of the seasonal fluctuation in rainfall and temperature; and the degree of disturbance from fire, grazing, or trampling (Yadava and Singh 1977, Melkania and Singh 1989).

Most published measurements of herbaceous wetland biomass are from India (i.e., Vyas et al. 1990). These data indicate that the peak above-ground biomass is 5 Mg C/ha or below in most herbaceous wetland vegetation, but values as high as 100 Mg C/ha have been reported. Like grasslands, herbaceous wetland communities may allocate considerable proportions of their total biomass to root systems (up to 50%).

The estimates of biomass per ha discussed in the preceding paragraphs may or may not accurately describe the status of the vegetation prior to 1880. Human activities, especially in the more densely populated areas of the study area, have depleted the standing stock of forests and woodlands. In extreme cases, these disturbances have caused the forests to be transformed into discontinuous forest, grass/shrub communities, or in severe cases, into barren or sparsely vegetated land. In most cases, however, the mean biomass within the forest has been reduced by overgrazing, the removal of firewood, and repeated fires.

8.2 MODELING OF CARBON CONTENT

The procedure for making time- and area-specific estimates of the mean above-ground and below-ground carbon per ha (CPH) for each ecological category is based on the following assumptions.

(1) There is a maximum limit to the biomass and carbon content per ha attainable by any vegetation type, where the variable M is the maximum carbon content per unit area for a sizeable stand of totally undisturbed vegetation growing under optimal environmental conditions. M, expressed in Mg of carbon per ha, includes both above- and below-ground carbon in live vegetation. High values of M are possible in closed forest communities in which the canopy species have the potential to achieve both great height and girth.

(2) At the scale of this analysis, mean forest carbon stock does not achieve or even approach M for any given vegetation class because of environmental factors that limit the development/retention of vegetation biomass.

Accordingly, the actual carbon stock of a given vegetation class is calculated as the product of its potential maximum carbon stock (M) and two fractional multipliers which quantify the estimated reduction of M by environmental limitations (E) and degradation (D). This equation is represented as follows:

$$CPH = M \times E \times D \qquad (2)$$

Within the tropics and subtropics, the amount of carbon sequestered in woody vegetation is positively correlated with precipitation and temperature. Accordingly, as prerequisites for estimating M for the closed forest class for a given ecological zone, the proportional representation of different climatic regions within each zone must be determined, and the potential climax vegetation by zone must be allocated to the major vegetation categories for which biomass information is available (e.g., tropical dry forest, tropical moist forest or coniferous forest).

8.2.1 Maximum Carbon Stock for each Land Use Category

In this data base, the M value for each major vegetation class was fixed at values comparable with the carbon stock of large stands of mature trees grown under optimal conditions. The same M values were applied to zones with comparable macroclimates, vegetation structures, and floristics. The highest M values, 350 to 375 Mg C/ha, were assigned only to locations where climate, soil, and topography are optimal for the development of either tropical dipterocarp forest or Himalayan coniferous forest over a large percentage of the total closed forest class in a given ecological zone. M values of 300 Mg C/ha are more typical for tropical rain forest and coniferous forest; and 300 Mg C/ha is frequently used for tropical moist forest where precipitation is more seasonal; 250 and 200 Mg C/ha was typically chosen for M in zones dominated by tropical mesic deciduous forest and tropical dry forest, respectively.

The M value for the interrupted wood class is estimated as 1/4 to 1/3 of the M value for closed forest in the same zone. The rationale for this decision is as follows. Forty per cent crown cover is used as the lower boundary of the Forest/woodland (closed forest) class, and the upper boundary of the Interrupted woods (discontinuous forest) class. Despite that 40% upper boundary, the average crown cover in the Interrupted woods category is considerably lower –about 10%. Forest volume and biomass are approximately proportional to crown closure, except in stands with relatively open canopies, where the expansion factor relating TAGB and CPH is greater (Brown et al. 1991). The limited data available indicate that forests in the 0 to 20% crown closure category typically have about 25%, and forests in the 20 to 40% crown closure category may have up to 50%, of the biomass of the same forest type in the 80 to 100% crown closure category (Tiwari and Singh 1987, Flint and Richards 1993). As a result, it is assumed that mean carbon content of vegetation in the interrupted woodland class is equivalent to 25 or 33% of the value for forest/woodland in the same zone. The higher value is used only in zones where climatic factors and population densities permit rapid regrowth of woody species after disturbance.

The M value for the wetlands class is a weighted average, by area, for both the woody and herbaceous vegetation within the wetlands. Published results indicate that wetland forest biomass is generally lower than that of tropical moist forest (Brown et al. 1991). Therefore, M for wetland forests is assumed to be 75% of the closed forest value used for the same zone, except where available data suggest another ratio. The maximum M for herbaceous wetlands is 80 Mg C/ha, which is near the top of the range of observed biomass estimates for the best-developed stand of tall emergent macrophytes.

The M value for the grass/shrub class represents the maximum biomass in those systems where significant annual fluctuations in the standing crop occur. Accumulation of carbon in live nonwoody vegetation is not as strongly associated with the amount and seasonality of precipitation as in the closed forest class; so a single M value of 15 Mg C/ha is applied to these zones, except where available data suggest another value. Reduced values of M are used for zones in which development of most of the grass/shrub vegetation is clearly constrained by low precipitation or temperatures.

Much of the land in the barren/sparsely vegetated class bears some plant cover. Even desert and alpine vegetation can achieve a peak biomass of several Mg C/ha when the below-ground component is included (Melkania and Tandon 1985). Accordingly, these systems are assigned an M value of 0 to 5 Mg C/ha based on the climatic factors (i.e., precipitation, mean temperature, and annual temperature range) that were used in determining E.

8.2.2 Environmental Limitation Multiplier

The environmental limitation multiplier (E) expresses the degree to which abiotic factors (e.g., soil types, hydrology, topography, and local climatic variations) constrain the maximum potential carbon content (M) in each category of vegetation. The value of E may be as high as 1 in cases where all factors are favorable to plant growth or as low as 0 where adverse environmental factors prevent the growth of vegetation.

One source utilized for scaling the E value is the extensive forestry literature relating forest yield to site quality. Site quality can be defined as the capability of the physical environment of a site to produce a crop of a given species. Site quality effectively integrates the limitations of vegetation growth imposed by local climatic, edaphic, and physiographic factors. Operationally, it is usually determined on the basis of one or more measurements of stand height (i.e., above-ground biomass).

The effects of both site quality and stand age on biomass can be quantified for each species by expressing all biomass values in a yield table as percentages of the biomass of a mature stand in the top-quality class. It is then possible to compare the percentages expressing the effect of site quality and stand age on biomass across species. Yield tables that predict the volume of fully stocked monospecific stands as a function of age for each site quality class, are available for a number of important Asian tree species. These tables reveal the range of volumes expected for commercial forests based on several environmental factors. Yield tables seldom provide estimates of biomass, but the few that do confirm the close correlation between forest biomass and forest volume. Using the methodology of Brown and Lugo (1984) and Brown et al. (1989, 1991, 1992), the potential biomass values associated with each site quality class can be extrapolated from the volume data in yield tables, and then scaled up from TAGB to total biomass (i.e., above- and below-ground biomass). The general method used to estimate TAGB is to first estimate the stem biomass [stem biomass = bole volume (from yield tables) × specific gravity of wood (for the given species)] and to then apply an expansion factor to convert stem biomass to total biomass. The expansion factor may be calculated from biomass partitioning data, available for some species for stands of known age, or the generalized factors developed by Brown et al. (1989, 1992) may be used.

Within the South Asian convention, quality I forests are of the highest quality and quality IV are the lowest. The following trends have been observed for both broad-leafed and coniferous species (Flint and Richards 1993). The biomass in quality II stands is 20 to 40% less than that of quality I stands. Quality III stands have 40 to 60% and quality IV stands 60 to 80% less biomass than quality I stands. (In Java the Roman numerals are used in the reverse order for teak forests; in Indonesia the finest locations are classified as site quality VI, and poorest and most noncommercial are site quality I.) Top-quality trees rarely cover more than a few percent of a sizeable forest tract, with the mean site quality of the best state-controlled forests seldom reaching quality II (Chakraborty 1972) and quality III being more typical (Sinha 1962, Dwivedi 1980).

The environmental limitation multiplier E represents the mean "site quality" of all forest/woodland or interrupted woodland within a given ecological zone. The maximum biomass M can only be attained by forests growing undisturbed for centuries under optimal conditions (i.e., E=1). Site-related limitations usually reduce the average forest biomass to 75% or less of the maximum value of M, even in forests dominated by commercially valuable species. Mean volume and biomass per ha for forests judged to be noncommercial tend to be lower than that of commercial forests. Accordingly, values for E are 0.75 or less for the forest/woodland and interrupted woodland categories in nearly all zones.

Wetlands include both woody and herbaceous vegetation. E is determined for the woody component using methods comparable to those described in the preceding paragraphs for the forest/woodland class. A separate estimate of E was made for nonwoody wetlands and an area-weighted average of the two values taken.

Generally, a single value of E is assigned to all land use classes dominated by nonwoody vegetation. E is estimated based on direct assessment of annual means and seasonal patterns of precipitation and temperature, along with variations in these factors generated by topographic relief (Melkania and Tandon 1988). Edaphic and hydrological factors known to affect biomass were also considered in the estimation of E for nonwoody vegetation.

For the 100 years covered in this data base, E is assumed to have remained constant for each land use class and zone. This assumption is made as no known major shifts in climate have been noted over this period and biotic conditions (e.g., soil chemistry) have also remained relatively constant.

8.2.3 Calculation of M × E

For all ecological zones covered by the biomass map of Iverson et al. (1993), the total above-ground biomass has already been calculated and was determined directly from the map. CPH is calculated as 50% of mean mapped TAGB for each zone, and an expansion factor, varying by forest type, is added to this value to account for the below-ground storage of carbon by vegetation.

For zones not included on the map, M × E has been estimated as follows. M was determined from the sources described in Sections 8.2.1 and 8.2.2. Extrapolations of E were then made from location-specific site quality information for several common gregarious tree species (Champion 1933, Dwivedi 1980). Site quality descriptions in older literature were used to assign E values for forests that no longer exist.

If published site quality data was unobtainable, as is often the case with mixed-species forests, other information is used to estimate E. For example, because site quality is strongly correlated with canopy height, it may be used as a proxy to assess the limitations placed by abiotic factors on the accumulation of carbon in vegetation. Alternatively, predictions of forest yield, with documented growth data, may be extrapolated from one zone to adjacent zones that have similar climate, topography, and soils. This comparison method was used with Peninsular Malaysia (as the control) to develop estimates of E for Sarawak, Sabah, Indonesia, and the Philippines.

8.2.4 Degradation Multiplier

In Eq. 2 the degradation multiplier (D) expresses the reduction of carbon content in vegetation in a given land use class resulting from the direct and indirect removal of biomass by human activities and livestock. It is assumed that D operates on existing vegetation (i.e., on the actual communities whose carbon content in an undisturbed state is M × E). D is expressed as a decimal fraction which, like E, can range in value from 0 to 1. D is equal to 1 only if the human population of a zone exerts so little impact on vegetation that its biomass per ha remains equal to that of virgin forest. The value of D decreases toward zero as human population increases.

To develop a method for estimating D, the processes by which human populations remove biomass and the linkage between population density, livestock density, and location and distance to market must be understood. Based on this understanding, a conceptual model can be developed that will predict the value of D as a function of human and livestock population density and other socioeconomic factors (e.g., timber production). Some general physical and economic constraints apply to all biomass removal processes. Per capita forest removal rates are high as long as supply is high, and decrease as the resource is depleted. Under conditions of scarcity, the real cost of an item will increase and people will change their pattern of resource use by resource substitution. Given this sequence of events, the mean per capita biomass removal should decrease as population density increases.

The removal of biomass will tend to be localized to forests/woodlands located near populated areas (or transportation networks), rather than being evenly distributed (Brown et al. 1993, Dawning et al. 1993). Because of this tendency, even sparse populations are likely to remove more biomass from accessible forests than these forests can replace. This biomass removal is not balanced by an increase in biomass in the inaccessible forests because the carbon stock of vegetation in these forests is already in a state of equilibrium. Therefore, even small human populations within an ecological zone can significantly reduce a zone's mean carbon stock.

The primary reasons for biomass removal in South and Southeast Asia involve the distinction between using the forest as a source of energy or materials for the maintenance of subsistence economies versus the removal of biomass to fulfill external demands (i.e., export activities). Within the category of subsistence biomass removal, a further subdivision is needed. The process of biomass removal required to maintain shifting agriculture (the burning of forests to clear a swidden plot) is distinctively different from those required by sedentary agriculture (the collection of firewood, poles, and fodder).

Case studies of biomass removal by Asian communities have been conducted for each of the three modes of agriculture production (Gadgil 1991). Based on this and other studies (see Flint and Richards 1993) ranges of D have been estimated for the forest/woodland category. D will vary based on the type of agriculture dominating in given region. For example, the degradation factor for subsistence sedentary agriculture ranges from 0.3 to 0.5, with subsistence shifting agriculture with > 10 years fallow period having D's of 0.2 to 0.3. In areas were forest products are exported, D ranges from 0.3 to 0.9.

8.2.5 Model of Forest Degradation

The conceptual model used in the calculation of D for Eq. 2 relates forest degradation to human population and other variables. In the simplest case,

(1) all biomass removals are driven by subsistence requirements of the local population (no biomass export),

(2) all biomass requirements are supplied by the resources available within the boundaries of a given ecological zones (no biomass import), and

(3) subsistence requirements for forest products are independent of population density (constant per capita demand),

Under these circumstances, an inverse relationship between the density of a zone's population and the live biomass of its forests is expected and can be expressed as follows:

$$D = 1 / (1 + P) \qquad (3)$$

where P represents the human population density per ha in a zone. Eq. 3 causes the value of D to vary between one, at zero population density, and zero, at infinite population density.

This form of model omits the influence of socioeconomic variables that can individually or collectively alter the nature of the relationship between D and P by modifying the assumptions stated above. It does not explain residual variations caused by any factor that may cause the subsistence requirement for forest biomass to become dependent on population density or by any factor that promotes the export (or import) of biomass across zone boundaries.

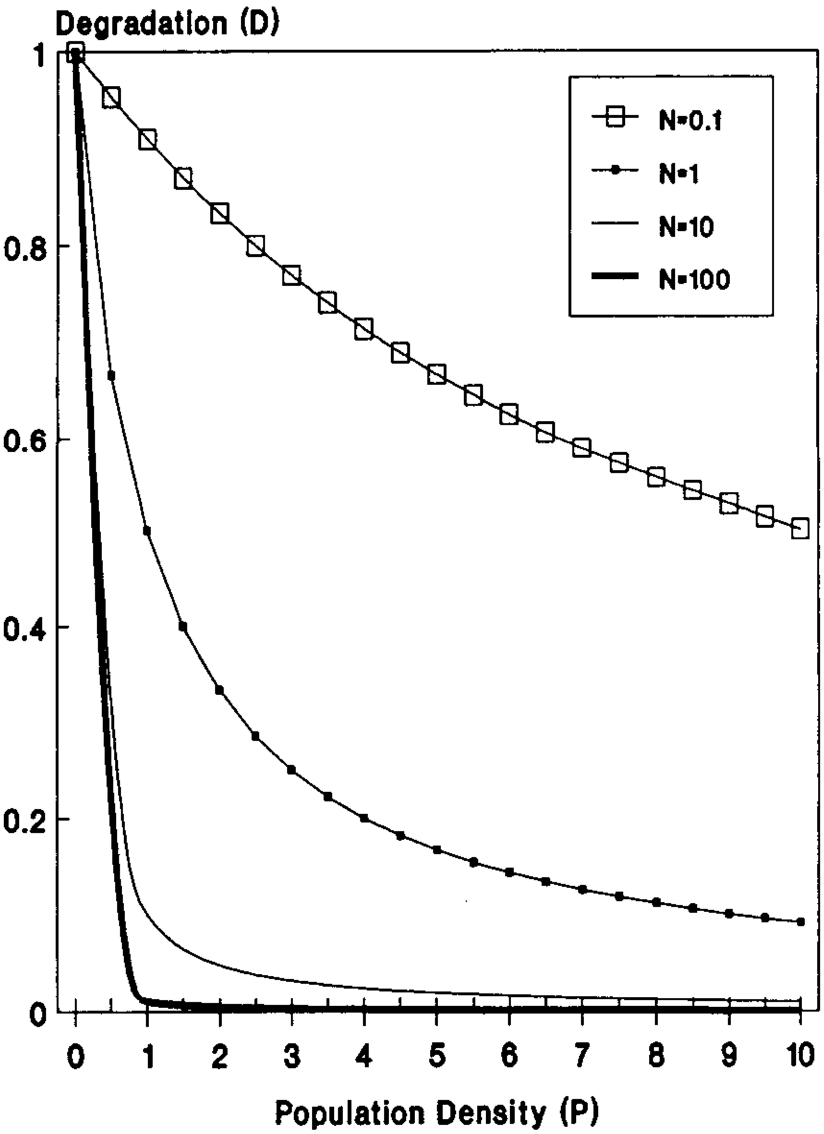

Figure 4. Estimated degradation values as determined by applying Eq. 4 for four N values.

Effects of these factors were modeled by constructing a product (N) of the following three factors, S, F, and A and rewriting Eq. 3 as follows:

$$D = 1 / [1 + (N \times P)] \tag{4}$$

where N is the product of S, the degree to which the agricultural system in a zone is dominated by shifting cultivation versus other components of a zone's agricultural sector; F, the degree to which a zone is a net exporter or importer of forest products; and A, the degree to which a zone is a net exporter or importer of agricultural products. Figure 4 shows the variations in D that occur with four different N values. Note that when N=1, Eq. 4 reduces to Eq. 3.

The value of S can vary from a minimum value of 1 (where shifting cultivation is absent) to a maximum of 10 (where shifting cultivation is dominant). The value of S can be estimated from the relative proportions of net sown area in a zone occupied by swidden (shifting cultivation) versus sedentary cropland. The following criteria were used to assign values of S to each zone for each year.

Percentage of crop area, or total production, in swidden cropland	Estimated value of S
0	1.0
1 - 10	1.0-1.5
11 - 20	1.5-2.0
21 - 30	2.1-3.0
31 - 40	3.1-4.0
41 - 50	4.1-5.0
51 - 60	5.1-6.0
61 - 70	6.1-7.0
71 - 80	7.1-8.0
81 - 90	8.1-9.0
91 -100	9.1-10

If information on crop area and production is unavailable for a zone at a given date, the value of S may also be estimated from the percentage of the total agricultural population of a zone that practices shifting cultivation, as determined from censuses or descriptive material. The value of S may also be based on estimates for other zones or other dates with comparable agricultural systems. Because of the importance of S, this factor has been weighted by giving it a range from 1 to 10 (unlike F and A, below) so that it provides ~50% of the calculated N value.

The value of F may range from a minimum of zero to a maximum of five. The value is set at 1 if the forestry sector output within a zone is equivalent to its subsistence demand, with no significant cross border movement of biomass. The maximum value of 5 is assigned to zones where most of the forestry sector output is exported. For zones in which forest sector production is equal to or greater than the internal demand, the value of F can be approximated as follows:

Exports as a percentage of total forestry production	Estimated value of F
0	1.0
1 - 25	1.1 - 2.0
26 - 50	2.1 - 3.0
51 - 75	3.1 - 4.0
> 75	4.1 - 5.0

F may also take on fractional values between one and zero. This occurs in zones that are net importers of forest materials. The fractional values are determined based on the equation, $F = 1 - I$, where I is the percent of a zones forest biomass consumption that is imported.

Like F, the value of A may range from zero to five. A value of 1 is used if all crop production is locally used for subsistence, with minimal exports or imports. In zones that produce significant quantities of export crops, the value of A increases as the relative importance of the export sector increases up to a limit of 5, according to the same criteria as used for factor F. The dedication of a zone's entire agricultural output to export (i.e., A=5) would leave the zone unable to feed even a small population; consequently, A seldom exceeds 2. In cases where imports exceed local production, fractional values are used. The fractional values are determined based on the equation, $A = 1 - I$, where I is the percentage of a zone's total food demand that is imported.

8.2.6 Application of the Model (Woody Vegetation)

For each of the 94 ecological zones at each date, the value of each of the three factors (S, F, and A) were estimated and N calculated. The calculated N, in combination with P (population density), was then used with Eq. 4 to calculate the value of D for woody vegetation. This value of D was then combined in Eq. 2 with the product of $M \times E$ (previously estimated according to the procedures summarized in Section 8.2.3), in order to calculate the estimated carbon stock per ha for each category of woody vegetation in each zone at each date. Except in cases where unusually detailed information was available, the same values of D were applied to the forest/woodland, interrupted woods, and to the woody subcategory of the wetland vegetation class in each zone.

The estimated total carbon stock for woody vegetation was cross-checked to ensure that the values were reasonably consistent with national level carbon-stock extrapolations from FAO forest volume statistics. The estimated carbon stocks for all zones within a nation were also cross-checked against available comparable data on forest productivity at the national level. (These data are generally available only for 1980.) In cases where the values of D differed considerably from published information, we tested the effects of alternative estimates of S, F, and A on the zonal carbon stock and adjusted our estimated N to fit the available empirical data. Because of the subjective nature of S, F, and A, these factor values have not been provided in a digital format; however, they are listed in Appendix B.

8.2.7 Application of the Model (Nonwoody Vegetation)

Equation 3 (Section 8.2.5) was used to obtain the degradation values for nonwoody vegetation. (Equation 4 was not used due to the absence of sufficient information to justify the inclusion of the S, F, and A factors). In its original form, as applied to forest vegetation, Eq. 3 defined the value of P as the density of the human population (in persons per ha). However, use of Eq. 3 to calculate the value of D for nonwoody vegetation required an alternative definition of P because several discrete processes actually contribute to the degradation of rangeland. Among them are the removal of above-ground biomass by grazing; damage to plants and the soil by trampling; and the deliberate burning of grasslands by pastoralist seeking to improve the forage quality. The total impact of these activities are directly related to livestock and human population densities within a zone (Dabadghao and Shankarnarayan 1973).

Thus, in South Asia the value of P, and by extension D, applied to the grass/shrub complexes, barren/sparse vegetation, and the herbaceous portion of the wetland class was estimated as a function of livestock density, since in South Asia livestock outnumber people by over 2 to 1 in lands available for grazing (i.e., land available for grazing = closed forest + discontinuous forest + grass/shrubs + wetlands + barren/sparse). In Southeast Asia, P was calculated as the sum of the human and livestock densities in each zone. Cultivated areas were omitted from the livestock density calculation because this land is unavailable for grazing due to the multicrop rotations used in most of Asia. Thus, the only difference in the application of Eq. 3 between South and Southeast Asia is that the density of livestock (L) was substituted for P in <u>South Asia</u> and in <u>Southeast Asia</u> livestock and population densities were combined.

Having already estimated the value of M $\times$ E according to the procedures summarized in Section 8.2.3, Eq. 2 was used to calculate the estimated carbon stock per ha for the nonwoody vegetation for all zones, at all dates, and within each nation. To allow future case-by-case modification of the estimated Mg of carbon per ha for each land cover class; the M, E, D, and N values used for each ecological zone have been provided in digital form with this NDP.

8.2.8 Estimation of the Carbon in Built-up and Cultivated Areas

Human settlements in the study area are seldom completely devoid of vegetation, but few studies have been published concerning the biomass of vegetation in settled areas. Therefore, 4 Mg C/ha has been selected as the maximum M value for carbon in settled and built-up areas. Such a value is intended as an average for a heterogeneous land use mosaic. Environmental multipliers for the settled/built-up land use class are directly related to rainfall. As for other categories, degradation multipliers were assigned on the basis of population density on the assumption that the mean biomass of vegetaion in settled areas will decline with an increase in the population density (as described for nonwooded vegetation).

The carbon content of live vegetation in monospecific crop stands cycles annually from a very low value to a maximum value just prior to harvesting. Standardized estimates of crop carbon content were calculated on the basis of the peak biomass of the crops. The peak biomass of each crop varies based on the crop species (Table 3). The biomass values shown in Table 3 were obtained under optimal environmental conditions. In South and Southeast Asia, biomass rarely reaches even 50% of this theoretical maximum. Therefore, to estimate the mean carbon content of temporary cropland in a zone, it was necessary to identify the major crops within a zone, estimate the proportional area planted in each, and determine the E value for the zone. This information was used to calculate a weighted mean crop biomass for each zone.

Table 3. **Total biomass and yield predictions by the United Nations Food and Agricultural Organization for selected tropical and subtropical crops growing in a field under optimal environmental conditions.**

Crop type	Total biomass (Mg/ha)	Crop yield (Mg/ha)	Yield as % of biomass
Cereals			
Rice	17.6	5.3	30
Spring wheat	14.3	5.7	40
Winter wheat	12.3	4.9	40
Maize	21.0	7.3	35
Sorghum	20.6	5.1	25
Pearl millet	15.3	3.8	25
Legumes			
Soybean	11.5	3.4	30
Phaseolus beans	11.5	3.4	30
Root crops			
White potato	15.7	9.4	60
Sweet potato	18.6	10.2	55
Cassava	24.8	13.6	55
Fiber crops			
Cotton	15.9	1.1	7

(Source: FAO, 1980)

Permanent crop biomass is higher than that of temporary crops. The area planted in permanent crops with a potentially high biomass (e.g., rubber) expanded dramatically during the twentieth century in many of the countries in the region (Aiken et al. 1982, Donner 1987). Biomass estimates for perennial crops in these zones were based on date-specific information, as the biomass for a given stand increases with age, on the relative proportions of different species, and the relative areas planted with mature and immature trees. Combining such information with published biomass measurements on immature and mature stands of important perennial crops (Flint and Richards 1993), mean values of CPH in Mg/ha were estimated for the permanent crop areas of each zone at each date.

8.3 ORGANIZATION OF CARBON DATA INTO SPREADSHEETS

In Section 8.2 the methods used to obtain estimates of the mean above-ground and below-ground CPH for each of the seven land use categories have been described (the carbon in live vegetation in the eighth class, surface water, was assumed to be 0.1 Mg/ha). For each zone, the Step 3 spreadsheet of the bookkeeping model generated estimates of the total carbon content of live vegetation in each category at each date, by multiplying the area of land in the category by the appropriate date-specific CPH value. Total carbon sequestered in live vegetation of a zone at each date was then calculated by summing the carbon contents of all categories, as in Eq. 1. Printouts of the national total spreadsheets produced by aggregating the Step 3 zone spreadsheets are contained within Appendix C.

Table 4. **Mean carbon content in Mg C/ha (above and below ground) for each land use class, at each of five dates, for all eight land use categories.**

Land use class	1880	1920	1950	1970	1980
NET CULTIVATED AREA	5.29	6.05	7.59	8.57	8.62
Temporary crops	4.35	4.54	4.61	4.83	5.14
Permanent crops	19.80	23.99	37.26	41.97	34.91
SETTLED/BUILT-UP	3.43	3.47	3.38	3.31	3.16
FOREST/WOODLAND	151.15	137.79	121.40	104.27	92.84
INTERRUPTED WOODS	34.18	31.06	27.35	24.08	21.36
WETLANDS	113.11	104.10	92.97	79.65	70.98
Forested wetlands	131.29	120.93	107.53	92.22	81.88
Nonforested wetlands	19.27	17.13	14.19	10.97	9.90
GRASS/SHRUB COMPLEXES	7.62	7.32	6.64	6.05	5.81
BARREN/SPARSELY VEGETATED	0.92	0.88	0.78	0.66	0.62
SURFACE WATER	0.10	0.10	0.10	0.10	0.10

To give a notion of the amount of carbon that is sequestered in live vegetation in each land use class, Table 4 was developed. Table 4 shows the mean carbon content per ha for each land use class for the entire 13-country study region. The downward trend in carbon content in all categories of natural vegetation is attributable to increased environmental degradation from the rapid increase in human and livestock population that has occurred since the 1900s.

8.4 CHANGES IN CARBON

The estimated total carbon content of live vegetation in South and Southeast Asia has dropped progressively from 59 $\times 10^9$ Mg in 1880 to 27 $\times 10^9$ Mg in 1980 (Table 5) -almost half of the initial 1880 value. The amount of carbon in live vegetation decreased by 8.9 $\times 10^9$ Mg for the 1880–1920 time period and by 8.6 $\times 10^9$ in the 1950–1980 time period. Throughout the 100 year study period, the carbon stock of the closed forest vegetation class was greater than the carbon content in all other categories combined, although its share of the total (for each time period) declined progressively from 81% in 1880 to 73% in 1980. This decline is due to a reduction in forest area, from 41% to 27% of the region, and the reduction in the mean carbon stock of the remaining forests (from degradation) from 151 to 93 Mg/ha (Flint and Richards 1993).

Table 5. **Total carbon content of live vegetation estimated by class (values are $\times 10^3$ Mg) for each year for the 13 countries in South and Southeast Asia.**

Land use class	1880	1920	1950	1970	1980
NET CULTIVATED AREA	659,435	901,698	1,351,325	1,828,431	2,006,009
Temporary crops	509,604	623,596	746,159	926,788	1,054,088
Permanent crops	149,830	278,103	605,165	901,643	951,926
SETTLED/BUILT-UP	16,444	21,316	30,537	42,948	51,393
FOREST/WOODLAND	47,956,365	40,434,080	32,113,177	24,360,071	19,529,263
INTERRUPTED WOODS	3,745,869	3,176,301	2,726,151	2,397,609	2,042,347
WETLANDS	6,065,796	5,001,497	3,969,971	3,068,683	2,431,672
Forested wetlands	5,898,142	4,868,098	3,875,422	3,003,297	2,380,296
Nonforested wetlands	167,655	133,398	94,549	65,386	51,373
GRASS/SHRUB COMPLEXES	939,334	989,871	940,519	844,446	859,292
BARREN/SPARSELY VEGETATED	37,637	35,485	30,549	23,950	23,000
SURFACE WATER	1,712	1,703	1,694	1,711	1,715
TOTAL C	59,422,587	50,561,951	41,163,921	32,567,842	26,944,694
TOTAL C IN FOREST COVER	57,600,375	48,478,478	38,714,749	29,760,976	23,951,908

In conclusion, the carbon sequestered in forest/woodland vegetation has been reduced by 28.4×10^9 Mg between 1880 and 1980, whereas the amount of carbon lost from interrupted woods, wetlands, and grass/shrub lands was 1.7, 3.6, and 0.1×10^9 Mg, respectively. The reduction in carbon stored in live vegetation was caused by two factors: the transfer of land from high biomass to low biomass classes (e.g., from the expansion of agriculture) and (2) a reduction in the mean biomass of each class (i.e., from degradation).

9. LIMITATIONS AND RESTRICTIONS OF THE DATA

The following paragraphs recap the limitations and caveats that should be considered when this data base is utilized. Failure to consider these limitations could result in erroneous interpretations of the data.

(1) The land use data contained within this NDP are base primarily on historical land use and census records collected by multinational organizations and local, regional, and national governments within the study area. The accuracy of these data vary by decade and location because of variations in the classification systems and methods used by each government to collect the data. Thus, the land use information contained within this data base may contain errors brought forward from the original data sources.

(2) To reduce the impacts of errors in the source data, mean values for each land use class were calculated (when possible) based on the available data for years bracketing the year of interest. For example, if the year of interest is 1920 and data were available for 1916 and 1922, the data value for 1920 in the data base would represent the weighted mean of these two years. Because of this averaging process the land use values contained herein should be seen as 10 year averages centered on the given date.

(3) The carbon data in this data base were developed utilizing several equations. It is important to recognize that these carbon data do not provide a detailed time course of carbon release or partition carbon into different decay pools, instead these equations were designed to allow an evaluation of the relative importance of each land use category as a carbon reservoir to be made.

(4) Ultimately, the accuracy of the carbon estimates are dependent not only on the assumptions explicitly stated in the description of the model, but also on the assumption that the available estimates of biomass and carbon content of South and Southeast Asian vegetation made by different investigators can be evaluated in a comparative framework, despite the variety of methods used to develop these estimates.

(5) The carbon estimates for 1880 for the closed forest class are relatively low when compared with the maximum potential carbon content for climax forests (i.e., M $\times$ E). For example, the average carbon value in 1880 was 99 Mg/ha for South Asia, 116 Mg/ha for Mainland Southeast Asia, and 178 Mg/ha for Insular Southeast Asia. Estimated carbon values in the wetland class for the same date and region are somewhat lower, and estimated values for the discontinuous forest class, lower still. The carbon estimates reflect the long-term removal of forest biomass before 1880 by nonindustrialized populations with modest per capita demands, and do not reflect the amount of carbon that would have been sequestered in live vegetation in an undisturbed (i.e., climax) landscape.

(6) Critical to the successful conversion of the historical land use and land cover data into the eight land use classes utilized in this NDP is an understanding of the inherent limitations of the source data. To assist the user in understanding these limitations, a set of 75 Lotus 1-2-3™ spreadsheets have been provided with this NDP. These spreadsheets describe how the original data sources for each country were translated. Appendix D provides a short description of each of these files. Because of the highly varied format of these spreadsheets, they have not been quality assured by CDIAC and are included in this NDP in the same form as they were received from the primary investigators.

10. DATA CHECKS PERFORMED BY CDIAC

An important part of the data packaging process at the CDIAC is the quality assurance (QA) of the data before its distribution. The QA process is an important component in the value-added concept of assuring accurate, usable information for researchers. The complete QA of a data set can be a time consuming process, since data received by CDIAC are rarely in condition for immediate distribution, regardless of source. The following summarizes the QA checks performed on the various data groups presented in this document.

1. The land use data in the Step 2 spreadsheets, for each of the 94 ecological zones, were compared with the Step 1 spreadsheets to ensure that no errors occurred during the aggregation process.

2. The carbon data, for each of the 94 ecological zones, were recalculated (based on the M, E, and D values) and compared with the carbon data contained within the Step 3 spreadsheets.

3. The maximum, minimum, and mean values were generated for all land use and carbon variables and checked for reasonableness.

4. The total land area in each country, along with the human population figures for 1970 and 1980, were compared against a data source with land and population data for 1974—75 (Berry et al. 1978). If significant differences were found between the values in this NDP and the Berry data, values were recalculated and corrected if necessary.

5. The data values for each data variable were graphed to check for outliers and identify discrepancies. Any questionable data were recalculated and corrected as necessary.

11. HOW TO OBTAIN THE PACKAGE

This document describes the historical land use and carbon data collected by Dr. John Richards and Dr. Elizabeth Flint for the U.S. Department of Energy's Global Climate Change Research Program. This data may be used with a vector or raster geographic information system (GIS) or non-GIS data base systems. The computerized data are available on 9-track magnetic tapes, Exabyte 8 mm tapes, QIC ¼" tape cartridges, IBM DOS-compatible floppy diskettes (3.5" or 5.25" diskettes), and through an anonymous File Transfer Protocol (FTP) service from CDIAC. Requests for magnetic media should include any specific instructions required by the user and/or the user's local computer system. Requests for this data package should be addressed to:

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, Tennessee 37831-6335
U.S.A.

Telephone: (615) 574-0390
FAX: (615) 574-2232

BITNET: CDP@ORNLSTC
INTERNET: CDP@STC10.CTD.ORNL.GOV
OMNET: CDIAC

The data files may be acquired via INTERNET from CDIAC's anonymous FTP service as follows:

- FTP to CDIAC.ESD.ORNL.GOV (128.219.24.36).
- Enter "ftp" as the user id.
- Enter your electronic mail address as the password (e.g., BIRDT@ORNL.GOV).
- Change to the directory "cd pub/ndp046".
- Set ftp to get ASCII files by using the FTP "ascii" command.
- Acquire the ASCII data files by using the FTP "mget *.asc" command.
- Acquire the ASCII FORTRAN files by using the FTP "mget *.for" command.
- Acquire the ASCII SAS™ files by using the FTP "mget *.sas" command.
- Set ftp to get binary files by using the FTP "binary" command.
- Acquire the binary Lotus 1-2-3™ data files by using the FTP "mget *.wk1" command.
- Acquire the binary ARC/INFO™ export files by using the FTP "mget *.e00" command.
- Exit the system by using the FTP "quit" command.
- Contact CDIAC by phone, FAX, or electronic mail to order a hard copy of this documentation.

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PART 2
INFORMATION ABOUT THE COMPUTERIZED DATA FILES

13. CONTENTS OF THE COMPUTERIZED DATA FILES

The following list describes the files distributed on the magnetic media distributed by CDIAC along with this documentation. These files are also available through CDIAC's anonymous file transfer protocol service via the INTERNET.

File number and description	Logical records	Records per file	Block size	Record length
1. General descriptive information file	1723	1723	8000	80
2. Land use, Mg carbon per ha, population, and total carbon data for the 94 zones and 13 countries in South and Southeast Asia (FLAT ASCII FILE)	105	4725	6000	60
3. SAS™ code to read and print File 2	95	95	8000	80
4. FORTRAN code to read and print File 2	51	51	8000	80
5. Land use accuracy flags (for file 2) based on the type and quality of source data (FLAT ASCII FILE)	94	470	6000	60
6. SAS™ code to read and print File 5	15	15	8000	80
7. FORTRAN code to read and print File 5	38	38	8000	80

File number and description		Logical records	Records per file	Block size	Record length
8.	Factors (M, E, D, and N) used to calculated the Mg C/ha for each land use type, for each time period, and each zone (FLAT ASCII FILE)	94	1128	8000	80
9.	SAS™ code to read and print File 8	29	29	8000	80
10.	FORTRAN code to read and print File 8	50	50	8000	80
11.	Base map with the Longitude, Latitude coordinates of the 13 countries in South and Southeast Asia (FLAT ASCII FILE)	280[V]	21214	3000	30
12.	Base map with the Longitude, Latitude coordinates of the 94 ecological zones in South and Southeast Asia (FLAT ASCII FILE)	348[V]	34619	3000	30
13.	SAS™ code to read and print File 11 and 12	15	15	8000	80
14.	FORTRAN code to read and print File 11 and 12	47	47	8000	80
15.	Land use, Mg carbon per ha, and total carbon data for Bangladesh (Lotus 1-2-3™ WK1 FILE)	x[N]	537	1000	100

File number and description		Logical records	Records per file	Block size	Record length
16.	Land use, Mg carbon per ha, and total carbon data for Brunei (Lotus 1-2-3™ WK1 FILE)	x^N	96	1000	100
17.	Land use, Mg carbon per ha, and total carbon data for India (Lotus 1-2-3™ WK1 FILE)	x^N	2335	1000	100
18.	Land use, Mg carbon per ha, and total carbon data for Indonesia (Lotus 1-2-3™ WK1 FILE)	x^N	1929	1000	100
19.	Land use, Mg carbon per ha, and total carbon data for Kampuchea (Cambodia) (Lotus 1-2-3™ WK1 FILE)	x^N	434	1000	100
20.	Land use, Mg carbon per ha, and total carbon data for Laos (Lotus 1-2-3™ WK1 FILE)	x^N	520	1000	100
21.	Land use, Mg carbon per ha, and total carbon data for Malaysia (Lotus 1-2-3™ WK1 FILE)	x^N	672	1000	100
22.	Land use, Mg carbon per ha, and total carbon data for Myanmar (Burma) (Lotus 1-2-3™ WK1 FILE)	x^N	603	1000	100

File number and description	Logical records	Records per file	Block size	Record length
23. Land use, Mg carbon per ha, and total carbon data for the Philippines (Lotus 1-2-3™ WK1 FILE)	x^N	438	1000	100
24. Land use, Mg carbon per ha, and total carbon data for Singapore (Lotus 1-2-3™ WK1 FILE)	x^N	96	1000	100
25. Land use, Mg carbon per ha, and total carbon data for Sri Lanka (Lotus 1-2-3™ WK1 FILE)	x^N	272	1000	100
26. Land use, Mg carbon per ha, and total carbon data for Thailand (Lotus 1-2-3™ WK1 FILE)	x^N	438	1000	100
27. Land use, Mg carbon per ha, and total carbon data for Vietnam (Lotus 1-2-3™ WK1 FILE)	x^N	741	1000	100
28. Land use accuracy flags based on the type and quality of source data for all zones within South and Southeast Asia (Lotus 1-2-3™ WK1 FILE)	x^N	512	1000	100

File number and description		Logical records	Records per file	Block size	Record length
29.	Factors (M, E, D, and N) used to calculated the Mg C/ha for each land use type, for each time period, and each zone within South and Southeast Asia (Lotus 1-2-3™ WK1 FILE)	x^N	2098	1000	100
30.	Land use data for the 94 ecological zones in South and Southeast Asia (ARC/INFO™ EXPORT FILE)	x^N	18116	8000	80
31.	Mg C/ha data for the 94 ecological zones in South and Southeast Asia (ARC/INFO™ EXPORT FILE)	x^N	16242	8000	80
32.	Carbon data for the 94 ecological zones in South and Southeast Asia (ARC/INFO™ EXPORT FILE)	x^N	15535	8000	80
	------------ Documentation Files Follow ------------				
33.	Chittagong Hill Tracts (zone 101) summary file (Lotus 1-2-3™ WK1 FILE)	x^N	341	1000	100
34.	Eastern Coast (zone 102) summary file (Lotus 1-2-3™ WK1 FILE)	x^N	978	1000	100
35.	Meghna Districts (zone 103) summary file (Lotus 1-2-3™ WK1 FILE)	x^N	1674	1000	100

File number and description		Logical records	Records per file	Block size	Record length
36.	Sundarbans (zone 104) summary file (Lotus 1-2-3™ WK1 FILE)	x^N	997	1000	100
37.	Western Districts (zone 105) summary file (Lotus 1-2-3™ WK1 FILE)	x^N	3017	1000	100
38.	Chittagong Hill Tracts (zone 101) land use documentation file (Lotus 1-2-3™ WK1 FILE)	x^N	892	1000	100
39.	Eastern Coast (zone 102) land use documentation file (Lotus 1-2-3™ WK1 FILE)	x^N	809	1000	100
40.	Meghna Districts (zone 103) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	839	1000	100
41.	Sundarbans (zone 104) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	841	1000	100
42.	Western Districts (zone 105) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	789	1000	100

File number and description		Logical records	Records per file	Block size	Record length
43.	Brunei (zone 200) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	327	1000	100
44.	India land use (total all zones) documentation file (Lotus 1-2-3™ WK1 File)	x^N	65	1000	100
45.	Andaman/Nicobar Islands (zone 301) summary file (Lotus 1-2-3™ WK1 File)	x^N	213	1000	100
46.	Andhra Pradesh (zone 302) summary file (Lotus 1-2-3™ WK1 File)	x^N	217	1000	100
47.	Arunachal Pradesh (zone 303) summary file (Lotus 1-2-3™ WK1 File)	x^N	182	1000	100
48.	Assam (zone 304) summary file (Lotus 1-2-3™ WK1 File)	x^N	178	1000	100
49.	Bihar (zone 305) summary file (Lotus 1-2-3™ WK1 File)	x^N	174	1000	100
50.	Delhi (zone 306) summary file (Lotus 1-2-3™ WK1 File)	x^N	197	1000	100

File number and description		Logical records	Records per file	Block size	Record length
51.	Part 1 of the Gujarat/ Dadra/Nagar Haveli (zone 307) summary file (Lotus 1-2-3™ WK1 File)	x^N	189	1000	100
52.	Part 2 of the Gujarat/ Dadra/Nagar Haveli (zone 307) summary file (Lotus 1-2-3™ WK1 File)	x^N	209	1000	100
53.	Gujarat/Dadra/Nagar H. (zone 307) land use totals from part 1 and 2 summary files (Lotus 1-2-3™ WK1 File)	x^N	89	1000	100
54.	Part 1 of the Haryana/ Chandigarh (zone 308) summary file (Lotus 1-2-3™ WK1 File)	x^N	195	1000	100
55.	Part 2 of the Haryana/ Chandigarh (zone 308) summary file (Lotus 1-2-3™ WK1 File)	x^N	196	1000	100
56.	Haryana/Chandigarh (zone 308) land use totals from part 1 and 2 summary files (Lotus 1-2-3™ WK1 File)	x^N	91	1000	100
57.	Himachal Pradesh (zone 309) summary file (Lotus 1-2-3™ WK1 File)	x^N	180	1000	100

File number and description		Logical records	Records per file	Block size	Record length
58.	Jammu/Kashmir (zone 310) summary file (Lotus 1-2-3™ WK1 File)	x^N	236	1000	100
59.	Karnataka (zone 311) summary file (Lotus 1-2-3™ WK1 File)	x^N	237	1000	100
60.	Kerala (zone 312) summary file (Lotus 1-2-3™ WK1 File)	x^N	204	1000	100
61.	Lakshadweep Islands (zone 313) summary file (Lotus 1-2-3™ WK1 File)	x^N	178	1000	100
62.	Madhya Pradesh (zone 314) summary file (Lotus 1-2-3™ WK1 File)	x^N	207	1000	100
63.	Part 1 of the Maharashtra/ Goa/Daman/Diu (zone 315) summary file (Lotus 1-2-3™ WK1 File)	x^N	192	1000	100
64.	Part 2 of the Maharashtra/ Goa/Daman/Diu (zone 315) summary file (Lotus 1-2-3™ WK1 File)	x^N	211	1000	100
65.	Maharashtra/Goa/Daman/Diu (zone 315) land use totals from part 1 and 2 summary files (Lotus 1-2-3™ WK1 File)	x^N	89	1000	100

File number and description		Logical records	Records per file	Block size	Record length
66.	Manipur (zone 316) summary file (Lotus 1-2-3™ WK1 File)	x^N	175	1000	100
67.	Meghalaya (zone 317) summary file (Lotus 1-2-3™ WK1 File)	x^N	179	1000	100
68.	Mizoram (zone 318) summary file (Lotus 1-2-3™ WK1 File)	x^N	178	1000	100
69.	Nagaland (zone 319) summary file (Lotus 1-2-3™ WK1 File)	x^N	175	1000	100
70.	Orissa (zone 320) summary file (Lotus 1-2-3™ WK1 File)	x^N	231	1000	100
71.	Punjab (zone 321) summary file (Lotus 1-2-3™ WK1 File)	x^N	230	1000	100
72.	Rajasthan (zone 322) summary file (Lotus 1-2-3™ WK1 File)	x^N	220	1000	100
73.	Sikkim (zone 323) summary file (Lotus 1-2-3™ WK1 File)	x^N	139	1000	100
74.	Part 1 of the Tamil Nadu/Pondichery (zone 324) summary file (Lotus 1-2-3™ WK1 File)	x^N	174	1000	100

File number and description		Logical records	Records per file	Block size	Record length
75.	Part 2 of the Tamil Nadu/Pondichery (zone 324) summary file (Lotus 1-2-3™ WK1 File)	x^N	219	1000	100
76.	Tamil Nadu/Pondichery (zone 324) land use totals from part 1 and 2 summary files (Lotus 1-2-3™ WK1 File)	x^N	91	1000	100
77.	Tripura (zone 325) summary file (Lotus 1-2-3™ WK1 File)	x^N	175	1000	100
78.	Uttar Pradesh (zone 326) summary file (Lotus 1-2-3™ WK1 File)	x^N	167	1000	100
79.	West Bengal (zone 327) summary file (Lotus 1-2-3™ WK1 File)	x^N	185	1000	100
80.	Indonesia human population documentation file (Lotus 1-2-3™ WK1 File)	x^N	234	1000	100
81.	Indonesia livestock documentation file (Lotus 1-2-3™ WK1 File)	x^N	417	1000	100
82.	Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, and Bengkulu/Lampung (zones 401-7) summary file (Lotus 1-2-3™ WK1 File)	x^N	1103	1000	100

File number and description		Logical records	Records per file	Block size	Record length
83.	West, Central, and East Java (zones 408-410) summary file (Lotus 1-2-3™ WK1 File)	x^N	537	1000	100
84.	Bali, West Nusa Tenggara, East Nusa Tenggara, and East Timor (zones 411-414) summary file (Lotus 1-2-3™ WK1 File)	x^N	1280	1000	100
85.	West, Central, East, and South Kalimantan (zones 415-418) summary file (Lotus 1-2-3™ WK1 File)	x^N	1330	1000	100
86.	North/Central and South/Southeast Sulawesi (zones 419 and 420) summary file (Lotus 1-2-3™ WK1 File)	x^N	760	1000	100
87.	Maluku and Irian Jaya (zones 421-422) summary file (Lotus 1-2-3™ WK1 File)	x^N	596	1000	100
88.	Kampuchea (all zones) summary file (Lotus 1-2-3™ WK1 File)	x^N	358	1000	100
89.	Kampuchea (all zones) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	649	1000	100
90.	Laos (all zones) summary file (Lotus 1-2-3™ WK1 File)	x^N	376	1000	100

File number and description	Logical records	Records per file	Block size	Record length
91. Laos (all zones) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	710	1000	100
92. Western Peninsular, Eastern Peninsular, and Johor (zones 701-703) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	674	1000	100
93. Western, Central, and Eastern Sarawak (zones 704-706) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	348	1000	100
94. Sabah (zone 707) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	170	1000	100
95. Chin/Arakan (zone 801) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	1421	1000	100
96. Northern zone (zone 802) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	1485	1000	100

File number and description		Logical records	Records per file	Block size	Record length
97.	Dry zone (zone 803) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	1457	1000	100
98.	Shan/Karen/Kayah (zone 804) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	2352	1000	100
99.	Delta zone (zone 805) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	1996	1000	100
100.	Peninsular zone (zone 806) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	1456	1000	100
101.	Philippines (all zones) summary file (Lotus 1-2-3™ WK1 File)	x^N	684	1000	100
102.	Philippines (all zones) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	711	1000	100
103.	Singapore summary and land use documentation file (zone 1000) (Lotus 1-2-3™ WK1 File)	x^N	297	1000	100

File number and description	Logical records	Records per file	Block size	Record length
104. Sri Lanka (all zones) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	468	1000	100
105. Thailand (all zones) summary and land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	396	1000	100
106. Vietnam (all zones) summary file (Lotus 1-2-3™ WK1 File)	x^N	411	1000	100
107. Vietnam (all zones) land use documentation file (Lotus 1-2-3™ WK1 File)	x^N	834	1000	100

^{V}indicates that the number of records (lines) per logical record varies.
^{N}indicates that the given file contains binary data. These files DO NOT have logical records since these files are in proprietary formats that are usable only by appropriate software packages (e.g., ARC/INFO™ or Lotus 1-2-3™).

1. ARC/INFO™ export files (Version 6.1) are coverages converted to flat ascii, fixed-block, files for data transfer purposes. The IMPORT command in ARC/INFO™ must be used to enter these files into your system.
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14. DESCRIPTIVE FILE ON THE MAGNETIC MEDIA

The following is a listing of the first file provided on the magnetic media distributed by CDIAC. This file provides variable descriptions, formats, units, and other pertinent information about each file associated with this data base.

TITLE OF THE DATA BASE

HISTORIC LAND USE AND CARBON ESTIMATES FOR SOUTH AND SOUTHEAST ASIA: 1880–1980

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SCOPE OF THE DATA

This data base contains estimates of land use and the carbon content of vegetation for South and Southeast Asia for the years 1880, 1920, 1950, 1970, and 1980. For purposes of this Numeric Data Package (NDP), South and Southeast Asia encompasses the countries of India, Sri Lanka, Bangladesh, Myanmar (Burma), Thailand, Laos, Kampuchea (Cambodia), Vietnam, Malaysia, Brunei, Singapore, Indonesia, and the Philippines.

Information on the population of each country and ecological zone, as well as information on the number of livestock in each country and zone, are included with this NDP. [An ecological zone is made up of one or more contiguous political units (e.g., districts) that have been grouped together based on socio-ecological similarities.] These data may be used by demographers, historians, geographers, or other researchers who are interested in the relationship between land cover change, land degradation, and anthropogenic activities.

The data within this NDP were collected by John Richards and Elizabeth Flint at Duke University, Durham, North Carolina. Data collection was sponsored by the Environmental Sciences Division, U.S. Department of Energy, in support of DOE's Global Carbon Cycle Research Program. The data base was collected to reduce the uncertainty associated with the historic release of carbon into the atmosphere by land use change in South and Southeast Asia.

DATA FORMATS

The data distributed with this NDP were initially received as Lotus 1-2-3™ WK1 or WK3 spreadsheets and the base maps were obtained as ARC/INFO™ export files. The Lotus 1-2-3™ spreadsheets have been standardized into the WK1 file format and have been exported into flat ASCII data files to allow for use by a wider audience. The ARC/INFO™ E00 files have also been exported (using the UNGENERATE command in ARC/INFO™) and are formatted in a flat ASCII format. Thus, the data contained in this NDP are available in their entirety in several flat ASCII files (data and base maps) as well as in Lotus 1-2-3™ WK1 and ARC/INFO™ E00 files.

Seventy-five supporting Lotus 1-2-3™ WK1 files have been provided with this NDP to help document how each of the primary data sources were utilized and how the conversion processes were used to transform the original (source) land use categories into the eight standard land use classes used in this data package. Because of the dissimilar and subjective nature of these files, they have not been quality assured by CDIAC. Questions regarding the contents of these files should be directed to the primary investigators.

All land use data values presented in these data files are expressed in units of 10^3 ha. The human and livestock population data are also expressed in thousands. The carbon content estimates for each land use type are expressed in Mg of carbon per ha (i.e., 1 Mg of carbon = 1 metric ton of carbon). The estimated carbon contents were multiplied by the land use figures to obtain the total amount of carbon sequestered in live vegetation for each land use class, zone, and year in the data set. These total carbon estimates are expressed in 10^3 Mg of carbon.

FLAT ASCII DATA FILES:

Five flat ASCII data files are provided with this data package. Four SAS™ and FORTRAN programs designed to read and print the contents of each data file are also provided. The information within these files will allow the user to ascertain the amount of change in land use, concentration of carbon per ha by land use class, and the change in the amount of carbon sequestered in live vegetation that has occurred in South and Southeast Asia over the last 100 years.

ARC/INFO™ is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, CA 92372.

SAS™ is a registered trademark of the SAS Institute, Inc., Cary, NC 27511-8000.

Lotus 1-2-3™ is a registered trademark of Lotus Development Corporation, Cambridge, MA 02142.

FILE: LANDCARB.ASC

What follows is a description of the contents and format (variable names, widths, etc.) of the five flat ASCII data files distributed with this data package. The name of the first flat ASCII file is LANDCARB.ASC (File 2). A summary of the FORTRAN format statements used to read File 2 follow.

```
      CHARACTER COUNTRY*20, ZONE*26
      REAL      XLAND(90),XMGCHA(60)
      INTEGER CARB(70), ID

 10   READ(5,100,END=999) ID, COUNTRY, ZONE
      READ(5,110) (XLAND(I),I=1,90),(XMGCHA(I),I=1,60),
     1     (CARB(I),I=1,65), (CARB(I),I=66,70)
C
100   FORMAT(I4,A20,A26)
110   FORMAT(18(5F10.2,/),12(5F10.2,/),13(5I10,/),5I10)
```

The variables in LANDCARB.ASC, listed in Table 6, are shown in the same order as they appear in File 2.

Table 6. Variable formats for LANDCARB.ASC (File 2).

Variable name	Variable type	Variable width	Start column	End column
ID	Integer	4	1	4
COUNTRY	Character	20	5	24
ZONE	Character	26	25	50
		-------------- END OF LINE 1 -------------		
LAG_ALL1	Real	10	1	10
LAG_ALL2	Real	10	11	20
LAG_ALL3	Real	10	21	30
LAG_ALL4	Real	10	31	40
LAG_ALL5	Real	10	41	50
		-------------- END OF LINE 2 -------------		
LAG_TMP1	Real	10	1	10
LAG_TMP2	Real	10	11	20
LAG_TMP3	Real	10	21	30
LAG_TMP4	Real	10	31	40
LAG_TMP5	Real	10	41	50
		-------------- END OF LINE 3 -------------		

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
LAG_PRM1	Real	10	1	10
LAG_PRM2	Real	10	11	20
LAG_PRM3	Real	10	21	30
LAG_PRM4	Real	10	31	40
LAG_PRM5	Real	10	41	50
	--------------- END OF LINE 4 --------------			
LSETTLE1	Real	10	1	10
LSETTLE2	Real	10	11	20
LSETTLE3	Real	10	21	30
LSETTLE4	Real	10	31	40
LSETTLE5	Real	10	41	50
	--------------- END OF LINE 5 --------------			
LFR_CON1	Real	10	1	10
LFR_CON2	Real	10	11	20
LFR_CON3	Real	10	21	30
LFR_CON4	Real	10	31	40
LFR_CON5	Real	10	41	50
	--------------- END OF LINE 6 --------------			
LFR_INT1	Real	10	1	10
LFR_INT2	Real	10	11	20
LFR_INT3	Real	10	21	30
LFR_INT4	Real	10	31	40
LFR_INT5	Real	10	41	50
	--------------- END OF LINE 7 --------------			
LWT_ALL1	Real	10	1	10
LWT_ALL2	Real	10	11	20
LWT_ALL3	Real	10	21	30
LWT_ALL4	Real	10	31	40
LWT_ALL5	Real	10	41	50
	--------------- END OF LINE 8 --------------			
LWT_FOR1	Real	10	1	10
LWT_FOR2	Real	10	11	20
LWT_FOR3	Real	10	21	30
LWT_FOR4	Real	10	31	40
LWT_FOR5	Real	10	41	50
	--------------- END OF LINE 9 --------------			

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
LWT_NON1	Real	10	1	10
LWT_NON2	Real	10	11	20
LWT_NON3	Real	10	21	30
LWT_NON4	Real	10	31	40
LWT_NON5	Real	10	41	50
		--------------- END OF LINE 10 -------------		
LGRASS1	Real	10	1	10
LGRASS2	Real	10	11	20
LGRASS3	Real	10	21	30
LGRASS4	Real	10	31	40
LGRASS5	Real	10	41	50
		--------------- END OF LINE 11 --------------		
LBARREN1	Real	10	1	10
LBARREN2	Real	10	11	20
LBARREN3	Real	10	21	30
LBARREN4	Real	10	31	40
LBARREN5	Real	10	41	50
		--------------- END OF LINE 12 --------------		
LWATER1	Real	10	1	10
LWATER2	Real	10	11	20
LWATER3	Real	10	21	30
LWATER4	Real	10	31	40
LWATER5	Real	10	41	50
		--------------- END OF LINE 13 --------------		
LTOT_LA1	Real	10	1	10
LTOT_LA2	Real	10	11	20
LTOT_LA3	Real	10	21	30
LTOT_LA4	Real	10	31	40
LTOT_LA5	Real	10	41	50
		--------------- END OF LINE 14 --------------		
LTOT_FR1	Real	10	1	10
LTOT_FR2	Real	10	11	20
LTOT_FR3	Real	10	21	30
LTOT_FR4	Real	10	31	40
LTOT_FR5	Real	10	41	50
		--------------- END OF LINE 15 --------------		

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
LTOT_HP1	Real	10	1	10
LTOT_HP2	Real	10	11	20
LTOT_HP3	Real	10	21	30
LTOT_HP4	Real	10	31	40
LTOT_HP5	Real	10	41	50
		-------------- END OF LINE 16 --------------		
LTOT_LP1	Real	10	1	10
LTOT_LP2	Real	10	11	20
LTOT_LP3	Real	10	21	30
LTOT_LP4	Real	10	31	40
LTOT_LP5	Real	10	41	50
		-------------- END OF LINE 17 --------------		
LDEN_H1	Real	10	1	10
LDEN_H2	Real	10	11	20
LDEN_H3	Real	10	21	30
LDEN_H4	Real	10	31	40
LDEN_H5	Real	10	41	50
		-------------- END OF LINE 18 --------------		
LDEN_L1	Real	10	1	10
LDEN_L2	Real	10	11	20
LDEN_L3	Real	10	21	30
LDEN_L4	Real	10	31	40
LDEN_L5	Real	10	41	50
		———— **END OF LAND USE DATA** ————		
TAG_ALL1	Real	10	1	10
TAG_ALL2	Real	10	11	20
TAG_ALL3	Real	10	21	30
TAG_ALL4	Real	10	31	40
TAG_ALL5	Real	10	41	50
		-------------- END OF LINE 20 --------------		
TAG_TMP1	Real	10	1	10
TAG_TMP2	Real	10	11	20
TAG_TMP3	Real	10	21	30
TAG_TMP4	Real	10	31	40
TAG_TMP5	Real	10	41	50
		-------------- END OF LINE 21 --------------		

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
TAG_PRM1	Real	10	1	10
TAG_PRM2	Real	10	11	20
TAG_PRM3	Real	10	21	30
TAG_PRM4	Real	10	31	40
TAG_PRM5	Real	10	41	50
	--------------- END OF LINE 22 --------------			
TSETTLE1	Real	10	1	10
TSETTLE2	Real	10	11	20
TSETTLE3	Real	10	21	30
TSETTLE4	Real	10	31	40
TSETTLE5	Real	10	41	50
	--------------- END OF LINE 23 --------------			
TFR_CON1	Real	10	1	10
TFR_CON2	Real	10	11	20
TFR_CON3	Real	10	21	30
TFR_CON4	Real	10	31	40
TFR_CON5	Real	10	41	50
	--------------- END OF LINE 24 --------------			
TFR_INT1	Real	10	1	10
TFR_INT2	Real	10	11	20
TFR_INT3	Real	10	21	30
TFR_INT4	Real	10	31	40
TFR_INT5	Real	10	41	50
	--------------- END OF LINE 25 --------------			
TWT_ALL1	Real	10	1	10
TWT_ALL2	Real	10	11	20
TWT_ALL3	Real	10	21	30
TWT_ALL4	Real	10	31	40
TWT_ALL5	Real	10	41	50
	--------------- END OF LINE 26 --------------			
TWT_FOR1	Real	10	1	10
TWT_FOR2	Real	10	11	20
TWT_FOR3	Real	10	21	30
TWT_FOR4	Real	10	31	40
TWT_FOR5	Real	10	41	50
	--------------- END OF LINE 27 --------------			

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
TWT_NON1	Real	10	1	10
TWT_NON2	Real	10	11	20
TWT_NON3	Real	10	21	30
TWT_NON4	Real	10	31	40
TWT_NON5	Real	10	41	50
	---------------- END OF LINE 28 ----------------			
TGRASS1	Real	10	1	10
TGRASS2	Real	10	11	20
TGRASS3	Real	10	21	30
TGRASS4	Real	10	31	40
TGRASS5	Real	10	41	50
	---------------- END OF LINE 29 ----------------			
TBARREN1	Real	10	1	10
TBARREN2	Real	10	11	20
TBARREN3	Real	10	21	30
TBARREN4	Real	10	31	40
TBARREN5	Real	10	41	50
	---------------- END OF LINE 30 ----------------			
TWATER1	Real	10	1	10
TWATER2	Real	10	11	20
TWATER3	Real	10	21	30
TWATER4	Real	10	31	40
TWATER5	Real	10	41	50
	———— **END OF Mg C/ha DATA** ————			
CAG_ALL1	Real	10	1	10
CAG_ALL2	Real	10	11	20
CAG_ALL3	Real	10	21	30
CAG_ALL4	Real	10	31	40
CAG_ALL5	Real	10	41	50
	---------------- END OF LINE 32 ----------------			
CAG_TMP1	Real	10	1	10
CAG_TMP2	Real	10	11	20
CAG_TMP3	Real	10	21	30
CAG_TMP4	Real	10	31	40
CAG_TMP5	Real	10	41	50
	---------------- END OF LINE 33 ----------------			

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
CAG_PRM1	Real	10	1	10
CAG_PRM2	Real	10	11	20
CAG_PRM3	Real	10	21	30
CAG_PRM4	Real	10	31	40
CAG_PRM5	Real	10	41	50
	-------------- END OF LINE 34 --------------			
CSETTLE1	Real	10	1	10
CSETTLE2	Real	10	11	20
CSETTLE3	Real	10	21	30
CSETTLE4	Real	10	31	40
CSETTLE5	Real	10	41	50
	-------------- END OF LINE 35 --------------			
CFR_CON1	Real	10	1	10
CFR_CON2	Real	10	11	20
CFR_CON3	Real	10	21	30
CFR_CON4	Real	10	31	40
CFR_CON5	Real	10	41	50
	-------------- END OF LINE 36 --------------			
CFR_INT1	Real	10	1	10
CFR_INT2	Real	10	11	20
CFR_INT3	Real	10	21	30
CFR_INT4	Real	10	31	40
CFR_INT5	Real	10	41	50
	-------------- END OF LINE 37 --------------			
CWT_ALL1	Real	10	1	10
CWT_ALL2	Real	10	11	20
CWT_ALL3	Real	10	21	30
CWT_ALL4	Real	10	31	40
CWT_ALL5	Real	10	41	50
	-------------- END OF LINE 38 --------------			
CWT_FOR1	Real	10	1	10
CWT_FOR2	Real	10	11	20
CWT_FOR3	Real	10	21	30
CWT_FOR4	Real	10	31	40
CWT_FOR5	Real	10	41	50
	-------------- END OF LINE 39 --------------			

Table 6. (Continued)

Variable name	Variable type	Variable width	Start column	End column
CWT_NON1	Real	10	1	10
CWT_NON2	Real	10	11	20
CWT_NON3	Real	10	21	30
CWT_NON4	Real	10	31	40
CWT_NON5	Real	10	41	50
	--------------- END OF LINE 40 -------------			
CGRASS1	Real	10	1	10
CGRASS2	Real	10	11	20
CGRASS3	Real	10	21	30
CGRASS4	Real	10	31	40
CGRASS5	Real	10	41	50
	--------------- END OF LINE 41 --------------			
CBARREN1	Real	10	1	10
CBARREN2	Real	10	11	20
CBARREN3	Real	10	21	30
CBARREN4	Real	10	31	40
CBARREN5	Real	10	41	50
	--------------- END OF LINE 42 --------------			
CWATER1	Real	10	1	10
CWATER2	Real	10	11	20
CWATER3	Real	10	21	30
CWATER4	Real	10	31	40
CWATER5	Real	10	41	50
	--------------- END OF LINE 43 --------------			
CTOT_LA1	Real	10	1	10
CTOT_LA2	Real	10	11	20
CTOT_LA3	Real	10	21	30
CTOT_LA4	Real	10	31	40
CTOT_LA5	Real	10	41	50
	--------------- END OF LINE 44 --------------			
CTOT_FR1	Real	10	1	10
CTOT_FR2	Real	10	11	20
CTOT_FR3	Real	10	21	30
CTOT_FR4	Real	10	31	40
CTOT_FR5	Real	10	41	50
	———— END OF TOTAL CARBON DATA ————			
	--------------- END OF RECORD --------------			

Where:

ID	is the identification number.
COUNTRY	is the country name.
ZONE	is the zone name.

The following variable names have a numeric value from 1 to 5 appended to them and a character (L, T, or C) prepended. The numeric values indicate the year for which the variable contains data. A values of 1 indicates that the variable holds data for 1880, 2 for 1920, 3 for 1950, 4 for 1970, and 5 for 1980. The prepended character indicates if the variable contains (L)and use data (in 10^3 ha); an estimate of the amount of carbon stored per a ha [in Mg/ha or (T)/ha]; or the total amount of (C)arbon sequestered in live vegetation (in Mg). For example purposes the L prefix is used to describe the remaining variables.

LAG_ALL	is the total amount of land devoted to agriculture in a given year.
LAG_TMP	is the amount of agricultural land devoted to temporary annaul crops in a given year.
LAG_PRM	is the amount of agricultural land devoted to permanent perennial crops in a given year.
LSETTLE	is the amount of land devoted to settled or built-up lands in a given year.
LFR_CON	is the amount of land covered with uninterrupted forest (forest lands with greater than 40% crown closure) in a given year.
LFR_INT	is the amount of land covered with interrupted woods (forest lands with less than 40% crown closure) in a given year.
LWT_ALL	is the total amount of land covered by wetlands in a given year.
LWT_FOR	is the amount of forested wetland (e.g., mangroves, swamp forest) in a given year.
LWT_NON	is the amount of wetland dominated by nonwoody vegetation in a given year.
LGRASS	is the amount of land covered by grass or brush lands in a given year.
LBARREN	is the amount of barren or sparsely vegetated land (e.g., desert or alpine tundra) in a given year.
LWATER	is the amount of land covered by standing water in a given year. The primary cause of changes in this value is the construction of water retention facilities.
LTOT_LA	is the total land area of the zone.

LTOT_FR is the total forest cover in the zone. This variable is the sum of LFR_CON, LFR_INT, and LWT_FOR.

LTOT_HP is the human population in thousands.

LTOT_LP is the livestock population in thousands. Livestock are defined as any four footed domesticated stock animal (e.g., cattle, water buffalo, goats, sheep, pigs, and equines).

LDEN_H is the human population density in persons per ha.

LDEN_L is the livestock population density in head per ha.

FILE: FLAGS.ASC

The second flat ASCII file provides accuracy flags derived based on the type and quality of the source data used in developing the values contained in LANDCARB.ASC (File 2). This file should be used when individual data values are extracted from this data base to determine the lineage of the data for a given time period in given ecological zone. What follows is a description of the contents and format (variable names, widths, etc.) of the second flat ASCII data file distributed with this data package. The name of the second flat ASCII file is FLAGS.ASC (File 5). A summary of the FORTRAN format statements used to read File 5 follow.

```
     CHARACTER COUNTRY*20, ZONE*26
     INTEGER ID, AG_FLG(5), NON_FLG(5), HP_FLG(5), LP_FLG(5)

 10  READ(5,100,END=999) ID, COUNTRY, ZONE
     READ(5,110) (AG_FLG(I),I=1,5), (NON_FLG(I),I=1,5),
                 (HP_FLG(I),I=1,5), (LP_FLG(I),I=1,5)
C
100  FORMAT(I4,A20,A26)
110  FORMAT(3(5I10,/),5I10)
```

The variables in FLAGS.ASC, listed in Table 7, are shown as they appear in File 5.

Table 7. Variable formats for FLAGS.ASC (File 5).

Variable name	Variable type	Variable width	Start column	End column
ID	Integer	4	1	4
COUNTRY	Character	20	5	24
ZONE	Character	26	25	50
	-------------- END OF LINE 1 -------------			
AG_FLG1	Real	10	1	10
AG_FLG2	Real	10	11	20
AG_FLG3	Real	10	21	30
AG_FLG4	Real	10	31	40
AG_FLG5	Real	10	41	50
	-------------- END OF LINE 2-------------			
NON_FLG1	Real	10	1	10
NON_FLG2	Real	10	11	20
NON_FLG3	Real	10	21	30
NON_FLG4	Real	10	31	40
NON_FLG5	Real	10	41	50
	-------------- END OF LINE 3-------------			
HP_FLG1	Real	10	1	10
HP_FLG2	Real	10	11	20
HP_FLG3	Real	10	21	30
HP_FLG4	Real	10	31	40
HP_FLG5	Real	10	41	50
	-------------- END OF LINE 4-------------			
LP_FLG1	Real	10	1	10
LP_FLG2	Real	10	11	20
LP_FLG3	Real	10	21	30
LP_FLG4	Real	10	31	40
LP_FLG5	Real	10	41	50
	------------- END OF RECORD -------------			

Where:

ID is the zone identification number.
COUNTRY is the country name.
ZONE is the zone name.

The following variable names have a numeric value from 1 to 5 appended to them. The numeric values indicate the year for which the variable contains data. A value of 1 indicates that the variable contains data for 1880, 2 for 1920, 3 for 1950, 4 for 1970, and 5 for 1980.

AG_FLG — a flag with a value from 0 to 10 that indicates the relative quality and quantity of source data used to estimate the cultivated (agricultural) and settled/built-up land data variables contained in file LANDUSE.ASC (File 2).

NON_FLG — a flag with a value from 0 to 10 that indicates the relative quality and quantity of source data used to estimate the nonagricultural and nonsettled/built-up land data variables (e.g., forest cover or barren land) contained in file LANDUSE.ASC (File 2).

HP_FLG — a flag with a value from 0 to 10 that indicates the relative quality and quantity of source data used to estimate the human population values contained in file LANDUSE.ASC (File 2).

LP_FLG — a flag with a value from 0 to 10 that indicates the relative quality and quantity of source data used to estimate the livestock population values contained in file LANDUSE.ASC (File 2).

Tables 8, 9, 10, and 11 define the valid values for each of the four flag variables listed above.

Table 8. System used to rank the quality of the data utilized in determining the amount of cultivated and settled land in each ecological zone. Values range from 0 to 10, 10 being the best (variable AG_FLG).

Rank	Description of minimum data requirements
0	Thin-air extrapolation: no description of land use/agriculture in zone or similar adjoining zone within 20 years of target date.
1	Descriptive information available only for adjacent, similar, or part of zone within 20 years of target date. Minimum: specify whether agriculture is shifting or sedentary and what the major crops are, but no areal estimates nor estimates of the number of agriculturalists are available.
2	Descriptive information for entire zone within 20 years of target date or for significant portions of the zone within 10 years of target date, but no areal estimates are available. Areal estimates are extrapolated from estimates for comparable zones within the same time period.
3	Crude estimate of cultivated area for the zone or a significant part thereof. No specificity as to crops, just overall cultivated or "occupied" area within 10 years of target date. Usually applies to data for 1880 or 1920.

Table 8. (Continued)

Rank	Description of minimum data requirements
4	Plausible estimate of cultivated area in zone within 5 years of target date. Includes official estimates requiring modifications for significant boundary changes (> 25% of modern area), general estimates of area in sedentary or swidden crops were found from secondary references. Also includes zones for which conflicting published contemporary estimates exist or official estimates that are believed to be unreliable. Alternative: official estimate for zone, assuming boundary changes (< 25%) of total area, but between 5 and 10 years from the target date.
5	Documented official or secondary estimates of cultivated area within 5 years of target date from an ongoing series for zones with boundary changes <25% of modern area. Minimum data: one estimate of total area in (major) annual crops, where those are dominant or one estimate of total area in (major) perennial crops, where those are dominant. Subdivision into major crops not necessarily available. No multiple-year coverage for annual crops. If swidden agriculture is significant, it is likely to be omitted from official estimates of this quality. Add one point for corroboration by contemporary map or aerial survey (1950–1980 data only).
6	Documented official or secondary estimates of cultivated area within 5 years of target date from an ongoing series. For zones dominated by annual crops, 2 years of coverage within 5 years of the target date are required for most or all of zone, data regarding the percentage of area in major annual crops; no perennial data required. For zones dominated by perennials, separate estimates of area in each major perennial crop, for at least one year within 5 years of target date, plus published estimate (not necessarily official) for annual crops. Includes any reasonable published estimate of swidden area based on population/area ratios and population estimates of swidden groups. No mapped corroboration for estimates of annual crops production, especially from swidden agriculture.
7	Documented official or secondary estimates of cultivated area within 5 years of target date from an ongoing series. Zones dominated by annual crops require 3–5 years of coverage within 5 years of target date for annual crops for most or all of zone, data regarding the percentage of area in major annual crops; no perennial data required. For zones dominated by perennials, separate estimates of area in each major perennial crop, for at least 2 years within 5 years of target date, or a single set of estimates within 2 years of target date, plus at least 1 published estimate of annual crop area as per rank 6.

Table 8. (Continued)

Rank	Description of minimum data requirements
8	Documented official or secondary estimates of cultivated area within 5 years of target date from an ongoing series. Zones dominated by annual crops required 3–5 years of coverage within 5 years of target date for annual crops for most or all of zone, data regarding the percentage of area in each major annual crop, and must have at least one estimate of perennial crop area by major crop within 5 years of target date. For zones dominated by perennials, separate estimates of area in each major perennial crop, for at least 2 years within 5 years of target date, or a single set of estimates within 2 years of target date, plus at least two estimates of total annual crop area within 5 years of target date, and percentages of major annual crops (minimum: upland rice/lowland rice/other). Alternative: complete agricultural data based on two exhaustive surveys bracketing target year with or without major crops or complete agricultural data based on a full-zone survey in date of target year.
9	Documented official or secondary estimates of cultivated area within 5 years of target date from an ongoing series. Zones dominated by annual crops required 4–5 years of coverage within 5 years of target date for annual crops for 90% or more of zone, data regarding the percentage of area in major annual crops, and must have at least 1 estimate of perennial crop area by major crop within 5 years of target date. Must have percentages of all major perennial crops. For zones dominated by perennials, separate estimates of area in each major perennial crop, for at least 2 years within 5 years of target date, or a single set of estimates within 2 years of target date. Plus at least three estimates of total annual crop area within 5 years of target date and percentages of all major annual crops.
10	Full series of five consecutive years around target date for annual crops, plus the percentage of area in all major annual crops within 1 year of date and equivalent information for all major perennial crops. Published estimate of settled area and information concerning what is in it and official statistics corroborated by full cadastral survey or satellite map.

Table 9. **System used to rank the quality of the data utilized in determining the amount of land in all land use classes except cultivated and built-up/settled land in each ecological zone. Values range from 0 to 10, 10 being the best (variable NON_FLG).**

Rank	Description of minimum data requirements
0	Thin-air extrapolation: no description of zone or similar adjoining district within 20 years of target date.
1	Descriptive information available only for adjacent or similar zone but not for the zone under consideration within 20 years of target date; or descriptive information for significant part of zone under consideration within same time limits.
2	Descriptive information only for a significant part of (but not entire) zone within 10 years of target date, or a full description of entire zone within 20 years of target date.
3	At least one adequate description covering essentially entire zone within 10 years of target date; or two or more texts allowing a composite description of the entire zone to be made (in cases of large boundary change), within same time limits. Example of "adequate description": Early or modern state gazetteer introduction describing "botany" or "vegetation"; brief discussion of vegetation at zone scale within national geography or economic history survey.

Categories 4—10 presuppose at least one description of quality rank (3) as a baseline, plus whatever else is specified. All references meet same time constraints as used for rank (3). If these criteria are not met, one point was subtracted from the rating.

Rank	Description of minimum data requirements
4	Additional descriptive material on vegetation, agriculture, forestry, or land use, which complements and extends (3); or additional descriptive information for parts of the zone or highly site-specific information useful for one but not all categories or parts of zone. Example: highly localized vegetation descriptions, village studies, or detailed coverage of vegetation or land use for zone in national or regional geographies or monographs. No quantitative data.
5	Good descriptive data of rank (4) with plausible estimates of zonal forest area, with descriptive material as backup or more detailed quantitative information on area covered by major vegetation types for part but not all of zone. Examples: forest working plan for significant or characteristic portion of zone; good botanical, ecological, forestry or geographical paper but not covering whole zone.

Table 9. (Continued)

Rank	Description of minimum data requirements
6	Good descriptive data of rank (4) with older vegetation map (partial or complete) in lieu of quantitative data, or a partial vegetation map of zone with partial quantitative data. Little or no quantitative data, or conflict between quantitative and map; or conflicts among multiple quantitative sources or among maps.
7	Good descriptive data of rank (4) with quantitative data for entire zone in only a few categories, or all categories and only part of zone; or tabular and map coverage that when combined cover the full zone.
8	Good descriptive data of rank (4) and either a quantitative estimate of land use/vegetation for entire zone for all major categories or total coverage by a modern map based on cadastral survey, aerial photography, or satellite images.
9	Good descriptive data of rank (4) and both a quantitative estimate of land use/vegetation for entire zone and all major categories and total coverage by modern map based on cadastral survey, aerial photography, or satellite images.
10	Excellent descriptive data of rank (4) with trustworthy, quantitative satellite survey covering entire district in a format easily convertible to our vegetation types with numbers, map, and text all available and data consistent with contemporary vegetation maps.

Table 10. **System used to rank the quality of the human population data in each ecological zone. Values range from 0 to 10, 10 being the best (variable HP_FLG).**

Rank	Description of minimum data requirements
0	No published estimate of population within 20 years of date for zone and no published estimate of population density for comparable zone at comparable times.
1	Published estimate (unofficial), by 19th century travelers or geographers within 20 years of date for zone. No published census figures and no explanation of published values.
2	Published estimate for population within 20 years of target date by modern author who has reviewed more recent population data (not an official estimate); or partial or seriously flawed census available officially within 20 years of target date, such that significant part of population is undercounted or overcounted. Official census, if involved, is isolated and not easily comparable to later series. Also includes crude national estimates within 20 years of target date that were subdivided to zone based on later census data.
3	Same as rank (2) above, but within 10 years of target date or two estimates within 20 years of target date that are reasonably consistent.
4	Isolated census available within 10 years of target date, with relatively good coverage, but available subdivisions of data obstruct adjustment for boundary changes; or the structure of the census not comparable to later censuses. Other official population data (e.g., estimates based on birth/death records in lieu of formal census) may be considered equivalent; or secondary estimates within 10 years of target date, consistent with later census data.
5	Two censuses available bracketing target date for total period of 30 years or less. Coverage reasonably complete for both. Interpolation using @RATE[1] function. May be corroborated by secondary estimates.
6	Census within 10 years of target date is part of ongoing regular series, with at least one preceding census and one following, or two preceding. However, significant problems were reported with nearest census to target date. Interpolation using @RATE[1] function. Wartime censuses would be included here.
7	Census within 3 years of target date, but otherwise equivalent to rank (6). Interpolation using @RATE[1] function.

Table 10. (Continued)

Rank	Description of minimum data requirements
8	Census within 2 years of target date, part of ongoing series; all values in series have been retrospectively adjusted to modern boundaries (e.g., India 1901–1981), but refer to older values which may have been less accurate or dealt with localities where a significant percentage of population was poorly accessible. Note: For rank (8) or above, subdivision by ethnic groups should be available if swidden agriculture is an important land use.
9	Same as rank (8) above, but after 1950. Quality of census ranked good and adjustments for undercounting or overcounting have been made.
10	Same as rank (9) above, but quality of census ranked excellent. Areas with longterm political stability, accessible topography, and solid census infrastructure.

Note: [1] The @RATE function is a Lotus 1-2-3™ procedure that calculates the periodic growth rate necessary for a *present value* to grow to a *future value* over a given *term*. For example, if at least two population values are known then a growth rate in percent can be calculated and used to predict past, intervening, or future populations.

Table 11. **System used to rank the quality of the livestock population data in each ecological zone. Values range from 0 to 10, 10 being the best (variable LP_FLG).**

Rank	Description of minimum data requirements
0	No published estimate of even the human population within 20 years of date for zone, and no livestock data.
1	No livestock data for zone within 20 years of target date; livestock population extrapolated from human population data of rank (1) or (2) on the basis of human/livestock ratios outside the 20 year period.
2	No livestock data for zone within 20 years of target date, but livestock population extrapolated from contemporary human census on the basis of human/livestock ratios outside the 20 years period.
3	Partial livestock data within 20 years of target date, permitting extrapolations from contemporary human population if subdivided appropriately. Livestock estimate based on ratios calculated for areas <50% or >150% of zone.
4	Partial livestock data within 10 years of target date or reasonably full coverage within 20 years of target date. Livestock estimate probably was derived from earlier human/livestock ratio. One or more major species may be excluded.
5	Complete livestock census within 10 years of target date, but district/unit for which censuses were taken has changed considerably (e.g., Bombay/Gujarat/Maharashtra over 1950–1960; or Bengal before versus after partition) or livestock census was separated from target date by major upheaval affecting animal population (migration, war, revolution, famine, etc.).
6	Livestock census within 10 years of target date is preceded or followed by at least one other census of same area. No major species excluded.
7	Livestock census within 5 years of target date for area within 10% of modern zone boundaries. Preceded or followed by at least one other census of same area.
8	Livestock estimates made annually based on regular censuses supplemented by spot checks or slaughter records, but actual censuses are at intervals of 5 or 10 years. Target date has estimate, but it is not census based.
9	Livestock census of reasonable quality available within 2 years of target date for zone at current boundaries; comparable human census also available.

Table 11. (Continued)

Rank	Description of minimum data requirements
10	Livestock census of excellent quality available within 2 years of target date; must be part of a series of at least three censuses covering zone at its modern boundaries. Comparable human censuses available, and zone is politically stable with a good bureaucratic infrastructure.

FILE: FACTORS.ASC

What follows is a description of the contents and format (variable names, widths, etc.) of the third flat ASCII data file distributed with this data package. The name of the third flat ASCII file is FACTORS.ASC (File 8). A summary of the FORTRAN format statements used to read File 8 follow.

```
      INTEGER   ID
      CHARACTER COUNTRY*20, ZONE*26, PRANGE*20
      REAL      AG_TMP(7), AG_PRM(7), SETTLE(7),
     1          FR_CON(7), FR_INT(7), WT_FOR(7),
     2          WT_NON(7), GRASS(7) , BARREN(7),
     3          WATER(7) , PMEAN, SPACE, N(3:7)

 10   READ(5,100,END=999) ID, COUNTRY, ZONE, PRANGE
      READ(5,110) AG_TMP(7), AG_PRM(7), SETTLE(7),
     1            FR_CON(7), FR_INT(7), WT_FOR(7),
     2            WT_NON(7), GRASS(7) , BARREN(7),
     3            WATER(7) , PMEAN, SPACE, N(3:7)
C
100   FORMAT(I4,A20,A26,A20)
110   FORMAT(10(7I10,/),7F10.2)
```

The variables in FACTORS.ASC, listed in Table 12, are shown as they appear in File 8.

Table 12. Variable formats for FACTORS.ASC (File 8).

Variable name	Variable type	Variable width	Start column	End column
ID	Integer	4	1	4
COUNTRY	Character	20	5	24
ZONE	Character	26	25	50
PRANGE	Character	20	51	70
	-------------- END OF LINE 1 --------------			
AG_TMP1	Real	10	1	10
AG_TMP2	Real	10	11	20
AG_TMP3	Real	10	21	30
AG_TMP4	Real	10	31	40
AG_TMP5	Real	10	41	50
AG_TMP6	Real	10	51	60
AG_TMP7	Real	10	61	70
	-------------- END OF LINE 2 --------------			

Table 12. (Continued)

Variable name	Variable type	Variable width	Start column	End column
AG_PRM1	Real	10	1	10
AG_PRM2	Real	10	11	20
AG_PRM3	Real	10	21	30
AG_PRM4	Real	10	31	40
AG_PRM5	Real	10	41	50
AG_PRM6	Real	10	51	60
AG_PRM7	Real	10	61	70
	--------------- END OF LINE 3 --------------			
SETTLE1	Real	10	1	10
SETTLE2	Real	10	11	20
SETTLE3	Real	10	21	30
SETTLE4	Real	10	31	40
SETTLE5	Real	10	41	50
SETTLE6	Real	10	51	60
SETTLE7	Real	10	61	70
	--------------- END OF LINE 4 --------------			
FR_CON1	Real	10	1	10
FR_CON2	Real	10	11	20
FR_CON3	Real	10	21	30
FR_CON4	Real	10	31	40
FR_CON5	Real	10	41	50
FR_CON6	Real	10	51	60
FR_CON7	Real	10	61	70
	--------------- END OF LINE 5 --------------			
FR_INT1	Real	10	1	10
FR_INT2	Real	10	11	20
FR_INT3	Real	10	21	30
FR_INT4	Real	10	31	40
FR_INT5	Real	10	41	50
FR_INT6	Real	10	51	60
FR_INT7	Real	10	61	70
	--------------- END OF LINE 6 --------------			
WT_FOR1	Real	10	1	10
WT_FOR2	Real	10	11	20
WT_FOR3	Real	10	21	30
WT_FOR4	Real	10	31	40
WT_FOR5	Real	10	41	50
WT_FOR6	Real	10	51	60
WT_FOR7	Real	10	61	70
	--------------- END OF LINE 7 --------------			

Table 12. (Continued)

Variable name	Variable type	Variable width	Start column	End column
WT_NON1	Real	10	1	10
WT_NON2	Real	10	11	20
WT_NON3	Real	10	21	30
WT_NON4	Real	10	31	40
WT_NON5	Real	10	41	50
WT_NON6	Real	10	51	60
WT_NON7	Real	10	61	70
	-------------- END OF LINE 8 --------------			
GRASS1	Real	10	1	10
GRASS2	Real	10	11	20
GRASS3	Real	10	21	30
GRASS4	Real	10	31	40
GRASS5	Real	10	41	50
GRASS6	Real	10	51	60
GRASS7	Real	10	61	70
	-------------- END OF LINE 9 --------------			
BARREN1	Real	10	1	10
BARREN2	Real	10	11	20
BARREN3	Real	10	21	30
BARREN4	Real	10	31	40
BARREN5	Real	10	41	50
BARREN6	Real	10	51	60
BARREN7	Real	10	61	70
	-------------- END OF LINE 10 --------------			
WATER1	Real	10	1	10
WATER2	Real	10	11	20
WATER3	Real	10	21	30
WATER4	Real	10	31	40
WATER5	Real	10	41	50
WATER6	Real	10	51	60
WATER7	Real	10	61	70
	-------------- END OF LINE 11 --------------			
PMEAN	Real	10	1	10
SPACE	Real	10	11	20
N3	Real	10	21	30
N4	Real	10	31	40
N5	Real	10	41	50
N6	Real	10	51	60
N7	Real	10	61	70
	-------------- END OF RECORD --------------			

Where:

ID	is the zone identification number.
COUNTRY	is the country name.
ZONE	is the zone name.
PRANGE	is the annual precipitation range for the ecological zone in mm/year. A range of 999–999 indicates that these data were not readily available from published data sources.

The following variable names have a numeric value 1, 2, 3, 4, 5, 6, or 7 appended to them. The variables with the number 1 contain the maximum potential carbon content for the given land use class in Mg/ha; variables with the number 2 contain the environmental limitation factor (determined based on PRANGE, soil characteristics, slope, etc.); and variables with numeric postfixes from 3–7 contain the degradation factor, with the numeric value indicating the year for which the variable contains data. A value of 3 indicates the variable contains data for 1880, 4 for 1920, 5 for 1950, 6 for 1970, and 7 for 1980.

AG_TMP	are data values for annual or semiannual crops (e.g., rice).
AG_PRM	are data values for permanent crops (e.g., rubber plantation).
SETTLE	are data values for settled/built-up land.
FR_CON	are data for continuously forested land (forests with crown closure of 40% or greater).
FR_INT	are data values for interrupted woodland.
WT_FOR	are data values for forested wetland.
WT_NON	are data values for nonforested wetland.
GRASS	are data values for grass/shrub lands.
BARREN	are data values for barren or sparsely vegetated land.
WATER	are data values for water (hydrophytes).
PMEAN	is the mean annual rainfall for the given ecological zone in mm/year. If these data were not available the data file will contain a value of 999.00.
SPACE	is a space holding variable that never contains actual data, should contain a value of 999.00.
N	is the N calculated using the S, F, and A values shown in Appendix B. This variable was utilized with the human population data (in LANDCARB.ASC -File 2) of each zone to calculated the degradation factors for the woody vegetation land use classes.

FILE: SEA_CTRY.ASC AND SEA_ZONE.ASC

The fourth and fifth flat ASCII files — SEA_CTRY.ASC (File 11) and SEA_ZONE.ASC (File 12), respectively, contain digitized base maps of South and Southeast Asia. The national boundaries were obtained at a scale of 1:2,000,000, while internal zone boundaries were obtained from several different publications. Thus, the accuracy of the zone boundaries varies between countries based on the scale and detail of each source map. To reduce edge matching problems that occurred when several maps were combined, the zone and nation boundaries were smoothed (in ARC/INFO™) to a nominal map scale of 1:4,000,000 with a minimal resolution of one point per 4 km. File 11 contains boundaries for the 13 countries within the study region and File 12 contains boundaries for the 94 ecological zones. These digital data are included to allow the land use/carbon data contained in the other flat ASCII data files distributed with this data base to be mapped. The "key" that links the polygons described in these two files to the land use/carbon data contained in Files 2, 5, and 8 is the zone identification number (for a complete listing of these identification numbers see Table 1). This number is contained in each record (of each file) and should be used to cross-reference the files.

Unlike the other data files within this data base, these files contain line segments that describe the polygon boundaries of each country or ecological zone. These polygons have no attribute data associated with each polygon (beyond the polygon name). Commands such as RELATE in ARC/INFO™ (or similar commands in other geographic information systems) may be used to associate the land use/carbon data with the appropriate polygon.

What follows is a description of the contents and format of the fourth and fifth flat ASCII data file distributed with this data package. A summary of the FORTRAN format statements used to read these files follows:

```
      CHARACTER ID*6, ALLNAME*7
      INTEGER   NUM
      REAL      X(4000), Y(4000)

 10   READ(5,100,END=999) ID, NUM
      DO 20 I=1,NUM
         READ(5,110) X(I), Y(I)
 20   CONTINUE
C
100   FORMAT(A6,1X,I5)
110   FORMAT(F10.6,1X,F10.6)
```

An example of the file format used in SEA_CTRY.ASC and SEA_ZONE.ASC is shown in Table 13.

Table 13. **Sample of the vector format used for SEA_CTRY.ASC (File 11) and SEA_ZONE.ASC (File 12).**

Zone code Number of points	
" 400", 13	-Polygon 400 uses 13 points to describe the region
121.859993,-10.610300	-Starts at 121.86°E, 10.61°S
121.795998,-10.600261	
121.734795,-10.600780	
121.696365,-10.561336	
121.753677,-10.531301	
121.811150,-10.502058	
121.847893,-10.452695	
121.902847,-10.419775	
121.960655,-10.441310	
122.001862,-10.467175	
121.987274,-10.528060	
121.933311,-10.562428	
121.859993,-10.610300	-Ends at 121.86°E, 10.61°S
" 400", 123	
122.478599,-10.768567	
...	-Continued

Note that the two example polygons in Table 13 have the same name (i.e., " 400"). This is intentional since in this case 400 is the zone identification number for Indonesia, a country that is made up of several islands. The polygon names may repeat, depending on the number of polygons it takes to describe the boundaries of each country or ecological zone. Along with the polygons that describe the different countries and ecological zones are two special polygon types that are identified by the following polygon identification numbers;

0 indicates that the given polygon is not within any of the defined ecological zones or countries, and

9999 indicates that the given polygon is a "island" or "lake" within another polygon.

The following is a short listing of the ecological zone identification numbers used throughout this data base as the primary sort key. This information is presented here in a condensed form, Table 1 in Part 1 of this document should be consulted for more detailed information.

Place name	Zone ID	Place name	Zone ID
BANGLADESH	100	Chittagong Hills Tracts	101
Eastern Coast	102	Meghna	103
Sundarbans	104	Western Districts	105
BRUNEI	200	Total	201
INDIA	300	Andaman/Nicobar Islands	301
Andhra Pradesh	302	Arunachal Pradesh	303
Assam	304	Bihar	305
Delhi	306	Gujarat/Dadra/Nagar H.	307
Haryana/Chandigarh	308	Himachal Pradesh	309
Jammu/Kashmir	310	Karnataka	311
Kerala	312	Lakshadweep Islands	313
Madhya Pradesh	314	Maharashtra/Goa/Daman/Diu	315
Manipur	316	Meghalaya	317
Mizoram	318	Nagaland	319
Orissa	320	Punjab	321
Rajasthan	322	Sikkim	323
Tamil Nadu/Pondichery	324	Tripura	325
Uttar Pradesh	326	West Bengal	327
INDONESIA	400	Aceh	401
North Sumatra	402	West Sumatra	403
Riau	404	Jambi	405
South Sumatra	406	Bengkulu/Lampung	407
West Java	408	Central Java	409
East Java	410	Bali	411
West Nusa Tenggara	412	East Nusa Tenggara	413
East Timor	414	West Kalimantan	415
Central Kalimantan	416	East Kalimantan	417
South Kalimantan	418	North/Central Sulawesi	419
South/Southeast Sulawesi	420	Maluku	421
Irian Jaya	422		
KAMPUCHEA	500	Northwest Region	501
Northeast Region	502	Southeast Lowlands	503
Southwest Highlands	504		
LAOS	600	Northwest Laos	601
Louang Phrabang	602	Central Laos	603
Annamite Chain	604	Champasak	605

Place name	Zone ID	Place name	Zone ID
MALAYSIA	700	Western Peninsular	701
Eastern Peninsular	702	Johor	703
Western Sarawak	704	Central Sarawak	705
Eastern Sarawak	706	Sabah	707
MYANMAR	800	Chin/Arakan	801
Northern Myanmar	802	Dry Zone	803
Shan/Karen/Kayah	804	Delta	805
Peninsular	805		
PHILIPPINES	900	Luzon	901
Palawan	902	Visayas	903
Mindanao	904		
SINGAPORE	1000	Total	1001
SRI LANKA	1100	Wet Zone	1101
Dry Zone	1102		
THAILAND	1200	Northern Region	1201
Northeastern Region	1202	Central Plain	1203
Southern Region	1204		
VIETNAM	1300	Northwest Highlands	1301
Tonkin Delta	1302	North Central Coast	1303
Central Highlands	1304	South Central Coast	1305
Mekong Delta	1306		

LOTUS 1-2-3™ WK1 SPREADSHEET FILES

Ninety Lotus 1-2-3™ WK1 spreadsheet files are provided with this NDP. The first 13 of these files contain the same data as is contained in File 2 (LANDCARB.ASC). The names of the these thirteen spreadsheets (Files 15 to 27) are 100LUC.WK1, 200LUC.WK1, 300LUC.WK1, 400LUC.WK1, 500LUC.WK1, 600LUC.WK1, 700LUC.WK1, 800LUC.WK1, 900LUC.WK1, 1000LUC.WK1, 1100LUC.WK1, 1200LUC.WK1, and 1300LUC.WK1. The numeric part of the filename is the zone identification number of the country for which the file contains data (e.g., 100 = Bangladesh). Each file contains data for all ecological zones that occur within the given country plus national totals. The 14th spreadsheet file, FLAGS.WK1 (File 28), contains the data accuracy flags found in File 5 (FLAGS.ASC). The 15th spreadsheet file, FACTORS.WK1 (File 29), contains the M, E, and D factors [i.e., the maximum potential carbon factor (M), environmental limitation factor (E), and the degradation factor (D)] that are contained in File 8 (FACTORS.ASC).

The remaining 75 spreadsheet files (Files 33-107) contain background documentation on the procedures used to obtain the land use data contained in this NDP. These files have been provided to help document the land use data contained in Files 1–32. Because of the wide variation in the format and content of these spreadsheets, CDIAC is distributing these files on an "as is" basis and any questions regarding the contents of these files should be directed to the primary investigators. Refer to Appendix D to obtain a summary of the contents of these files.

The primary advantages of the Lotus 1-2-3™ files over the flat ASCII data is that the data values have been separated by country, are maintained within Lotus 1-2-3™ to the 14th decimal place (reducing problems with rounding errors). In addition, the Lotus 1-2-3™ files contain the formulas that were used to calculate the total carbon portion of the spreadsheets. The formulas allow the total carbon estimates to be recalculated automatically if the user wishes to change the estimated carbon values for one of the land use classes.

The general format of the Lotus 1-2-3™ data files are depicted in Tables 14, 15, and 16 for portions of spreadsheet 100LUC.WK1 (File 15), FLAGS.WK1 (File 28), and FACTORS.WK1 (File 29), respectively.

Table 14. **Display of a portion of the land use and carbon data in spreadsheet 100LUC.WK1.**

"100"						
"BANGLADESH"	"Total"	1880.00	1920.00	1950.00	1970.00	1980.00
"Landuse(10^3 ha)"	"NET CULTIVATED AREA"	7191.02	7449.88	8373.98	8468.74	8418.78
" "	" Temporary crops"	6952.94	7186.37	8121.55	8215.76	8161.55
" "	" Permanent crops"	238.07	263.52	252.43	252.98	257.23
" "	"SETTLED/BUILT-UP"	307.14	405.85	492.22	824.18	982.43
" "	"FOREST/WOODLAND"	654.83	544.39	456.46	355.17	307.41
" "	"INTERRUPTED WOODS"	786.22	634.22	506.13	457.02	431.59
" "	"WETLANDS"	1739.20	1680.88	1290.17	1115.16	986.55
" "	" Forested wetlands"	930.05	816.03	638.35	545.53	510.82
" "	" Nonforested wetlands"	809.15	864.85	651.81	569.63	475.73

"	"	"GRASS/SHRUB COMPLEXES"	2824.63	2868.77	2505.64	2281.63	2348.51
"	"	"BARREN/SPARSELY VEGETATED"	193.83	216.43	237.24	267.72	294.35
"	"	"SURFACE WATER"	1100.15	996.59	935.18	1027.39	1027.39
"	"	"TOTAL LAND AREA"	14797.01	14797.01	14797.01	14797.01	14797.01
"	"	"TOTAL FOREST COVER"	2371.09	1994.64	1600.94	1357.72	1249.82
"	"	"TOTAL POPULATION"	24894.90	33434.29	41881.38	71341.81	86967.00
"	"	"TOTAL LIVESTOCK"	15494.54	21078.51	19028.42	35603.00	36073.31
"	"	"POPULATION PER HA"	1.68	2.26	2.83	4.82	5.88
"	"	"LIVESTOCK PER HA"	2.58	3.68	4.00	8.46	8.85
"Carbon (Mg C/ha)"		"NET CULTIVATED AREA"	5.31	5.33	5.28	5.28	5.29
"	"	" Temporary crops"	5.01	5.00	5.00	5.01	5.01
"	"	" Permanent crops"	14.13	14.26	14.26	14.05	14.04
"	"	"SETTLED/BUILT-UP"	3.57	3.61	3.64	3.61	3.17
"	"	"FOREST/WOODLAND"	108.03	96.73	79.78	57.63	50.17
"	"	"INTERRUPTED WOODS"	25.72	22.54	18.65	13.47	11.67
"	"	"WETLANDS"	34.01	28.43	25.09	18.81	17.77
"	"	" Forested wetlands"	56.73	52.36	45.33	34.64	30.99
"	"	" Nonforested wetlands"	7.89	5.85	5.26	3.65	3.58
"	"	"GRASS/SHRUB COMPLEXES"	4.32	3.80	4.09	3.39	3.23
"	"	"BARREN/SPARSELY VEGETATED"	0.97	0.83	0.79	0.63	0.63
"	"	"SURFACE WATER"	0.10	0.10	0.10	0.10	0.10
"Total C(10^3 Mg)"		"NET CULTIVATED AREA"	38189	39694	44238	44680	44494
"	"	" Temporary crops"	34824	35936	40638	41126	40881
"	"	" Permanent crops"	3365	3758	3599	3554	3613
"	"	"SETTLED/BUILT-UP"	1098	1466	1791	2976	3112
"	"	"FOREST/WOODLAND"	70738	52656	36415	20470	15424
"	"	"INTERRUPTED WOODS"	20225	14298	9442	6156	5036
"	"	"WETLANDS"	59142	47788	32368	20977	17533
"	"	" Forested wetlands"	52757	42730	28937	18898	15830
"	"	" Nonforested wetlands"	6385	5058	3431	2079	1703
"	"	"GRASS/SHRUB COMPLEXES"	12192	10914	10249	7729	7593
"	"	"BARREN/SPARSELY VEGETATED"	189	180	187	168	185
"	"	"SURFACE WATER"	110	100	94	103	103
"	"	"TOTAL C"	201883	167096	134784	103257	93478
"	"	"TOTAL C IN FOREST COVER"	143720	109684	74794	45523	36290

Table 15. Display of a portion of the data accuracy flags in spreadsheet FLAGS.WK1.

"101"						
"BANGLADESH"	"Chittagong Hill Tracts"	1880	1920	1950	1970	1980
" "	"Net Sown"	2	6	6	7	7
" "	"Non-Ag Landuse"	2	4	5	6	8
" "	"Population"	5	6	8	6	8
" "	"Livestock"	0	5	5	6	7

Table 16. Display of a portion of the M, E, D, and N data in spreadsheet FACTORS.WK1.

"101"								
"BANGLADESH"	"Chittagong Hill Tracts"	"M"	"E"	"D1880"	"D1920"	"D1950"	"D1970"	"D1980"
" "	"NET CULTIVATED AREA"	999.00	999.00	999.00	999.00	999.00	999.00	999.00
" "	" Temporary Crops"	4.80	1.00	1.00	1.00	1.00	1.00	1.00
" "	" Permanent Crops"	100.00	1.00	0.15	0.15	0.15	0.15	0.15
" "	"SETTLED/BUILT-UP"	4.00	1.00	1.00	1.00	1.00	1.00	1.00
" "	"FOREST/WOODLAND"	350.00	0.71	0.50	0.44	0.34	0.26	0.22
" "	"INTERRUPTED WOODS"	87.50	0.71	0.50	0.44	0.34	0.26	0.22
" "	"WETLANDS"	999.00	999.00	999.00	999.00	999.00	999.00	999.00
" "	" Forested Wetlands"	225.00	0.71	0.50	0.44	0.34	0.26	0.22
" "	" Nonforest Wetlands"	30.00	1.00	0.89	0.83	0.77	0.64	0.61
" "	"GRASS/SHRUB COMPLEXES"	12.00	1.00	0.89	0.83	0.77	0.64	0.61
" "	"BARREN/SPARSELY VEGETATED"	2.40	1.00	0.89	0.83	0.77	0.64	0.61
" "	"SURFACE WATER"	0.10	1.00	1.00	1.00	1.00	1.00	1.00
"2000-3000"	"Range/Mean Rainfall/N"	2500.00	999.00	10.00	9.00	9.00	8.00	8.00

ARC/INFO™ (Version 6.1) EXPORT FILES

Three ARC/INFO™ E00 export files are provided with this NDP to allow mapping of the land use and carbon data and comparisons to be made between this and other geographic data sets. These files contain the same data as File 2 (LANDCARB.ASC). The names of files 30, 31, and 32 are SEA_LAND.E00, SEA_TCHA.E00, and SEA_CARB.E00, respectively. Each file contains data for all 94 ecological zones that occur within the study region. File SEA_LAND contains land use data and human and livestock population data by year (all values are given in thousands). File SEA_TCHA contains the estimated carbon contents per ha for each of the eight land use class in Mg/ha by time period. File SEA_CARB contains the total carbon sequestered in live vegetation by land use class, zone, and time period in 10^3 Mg of carbon (i.e., this file is the product of SEA_LAND and SEA_TCHA).

The ARC/INFO™ E00 export files were produced using the EXPORT command with the NONE option in ARC/INFO™ Version 6.1. These files are in an uncompressed, fixed block format that can be moved across computer systems. The coverages are in a GEOGRAPHIC projection, a spherical reference system that locates positions using latitude and longitude coordinates that are stored in decimal degrees. As a result of this, the reference system in which the data are stored is not uniform in size or area.

After these files are loaded onto your system and imported into ARC/INFO™, data from any of the three coverages may be accessed directly (e.g., in INFO) or a RELATE may be created that links the coverages based on a common variable. If this is done we suggest that the "relate item" used be the zone identification number (variable ZONE). A listing of the variable names and data formats for these E00 files are depicted in Tables 17, 18, and 19. Variable names are similar to those used in LANDCARB.ASC (File 2), with the primary difference being that prefix letters have been dropped because the data in LANDCARB.ASC have been split into three E00 files, the numeric postfixes have also been replaced by the actual year they represent (e.g., the variable name LAG_ALL1 in LANDCARB.ASC has been replaced by AG_ALL_1880).

Table 17. Variable formats for SEA_LAND.E00 (File 30).

Start column	Item name	Data width	Display width	Data type*	Decimal places
1	AREA	4	12	F	3
5	PERIMETER	4	12	F	3
9	SEA_LAND	4	5	B	-
13	SEA_LAND-ID	4	5	B	-
17	CTRY	4	4	I	-
21	CTRY-NAME	20	20	C	-
41	ZONE	4	4	I	-
45	ZONE-NAME	26	26	C	-

Table 17. (Continued)

Start column	Item name	Data width	Display width	Data type	Decimal places
71	AG_ALL_1880	10	10	N	2
81	AG_ALL_1920	10	10	N	2
91	AG_ALL_1950	10	10	N	2
101	AG_ALL_1970	10	10	N	2
111	AG_ALL_1980	10	10	N	2
121	AG_TEMP_1880	10	10	N	2
131	AG_TEMP_1920	10	10	N	2
141	AG_TEMP_1950	10	10	N	2
151	AG_TEMP_1970	10	10	N	2
161	AG_TEMP_1980	10	10	N	2
171	AG_PERM_1880	10	10	N	2
181	AG_PERM_1920	10	10	N	2
191	AG_PERM_1950	10	10	N	2
201	AG_PERM_1970	10	10	N	2
211	AG_PERM_1980	10	10	N	2
221	SETTLED_1880	10	10	N	2
231	SETTLED_1920	10	10	N	2
241	SETTLED_1950	10	10	N	2
251	SETTLED_1970	10	10	N	2
261	SETTLED_1980	10	10	N	2
271	FOR_CON_1880	10	10	N	2
281	FOR_CON_1920	10	10	N	2
291	FOR_CON_1950	10	10	N	2
301	FOR_CON_1970	10	10	N	2
311	FOR_CON_1980	10	10	N	2
321	FOR_INT_1880	10	10	N	2
331	FOR_INT_1920	10	10	N	2
341	FOR_INT_1950	10	10	N	2
351	FOR_INT_1970	10	10	N	2
361	FOR_INT_1980	10	10	N	2
371	WET_ALL_1880	10	10	N	2
381	WET_ALL_1920	10	10	N	2
391	WET_ALL_1950	10	10	N	2
401	WET_ALL_1970	10	10	N	2
411	WET_ALL_1980	10	10	N	2
421	WET_FOR_1880	10	10	N	2
431	WET_FOR_1920	10	10	N	2
441	WET_FOR_1950	10	10	N	2
451	WET_FOR_1970	10	10	N	2
461	WET_FOR_1980	10	10	N	2

Table 17. (Continued)

Start column	Item name	Data width	Display width	Data type	Decimal places
471	WET_NON_1880	10	10	N	2
481	WET_NON_1920	10	10	N	2
491	WET_NON_1950	10	10	N	2
501	WET_NON_1970	10	10	N	2
511	WET_NON_1980	10	10	N	2
521	GRASS_1880	10	10	N	2
531	GRASS_1920	10	10	N	2
541	GRASS_1950	10	10	N	2
551	GRASS_1970	10	10	N	2
561	GRASS_1980	10	10	N	2
571	BARREN_1880	10	10	N	2
581	BARREN_1920	10	10	N	2
591	BARREN_1950	10	10	N	2
601	BARREN_1970	10	10	N	2
611	BARREN_1980	10	10	N	2
621	WATER_1880	10	10	N	2
631	WATER_1920	10	10	N	2
641	WATER_1950	10	10	N	2
651	WATER_1970	10	10	N	2
661	WATER_1980	10	10	N	2
671	TOT_LAND_1880	10	10	N	2
681	TOT_LAND_1920	10	10	N	2
691	TOT_LAND_1950	10	10	N	2
701	TOT_LAND_1970	10	10	N	2
711	TOT_LAND_1980	10	10	N	2
721	TOT_FOR_1880	10	10	N	2
731	TOT_FOR_1920	10	10	N	2
741	TOT_FOR_1950	10	10	N	2
751	TOT_FOR_1970	10	10	N	2
761	TOT_FOR_1980	10	10	N	2
771	TOT_HPOP_1880	10	10	N	2
781	TOT_HPOP_1920	10	10	N	2
791	TOT_HPOP_1950	10	10	N	2
801	TOT_HPOP_1970	10	10	N	2
811	TOT_HPOP_1980	10	10	N	2
821	TOT_LPOP_1880	10	10	N	2
831	TOT_LPOP_1920	10	10	N	2
841	TOT_LPOP_1950	10	10	N	2
851	TOT_LPOP_1970	10	10	N	2
861	TOT_LPOP_1980	10	10	N	2

Table 17. (Continued)

Start column	Item name	Data width	Display width	Data type	Decimal places
871	DEN_H_1880	10	10	N	2
881	DEN_H_1920	10	10	N	2
891	DEN_H_1950	10	10	N	2
901	DEN_H_1970	10	10	N	2
911	DEN_H_1980	10	10	N	2
921	DEN_L_1880	10	10	N	2
931	DEN_L_1920	10	10	N	2
941	DEN_L_1950	10	10	N	2
951	DEN_L_1970	10	10	N	2
961	DEN_L_1980	10	10	N	2

[a]Data types are B-binary, C-character, F-float, I-integer, and N-numeric. F and N data types are real numbers with different precisions (precision is system dependent).

Table 18. **Variable formats for SEA_TCHA.E00 (File 31).**

Start Column	Item Name	Data Width	Display Width	Data Type*	Decimal Places
1	AREA	4	12	F	3
5	PERIMETER	4	12	F	3
9	SEA_TCHA	4	5	B	-
13	SEA_TCHA-ID	4	5	B	-
17	CTRY	4	4	I	-
21	CTRY-NAME	20	20	C	-
41	ZONE	4	4	I	-
45	ZONE-NAME	26	26	C	-
71	AG_ALL_1880	10	10	N	2
81	AG_ALL_1920	10	10	N	2
91	AG_ALL_1950	10	10	N	2
101	AG_ALL_1970	10	10	N	2
111	AG_ALL_1980	10	10	N	2
121	AG_TEMP_1880	10	10	N	2
131	AG_TEMP_1920	10	10	N	2
141	AG_TEMP_1950	10	10	N	2
151	AG_TEMP_1970	10	10	N	2
161	AG_TEMP_1980	10	10	N	2
171	AG_PERM_1880	10	10	N	2
181	AG_PERM_1920	10	10	N	2
191	AG_PERM_1950	10	10	N	2
201	AG_PERM_1970	10	10	N	2
211	AG_PERM_1980	10	10	N	2
221	SETTLED_1880	10	10	N	2
231	SETTLED_1920	10	10	N	2
241	SETTLED_1950	10	10	N	2
251	SETTLED_1970	10	10	N	2
261	SETTLED_1980	10	10	N	2
271	FOR_CON_1880	10	10	N	2
281	FOR_CON_1920	10	10	N	2
291	FOR_CON_1950	10	10	N	2
301	FOR_CON_1970	10	10	N	2
311	FOR_CON_1980	10	10	N	2
321	FOR_INT_1880	10	10	N	2
331	FOR_INT_1920	10	10	N	2
341	FOR_INT_1950	10	10	N	2
351	FOR_INT_1970	10	10	N	2
361	FOR_INT_1980	10	10	N	2

Table 18. (Continued)

Start Column	Item Name	Data Width	Display Width	Data Type	Decimal Places
371	WET_ALL_1880	10	10	N	2
381	WET_ALL_1920	10	10	N	2
391	WET_ALL_1950	10	10	N	2
401	WET_ALL_1970	10	10	N	2
411	WET_ALL_1980	10	10	N	2
421	WET_FOR_1880	10	10	N	2
431	WET_FOR_1920	10	10	N	2
441	WET_FOR_1950	10	10	N	2
451	WET_FOR_1970	10	10	N	2
461	WET_FOR_1980	10	10	N	2
471	WET_NON_1880	10	10	N	2
481	WET_NON_1920	10	10	N	2
491	WET_NON_1950	10	10	N	2
501	WET_NON_1970	10	10	N	2
511	WET_NON_1980	10	10	N	2
521	GRASS_1880	10	10	N	2
531	GRASS_1920	10	10	N	2
541	GRASS_1950	10	10	N	2
551	GRASS_1970	10	10	N	2
561	GRASS_1980	10	10	N	2
571	BARREN_1880	10	10	N	2
581	BARREN_1920	10	10	N	2
591	BARREN_1950	10	10	N	2
601	BARREN_1970	10	10	N	2
611	BARREN_1980	10	10	N	2
621	WATER_1880	10	10	N	2
631	WATER_1920	10	10	N	2
641	WATER_1950	10	10	N	2
651	WATER_1970	10	10	N	2
661	WATER_1980	10	10	N	2

*Data types are B-binary, C-character, F-float, I-integer, and N-numeric. F and N data types are real numbers with different precisions (precision is system dependent).

Table 19. **Variable formats for SEA_CARB.E00 (File 32).**

Start Column	Item Name	Data Width	Display Width	Data Type*	Decimal Places
1	AREA	4	12	F	3
5	PERIMETER	4	12	F	3
9	SEA_CARB	4	5	B	-
13	SEA_CARB-ID	4	5	B	-
17	CTRY	4	4	I	-
21	CTRY-NAME	20	20	C	-
41	ZONE	4	4	I	-
45	ZONE-NAME	26	26	C	-
71	AG_ALL_1880	10	10	I	-
81	AG_ALL_1920	10	10	I	-
91	AG_ALL_1950	10	10	I	-
101	AG_ALL_1970	10	10	I	-
111	AG_ALL_1980	10	10	I	-
121	AG_TEMP_1880	10	10	I	-
131	AG_TEMP_1920	10	10	I	-
141	AG_TEMP_1950	10	10	I	-
151	AG_TEMP_1970	10	10	I	-
161	AG_TEMP_1980	10	10	I	-
171	AG_PERM_1880	10	10	I	-
181	AG_PERM_1920	10	10	I	-
191	AG_PERM_1950	10	10	I	-
201	AG_PERM_1970	10	10	I	-
211	AG_PERM_1980	10	10	I	-
221	SETTLED_1880	10	10	I	-
231	SETTLED_1920	10	10	I	-
241	SETTLED_1950	10	10	I	-
251	SETTLED_1970	10	10	I	-
261	SETTLED_1980	10	10	I	-
271	FOR_CON_1880	10	10	I	-
281	FOR_CON_1920	10	10	I	-
291	FOR_CON_1950	10	10	I	-
301	FOR_CON_1970	10	10	I	-
311	FOR_CON_1980	10	10	I	-
321	FOR_INT_1880	10	10	I	-
331	FOR_INT_1920	10	10	I	-
341	FOR_INT_1950	10	10	I	-
351	FOR_INT_1970	10	10	I	-
361	FOR_INT_1980	10	10	I	-

Table 19. (Continued)

Start Column	Item Name	Data Width	Display Width	Data Type	Decimal Places
371	WET_ALL_1880	10	10	I	-
381	WET_ALL_1920	10	10	I	-
391	WET_ALL_1950	10	10	I	-
401	WET_ALL_1970	10	10	I	-
411	WET_ALL_1980	10	10	I	-
421	WET_FOR_1880	10	10	I	-
431	WET_FOR_1920	10	10	I	-
441	WET_FOR_1950	10	10	I	-
451	WET_FOR_1970	10	10	I	-
461	WET_FOR_1980	10	10	I	-
471	WET_NON_1880	10	10	I	-
481	WET_NON_1920	10	10	I	-
491	WET_NON_1950	10	10	I	-
501	WET_NON_1970	10	10	I	-
511	WET_NON_1980	10	10	I	-
521	GRASS_1880	10	10	I	-
531	GRASS_1920	10	10	I	-
541	GRASS_1950	10	10	I	-
551	GRASS_1970	10	10	I	-
561	GRASS_1980	10	10	I	-
571	BARREN_1880	10	10	I	-
581	BARREN_1920	10	10	I	-
591	BARREN_1950	10	10	I	-
601	BARREN_1970	10	10	I	-
611	BARREN_1980	10	10	I	-
621	WATER_1880	10	10	I	-
631	WATER_1920	10	10	I	-
641	WATER_1950	10	10	I	-
651	WATER_1970	10	10	I	-
661	WATER_1980	10	10	I	-
671	TOT_LAND_1880	10	10	I	-
681	TOT_LAND_1920	10	10	I	-
691	TOT_LAND_1950	10	10	I	-
701	TOT_LAND_1970	10	10	I	-
711	TOT_LAND_1980	10	10	I	-

Table 19. (Continued)

Start Column	Item Name	Data Width	Display Width	Data Type	Decimal Places
721	TOT_FOR_1880	10	10	I	-
731	TOT_FOR_1920	10	10	I	-
741	TOT_FOR_1950	10	10	I	-
751	TOT_FOR_1970	10	10	I	-
761	TOT_FOR_1980	10	10	I	-

*Data types are B-binary, C-character, F-float, I-integer, and N-numeric. F and N data types are real numbers with different precisions (precision is system dependent).

15. LISTING OF THE FORTRAN DATA RETRIEVAL PROGRAMS

What follows is a listing of the four FORTRAN data retrieval programs provided by CDIAC with this data base. Each program is designed to read and write the contents of one or more of the five flat ASCII data files.

The first FORTRAN program (File 4 on the magnetic tape) is designed to read and print the file LANDCARB.ASC (File 2).

```
C***********************************************************
C* FORTRAN PROGRAM TO READ AND PRINT LANDCARB.ASC (FILE 2)*
C***********************************************************
      INTEGER I, ID, NLIN
      CHARACTER COUNTRY*20, ZONE*26
      REAL      XLAND(90), XMGCHA(60)
      INTEGER   CARB(70)

C***********************************************************
C*                OPEN FILES FOR INPUT/OUTPUT              *
C***********************************************************
      OPEN(UNIT=5,FILE='landcarb.asc',STATUS='OLD')
      OPEN(UNIT=6,FILE='print.out',STATUS='NEW')

C***********************************************************
C* READ AND PRINT THE LAND USE, MG C/HA, AND TOTAL CARBON *
C* DATA VARIABLES                                          *
C***********************************************************
 10   READ(5,100,END=999) ID, COUNTRY, ZONE
      READ(5,110) (XLAND(I),I=1,90), (XMGCHA(I),I=1,60),
     1              (CARB(I),I=1,65), (CARB(I),I=66,70)
      WRITE(6,120) ID, COUNTRY, ZONE
      DO 20 I=1,18
       NLIN=I*5
       WRITE(6,130) XLAND(NLIN-4), XLAND(NLIN-3),
     1         XLAND(NLIN-2), XLAND(NLIN-1), XLAND(NLIN)
 20   CONTINUE
      DO 30 I=1,12
       NLIN=I*5
       WRITE(6,130) XMGCHA(NLIN-4), XMGCHA(NLIN-3),
     1         XMGCHA(NLIN-2), XMGCHA(NLIN-1), XMGCHA(NLIN)
 30   CONTINUE
      DO 40 I=1,14
       NLIN=I*5
       WRITE(6,140) CARB(NLIN-4), CARB(NLIN-3),
     1         CARB(NLIN-2), CARB(NLIN-1), CARB(NLIN)
 40   CONTINUE
      GO TO 10
```

```
C
 100    FORMAT(I4,A20,A26)
 110    FORMAT(18(5F10.2,/),12(5F10.2,/),13(5I10,/),5I10)
 120    FORMAT(1X,'ID= ',I4,1X,A20,A26)
 130    FORMAT(1X,5F10.2)
 140    FORMAT(1X,5I10)
C***********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY                 *
C***********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

The second FORTRAN program (File 7 on the magnetic tape) is designed to read and print the file FLAGS.ASC (File 5).

```
C***********************************************************
C* FORTRAN PROGRAM TO READ AND PRINT FLAGS.ASC (FILE 5    )*
C***********************************************************
       INTEGER I, ID
       CHARACTER COUNTRY*20, ZONE*26
       INTEGER AG_FLG(5), NON_FLG(5), HP_FLG(5), LP_FLG(5)

C***********************************************************
C*               OPEN FILES FOR INPUT/OUTPUT                *
C***********************************************************
       OPEN(UNIT=5,FILE='flags.asc',STATUS='OLD')
       OPEN(UNIT=6,FILE='print.out',STATUS='NEW')

C***********************************************************
C* READ AND PRINT THE DATA ACCURACY FLAGS DEVELOPED FOR     *
C* LANDCARB.ASC (FILE 2)                                    *
C***********************************************************
  10   READ(5,100,END=999) ID, COUNTRY, ZONE
       READ(5,110) (AG_FLG(I),I=1,5), (NON_FLG(I),I=1,5),
     1             (HP_FLG(I),I=1,5), (LP_FLG(I),I=1,5)
       WRITE(6,120) ID, COUNTRY, ZONE
       WRITE(6,130) (AG_FLG(I),I=1,5), (NON_FLG(I),I=1,5),
     1              (HP_FLG(I),I=1,5), (LP_FLG(I),I=1,5)
  20   CONTINUE
       GO TO 10

C
 100   FORMAT(I4,A20,A26)
 110   FORMAT(3(5I10,/),5I10)
 120   FORMAT(1X,'ID= ',I4,1X,A20,A26)
 130   FORMAT(1X,3(5I10,/,1X),5I10)
```

```
C**********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY               *
C**********************************************************
 999   CLOSE(UNIT=5)
       CLOSE(UNIT=6)
       STOP
       END
```

The third FORTRAN program (File 10 on the magnetic tape) is designed to read and print the file FACTORS.ASC (File 8).

```
C**********************************************************
C* FORTRAN PROGRAM TO READ AND PRINT FACTORS.ASC (FILE 8) *
C**********************************************************
       INTEGER I, ID
       CHARACTER COUNTRY*20, ZONE*26, PRANGE*20
       REAL      AG_TMP(7), AG_PRM(7), SETTLE(7),
     1            FR_CON(7), FR_INT(7), WT_FOR(7),
     2            WT_NON(7), GRASS(7),  BARREN(7),
     3            WATER(7) , PMEAN, SPACE, N(3:7)

C**********************************************************
C*               OPEN FILES FOR INPUT/OUTPUT              *
C**********************************************************
       OPEN(UNIT=5,FILE='factors.asc',STATUS='OLD')
       OPEN(UNIT=6,FILE='print.out',STATUS='NEW')

C**********************************************************
C* READ AND PRINT THE M, E, D, N, AND MEAN AND RANGE FOR  *
C* PRECIPITATION. M, E, D, AND N WERE USED TO CALC THE    *
C* MG C/HA CONTAINED IN LANDCARB.ASC (FILE 2)             *
C**********************************************************
  10   READ(5,100,END=999) ID, COUNTRY, ZONE, PRANGE
       READ(5,110) (AG_TMP(I),I=1,7), (AG_PRM(I),I=1,7),
     1                  (SETTLE(I),I=1,7), (FR_CON(I),I=1,7),
     2             (FR_INT(I),I=1,7), (WT_FOR(I),I=1,7),
     3             (WT_NON(I),I=1,7), (GRASS(I), I=1,7),
     4             (BARREN(I),I=1,7), (WATER(I), I=1,7),
     5             PMEAN, SPACE, (N(I),I=3,7)
       WRITE(6,120) ID, COUNTRY, ZONE, PRANGE
       WRITE(6,130) (AG_TMP(I),I=1,7), (AG_PRM(I),I=1,7),
     1              (SETTLE(I),I=1,7), (FR_CON(I),I=1,7),
     2              (FR_INT(I),I=1,7), (WT_FOR(I),I=1,7),
     3              (WT_NON(I),I=1,7), (GRASS(I), I=1,7),
     4              (BARREN(I),I=1,7), (WATER(I), I=1,7),
     5              PMEAN, SPACE, (N(I),I=3,7)
  20   CONTINUE
       GO TO 10
```

```
C
 100    FORMAT(I4,A20,A26,A20)
 110    FORMAT(10(7F10.2,/),7F10.2)
 120    FORMAT(1X,'ID= ',I4,1X,A20,A26,/,1X,
     1          'Precip. Range= ',A20)
 130    FORMAT(1X,10(7F10.2,/,1X),7F10.2)
C***********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY                *
C***********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

The last FORTRAN program (File 14 on the magnetic tape) is designed to read and print the files SEA_CTRY.ASC (File 11) and SEA_ZONE.ASC (File 12).

```
C***********************************************************
C* FORTRAN PROGRAM TO READ AND PRINT SEA_ZONE.ASC AND      *
C* SEA_CTRY.ASC (FILES 11 AND 12 )                         *
C***********************************************************
       CHARACTER  ID*6, ALLNAME*7
       INTEGER I, NUM
       REAL  X , Y

C***********************************************************
C*                 OPEN FILES FOR INPUT/OUTPUT             *
C***********************************************************
C*     OPEN(UNIT=5,FILE='sea_ctry.asc',STATUS='OLD')       *
C***********************************************************
       OPEN(UNIT=5,FILE='sea_zone.asc',STATUS='OLD')
       OPEN(UNIT=6,FILE='print.out',STATUS='NEW')

C***********************************************************
C* READ AND PRINT LINE NAME AND NUMBER OF POINTS IN LINE   *
C***********************************************************
  10   READ (5,100,END=999) ID, NUM
       ALLNAME=ID//','
       WRITE(6,130)
       WRITE(6,110) ALLNAME,NUM
       WRITE(6,140)
C***********************************************************
C*      READ AND PRINT X,Y COORDINATES FOR THE LINE        *
C***********************************************************
       DO 20 I = 1,NUM
        READ (5,120) X, Y
        WRITE(6,125) X, ', ', Y
  20   CONTINUE
       GO TO 10
```

```
C
 100    FORMAT(A6,1X,I5)
 110    FORMAT(1X,A7,I6)
 120    FORMAT(F10.6,1X,F10.6)
 125    FORMAT(1X,F10.6,A2,F10.6)
 130    FORMAT(1X,'NAME   ,NUMBER')
 140    FORMAT(1X,'X            , Y')
C***********************************************************
C*           CLOSE FILES AND EXIT GRACEFULLY              *
C***********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

16. LISTING OF THE SAS™ DATA RETRIEVAL PROGRAMS

The following pages list the four SAS™ data retrieval programs provided by CDIAC with this data base. Each program is designed to read and write the contents of one or more of the five flat ASCII data files.

The first program (File 3 on the magnetic tape) is designed to read and print the file LANDCARB.ASC (File 2).

```
OPTIONS LINESIZE=77 PAGESIZE=68;
filename IN 'landcarb.asc';
DATA LANDCARB;
INFILE IN;
INPUT ID 1-4 COUNTRY $ 5-24 ZONE $ 25-50;
INPUT LAG_ALL1  1-10 LAG_ALL2 11-20 LAG_ALL3 21-30
      LAG_ALL4 31-40 LAG_ALL5 41-50;
INPUT LAG_TMP1  1-10 LAG_TMP2 11-20 LAG_TMP3 21-30
      LAG_TMP4 31-40 LAG_TMP5 41-50;
INPUT LAG_PRM1  1-10 LAG_PRM2 11-20 LAG_PRM3 21-30
      LAG_PRM4 31-40 LAG_PRM5 41-50;
INPUT LSETTLE1  1-10 LSETTLE2 11-20 LSETTLE3 21-30
      LSETTLE4 31-40 LSETTLE5 41-50;
INPUT LFR_CON1  1-10 LFR_CON2 11-20 LFR_CON3 21-30
      LFR_CON4 31-40 LFR_CON5 41-50;
INPUT LFR_INT1  1-10 LFR_INT2 11-20 LFR_INT3 21-30
      LFR_INT4 31-40 LFR_INT5 41-50;
INPUT LWT_ALL1  1-10 LWT_ALL2 11-20 LWT_ALL3 21-30
      LWT_ALL4 31-40 LWT_ALL5 41-50;
INPUT LWT_FOR1  1-10 LWT_FOR2 11-20 LWT_FOR3 21-30
      LWT_FOR4 31-40 LWT_FOR5 41-50;
INPUT LWT_NON1  1-10 LWT_NON2 11-20 LWT_NON3 21-30
      LWT_NON4 31-40 LWT_NON5 41-50;
INPUT LGRASS1   1-10 LGRASS2  11-20 LGRASS3  21-30
      LGRASS4  31-40 LGRASS5  41-50;
INPUT LBARREN1  1-10 LBARREN2 11-20 LBARREN3 21-30
      LBARREN4 31-40 LBARREN5 41-50;
INPUT LWATER1   1-10 LWATER2  11-20 LWATER3  21-30
      LWATER4  31-40 LWATER5  41-50;
INPUT LTOT_LA1  1-10 LTOT_LA2 11-20 LTOT_LA3 21-30
      LTOT_LA4 31-40 LTOT_LA5 41-50;
INPUT LTOT_FR1  1-10 LTOT_FR2 11-20 LTOT_FR3 21-30
      LTOT_FR4 31-40 LTOT_FR5 41-50;
INPUT LTOT_HP1  1-10 LTOT_HP2 11-20 LTOT_HP3 21-30
      LTOT_HP4 31-40 LTOT_HP5 41-50;
INPUT LTOT_LP1  1-10 LTOT_LP2 11-20 LTOT_LP3 21-30
      LTOT_LP4 31-40 LTOT_LP5 41-50;
INPUT LDEN_H1   1-10 LDEN_H2  11-20 LDEN_H3  21-30
      LDEN_H4  31-40 LDEN_H5  41-50;
INPUT LDEN_L1   1-10 LDEN_L2  11-20 LDEN_L3  21-30
      LDEN_L4  31-40 LDEN_L5  41-50;
```

```
INPUT TAG_ALL1  1-10 TAG_ALL2 11-20 TAG_ALL3 21-30
      TAG_ALL4 31-40 TAG_ALL5 41-50;
INPUT TAG_TMP1  1-10 TAG_TMP2 11-20 TAG_TMP3 21-30
      TAG_TMP4 31-40 TAG_TMP5 41-50;
INPUT TAG_PRM1  1-10 TAG_PRM2 11-20 TAG_PRM3 21-30
      TAG_PRM4 31-40 TAG_PRM5 41-50;
INPUT TSETTLE1  1-10 TSETTLE2 11-20 TSETTLE3 21-30
      TSETTLE4 31-40 TSETTLE5 41-50;
INPUT TFR_CON1  1-10 TFR_CON2 11-20 TFR_CON3 21-30
      TFR_CON4 31-40 TFR_CON5 41-50;
INPUT TFR_INT1  1-10 TFR_INT2 11-20 TFR_INT3 21-30
      TFR_INT4 31-40 TFR_INT5 41-50;
INPUT TWT_ALL1  1-10 TWT_ALL2 11-20 TWT_ALL3 21-30
      TWT_ALL4 31-40 TWT_ALL5 41-50;
INPUT TWT_FOR1  1-10 TWT_FOR2 11-20 TWT_FOR3 21-30
      TWT_FOR4 31-40 TWT_FOR5 41-50;
INPUT TWT_NON1  1-10 TWT_NON2 11-20 TWT_NON3 21-30
      TWT_NON4 31-40 TWT_NON5 41-50;
INPUT TGRASS1   1-10 TGRASS2  11-20 TGRASS3  21-30
      TGRASS4  31-40 TGRASS5  41-50;
INPUT TBARREN1  1-10 TBARREN2 11-20 TBARREN3 21-30
      TBARREN4 31-40 TBARREN5 41-50;
INPUT TWATER1   1-10 TWATER2  11-20 TWATER3  21-30
      TWATER4  31-40 TWATER5  41-50;
INPUT CAG_ALL1  1-10 CAG_ALL2 11-20 CAG_ALL3 21-30
      CAG_ALL4 31-40 CAG_ALL5 41-50;
INPUT CAG_TMP1  1-10 CAG_TMP2 11-20 CAG_TMP3 21-30
      CAG_TMP4 31-40 CAG_TMP5 41-50;
INPUT CAG_PRM1  1-10 CAG_PRM2 11-20 CAG_PRM3 21-30
      CAG_PRM4 31-40 CAG_PRM5 41-50;
INPUT CSETTLE1  1-10 CSETTLE2 11-20 CSETTLE3 21-30
      CSETTLE4 31-40 CSETTLE5 41-50;
INPUT CFR_CON1  1-10 CFR_CON2 11-20 CFR_CON3 21-30
      CFR_CON4 31-40 CFR_CON5 41-50;
INPUT CFR_INT1  1-10 CFR_INT2 11-20 CFR_INT3 21-30
      CFR_INT4 31-40 CFR_INT5 41-50;
INPUT CWT_ALL1  1-10 CWT_ALL2 11-20 CWT_ALL3 21-30
      CWT_ALL4 31-40 CWT_ALL5 41-50;
INPUT CWT_FOR1  1-10 CWT_FOR2 11-20 CWT_FOR3 21-30
      CWT_FOR4 31-40 CWT_FOR5 41-50;
INPUT CWT_NON1  1-10 CWT_NON2 11-20 CWT_NON3 21-30
      CWT_NON4 31-40 CWT_NON5 41-50;
INPUT CGRASS1   1-10 CGRASS2  11-20 CGRASS3  21-30
      CGRASS4  31-40 CGRASS5  41-50;
INPUT CBARREN1  1-10 CBARREN2 11-20 CBARREN3 21-30
      CBARREN4 31-40 CBARREN5 41-50;
INPUT CWATER1   1-10 CWATER2  11-20 CWATER3  21-30
      CWATER4  31-40 CWATER5  41-50;
INPUT CTOT_LA1  1-10 CTOT_LA2 11-20 CTOT_LA3 21-30
      CTOT_LA4 31-40 CTOT_LA5 41-50;
```

```
INPUT CTOT_FR1  1-10 CTOT_FR2 11-20 CTOT_FR3 21-30
      CTOT_FR4 31-40 CTOT_FR5 41-50;
PROC PRINT;
RUN;
```

The second SAS™ program (File 6 on the magnetic tape) is designed to read and print the file FLAGS.ASC (File 5).

```
OPTIONS LINESIZE=77 PAGESIZE=68;
filename IN 'flags.asc';
DATA FLAGS;
INFILE IN;
INPUT ID 1-4 COUNTRY $ 5-24 ZONE $ 25-50;
INPUT AG_FLG1   1-10 AG_FLG2  11-20 AG_FLG3  21-30
      AG_FLG4  31-40 AG_FLG5  41-50;
INPUT NON_FLG1  1-10 NON_FLG2 11-20 NON_FLG3 21-30
      NON_FLG4 31-40 NON_FLG5 41-50;
INPUT HP_FLG1   1-10 HP_FLG2  11-20 HP_FLG3  21-30
      HP_FLG4  31-40 HP_FLG5  41-50;
INPUT LP_FLG1   1-10 LP_FLG2  11-20 LP_FLG3  21-30
      LP_FLG4  31-40 LP_FLG5  41-50;
PROC PRINT;
RUN;
```

The third SAS™ program (File 9 on the magnetic tape) is designed to read and print the file FACTORS.ASC (File 8).

```
OPTIONS LINESIZE=77 PAGESIZE=68;
filename IN 'factors.asc';
DATA FACTORS;
INFILE IN;
INPUT ID 1-6 COUNTRY $ 5-24 ZONE $ 25-50 PRANGE $ 51-70;
INPUT AG_TMP1  1-10 AG_TMP2 11-20 AG_TMP3 21-30 AG_TMP4 31-40
      AG_TMP5 41-50 AG_TMP6 51-60 AG_TMP7 61-70;
INPUT AG_PRM1  1-10 AG_PRM2 11-20 AG_PRM3 21-30 AG_PRM4 31-40
      AG_PRM5 41-50 AG_PRM6 51-60 AG_PRM7 61-70;
INPUT SETTLE1  1-10 SETTLE2 11-20 SETTLE3 21-30 SETTLE4 31-40
      SETTLE5 41-50 SETTLE6 51-60 SETTLE7 61-70;
INPUT FR_CON1  1-10 FR_CON2 11-20 FR_CON3 21-30 FR_CON4 31-40
      FR_CON5 41-50 FR_CON6 51-60 FR_CON7 61-70;
INPUT FR_INT1  1-10 FR_INT2 11-20 FR_INT3 21-30 FR_INT4 31-40
      FR_INT5 41-50 FR_INT6 51-60 FR_INT7 61-70;
INPUT WT_FOR1  1-10 WT_FOR2 11-20 WT_FOR3 21-30 WT_FOR4 31-40
      WT_FOR5 41-50 WT_FOR6 51-60 WT_FOR7 61-70;
```

```
INPUT WT_NON1  1-10 WT_NON2 11-20 WT_NON3 21-30 WT_NON4 31-40
      WT_NON5 41-50 WT_NON6 51-60 WT_NON7 61-70;
INPUT GRASS1  1-10 GRASS2 11-20 GRASS3 21-30 GRASS4 31-40
      GRASS5 41-50 GRASS6 51-60 GRASS7 61-70;
INPUT BARREN1  1-10 BARREN2 11-20 BARREN3 21-30 BARREN4 31-40
      BARREN5 41-50 BARREN6 51-60 BARREN7 61-70;
INPUT WATER1  1-10 WATER2 11-20 WATER3 21-30 WATER4 31-40
      WATER5 41-50 WATER6 51-60 WATER7 61-70;
INPUT PMEAN   1-10 SPACE  11-20 N3     21-30 N4     31-40
      N5     41-50 N6     51-60 N7     61-70;
PROC PRINT;
RUN;
```

The last SAS™ program (File 13 on the magnetic tape) is designed to read and print the files SEA_CTRY.ASC (File 11), or SEA_ZONE.ASC (File 12) with modification.

```
OPTIONS LINESIZE=77 PAGESIZE=68;
filename IN 'sea_ctry.asc';
DATA SEA_MAP;
FILE PRINT;
INFILE IN;
INPUT NAME $ 1-6 COMMA $ 7  NUM 8-12;
PUT 'NAME    ,  NUMBER OF POINTS';
PUT NAME $ COMMA $ NUM;
LENGTH DEFAULT=4;
PUT 'X          , Y';
DO I = 1 TO NUM;
   INPUT X 1-10 COMMA $ 11 Y 12-21;
   PUT X COMMA $ Y;
   END;
RUN;
```

17. PARTIAL LISTINGS OF THE FLAT ASCII DATA FILES

What follows is a sample listing of the first 15 lines in each of the flat ASCII data files provided with this data base.

Sample listing of LANDCARB.ASC (File 2).

```
100          "BANGLADESH"                          "Total"
   7191.02    7449.88    8373.98    8468.74    8418.78
   6952.94    7186.37    8121.55    8215.76    8161.55
    238.07     263.52     252.43     252.98     257.23
    307.14     405.85     492.22     824.18     982.43
    654.83     544.39     456.46     355.17     307.41
    786.22     634.22     506.13     457.02     431.59
   1739.20    1680.88    1290.17    1115.16     986.55
    930.05     816.03     638.35     545.53     510.82
    809.15     864.85     651.81     569.63     475.73
   2824.63    2868.77    2505.64    2281.63    2348.51
    193.83     216.43     237.24     267.72     294.35
   1100.15     996.59     935.18    1027.39    1027.39
  14797.01   14797.01   14797.01   14797.01   14797.01
   2371.09    1994.64    1600.94    1357.72    1249.82
```

Sample listing of FLAGS.ASC (File 5).

```
101          "BANGLADESH"  "Chittagong Hill Tracts"
          2          6          6          7          7
          2          4          5          6          8
          5          6          8          6          8
          0          5          5          6          7
102          "BANGLADESH"          "Eastern Coast"
          4          7          7          8          8
          4          4          6          6          7
          7          8          8          6          8
          2          5          5          6          7
103          "BANGLADESH"       "Meghna Districts"
          4          7          7          8          9
          4          5          6          6          7
          7          8          8          6          8
          2          5          5          6          7
```

Sample listing of FACTORS.ASC (File 8).

```
101          "BANGLADESH"  "Chittagong Hill Tracts"           "2000-3000"
    4.80       1.00       1.00       1.00       1.00       1.00       1.00
  100.00       1.00       0.15       0.15       0.15       0.15       0.15
    4.00       1.00       1.00       1.00       1.00       1.00       1.00
  350.00       0.71       0.50       0.44       0.34       0.26       0.22
   87.50       0.71       0.50       0.44       0.34       0.26       0.22
  225.00       0.71       0.50       0.44       0.34       0.26       0.22
   30.00       1.00       0.89       0.83       0.77       0.64       0.61
   12.00       1.00       0.89       0.83       0.77       0.64       0.61
    2.40       1.00       0.89       0.83       0.77       0.64       0.61
    0.10       1.00       1.00       1.00       1.00       1.00       1.00
 2500.00     999.00      10.00       9.00       9.00       8.00       8.00
102          "BANGLADESH"          "Eastern Coast"            "2800-3500"
    5.00       1.00       1.00       1.00       1.00       1.00       1.00
  100.00       1.00       0.15       0.15       0.15       0.15       0.15
```

Sample listing of SEA_CTRY.ASC (File 11).

```
" 300", 3363
 73.851997, 30.079775
 73.890816, 30.114367
 73.927193, 30.142658
 73.967690, 30.167334
 74.010643, 30.191696
 73.963776, 30.214712
 73.959106, 30.280006
 73.921059, 30.307379
 73.886314, 30.338505
 73.886917, 30.372524
 73.915848, 30.407366
 73.946342, 30.440830
 73.979813, 30.471676
 73.977806, 30.533745
```

Sample listing of SEA_ZONE.ASC (File 12).

```
" 310",  487
 75.384109, 32.220661
 75.380653, 32.304546
 75.333771, 32.321987
 75.292931, 32.346195
 75.257011, 32.375904
 75.225777, 32.410862
 75.158730, 32.405712
 75.121193, 32.433640
 75.077171, 32.454288
 75.023506, 32.465755
 74.994484, 32.430923
 74.953201, 32.455288
 74.892960, 32.457699
 74.861343, 32.492290
```

18. VERIFICATION OF DATA TRANSPORT: FLAT ASCII DATA FILES

After the flat ASCII data files have been loaded onto your system, verify that the files have not been corrupted during transport. To do this, some or all of the characteristics presented in the following tables should be checked by using operating system commands (e.g., ls -l). This information is presented as a tool to ensure proper reading of the flat ASCII data files.

Table 20. File characteristics of the five flat ASCII data files provided with this numeric data package.

File name	File contents	File number	File size (bytes)	File length (lines)
LANDCARB.ASC	Land use, Mg C/ha, total carbon, and population estimates for all 94 zones and 13 countries	2	283,500	4,725
FLAGS.ASC	Accuracy flags for the land use and population data for all 94 zones	5	28,200	470
FACTORS.ASC	Listing of the M, E, D, and N factors used in calculating the Mg C/ha for each land use class for all 94 zones	8	90,240	1,128
SEA_CTRY.ASC	Country boundaries	11	636,420	21,214
SEA_ZONE.ASC	Ecological zone boundaries	12	1,038,570	34,619

19. VERIFICATION OF DATA TRANSPORT: LOTUS 1-2-3™ SPREADSHEET FILES

After the Lotus 1-2-3™ WK1 files have been loaded onto your system, verify that the files have not been corrupted during transport. To do this, the size of the files should be checked by using operating system commands (e.g., ls -l), and after loading the data into Lotus 1-2-3™, the total number of rows in each spreadsheet should be compared with those presented in Table 21. If the file sizes differ from those presented by > 1 byte or the number of rows in the spreadsheet do not match, the file may have been corrupted in transport.

Table 21. **File characteristics of the 90 Lotus 1-2-3™ WK1 spreadsheets provided with this numeric data package.**

File name	File contents	File number	File size (bytes)	File length (rows)
100LUC.WK1	Land use, Mg C/ha, total carbon, and population estimates for Bangladesh (total) and all zones	15	53,700	276
200LUC.WK1	Brunei	16	9,600	46
300LUC.WK1	India	17	233,500	1288
400LUC.WK1	Indonesia	18	192,900	966
500LUC.WK1	Kampuchea	19	43,400	230
600LUC.WK1	Laos	20	52,000	276
700LUC.WK1	Malaysia	21	67,200	368
800LUC.WK1	Myanmar	22	60,300	322
900LUC.WK1	Philippines	23	43,800	230
1000LUC.WK1	Singapore	24	9,600	46
1100LUC.WK1	Sri Lanka	25	27,200	138
1200LUC.WK1	Thailand	26	43,800	230

Table 21. (Continued)

File name	File contents	File number	File size (bytes)	File length (rows)
1300LUC.WK1	Vietnam	27	74,100	322
FLAGS.WK1	Accuracy flags for the land use and population data	28	51,200	564
FACTORS.WK1	Listing of the M, E, D, and N factors used in calculating the Mg C/ha for each land use class	29	209,800	1410

THE FOLLOWING WK1 FILES CONTAIN EXPLANATORY AND DOCUMENTATION INFORMATION ON THE DATA SOURCES AND PROCEDURES USED TO OBTAIN THE LAND USE DATA CONTAINED IN FILES 2, 15-27, AND 30-32. FOR A DESCRIPTION OF THE CONTENTS OF THESE FILES REFER TO APPENDIX D.

D101S.WK1	Bangladesh	33	34,100	
D102S.WK1	"	34	97,800	
D103S.WK1	"	35	167,400	
D104S.WK1	"	36	99,700	
D105S.WK1	"	37	301,700	
D101L.WK1	"	38	89,200	
D102L.WK1	"	39	80,900	
D103L.WK1	"	40	83,900	
D104L.WK1	"	41	84,100	
D105L.WK1	"	42	78,900	
D200A.WK1	Brunei	43	32,700	
D300T.WK1	India	44	6,500	
D301S.WK1	"	45	21,300	
D302S.WK1	"	46	21,700	
D303S.WK1	"	47	18,200	
D304S.WK1	"	48	17,800	
D305S.WK1	"	49	17,400	
D306S.WK1	"	50	19,700	
D307P1S.WK1	"	51	18,900	
D307P2S.WK1	"	52	20,900	
D307T.WK1	"	53	8,900	
D308P1S.WK1	"	54	19,500	

Table 21. (Continued)

File name	File contents	File number	File size (bytes)
D308P2S.WK1	India (Continued)	55	19,600
D308T.WK1	"	56	9,100
D309S.WK1	"	57	18,000
D310S.WK1	"	58	23,600
D311S.WK1	"	59	23,700
D312S.WK1	"	60	20,400
D313S.WK1	"	61	17,800
D314S.WK1	"	62	20,700
D315P1S.WK1	"	63	19,200
D315P2S.WK1	"	64	21,100
D315T.WK1	"	65	8,900
D316S.WK1	"	66	17,500
D317S.WK1	"	67	17,900
D318S.WK1	"	68	17,800
D319S.WK1	"	69	17,500
D320S.WK1	"	70	23,100
D321S.WK1	"	71	23,000
D322S.WK1	"	72	22,000
D323S.WK1	"	73	13,900
D324P1S.WK1	"	74	17,400
D324P2S.WK1	"	75	21,900
D324T.WK1	"	76	9,100
D325S.WK1	"	77	17,500
D326S.WK1	"	78	16,700
D327S.WK1	"	79	18,500
D400HP.WK1	Indonesia	80	23,400
D400LP.WK1	"	81	41,700
D401-7S.WK1	"	82	110,300
D408-10S.WK1	"	83	53,700
D411-14S.WK1	"	84	128,000
D415-18S.WK1	"	85	133,000
D419-20S.WK1	"	86	76,000
D421-22S.WK1	"	87	59,600
D500S.WK1	Kampuchea	88	35,800
D500L.WK1	"	89	64,900
D600S.WK1	Laos	90	37,600
D600L.WK1	"	91	71,000

Table 21. (Continued)

File name	File contents	File number	File size (bytes)
D701-3A.WK1	Malaysia	92	67,400
D704-6A.WK1	"	93	34,800
D707A.WK1	"	94	17,000
D801A.WK1	Myanmar	95	142,100
D802A.WK1	"	96	148,500
D803A.WK1	"	97	145,700
D804A.WK1	"	98	235,200
D805A.WK1	"	99	199,600
D806A.WK1	"	100	145,600
D900S.WK1	Philippines	101	68,400
D900L.WK1	"	102	71,100
D1000A.WK1	Singapore	103	29,700
D1100A.WK1	Sri Lanka	104	46,800
D1200A.WK1	Thailand	105	39,600
D1300S.WK1	Vietnam	106	41,100
D1300L.WK1	"	107	83,400

20. VERIFICATION OF DATA TRANSPORT: ARC/INFO™ EXPORT FILES

The three ARC/INFO™ export files provided with this NDP were created in ARC/INFO™, Version 6.1, using the EXPORT command with the COVER and NONE options. Each export file contains an entire coverage and its associated INFO data files in a fixed-length, uncompressed format.

The exported coverages are in a GEOGRAPHIC projection, which is a spherical reference system that locates positions by using latitude and longitude coordinates that are stored in decimal degrees. As a result of this, the reference grids in which the data are stored are not uniform in size or area. The source maps from which these coverages were obtained varied widely in scale and detail. National boundaries were obtained at a scale of 1:2,000,000, while internal zone boundaries were obtained from several different publications (with scales varying from 1:1,000,000 to 1:20,000,000). To reduce edge matching problems that occurred when these data sources were combined, the zone and nation boundaries were smoothed (in ARC/INFO™) to a nominal map scale of 1:4,000,000 with a minimum resolution of one point per 4 km.

After loading the ARC/INFO™ export files onto a system, the user should verify that the files have been correctly transported. To verify the integrity of the files, the size of the export files and (after importing the data into ARC/INFO™) the total number of INFO data records in each coverage should be compared with those presented in Table 22. If the file sizes differ from those presented by > 1 byte or the number of INFO data records do not match those shown in Table 22, the coverage may have been corrupted in transport. Importation of the ARC/INFO™ E00 files into the user's ARC/INFO™ system can be accomplished by using the IMPORT command with the COVER option. The IMPORT command will automatically recognize that the export file is in an uncompressed format (files should be EXTERNALED after being imported [e.g., ARC> external SEA_ZONE]).

Table 22. File characteristics of the three ARC/INFO™ E00 export files provided with this numeric data package.

Export file name	File number	File size (bytes)	File size (blocks*)	ARC/INFO™ data type	Number of ARC/INFO™ records
SEA_LAND.E00	30	1,449,200	2,831	PAT	347
SEA_TCHA.E00	31	1,299,280	2,538	PAT	347
SEA_CARB.E00	32	1,242,640	2,428	PAT	347

*one block equals 512 bytes.

APPENDIX A

PRINTOUTS OF THE STEP 2 (LAND USE) LOTUS 1-2-3™ SPREADSHEETS FOR 13 COUNTRIES (TOTALS)

PRINTOUTS OF THE STEP 2 (LAND USE) LOTUS 1-2-3™ SPREADSHEETS FOR 13 COUNTRIES (TOTALS)

What follows is a listing of the land use change spreadsheets compiled for each country. The data were obtained by aggregating the data values from all ecological zones located within the given country. These data, along with the data for each of the 94 ecological zones, are contained within the digital data files included with this NDP. Data values are in thousands of hectares, with the first two lines in each country listing containing the country identification code (zone code), country name, zone name (i.e., "Total"), and a listing of the years for which data was obtained.

100						
BANGLADESH	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	7191	7450	8374	8469	8419
	Temporary crops	6953	7186	8122	8216	8162
	Permanent crops	238	264	252	253	257
	SETTLED/BUILT-UP	307	406	492	824	982
	FOREST/WOODLAND	655	544	456	355	307
	INTERRUPTED WOODS	786	634	506	457	432
	WETLANDS	1739	1681	1290	1115	987
	Forested wetlands	930	816	638	546	511
	Nonforested wetlands	809	865	652	570	476
	GRASS/SHRUB COMPLEXES	2825	2869	2506	2282	2349
	BARREN/SPARSELY VEGETATED	194	216	237	268	294
	SURFACE WATER	1100	997	935	1027	1027
	TOTAL LAND AREA	14797	14797	14797	14797	14797
	TOTAL FOREST COVER	2371	1995	1601	1358	1250
	TOTAL POPULATION	24895	33434	41881	71342	86967
	TOTAL LIVESTOCK	15495	21079	19028	35603	36073
200						
BRUNEI	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	3	7	17	15	9
	Temporary crops	2	2	5	5	3
	Permanent crops	1	4	12	10	6
	SETTLED/BUILT-UP	2	2	4	11	16
	FOREST/WOODLAND	229	225	213	205	193
	INTERRUPTED WOODS	127	124	118	119	128
	WETLANDS	143	141	134	143	130
	Forested wetlands	143	141	134	143	130
	Nonforested wetlands	0	0	0	0	0
	GRASS/SHRUB COMPLEXES	20	24	37	30	47
	BARREN/SPARSELY VEGETATED	3	3	3	3	3
	SURFACE WATER	50	50	50	50	50
	TOTAL LAND AREA	577	577	577	577	577
	TOTAL FOREST COVER	499	490	465	467	451
	TOTAL POPULATION	20	25	48	130	185
	TOTAL LIVESTOCK	6	7	14	32	33

300

INDIA	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	100809	106753	123234	140886	142444
	Temporary crops	96119	101891	117468	135878	137483
	Permanent crops	4734	4919	5841	5008	5057
	SETTLED/BUILT-UP	3742	4317	5981	8162	10080
	FOREST/WOODLAND	65071	58971	51352	44498	39227
	INTERRUPTED WOODS	35228	33746	29664	28590	24335
	WETLANDS	6346	5833	4912	4393	4057
	Forested wetlands	2383	2076	1522	1217	1030
	Nonforested wetlands	3963	3757	3390	3176	3027
	GRASS/SHRUB COMPLEXES	63698	66566	62877	54498	60528
	BARREN/SPARSELY VEGETATED	36159	34858	33055	30060	30349
	SURFACE WATER	8649	8659	8630	8646	8683
	TOTAL LAND AREA	319703	319703	319703	319703	319703
	TOTAL FOREST COVER	102682	94793	82537	74305	64591
	TOTAL POPULATION	225439	251647	356884	536125	670037
	TOTAL LIVESTOCK	184319	212395	282591	342718	377025

400

INDONESIA	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	5471	11891	16561	22237	29346
	Temporary crops	4629	9647	12504	15642	19120
	Permanent crops	842	2244	4057	6634	10226
	SETTLED/BUILT-UP	165	363	622	989	1294
	FOREST/WOODLAND	112258	107208	99438	90946	84008
	INTERRUPTED WOODS	17514	15563	18236	15321	15219
	WETLANDS	29647	28424	26428	24639	22778
	Forested wetlands	29473	28252	26259	24475	22616
	Nonforested wetlands	174	172	169	164	162
	GRASS/SHRUB COMPLEXES	22351	23774	25762	32723	34026
	BARREN/SPARSELY VEGETATED	1905	2088	2265	2456	2640
	SURFACE WATER	3494	3494	3494	3494	3494
	TOTAL LAND AREA	192805	192805	192805	192805	192805
	TOTAL FOREST COVER	159245	151023	143932	130743	121843
	TOTAL POPULATION	26009	50100	78369	117365	147400
	TOTAL LIVESTOCK	8246	11190	18518	25470	28899

500

KAMPUCHEA	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	459	697	1651	2412	1608
	Temporary crops	442	672	1576	2261	1462
	Permanent crops	17	25	75	152	146
	SETTLED/BUILT-UP	17	26	43	69	63
	FOREST/WOODLAND	9467	9305	8653	7355	6763
	INTERRUPTED WOODS	4640	4517	4293	4695	5480
	WETLANDS	1280	1204	902	690	657
	Forested wetlands	721	678	498	398	388
	Nonforested wetlands	559	525	404	292	269
	GRASS/SHRUB COMPLEXES	1698	1794	1965	2268	2900
	BARREN/SPARSELY VEGETATED	91	109	145	163	181
	SURFACE WATER	452	452	452	452	452
	TOTAL LAND AREA	18104	18104	18104	18104	18104
	TOTAL FOREST COVER	14829	14500	13444	12447	12631
	TOTAL POPULATION	1685	2562	4289	6938	6302
	TOTAL LIVESTOCK	1329	2020	1630	4314	1819

		1880	1920	1950	1970	1980
600						
LAOS	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	345	479	815	1180	1350
	Temporary crops	342	475	807	1170	1338
	Permanent crops	3	5	8	10	12
	SETTLED/BUILT-UP	11	16	25	35	42
	FOREST/WOODLAND	16576	15656	14208	13651	12295
	INTERRUPTED WOODS	3602	4262	4967	5159	5600
	WETLANDS	222	210	191	183	165
	Forested wetlands	36	34	31	29	26
	Nonforested wetlands	187	176	160	154	139
	GRASS/SHRUB COMPLEXES	2665	2775	3145	3119	3852
	BARREN/SPARSELY VEGETATED	118	142	189	213	237
	SURFACE WATER	140	140	140	140	140
	TOTAL LAND AREA	23680	23680	23680	23680	23680
	TOTAL FOREST COVER	20213	19952	19206	18839	17921
	TOTAL POPULATION	860	1195	1949	2716	3206
	TOTAL LIVESTOCK	578	803	514	2516	2065
700						
MALAYSIA	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	511	1716	2609	3767	4530
	Temporary crops	243	379	606	719	842
	Permanent crops	268	1337	2003	3048	3688
	SETTLED/BUILT-UP	26	67	109	190	272
	FOREST/WOODLAND	23504	21469	19584	17627	15770
	INTERRUPTED WOODS	2553	3519	4699	6138	7616
	WETLANDS	4634	4166	3835	3448	2805
	Forested wetlands	4634	4166	3835	3448	2805
	Nonforested wetlands	0	0	0	0	0
	GRASS/SHRUB COMPLEXES	1177	1468	1571	1239	1313
	BARREN/SPARSELY VEGETATED	247	247	246	245	347
	SURFACE WATER	346	346	346	346	346
	TOTAL LAND AREA	32998	32998	32998	32998	32998
	TOTAL FOREST COVER	32098	30561	29451	28780	27853
	TOTAL POPULATION	1458	3614	5805	10078	13195
	TOTAL LIVESTOCK	463	1155	1321	1985	2769
800						
MYANMAR	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	2974	6418	6145	7723	8309
	Temporary crops	2880	6173	5834	7384	7960
	Permanent crops	94	245	311	338	350
	SETTLED/BUILT-UP	184	342	508	765	906
	FOREST/WOODLAND	27415	23152	20880	19332	18204
	INTERRUPTED WOODS	22256	20375	19878	19458	18948
	WETLANDS	2783	1944	1562	1360	1205
	Forested wetlands	2067	1409	1106	959	821
	Nonforested wetlands	717	534	456	400	384
	GRASS/SHRUB COMPLEXES	9666	13028	16232	16538	17590
	BARREN/SPARSELY VEGETATED	824	844	898	926	940
	SURFACE WATER	1555	1555	1555	1555	1555
	TOTAL LAND AREA	67658	67658	67658	67658	67658
	TOTAL FOREST COVER	51738	44936	41863	39750	37973
	TOTAL POPULATION	7591	13198	18785	28237	35037
	TOTAL LIVESTOCK	2869	6928	8353	10933	15392

		1880	1920	1950	1970	1980
900						
PHILIPPINES	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	2010	3494	4745	6437	9725
	Temporary crops	1335	2321	3233	3892	5683
	Permanent crops	675	1173	1512	2546	4042
	SETTLED/BUILT-UP	105	187	355	640	844
	FOREST/WOODLAND	17538	16120	14276	9933	7902
	INTERRUPTED WOODS	2962	2723	1599	3581	2161
	WETLANDS	681	613	613	503	356
	Forested wetlands	500	450	401	288	241
	Nonforested wetlands	181	163	212	215	115
	GRASS/SHRUB COMPLEXES	6274	6413	7943	8353	8431
	BARREN/SPARSELY VEGETATED	318	338	358	378	398
	SURFACE WATER	112	112	112	175	183
	TOTAL LAND AREA	30000	30000	30000	30000	30000
	TOTAL FOREST COVER	21000	19293	16276	13802	10304
	TOTAL POPULATION	6000	10750	20335	36684	48098
	TOTAL LIVESTOCK	3545	6352	7088	13632	13977
1000						
SINGAPORE	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	31	30	17	17	11
	Temporary crops	2	1	3	6	5
	Permanent crops	29	24	14	11	6
	SETTLED/BUILT-UP	1	4	10	19	28
	FOREST/WOODLAND	6	6	1	3	3
	INTERRUPTED WOODS	6	6	3	1	3
	WETLANDS	6	5	5	3	3
	Forested wetlands	6	4	4	2	2
	Nonforested wetlands	1	0	0	1	1
	GRASS/SHRUB COMPLEXES	7	7	22	16	14
	BARREN/SPARSELY VEGETATED	0	0	0	0	0
	SURFACE WATER	4	4	4	3	2
	TOTAL LAND AREA	62	62	62	62	62
	TOTAL FOREST COVER	18	16	8	5	8
	TOTAL POPULATION	139	431	1022	2075	2414
	TOTAL LIVESTOCK	64	197	119	1008	1203
1100						
SRI LANKA	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	679	1133	1462	1979	2147
	Temporary crops	283	388	425	895	1025
	Permanent crops	395	744	1038	1084	1122
	SETTLED/BUILT-UP	7	11	20	32	90
	FOREST/WOODLAND	3703	3474	3170	2011	1680
	INTERRUPTED WOODS	1174	945	746	1169	866
	WETLANDS	70	64	58	55	53
	Forested wetlands	14	13	12	11	11
	Nonforested wetlands	56	51	46	44	42
	GRASS/SHRUB COMPLEXES	688	690	858	1051	1455
	BARREN/SPARSELY VEGETATED	37	41	46	62	68
	SURFACE WATER	202	202	202	202	202
	TOTAL LAND AREA	6561	6561	6561	6561	6561
	TOTAL FOREST COVER	4892	4432	3927	3190	2556
	TOTAL POPULATION	2760	4498	7678	12690	14847
	TOTAL LIVESTOCK	1100	1874	2233	3025	3079

1200						
THAILAND	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	1632	3595	8035	12671	17989
	Temporary crops	1507	3283	7211	10824	15891
	Permanent crops	125	312	824	1847	1900
	SETTLED/BUILT-UP	108	159	410	590	804
	FOREST/WOODLAND	24757	22850	19449	16665	13998
	INTERRUPTED WOODS	11614	10431	9463	9858	10252
	WETLANDS	3823	2689	1976	1310	599
	Forested wetlands	2221	1422	1107	699	309
	Nonforested wetlands	1603	1267	869	611	289
	GRASS/SHRUB COMPLEXES	8130	10262	10546	8656	6028
	BARREN/SPARSELY VEGETATED	852	930	1036	1166	1245
	SURFACE WATER	397	397	397	397	397
	TOTAL LAND AREA	51312	51312	51312	51312	51312
	TOTAL FOREST COVER	38591	34702	30019	27222	24560
	TOTAL POPULATION	6200	9178	18313	34397	46961
	TOTAL LIVESTOCK	3922	6018	15754	15793	15839
1300						
VIETNAM	Total	1880	1920	1950	1970	1980
Landuse(10^3 ha)	NET CULTIVATED AREA	2640	5306	4370	5676	6728
	Temporary crops	2494	5013	4073	5131	6268
	Permanent crops	146	294	297	545	460
	SETTLED/BUILT-UP	115	239	443	646	829
	FOREST/WOODLAND	16087	14474	12852	11042	9997
	INTERRUPTED WOODS	7131	5427	5509	5034	4558
	WETLANDS	2250	1071	797	685	465
	Forested wetlands	1798	795	493	353	181
	Nonforested wetlands	452	276	304	332	284
	GRASS/SHRUB COMPLEXES	3994	5632	8079	8867	9309
	BARREN/SPARSELY VEGETATED	332	398	498	597	663
	SURFACE WATER	620	620	620	620	620
	TOTAL LAND AREA	33169	33169	33169	33169	33169
	TOTAL FOREST COVER	25016	20696	18855	16429	14735
	TOTAL POPULATION	7432	15487	28681	41864	53722
	TOTAL LIVESTOCK	1564	3260	2619	13423	13345

APPENDIX B

LISTING OF THE FACTORS (S, F, AND A) USED IN CALCULATING THE DEGRADATION (D) MULTIPLIER

LISTING OF THE FACTORS (S, F, AND A) USED IN CALCULATING THE DEGRADATION (D) MULTIPLIER

The S, F, and A factors were used by the primary investigators to estimate N, where S represents the degree to which the agricultural system of a zone is dominated by shifting versus sedentary cultivation; F represents the degree to which a zone is a net exporter or importer of forest products; and A represents the degree to which a zone is a net exporter or importer of agricultural products. (See Sect. 8.2.5 for a description of the methods used in determining S, F, and A). The calculated N (N = S x F x A) values were used in conjunction with the human population density data (in people per ha) to calculate the degradation (D) multiplier for the forested/woodland, interrupted woods, and forested wetland land use classes. The maximum potential biomass (M) was then multiplied by the environmental limitation (E), and D factors to obtain the mean carbon content per ha (in Mg) for the woody land use classes, and each zone and year. These carbon estimates were then multiplied by the land use data to obtain the total carbon estimates for each year and ecological zone.

The values assigned to each of the three factors was highly subjective. Due to this, the factors have not been provided in a digital file. These factors are listed by zone in this appendix to assist the user in understanding how the S, F, and A factors determined N, and influenced D. The factors in this list have been rounded to the nearest tenth. Because of this, the N values shown here may vary slightly from those contained in the flat ASCII data file FACTORS.ASC (File 8).

Zone name	Zone code	Year	S	F	A	N
BANGLADESH						
Chittagong Hill Tracts	101	1880	10.0	1.0	1.0	10.0
		1920	9.0	1.0	1.0	9.0
		1950	7.5	1.2	1.0	9.0
		1970	6.0	1.3	1.0	7.8
		1980	6.0	1.3	1.0	7.8
Eastern Coast	102	1880	1.0	1.0	1.0	1.0
		1920	1.0	1.0	0.8	0.8
		1950	1.0	1.0	0.8	0.8
		1970	1.0	1.0	0.8	0.8
		1980	1.0	1.0	0.8	0.8
Meghna Districts	103	1880	1.1	1.1	0.8	1.0
		1920	1.0	1.0	0.8	0.8
		1950	1.0	1.0	0.7	0.7
		1970	1.0	0.9	0.7	0.6
		1980	1.0	0.9	0.7	0.6

Zone name	Zone code	Year	S	F	A	N
Sundarbans	104	1880	1.0	1.5	0.8	1.2
		1920	1.0	1.3	0.8	1.0
		1950	1.0	1.3	0.8	1.0
		1970	1.0	1.2	0.8	1.0
		1980	1.0	1.1	0.8	0.9
Western Districts	105	1880	1.0	1.0	1.0	1.0
		1920	1.0	1.0	1.0	1.0
		1950	1.0	1.0	1.0	1.0
		1970	1.0	0.9	0.9	0.8
		1980	1.0	0.9	0.9	0.8
BRUNEI						
Total	201	1880	8.0	1.0	1.0	8.0
		1920	6.0	1.3	1.0	8.0
		1950	4.0	1.5	1.0	6.0
		1970	3.0	1.0	1.0	3.0
		1980	2.0	1.0	1.0	2.0
INDIA						
Andaman/Nicobar Islands	301	1880	10.0	2.0	0.5	10.0
		1920	10.0	2.0	0.5	10.0
		1950	10.0	2.0	0.5	10.0
		1970	6.0	2.0	0.5	6.0
		1980	6.0	2.0	0.5	6.0
Andhra Pradesh	302	1880	1.5	0.8	0.9	1.0
		1920	1.5	0.8	0.9	1.0
		1950	1.2	0.8	0.9	0.8
		1970	1.0	0.8	0.9	0.7
		1980	1.0	0.7	0.9	0.6
Arunachal Pradesh	303	1880	10.0	1.0	1.0	10.0
		1920	9.0	1.0	1.0	9.0
		1950	7.5	1.0	1.0	7.5
		1970	6.0	1.0	1.0	6.0
		1980	5.0	1.5	1.0	7.5
Assam	304	1880	1.5	1.5	1.5	3.4
		1920	1.5	1.3	1.5	2.9
		1950	1.3	1.3	1.3	1.7
		1970	1.2	1.2	1.1	1.6
		1980	1.2	1.2	1.0	1.4

Zone name	Zone code	Year	S	F	A	N
Bihar	305	1880	1.0	1.0	1.0	1.0
		1920	1.0	1.0	1.0	1.0
		1950	1.0	1.0	1.0	1.0
		1970	1.0	1.0	1.0	1.0
		1980	1.0	1.0	1.0	1.0
Delhi	306	1880	1.0	0.8	0.9	0.7
		1920	1.0	0.8	0.9	0.7
		1950	1.0	0.6	0.5	0.3
		1970	1.0	0.5	0.4	0.2
		1980	1.0	0.5	0.4	0.2
Gujarat/Dadra/Nagar Haveli	307	1880	1.0	1.0	1.0	1.0
		1920	1.0	1.0	1.0	1.0
		1950	1.0	1.0	1.0	1.0
		1970	1.0	1.0	1.0	1.0
		1980	1.0	1.0	1.0	1.0
Haryana/Chandigarh	308	1880	1.0	0.9	1.4	1.3
		1920	1.0	0.9	1.4	1.3
		1950	1.0	0.9	1.4	1.3
		1970	1.0	0.8	1.5	1.2
		1980	1.0	0.7	1.5	1.0
Himachal Pradesh	309	1880	1.0	1.8	1.0	1.8
		1920	1.0	1.8	1.0	1.8
		1950	1.0	1.8	1.0	1.8
		1970	1.0	1.6	1.0	1.6
		1980	1.0	1.6	1.0	1.6
Jammu/Kashmir	310	1880	1.0	1.5	0.7	1.0
		1920	1.0	1.5	0.7	1.0
		1950	1.0	1.5	0.7	1.0
		1970	1.0	1.5	0.7	1.0
		1980	1.0	1.5	0.7	1.0
Karnataka	311	1880	1.0	1.2	1.0	1.2
		1920	1.0	1.2	1.0	1.2
		1950	1.0	1.0	1.0	1.0
		1970	1.0	1.0	1.0	1.0
		1980	1.0	1.0	1.0	1.0

Zone name	Zone code	Year	S	F	A	N
Kerala	312	1880	1.0	0.8	0.7	0.6
		1920	1.0	0.8	0.7	0.6
		1950	1.0	0.8	0.6	0.5
		1970	1.0	0.8	0.6	0.5
		1980	1.0	0.8	0.6	0.5
Lakshadweep Islands	313	1880	1.0	0.5	0.4	0.2
		1920	1.0	0.5	0.4	0.2
		1950	1.0	0.5	0.4	0.2
		1970	1.0	0.5	0.4	0.2
		1980	1.0	0.5	0.4	0.2
Madhya Pradesh	314	1880	2.0	1.3	1.0	2.6
		1920	2.0	1.3	1.0	2.6
		1950	1.8	1.3	1.0	2.3
		1970	1.5	1.1	1.0	1.7
		1980	1.5	1.1	1.0	1.7
Maharashtra/Goa/Daman/Diu	315	1880	1.0	1.0	1.0	1.0
		1920	1.0	1.0	1.0	1.0
		1950	1.0	1.0	1.0	1.0
		1970	1.0	1.0	1.0	1.0
		1980	1.0	1.0	1.0	1.0
Manipur	316	1880	6.0	2.0	1.0	12.0
		1920	5.0	2.0	1.0	10.0
		1950	5.0	1.3	1.0	6.5
		1970	4.0	1.2	1.0	4.8
		1980	4.0	1.2	1.0	4.8
Meghalaya	317	1880	7.5	1.0	1.0	7.5
		1920	6.0	1.0	1.0	6.0
		1950	5.5	1.0	1.0	5.5
		1970	4.5	1.0	1.0	4.5
		1980	4.0	1.0	1.0	4.0
Mizoram	318	1880	10.0	1.0	1.0	10.0
		1920	10.0	1.0	1.0	10.0
		1950	10.0	1.0	1.0	10.0
		1970	8.0	1.0	1.0	8.0
		1980	6.0	1.3	1.0	7.8

Zone name	Zone code	Year	S	F	A	N
Nagaland	319	1880	10.0	1.0	1.0	10.0
		1920	10.0	1.0	1.0	10.0
		1950	10.0	1.0	1.0	10.0
		1970	6.0	1.0	1.0	6.0
		1980	5.0	1.0	1.0	5.0
Orissa	320	1880	2.0	1.3	1.0	2.6
		1920	1.5	1.3	1.0	2.0
		1950	1.3	1.3	1.0	1.7
		1970	1.3	1.2	1.0	1.6
		1980	1.2	1.0	1.0	1.2
Punjab	321	1880	1.0	0.8	1.3	1.0
		1920	1.0	0.8	1.3	1.0
		1950	1.0	0.8	1.3	1.0
		1970	1.0	0.7	1.5	1.0
		1980	1.0	0.5	2.0	1.0
Rajasthan	322	1880	1.0	1.0	1.0	1.0
		1920	1.0	1.0	1.0	1.0
		1950	1.0	1.0	1.0	1.0
		1970	1.0	1.0	1.0	1.0
		1980	1.0	1.0	1.0	1.0
Sikkim	323	1880	2.0	2.5	1.5	7.5
		1920	1.3	2.0	1.0	2.6
		1950	1.0	2.0	1.0	2.0
		1970	1.0	2.0	1.0	2.0
		1980	1.0	2.0	1.0	2.0
Tamil Nadu/Pondichery	324	1880	1.0	0.9	0.9	0.8
		1920	1.0	0.9	0.9	0.8
		1950	1.0	0.9	0.9	0.8
		1970	1.0	0.8	0.8	0.6
		1980	1.0	0.8	0.8	0.6
Tripura	325	1880	8.0	1.3	1.0	10.4
		1920	5.0	1.0	1.0	5.0
		1950	4.0	1.0	1.0	4.0
		1970	2.0	1.0	1.0	2.0
		1980	1.5	1.3	1.0	2.0

Zone name	Zone code	Year	S	F	A	N
Uttar Pradesh	326	1880	1.0	0.9	0.9	0.8
		1920	1.0	0.9	0.9	0.8
		1950	1.0	0.9	0.8	0.7
		1970	1.0	0.8	0.6	0.5
		1980	1.0	0.8	0.6	0.5
West Bengal	327	1880	1.0	0.9	0.9	0.8
		1920	1.0	0.9	0.9	0.8
		1950	1.0	0.8	0.8	0.6
		1970	1.0	0.7	0.6	0.4
		1980	1.0	0.7	0.6	0.4

Note: Most logging in India is limited to mountain areas (Himalayas or Western Ghats). Some states which export timber to other states are not shown as net exporters because their internal fuelwood demand is much greater than their roundwood output. Most "export" of wood products in Indian zones is to other Indian zones. On the whole, India has not been a net exporter of wood during the 1880-1980 period.

Note: Some values of N have been rounded to nearest integer or 0.5 when transferred to carbon calculation spreadsheets.

Zone name	Zone code	Year	S	F	A	N
INDONESIA						
Aceh	401	1880	7.5	1.0	1.0	7.5
		1920	5.0	1.0	1.0	5.0
		1950	4.0	1.3	1.0	5.2
		1970	3.0	1.7	1.0	5.1
		1980	3.0	1.7	1.0	5.1
North Sumatra	402	1880	3.0	1.0	1.3	3.9
		1920	2.5	1.0	1.2	3.0
		1950	1.5	1.0	1.7	2.5
		1970	1.2	1.0	1.9	2.3
		1980	1.0	1.0	2.0	2.0
West Sumatra	403	1880	3.0	1.0	1.3	3.9
		1920	2.5	1.0	1.2	3.0
		1950	1.5	1.0	1.7	2.5
		1970	1.2	1.0	1.9	2.3
		1980	1.0	1.0	2.0	2.0

Zone name	Zone code	Year	S	F	A	N
Riau	404	1880	8.0	1.3	1.0	10.4
		1920	8.0	1.3	1.0	10.4
		1950	5.0	1.2	1.0	6.0
		1970	3.0	1.3	1.0	3.9
		1980	3.0	1.3	1.0	3.9
Jambi	405	1880	8.0	1.0	1.0	8.0
		1920	6.0	1.0	1.0	6.0
		1950	4.0	1.3	1.0	5.2
		1970	3.0	1.3	1.0	3.9
		1980	3.0	1.3	1.0	3.9
South Sumatra	406	1880	8.0	1.3	1.0	10.4
		1920	5.0	1.5	1.0	7.5
		1950	4.0	1.3	1.0	5.2
		1970	3.0	1.3	1.3	5.0
		1980	3.0	1.3	1.3	5.0
Bengkulu/Lampung	407	1880	8.0	1.3	1.0	10.4
		1920	4.0	1.5	1.0	6.0
		1950	3.0	1.3	1.0	3.9
		1970	2.0	1.3	1.0	2.6
		1980	1.5	1.3	1.0	2.0
West Java	408	1880	1.5	0.8	0.8	1.0
		1920	1.0	0.8	0.8	0.6
		1950	1.0	0.7	0.7	0.5
		1970	1.0	0.7	0.6	0.4
		1980	1.0	0.7	0.6	0.4
Central Java	409	1880	1.0	0.8	0.8	0.6
		1920	1.0	0.7	0.7	0.5
		1950	1.0	0.7	0.7	0.5
		1970	1.0	0.7	0.6	0.4
		1980	1.0	0.7	0.6	0.4
East Java	410	1880	1.0	0.9	0.9	0.8
		1920	1.0	0.8	0.8	0.6
		1950	1.0	0.7	0.7	0.5
		1970	1.0	0.7	0.6	0.4
		1980	1.0	0.7	0.6	0.4

Zone name	Zone code	Year	S	F	A	N
Bali	411	1880	1.2	1.0	1.0	1.2
		1920	1.0	1.0	1.0	1.0
		1950	1.0	0.9	0.9	0.8
		1970	1.0	0.8	0.8	0.6
		1980	1.0	0.7	0.7	0.5
West Nusa Tenggara	412	1880	3.0	1.0	1.0	3.0
		1920	2.0	1.0	1.0	2.0
		1950	1.8	1.0	1.0	1.8
		1970	1.5	1.0	1.0	1.5
		1980	1.5	1.0	1.0	1.5
East Nusa Tenggara	413	1880	5.0	1.0	1.0	5.0
		1920	4.0	1.0	1.0	4.0
		1950	3.0	1.0	1.0	3.0
		1970	3.0	1.0	1.0	3.0
		1980	3.0	1.0	1.0	3.0
East Timor	414	1880	4.0	1.0	1.0	4.0
		1920	4.0	1.0	1.0	4.0
		1950	4.0	1.0	1.0	4.0
		1970	4.0	1.0	1.0	4.0
		1980	4.0	1.3	1.0	5.2
West Kalimantan	415	1880	10.0	1.5	1.0	15.0
		1920	10.0	1.5	1.0	15.0
		1950	7.5	2.0	1.0	15.0
		1970	6.0	2.0	1.0	12.0
		1980	6.0	2.0	1.0	12.0
Central Kalimantan	416	1880	10.0	2.0	1.0	20.0
		1920	10.0	2.0	1.0	20.0
		1950	10.0	2.0	1.0	20.0
		1970	8.0	2.5	1.0	20.0
		1980	8.0	2.5	1.0	20.0
East Kalimantan*	417	1880	10.0	2.0	1.0	20.0
		1920	10.0	2.0	1.0	20.0
		1950	10.0	2.0	1.0	20.0
		1970	10.0	2.0	1.0	20.0
		1980	8.0	2.5	1.0	20.0

Zone name	Zone code	Year	S	F	A	N
South Kalimantan	418	1880	4.0	1.3	1.0	5.2
		1920	4.0	1.3	1.0	5.2
		1950	3.5	1.3	1.0	4.5
		1970	3.0	1.3	1.0	3.9
		1980	3.0	1.3	1.0	3.9
North/Central Sulawesi	419	1880	10.0	1.0	1.0	10.0
		1920	8.0	1.0	1.0	8.0
		1950	5.0	1.2	1.0	6.0
		1970	4.0	1.3	1.0	5.2
		1980	3.5	1.3	1.0	4.5
South/Southeast Sulawesi	420	1880	8.0	1.0	1.0	8.0
		1920	5.0	1.0	1.0	5.0
		1950	3.0	1.3	1.0	3.9
		1970	2.4	1.3	1.0	3.1
		1980	2.0	1.5	1.0	3.0
Maluku	421	1880	9.0	1.3	1.3	15.2
		1920	9.0	1.3	1.3	15.2
		1950	6.0	1.5	1.3	11.7
		1970	5.0	2.0	1.0	10.0
		1980	5.0	2.0	1.0	10.0
Irian Jaya	422	1880	10.0	1.5	1.0	15.0
		1920	10.0	1.5	1.0	15.0
		1950	10.0	1.2	1.0	12.0
		1970	10.0	1.2	1.0	12.0
		1980	10.0	1.2	1.0	12.0

Note: Some values of N have been rounded to nearest integer or 0.5 when transferred to carbon calculation spreadsheets.

Note: Values of S, F, and A initially chosen generated a set of N values which did not correspond optimally with carbon content estimates generated from provincial forest volume data. Some S, F, and A values were adjusted to generate a set of N values consistent with biomass extrapolations from provincial data.

Note: Irian Jaya did not export forest products during this period, but F has been artifically increased to account for extra loss of forest biomass associated with the agricultural practices required to maintain locally dense populations at high elevations for long periods of time.

Zone name	Zone code	Year	S	F	A	N
KAMPUCHEA (Cambodia)						
Northwestern Region	501	1880	5.0	1.0	1.0	5.0
		1920	5.0	1.0	1.0	5.0
		1950	3.0	1.0	1.0	3.0
		1970	2.0	1.0	1.0	2.0
		1980	3.0	1.0	1.0	3.0
Northeast Region	502	1880	8.0	1.5	1.0	12.0
		1920	8.0	1.5	1.0	12.0
		1950	3.0	1.2	1.0	3.6
		1970	2.7	1.2	1.0	3.2
		1980	3.0	1.3	1.0	3.9
Southeast Lowlands	503	1880	1.5	1.0	1.0	1.5
		1920	1.3	1.0	1.0	1.3
		1950	1.3	1.0	1.0	1.3
		1970	1.0	1.0	1.0	1.0
		1980	1.0	1.2	1.0	1.2
Southwest Highlands	504	1880	5.0	1.0	1.0	5.0
		1920	5.0	1.0	1.0	5.0
		1950	3.6	1.0	1.0	3.6
		1970	2.8	1.0	1.0	2.8
		1980	3.6	1.0	1.0	3.6

Note: Some values of N have been rounded to nearest integer when transferred to carbon calculation spreadsheets.

LAOS						
Northwestern Laos	601	1880	10.0	1.0	1.0	10.0
		1920	10.0	1.0	1.0	10.0
		1950	10.0	1.0	1.0	10.0
		1970	10.0	1.0	1.0	10.0
		1980	8.0	1.3	1.0	10.4
Louang Phrabang	602	1880	8.0	1.6	1.0	12.8
		1920	8.0	1.6	1.0	12.8
		1950	7.0	1.6	1.0	11.2
		1970	7.0	1.6	1.0	11.2
		1980	7.0	1.6	1.0	11.2

Zone name	Zone code	Year	S	F	A	N
Central Laos	603	1880	7.5	2.0	1.0	15.0
		1920	6.0	2.0	1.0	12.0
		1950	5.0	2.0	1.0	10.0
		1970	4.0	2.0	1.0	8.0
		1980	4.0	2.0	1.0	8.0
Annamite Chain	604	1880	10.0	1.0	1.0	10.0
		1920	10.0	1.0	1.0	10.0
		1950	10.0	1.0	1.0	10.0
		1970	8.0	1.0	1.0	8.0
		1980	8.0	1.1	1.0	8.8
Champasak	605	1880	5.0	1.0	1.0	5.0
		1920	4.0	1.0	1.0	4.0
		1950	4.0	1.0	1.0	4.0
		1970	4.0	1.0	1.0	4.0
		1980	4.0	1.1	1.0	4.4

Note: Some values of N have been rounded to nearest integer or 0.5 when transferred to carbon calculation spreadsheets.

MALAYSIA						
Western Peninsular Malaysia	701	1880	1.5	2.0	1.0	3.0
		1920	1.0	2.0	1.0	2.0
		1950	1.0	1.5	1.0	1.5
		1970	1.0	1.2	1.3	1.6
		1980	1.0	1.0	1.5	1.5
Eastern Peninsular Malaysia	702	1880	3.0	1.3	1.0	3.9
		1920	2.0	1.8	1.0	3.6
		1950	1.5	1.8	1.2	3.2
		1970	1.0	2.0	1.5	3.0
		1980	1.0	1.5	2.0	3.0
Johore	703	1880	1.5	2.0	1.0	3.0
		1920	1.0	2.0	1.0	2.0
		1950	1.0	1.5	1.0	1.5
		1970	1.0	1.5	1.0	1.5
		1980	1.0	1.0	1.0	1.0

Zone name	Zone code	Year	S	F	A	N
Western Sarawak	704	1880	8.0	1.0	1.0	8.0
		1920	8.0	1.0	1.0	8.0
		1950	6.0	1.3	1.0	7.8
		1970	4.0	2.0	1.0	8.0
		1980	4.0	2.0	1.0	8.0
Central Sarawak	705	1880	10.0	1.0	1.0	10.0
		1920	10.0	1.0	1.0	10.0
		1950	10.0	1.2	1.0	12.0
		1970	8.0	1.5	1.0	12.0
		1980	7.5	2.0	1.0	15.0
Eastern Sarawak	706	1880	10.0	1.0	1.0	10.0
		1920	10.0	1.0	1.0	10.0
		1950	8.0	1.6	1.0	12.8
		1970	6.0	2.5	1.0	15.0
		1980	6.0	2.5	1.0	15.0
Sabah	707	1880	8.0	1.5	1.0	12.0
		1920	6.0	1.7	1.0	10.2
		1950	4.3	3.0	1.0	12.9
		1970	4.0	3.0	1.0	12.0
		1980	4.0	3.0	1.0	12.0

Note: Some values of N have been rounded to nearest integer or 0.5 when transferred to carbon calculation spreadsheets.

Zone name	Zone code	Year	S	F	A	N
MYANMAR (Burma)						
Chin/Arakan States	801	1880	9.0	1.7	1.0	15.3
		1920	8.0	1.5	1.0	12.0
		1950	6.0	1.5	1.0	9.0
		1970	6.0	1.5	1.0	9.0
		1980	6.0	1.5	1.0	9.0
Northern Myanmar	802	1880	8.0	1.8	1.3	18.7
		1920	8.0	1.5	1.3	15.6
		1950	6.0	2.0	1.3	15.6
		1970	4.0	2.0	1.5	12.0
		1980	4.0	2.0	1.5	12.0

Zone name	Zone code	Year	S	F	A	N
Dry Zone	803	1880	6.0	1.0	1.0	6.0
		1920	5.0	1.0	1.0	5.0
		1950	4.5	1.0	1.0	4.5
		1970	4.0	1.0	1.0	4.0
		1980	4.0	1.0	1.0	4.0
Shan/Karen/Kayah	804	1880	7.0	2.0	1.0	14.0
		1920	6.0	2.0	1.0	12.0
		1950	6.0	2.0	1.0	12.0
		1970	4.5	2.0	1.0	9.0
		1980	4.5	2.0	1.0	9.0
Delta	805	1880	2.0	2.3	1.0	4.6
		1920	1.3	2.0	1.2	3.1
		1950	1.0	2.0	1.2	2.4
		1970	1.0	2.0	1.2	2.4
		1980	1.0	2.0	1.0	2.0
Peninsular	806	1880	8.0	2.5	1.0	20.0
		1920	4.5	2.0	1.0	9.0
		1950	3.5	2.0	1.0	7.0
		1970	3.0	1.8	1.0	5.4
		1980	3.0	1.7	1.0	5.1

Note: Some values of N have been rounded to nearest integer or 0.5 when transferred to carbon calculation spreadsheets.

PHILIPPINES						
Luzon	901	1880	3.0	1.3	0.8	3.1
		1920	2.0	1.3	0.8	2.1
		1950	2.0	1.3	0.8	2.1
		1970	1.5	1.5	0.8	1.8
		1980	1.5	1.5	0.8	1.8
Palawan	902	1880	8.0	1.0	1.0	8.0
		1920	7.0	1.0	1.0	7.0
		1950	7.0	1.0	1.0	7.0
		1970	5.0	1.2	1.0	6.0
		1980	3.0	1.7	1.0	5.1

Zone name	Zone code	Year	S	F	A	N
Visayas	903	1880	3.0	1.3	0.8	3.1
		1920	2.0	1.3	0.8	2.1
		1950	1.5	1.5	0.8	1.8
		1970	1.5	1.5	0.8	1.8
		1980	1.5	1.5	0.8	1.8
Mindanao	904	1880	4.0	1.3	1.0	5.2
		1920	3.0	1.3	1.0	3.9
		1950	1.5	1.5	0.9	2.0
		1970	1.3	1.5	0.8	1.6
		1980	1.2	1.5	0.8	1.4

Note: These estimates were revised after the mean forest biomass values calculated for 1980 were compared with independent forest biomass estimates by S. Brown and colleagues from national inventory data. (Initial estimates of S, F, and A generated values of N which were not compatible with the inventory-based biomass data.)

Zone name	Zone code	Year	S	F	A	N
SINGAPORE						
Total	1001	1880	2.0	0.5	0.5	0.5
		1920	1.2	0.5	0.5	0.3
		1950	1.0	0.5	0.3	0.2
		1970	1.0	0.3	0.3	0.1
		1980	1.0	0.3	0.3	0.1
SRI LANKA						
Wet Zone	1101	1880	1.5	1.0	0.7	1.0
		1920	1.3	1.0	0.6	0.8
		1950	1.2	0.9	0.6	0.6
		1970	1.1	0.8	0.5	0.4
		1980	1.1	0.8	0.5	0.4
Dry Zone	1102	1880	7.0	0.9	0.8	5.0
		1920	5.5	0.9	0.8	4.0
		1950	4.0	0.9	0.7	2.5
		1970	3.5	0.8	0.7	2.0
		1980	3.0	0.8	0.6	1.4

Note: These estimates were revised after the mean forest biomass values calculated for 1980 were compared with independent forest biomass estimates by S. Brown and colleagues from national inventory data. (Initial estimates of S, F, and A generated values of N which were not compatible with the inventory-based biomass data.)

Zone name	Zone code	Year	S	F	A	N
THAILAND						
Northern Region	1201	1880	5.0	2.0	1.2	12.0
		1920	4.0	2.0	1.3	10.4
		1950	3.5	1.8	1.3	8.9
		1970	3.0	1.8	1.3	7.0
		1980	3.0	1.8	1.3	7.0
Northeastern Region	1202	1880	2.5	2.0	1.0	5.0
		1920	2.0	2.0	1.0	4.0
		1950	2.0	1.8	1.0	3.6
		1970	2.0	1.5	1.0	3.0
		1980	2.0	1.5	1.0	3.0
Central Plain	1203	1880	2.0	3.0	1.0	6.0
		1920	1.3	2.5	1.5	4.9
		1950	1.1	2.5	1.5	4.1
		1970	1.1	1.5	1.5	2.5
		1980	1.1	1.2	1.5	2.0
Southern Region	1204	1880	3.0	1.7	1.0	5.1
		1920	3.0	1.7	1.0	5.1
		1950	2.5	1.5	1.1	4.1
		1970	2.0	1.3	1.2	3.1
		1980	1.5	1.3	1.5	2.9

Note: Some values of N have been rounded to nearest integer when transferred to carbon calculation spreadsheets.

VIETNAM						
Northwest Highlands	1301	1880	10.0	1.5	1.0	15.0
		1920	8.0	1.3	1.0	10.4
		1950	5.0	1.0	1.0	5.0
		1970	3.5	1.0	1.0	3.5
		1980	3.0	1.0	1.0	3.0
Tonkin Delta	1302	1880	1.5	1.0	1.0	1.5
		1920	1.2	1.0	1.0	1.2
		1950	1.0	1.0	0.8	0.8
		1970	1.0	1.0	0.8	0.8
		1980	1.0	1.0	0.8	0.8

Zone name	Zone code	Year	S	F	A	N
North Central Coast	1303	1880	4.0	1.0	1.0	4.0
		1920	2.5	1.0	1.0	2.5
		1950	1.8	1.0	1.0	1.8
		1970	1.2	1.5	1.0	1.8
		1980	1.0	1.5	1.0	1.5
Central Highlands	1304	1880	8.0	2.0	1.0	16.0
		1920	6.0	1.5	1.1	9.9
		1950	5.0	1.5	1.2	9.0
		1970	3.0	2.0	1.0	6.0
		1980	2.5	2.0	1.0	5.0
South Central Coast	1305	1880	4.0	1.0	1.0	4.0
		1920	3.0	1.0	1.0	3.0
		1950	2.4	1.0	1.0	2.4
		1970	1.5	1.1	0.7	1.2
		1980	1.0	1.1	1.0	1.1
Mekong Delta	1306	1880	2.0	1.0	1.0	2.0
		1920	1.5	1.0	1.2	1.8
		1950	1.5	1.0	1.2	1.8
		1970	1.0	1.3	1.0	1.3
		1980	1.0	1.2	1.0	1.2

Note: Some values of N have been rounded to nearest integer when transferred to carbon calculation spreadsheets.

Note: Some 1970 and 1980 values of S, F, and A incorporate assessment of wartime effects on farming patterns and resource consumption.

APPENDIX C

PRINTOUTS OF THE STEP 3 (CARBON) LOTUS 1-2-3™ SPREADSHEETS FOR 13 COUNTRIES (TOTALS)

PRINTOUTS OF THE STEP 3 (CARBON) LOTUS 1-2-3™ SPREADSHEETS FOR 13 COUNTRIES (TOTALS)

What follows is a listing of the total carbon spreadsheets compiled for each country. The data were obtained by aggregating the data values from all the ecological zones present within the given country. These data, along with the data for each of the 94 ecological zones, are contained within the digital data files included with this NDP. Data values are expressed in thousands of Mg, with the first two lines in each country listing containing the country identification code (zone code), country name, zone name (i.e., "Total"), and a listing of the years for which data were obtained.

100						
BANGLADESH	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	38189	39694	44238	44680	44494
	Temporary crops	34824	35936	40638	41126	40881
	Permanent crops	3365	3758	3599	3554	3613
	SETTLED/BUILT-UP	1098	1466	1791	2976	3112
	FOREST/WOODLAND	70738	52656	36415	20470	15424
	INTERRUPTED WOODS	20225	14298	9442	6156	5036
	WETLANDS	59142	47788	32368	20977	17533
	Forested wetlands	52757	42730	28937	18898	15830
	Nonforested wetlands	6385	5058	3431	2079	1703
	GRASS/SHRUB COMPLEXES	12192	10914	10249	7729	7593
	BARREN/SPARSELY VEGETATED	189	180	187	168	185
	SURFACE WATER	110	100	94	103	103
	TOTAL C	201883	167096	134784	103257	93478
	TOTAL C IN FOREST COVER	143720	109684	74794	45523	36290
200						
BRUNEI	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	40	149	1024	863	463
	Temporary crops	11	14	32	35	21
	Permanent crops	29	135	992	828	443
	SETTLED/BUILT-UP	7	9	17	45	64
	FOREST/WOODLAND	43479	40469	35197	31775	28941
	INTERRUPTED WOODS	6018	5601	4872	4611	4796
	WETLANDS	19080	17759	15445	15560	13651
	Forested wetlands	19080	17759	15445	15560	13651
	Nonforested wetlands	0	0	0	0	0
	GRASS/SHRUB COMPLEXES	231	278	400	275	411
	BARREN/SPARSELY VEGETATED	8	8	8	7	6
	SURFACE WATER	5	5	5	5	5
	TOTAL C	68868	64277	56967	53140	48338
	TOTAL C IN FOREST COVER	68577	63829	55514	51946	47389
300						
INDIA	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	469448	494279	583212	676803	713749
	Temporary crops	385523	407223	476659	581893	616753
	Permanent crops	83926	87056	106553	94910	96997
	SETTLED/BUILT-UP	12528	14402	19026	24674	28482
	FOREST/WOODLAND	6650147	5635470	4584801	3556849	2847622
	INTERRUPTED WOODS	1112246	989378	794279	693136	528610
	WETLANDS	242607	198649	134547	91826	70522
	Forested wetlands	177581	140994	94109	65839	49468
	Nonforested wetlands	65026	57655	40438	25987	21053
	GRASS/SHRUB COMPLEXES	344612	335342	260491	176748	190666
	BARREN/SPARSELY VEGETATED	27343	25014	20091	13919	12806
	SURFACE WATER	865	866	863	865	868
	TOTAL C	8859795	7693400	6397310	5234819	4393326
	TOTAL C IN FOREST COVER	7939973	6765842	5473188	4315824	3425700

		1880	1920	1950	1970	1980
400						
INDONESIA	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	51643	124296	297641	447923	451053
	Temporary crops	34247	71413	90597	112174	142732
	Permanent crops	17396	52883	207044	335749	308322
	SETTLED/BUILT-UP	659	1450	2488	3958	5176
	FOREST/WOODLAND	21745358	18696165	15205774	12038489	9837985
	INTERRUPTED WOODS	749898	585665	602093	443299	387852
	WETLANDS	4309443	3750183	3063427	2436874	1988819
	Forested wetlands	4304249	3745048	3058398	2432022	1984039
	Nonforested wetlands	5193	5135	5029	4853	4780
	GRASS/SHRUB COMPLEXES	237437	257398	270056	321498	331903
	BARREN/SPARSELY VEGETATED	4224	4555	4682	4743	4929
	SURFACE WATER	349	349	349	349	349
	TOTAL C	27099011	23420062	19446509	15697132	13008067
	TOTAL C IN FOREST COVER	26799505	23026878	18866264	14913809	12209876
500						
KAMPUCHEA	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	2574	3914	10361	17242	10781
	Temporary crops	2240	3406	7962	11468	7419
	Permanent crops	334	508	2400	5774	3363
	SETTLED/BUILT-UP	67	102	172	278	252
	FOREST/WOODLAND	1615491	1449832	1215539	963090	834948
	INTERRUPTED WOODS	264751	236636	200251	202944	223217
	WETLANDS	82776	70168	49260	36919	34106
	Forested wetlands	69400	58550	40660	30734	28571
	Nonforested wetlands	13376	11618	8600	6185	5534
	GRASS/SHRUB COMPLEXES	18671	19108	19137	20515	24224
	BARREN/SPARSELY VEGETATED	197	224	277	299	325
	SURFACE WATER	45	45	45	45	45
	TOTAL C	1984572	1780029	1495043	1241332	1127898
	TOTAL C IN FOREST COVER	1949642	1745017	1456450	1196768	1086737
600						
LAOS	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	1595	2216	3781	5449	6233
	Temporary crops	1526	2121	3620	5246	5993
	Permanent crops	68	95	161	203	240
	SETTLED/BUILT-UP	45	62	101	141	167
	FOREST/WOODLAND	2191464	1938819	1513548	1235449	1059632
	INTERRUPTED WOODS	117515	129405	131633	136533	121904
	WETLANDS	8877	8118	6905	5671	5160
	Forested wetlands	3580	3216	2557	2042	1753
	Nonforested wetlands	5297	4901	4348	3629	3407
	GRASS/SHRUB COMPLEXES	30007	30565	34274	31196	38327
	BARREN/SPARSELY VEGETATED	268	315	412	420	466
	SURFACE WATER	14	14	14	14	14
	TOTAL C	2349784	2109514	1690669	1414872	1231902
	TOTAL C IN FOREST COVER	2312559	2071441	1647738	1374024	1183288
700						
MALAYSIA	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	7576	60843	156275	216606	250340
	Temporary crops	1581	2473	3931	4925	5951
	Permanent crops	5995	58370	152343	211682	244390
	SETTLED/BUILT-UP	104	269	437	759	1087
	FOREST/WOODLAND	4879681	4074133	3309654	2457719	1774534
	INTERRUPTED WOODS	125877	159198	189289	194736	198968
	WETLANDS	701904	567464	455414	327667	216897
	Forested wetlands	701904	567464	455414	327667	216897
	Nonforested wetlands	0	0	0	0	0
	GRASS/SHRUB COMPLEXES	13332	15863	16057	12057	12780
	BARREN/SPARSELY VEGETATED	688	665	630	570	686
	SURFACE WATER	35	35	35	35	35
	TOTAL C	5729196	4878469	4127790	3210148	2455328
	TOTAL C IN FOREST COVER	5707462	4800796	3954357	2980122	2190400

800

MYANMAR	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	20291	45757	46660	58076	62382
	Temporary crops	17151	37230	34816	44218	47568
	Permanent crops	3140	8527	11844	13858	14815
	SETTLED/BUILT-UP	647	1234	1854	2787	3279
	FOREST/WOODLAND	2704394	1947302	1464388	1163288	990406
	INTERRUPTED WOODS	537332	436575	359125	303639	262860
	WETLANDS	171787	105703	73888	57958	46937
	Forested wetlands	152997	92795	63274	49157	39053
	Nonforested wetlands	18790	12908	10613	8801	7884
	GRASS/SHRUB COMPLEXES	100897	122697	141792	134033	132484
	BARREN/SPARSELY VEGETATED	1695	1539	1531	1414	1306
	SURFACE WATER	156	156	156	156	156
	TOTAL C	3537198	2660962	2089393	1721350	1499810
	TOTAL C IN FOREST COVER	3394723	2476672	1886787	1516084	1292319

900

PHILIPPINES	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	28306	49151	64945	100726	161014
	Temporary crops	8057	13955	19588	24361	39760
	Permanent crops	20249	35196	45357	76365	121254
	SETTLED/BUILT-UP	419	750	1418	2559	3376
	FOREST/WOODLAND	3025476	2525366	1878768	965996	668501
	INTERRUPTED WOODS	159846	136965	65679	104622	52733
	WETLANDS	41613	33810	27351	15696	11332
	Forested wetlands	37812	31039	24113	13509	10342
	Nonforested wetlands	3802	2771	3238	2187	990
	GRASS/SHRUB COMPLEXES	55911	48524	52183	36481	33538
	BARREN/SPARSELY VEGETATED	583	525	478	340	305
	SURFACE WATER	11	11	11	17	18
	TOTAL C	3312165	2795102	2090834	1226438	930818
	TOTAL C IN FOREST COVER	3223134	2693369	1968560	1084127	731576

1000

SINGAPORE	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	745	862	646	557	335
	Temporary crops	11	10	24	43	35
	Permanent crops	734	852	622	513	300
	SETTLED/BUILT-UP	6	17	41	76	110
	FOREST/WOODLAND	711	440	39	142	140
	INTERRUPTED WOODS	237	165	63	12	55
	WETLANDS	455	253	176	75	60
	Forested wetlands	448	249	173	70	57
	Nonforested wetlands	8	4	3	5	3
	GRASS/SHRUB COMPLEXES	46	28	66	28	20
	BARREN/SPARSELY VEGETATED	0	0	0	0	0
	SURFACE WATER	0	0	0	0	0
	TOTAL C	2199	1765	1031	890	721
	TOTAL C IN FOREST COVER	1395	854	275	224	252

1100

SRI LANKA	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	9888	17968	27440	38509	38866
	Temporary crops	1728	2324	2545	5118	6157
	Permanent crops	8160	15644	24895	33391	32708
	SETTLED/BUILT-UP	28	46	78	129	361
	FOREST/WOODLAND	389774	340195	262057	156020	128924
	INTERRUPTED WOODS	44861	32802	22079	31983	23189
	WETLANDS	2388	1924	1569	1287	1207
	Forested wetlands	1049	889	695	616	579
	Nonforested wetlands	1339	1035	874	670	628
	GRASS/SHRUB COMPLEXES	5745	4879	5562	5522	7487
	BARREN/SPARSELY VEGETATED	75	71	75	80	87
	SURFACE WATER	20	20	20	20	20
	TOTAL C	452779	397905	318881	233550	200142
	TOTAL C IN FOREST COVER	435684	373886	284832	188619	152693

		1880	1920	1950	1970	1980
1200						
THAILAND	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	12551	28554	84323	177395	215694
	Temporary crops	9037	19704	43255	68105	103323
	Permanent crops	3514	8851	41068	109290	112371
	SETTLED/BUILT-UP	377	553	1343	1980	2609
	FOREST/WOODLAND	2689416	2228827	1459525	930351	632727
	INTERRUPTED WOODS	323504	266964	185924	145346	122499
	WETLANDS	207768	124300	74846	39293	15245
	Forested wetlands	168788	96540	60866	31242	11974
	Nonforested wetlands	38980	27760	13980	8051	3270
	GRASS/SHRUB COMPLEXES	79667	93008	72436	51949	34414
	BARREN/SPARSELY VEGETATED	1719	1725	1452	1352	1251
	SURFACE WATER	40	40	40	40	40
	TOTAL C	3315042	2743972	1879887	1347706	1024478
	TOTAL C IN FOREST COVER	3181708	2592331	1706315	1106939	767200
1300						
VIETNAM	Total	1880	1920	1950	1970	1980
Total C(10^3 Mg)	NET CULTIVATED AREA	16589	34015	30779	43602	50605
	Temporary crops	13668	27787	22492	28076	37495
	Permanent crops	2920	6228	8287	15526	13110
	SETTLED/BUILT-UP	459	956	1771	2586	3318
	FOREST/WOODLAND	1950236	1504406	1147472	840433	709479
	INTERRUPTED WOODS	283559	182649	161422	130592	110628
	WETLANDS	217956	75378	34775	18880	10203
	Forested wetlands	208497	70825	30781	15941	8082
	Nonforested wetlands	9459	4553	3995	2939	2121
	GRASS/SHRUB COMPLEXES	40586	51267	57816	46415	45445
	BARREN/SPARSELY VEGETATED	648	664	726	638	648
	SURFACE WATER	62	62	62	62	62
	TOTAL C	2510095	1849398	1434823	1083208	930388
	TOTAL C IN FOREST COVER	2442293	1757879	1339675	986967	828188

APPENDIX D

EXPLANATORY LOTUS 1-2-3™ SPREADSHEETS PROVIDED BY THE PRIMARY INVESTIGATORS

EXPLANATORY LOTUS 1-2-3™ SPREADSHEETS PROVIDED BY THE PRIMARY INVESTIGATORS

This appendix provides a short description for each of the 75 Lotus 1-2-3™ WK1 files provided for documentation purposes with this NDP. These files document when and how each of the primary data sources were used to obtain the land use estimates contained in this data package. In most cases these files also describe the data sources used to obtain the livestock and human population values.

Due to the subjective nature of selecting, interpreting, and utilizing historical data, CDIAC has only conducted a cursory review of these files. Because of this, these files are being provided by CDIAC on an "as is" basis, and any questions regarding the validity of the assumptions used in these files should be directed to the primary investigators.

To allow the user to rapidly identify the documentation files, they have been named on the basis of the zone numbering system defined in Table 1, Part 1, of this document. The name of each file conforms to the following pattern, DXXXX(PX)A.WK1, where the letter D indicates that the file is a documentation file, XXXX is the ecological zone code(s) for which the file contains data, PX is an optional postfix that is used when more than one file contains data for the same zone, and the final letter is one of the following: S –summary of sources, L –derivation of land use data, A –a union of S and L, HP –summary of sources for human population data, LP –summary of sources for livestock data, and T –union of all summaries that fall within or below the given zone code (i.e., a national summary). For example, file D308P1S.WK1 is a summary documentation file that contains data for zone 308, and the file is part 1 of several files that contain information for this zone.

The following table provides a short description of each file. This description includes the file number, file name, and a short summary of the files contents. The textual description is included to assist the user in selecting pertinent files from which to obtain information on the methods and sources used in estimating the land use and population data for a given ecological zone.

File number	File name	File description
33.	D101S.WK1	Data source listing, decadal agricultural statistics from 1880–1980, and population and settled/built-up area data for the Chittagong Hill Tracts zone and subdivisions thereof in Bangladesh.
34.	D102S.WK1	Same as File 33, but data are for the Eastern Coast zone and subdivisions thereof in Bangladesh.

File number	File name	File description
35.	D103S.WK1	Same as File 33, but data are for the Meghna Districts zone and subdivisions thereof in Bangladesh.
36.	D104S.WK1	Same as File 33, but data are for the Sundarbans zone and subdivisions thereof in Bangladesh.
37.	D105S.WK1	Same as File 33, but data are for the Western Districts zone and subdivisions thereof in Bangladesh.
38.	D101L.WK1	History of boundary changes in the zone, allocation of national land use data into the 8 land use classes used in this data base, record of modifications made to data based on secondary sources (listed) for the Chittagong Hill Tracts zone in Bangladesh.
39.	D102L.WK1	History of boundary changes in the zone, allocation of national land use data into the 8 land use classes used in this data base for the Eastern Coast zone in Bangladesh
40.	D103L.WK1	Same as File 39, but data are for the Meghna Districts zone in Bangladesh
41.	D104L.WK1	Same as File 39, but data are for the Sundarbans zone in Bangladesh
42.	D105L.WK1	Same as File 39, but data are for the Western Districts zone in Bangladesh
43.	D200A.WK1	Data source listing for livestock, human population, and land use data; discussion of data limitations; allocation of national land use data into the 8 land use classes used in this data base for the country of Brunei.

File number	File name	File description
44.	D300T.WK1	Total land use, livestock, and human population data for India as aggregated from this data base; comparison of these totals with alternate totals available from the FAO.
45.	D301S.WK1	Data source listing for land use data; listing of livestock data by species; listing of modification assumptions used to revise official data; allocation of national land use data into the 8 land use classes used in this data base for the Andaman and Nicobar Islands zone in India (limited human population data).
46.	D302S.WK1	Same as File 45, but data are for the Andhra Pradesh zone in India.
47.	D303S.WK1	Same as File 45, but data are for the Arunachal Pradesh zone in India.
48.	D304S.WK1	Same as File 45, but data are for the Assam zone in India.
49.	D305S.WK1	Same as File 45, but data are for the Bihar zone in India.
50.	D306S.WK1	Same as File 45, but data are for the Delhi zone in India.
51.	D307P1S.WK1	Same as File 45, but data are for the Dadra and Nagar Haveli subdivisions of the Gujarat/Dadra/Nagar H. zone in India.
52.	D307P2S.WK1	Same as File 45, but data are for the Gujarat subdivision of the Gujarat/Dadra/Nagar H. zone in India.
53.	D307T.WK1	Total of the land use and population data in Files 51 and 52 for the Gujarat/ Dadra/Nagar H. zone in India.

File number	File name	File description
54.	D308P1S.WK1	Same as File 45, but data are for the Chandigarh subdivision of the Haryana/Chandigarh zone in India.
55.	D308P2S.WK1	Same as File 45, but data are for the Haryana subdivision of the Haryana/Chandigarh zone in India.
56.	D308T.WK1	Total of the land use and population data in Files 54 and 55 for the Haryana/Chandigarh zone in India.
57.	D309S.WK1	Same as File 45, but data are for the Himachal Pradesh zone in India.
58.	D310S.WK1	Same as File 45, but data are for the Jammu/Kashmir zone in India.
59.	D311S.WK1	Same as File 45, but data are for the Karnataka zone in India.
60.	D312S.WK1	Same as File 45, but data are for the Kerala zone in India.
61.	D313S.WK1	Same as File 45, but data are for the Lakshadweep Islands zone in India.
62.	D314S.WK1	Same as File 45, but data are for the Madhya Pradesh zone in India.
63.	D315P1S.WK1	Same as File 45, but data are for the Goa, Daman, and Diu subdivisions of the Maharashtra/Goa/Daman/Diu zone in India.
64.	D315P2S.WK1	Same as File 45, but data are for the Maharashtra subdivision of the Maharashtra/Goa/Daman/Diu zone in India.

File number	File name	File description
65.	D315T.WK1	Total of the land use and population data in Files 63 and 64 for the Maharashtra/ Goa/Daman/Diu zone in India.
66.	D316S.WK1	Same as File 45, but data are for the Manipur zone in India.
67.	D317S.WK1	Same as File 45, but data are for the Meghalaya zone in India.
68.	D318S.WK1	Same as File 45, but data are for the Mizoram zone in India.
69.	D319S.WK1	Same as File 45, but data are for the Nagaland zone in India.
70.	D320S.WK1	Same as File 45, but data are for the Orissa zone in India.
71.	D321S.WK1	Same as File 45, but data are for the Punjab zone in India.
72.	D322S.WK1	Same as File 45, but data are for the Rajasthan zone in India.
73.	D323S.WK1	Same as File 45, but data are for the Sikkim zone in India.
74.	D324P1S.WK1	Same as File 45, but data are for the Pondichery subdivision of the Tamil Nadu/Pondichery zone in India.
75.	D324P2S.WK1	Same as File 45, but data are for the Tamil Nadu subdivision of the Tamil Nadu/Pondichery zone in India.
76.	D324T.WK1	Total of the land use and population data in Files 74 and 75 for the Tamil Nadu/Pondichery zone in India.

File number	File name	File description
77.	D325S.WK1	Same as File 45, but data are for the Tripura zone in India.
78.	D326S.WK1	Same as File 45, but data are for the Uttar Pradesh zone in India.
79.	D327S.WK1	Same as File 45, but data are for the West Bengal zone in India.
80.	D400HP.WK1	Data source listing for human population data, data are presented by province when available and are then aggregated by ecological zone for the country of Indonesia.
81.	D400LP.WK1	Data source listing for livestock population data, data are presented by province when available and are then aggregated by ecological zone for the country of Indonesia.
82.	D401-7S.WK1	Data source listing for land use data, listing of modification assumptions used to revise official data; allocation of national land use data into the 8 land use classes used in this data base for Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, and Bengkulu/Lampung zones in Indonesia (this file refers to several spreadsheets not distributed with this data package, when the referenced files pertain to human or livestock populations, Files 80 and 81 may be consulted to obtain equivalent background information).
83.	D408-10S.WK1	Same as File 82, but data are for the West Java, Central Java, and East Java zones in Indonesia.

File number	File name	File description
84.	D411-14S.WK1	Same as File 82 except discussion of data sources is separated by zone due to the diversity of sources; the land use data for all zones have been summed for error checking (data are separated by zone in the primary data files); data are for the Bali, West Nusa Tenggara, East Nusa Tenggara, and East Timor zones in Indonesia.
85.	D415-18S.WK1	Same as File 82, but data are for the West, Central, East, and South Kalimantan zones in Indonesia.
86.	D419-20S.WK1	Same as File 82, but data are for the North/Central and South/Southeast Sulawesi zones in Indonesia.
87.	D421-22S.WK1	Same as File 82, but data are for the Maluku and Irian Jaya zones in Indonesia.
88.	D500S.WK1	Data source listing for land use, livestock, and human population data; listing of modification assumptions used to revise official data; discussion of why population values may vary significantly by period; calculation of land use/population ratios to allow estimation of missing data for individual zones within the country of Kampuchea (Cambodia).
89.	D500L.WK1	Allocation of national land use data into the 8 land use classes used in this data base for each ecological zone; land use allocations for each zone are based on percent ratios calculated in File 88.
90.	D600S.WK1	Same as File 88, but data are for the country of Laos.

File number	File name	File description
91.	D600L.WK1	Same as File 89, but data are for the country of Laos.
92.	D701-3A.WK1	Data source listing for land use data; listing of modification assumptions used to revise official data; allocation of national land use data into the 8 land use classes used in this data base for the Western Peninsular, Eastern Peninsular, and Johor zones in Malaysia.
93.	D704-6A.WK1	Same as File 92, except several land use values are estimated based on human population/land use class ratios; data are for the Western, Central, and Eastern Sarawak zones in Malaysia.
94.	D707A.WK1	Same as File 92, except a listing of the data sources used in determining human populations is included, data are for the Sabah zone in Malaysia.
95.	D801A.WK1	Data source listing; decadal agricultural statistics for 1880–1980; and population and settled/built-up area data for the Chin/Arakan zone and subdivisions thereof in Myanmar.
96.	D802A.WK1	Same as File 95, but data are for the Northern zone and subdivisions thereof in Myanmar.
97.	D803A.WK1	Same as File 95, but data are for the Dry zone and subdivisions thereof in Myanmar.
98.	D804A.WK1	Same as File 95, but data are for the Shan/Karen/Kayah zone and subdivisions thereof in Myanmar.

File number	File name	File description
99.	D805A.WK1	Same as File 95, but data are for the Delta zone and subdivisions thereof in Myanmar.
100.	D806A.WK1	Same as File 95, but data are for the Peninsular zone and subdivisions thereof in Myanmar.
101.	D900S.WK1	Data source listing for land use, livestock, and human population data; listing of modification assumptions used to revise official data, discussion of why livestock values vary significantly by period; calculation of land use/population ratios to allow estimation of missing data for individual zones within the country of the Philippines.
102.	D900L.WK1	Allocation of national land use data into the 8 land use classes used in this data base for each ecological zone (land use allocation for each zone is based on percent ratios calculated in File 101).
103.	D1000A.WK1	Data source listing for livestock, human population, and land use data; conversion of English to metric units; allocation of national land use data into the 8 land use classes used in this data base for the country of Singapore.
104.	D1100A.WK1	Same as Files 101 and 102, but data are for the country of Sri Lanka and subdivisions thereof.

File number	File name	File description
105.	D1200A.WK1	Data source listing for livestock, human population, and land use data (data were obtained based on the physiographic region), allocation of land use data into the 8 land use classes used in this data base for the country of Thailand and subdivisions thereof.
106.	D1300S.WK1	Data source listing for land use, livestock, and human population data, listing of assumptions used to revise official data, calculation of land use/population ratios used to estimate missing data for individual zones within the country of Vietnam.
107.	D1300L.WK1	Allocation of national land use data into the 8 land use classes used in this data base for each ecological zone; listing of assumptions used to revise the allocation of land area (allocation for each zone is based on percent ratios calculated in File 106).

APPENDIX E

REPRINT OF PERTINENT LITERATURE

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Note: The carbon and land use values shown in this article have been revised. The revised data are contained with the digital data distributed with this documentation.

Historical analysis of changes in land use and carbon stock of vegetation in south and southeast Asia

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FLINT, E. P., and RICHARDS, J. F. 1991. Historical analysis of changes in land use and carbon stock of vegetation in south and southeast Asia. Can. J. For. Res. 21: 91–110.

A time series (1880, 1920, 1950, 1980) of estimates of land use and carbon content of vegetation is presented for a contiguous area of 1.7×10^6 km^2 in northern India, Bangladesh, and Burma. This was developed using sequential bookkeeping models, which systematically incorporate official agricultural and forest statistics with ecological, botanical, historical, geographical, and demographic data. For 149 administrative units, aggregated into 39 ecological zones, we estimated area and carbon content for each of the following land-use categories: net cultivated area, settled-built-up area, forest-woodland, interrupted woods, grass-shrub complexes, barren - sparsely vegetated areas, wetlands, and surface water. Dominant patterns of land-use change were deforestation, agricultural expansion, and wetland clearance, but significant regional and temporal disparities were observed. For the entire study region, the estimated standing stock of carbon in biomass declined by 2.62 Gt over the century. Release by periods was 911 Mt for 1880–1920, 750 Mt for 1920–1950, and 964 Mt for 1950–1980. Forest-woodland and interrupted woods vegetation released carbon equivalent to over 90% of the total release. Both conversion of forest to other vegetation types and reduction over time of biomass within vegetation types contributed significantly to decreases in total standing carbon stock during the period.

FLINT, E. P., et RICHARDS, J. F. 1991. Historical analysis of changes in land use and carbon stock of vegetation in south and southeast Asia. Can. J. For. Res. 21 : 91–110.

Les auteurs présentent une série chronologique (1880, 1920, 1950, 1980) d'estimés de l'utilisation des terres et de la teneur en carbone de la végétation pour une superficie contiguë de $1,7 \times 10^6$ km^2 située dans le nord de l'Inde, au Bangla Desh et en Birmanie. Ils ont utilisé pour cela des modèles séquentiels de la tenue des livres qui incorporaient systématiquement des statistiques officielles agricoles et forestières et des données écologiques, botaniques, historiques, géographiques et démographiques. Pour les 149 unités administratives, regroupées en 39 zones écologiques, ils ont estimé la superficie et la teneur en carbone pour chacune des catégories d'utilisation des terres suivantes : cultures, urbanisation, forêt et forêt claire, bois discontinus, herbaçaies et arbustaies, terrains sans végétation, terrains humides et eaux libres. Les patrons dominants de changement de l'utilisation des terres étaient le déboisement, l'expansion de l'agriculture et le défrichement des terrains humides bien qu'on ait observé de fortes disparités régionales et temporelles. Pour l'ensemble de la région étudiée, le contenu estimé en carbone dans la biomasse a diminué, au cours du siècle, de 2,62 Gt. La perte, par périodes, a ete de 911 Mt de 1880 à 1920, de 750 Mt entre 1920 et 1950 et de 964 Mt entre 1950 et 1980. Les catégories forêt et forêt claire et bois discontinus ont contribué à plus de 90% de la perte totale. Durant la période étudiée, ce sont et la conversion de la forêt en autres types de végétation et la réduction, dans le temps, de la biomasse des types de végétation qui ont contribué, de façon significative, à diminuer le stock total sur pied du carbone.

[Traduit par la Rédaction]

Introduction

Importance of land-use change as a contributory factor to global carbon release

The potential political and economic dislocations that may result from anthropogenic climate change lend some urgency to the task of developing a global model that can predict the timing and magnitude of future increases in global atmospheric carbon dioxide concentration (as well as changes in concentrations of other radiatively active gases, such as methane). Development of a carbon cycle model with predfctive value requires an understanding of all major processes leading to the release or storage of carbon. Uncertainty concerning the magnitude, time course, causal factors, geographical localization (and in some cases the sign) of flux due to some processes still exists. A case in point is the release of carbon from biotic systems as a result of human activities. Various methods of estimating biotic carbon release have generated a total flux of the same order of magnitude as that due to fossil-fuel combustion, but the time courses of estimated releases vary widely (91). Further information on the causes and components of carbon release from biotic systems is therefore highly desirable, particularly for tropical regions (91). It is known that transformations of land between forest and nonforest vegetation categories are responsible for a major proportion of changes in terrestrial carbon stocks, but the effects of degradation over time on carbon content within vegetation categories are also important (92). This paper presents the results of a detailed study of a century of changes in land use in south and southeast Asia and an analysis of changes in the standing stock of carbon in the vegetation of these systems from 1880 to 1980. It includes an assessment of the relative contributions of both transformation of land from one category to another and degradation within categories.

The study region

The area under consideration includes the nations of Burma and Bangladesh and the following states in northern India: Himachal Pradesh, Uttar Pradesh, Bihar, West

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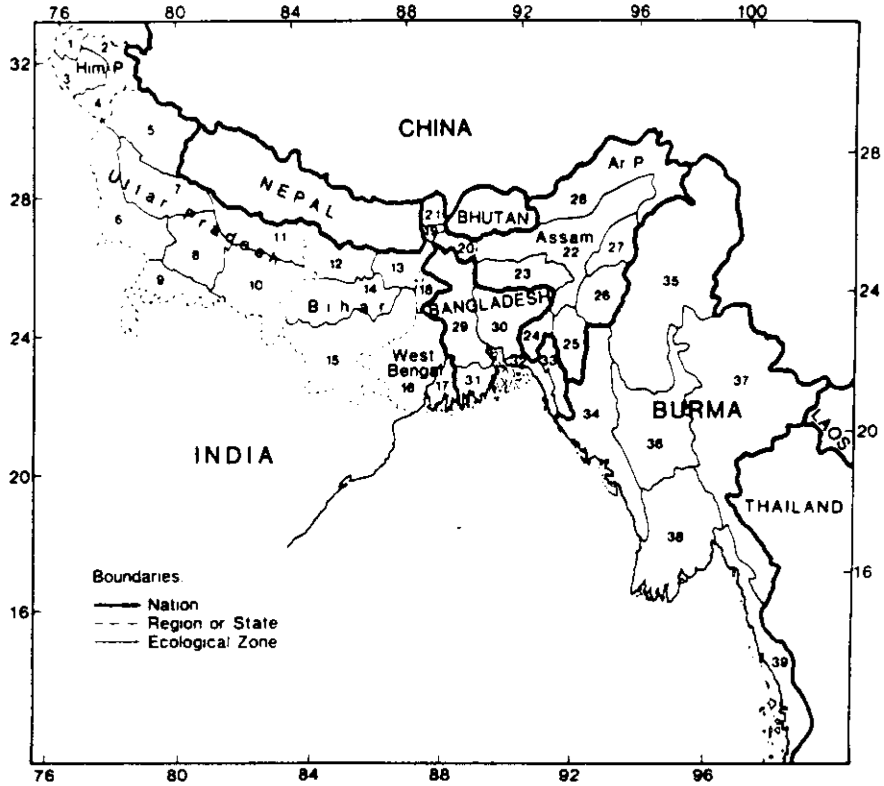

FIG. 1. Map of study area (northern India, Bangladesh, and Burma), showing relevant national boundaries, state or regional boundaries within northern India, and boundaries of the 39 ecological zones. National names are indicated in capital letters. The larger northern Indian states (Uttar Pradesh, Bihar, West Bengal, Assam, Himachal Pradesh (Him P), and Arunachal Pradesh (Ar P)) are also identified. Each ecological zone is identified by a number; refer to Table 1 for a key to these map location numbers. The map is drawn on the same conic projection used in the physiographic and administrative south Asian maps of Schwartzberg (176).

Bengal, Sikkim, Assam, Meghalaya, Tripura, Mizoram, Manipur, Nagaland, and Arunachal Pradesh (Fig. 1, Table 1). Total area of the region is 1695 × 10^6 km^2, amounting to 1.3% of the world's land surface. The study covers the century from 1880 through 1980.

The topography of this region is enormously diverse, encompassing the range from coastal lowlands to high Himalayan peaks (176). Climate in south and southeast Asia is monsoonal, dominated by moisture-laden southwesterly winds in summer and dry northeasterly winds in winter; thus precipitation in the study region is strongly seasonal (162). Mean annual precipitation ranges from below 500 mm in parts of Himachal Pradesh (132) to over 10 000 mm in parts of Meghalaya (160, 216). Mean annual temperature varies strongly with elevation and latitude, ranging from 27°C (in parts of Burma, West Bengal, and Bangladesh) to below 0°C (above the snow line throughout the Himalayas), and there is a wide range of amplitudes of diurnal and seasonal temperature variation (175, 120, 142, 143). A wide variety of life zones (89) is represented in the region, including such extreme types as tropical rain forest, subtropical thorn woodland, and nival (60). Soil types of the region include Inceptisols, Ultisols, Alfisols, Entisols, Vertisols, Aridisols, Mollisols, and Histosols (55, 32, 168, 4).

The wide range of natural vegetation types occurring in the region reflects this environmental heterogeneity (Fig. 2). Vegetation formations represented include tropical forest types (ranging from evergreen rain forest to thorn forest) and a continuum of wet to dry subtropical and temperate montane forest types, including both broad-leaved and coniferous associations. In addition, high-elevation sites support subalpine vegetation, krummholz, and wet and dry alpine tundra (85, 169, 177).

In some portions of the study region, notably parts of Arunachal Pradesh (114, 116, 185) and the high mountains of Burma (119, 192), forests still dominate the land-use pattern, and human disturbance has been limited to the operations of relatively small populations of shifting cultivators. In contrast, archaeological evidence indicates (165) that some Gangetic Plain sites in Uttar Pradesh and Bihar supported sedentary agriculture as early as the Harappan period (ca. 2500–1500 B.C.). Vegetation maps of south Asia constructed from historical sources (10) indicate that cropland had displaced forest in core areas of settlement in the Gangetic Plain before A.D. 650. Records of the Mughal period indicate further expansion of agriculture in the Gangetic Plain at the expense of tropical forest before A.D. 1600. (137). Maps reconstructed from the Ain-i-Akbari (ca. 1561–1595) indicate that at this time the extent of deforestation was considerably greater in the relatively dry upper Gangetic Plain than downriver (10, 86). Rice cultivation was well established at this time in the lower Gangetic Plain (corresponding to modern Bihar, West Bengal, and Bangladesh) but had not yet completely displaced the

TABLE 1. List of ecological zones in study region, including key to location on map, zone area, and number of districts or divisions in zone

Key to map location (Fig. 1)	Ecological zone, state, nation	Area (10^6 ha)	Number of districts or divisions
1	Chamba	0.652	1
2	Trans-Himalaya	1.876	2
3	Greater Kangra	1.860	4
4	Greater Simia	0.989	3
	Total Himachal Pradesh, India	5.377	10
5	Himalayan Uttar Pradesh	5.337	8
6	Western Uttar Pradesh	4.728	11
7	West Central Uttar Pradesh	3.823	8
8	Central Uttar Pradesh	3.818	8
9	Bundelkhand	2.946	4
10	Southeastern Uttar Pradesh	5.258	10
11	Eastern Terai	3.323	5
	Total Uttar Pradesh, India	29.231	54
12	Mithila Plain	3.267	4
13	Kosi Plain	1.690	2
14	Magadh-Shahabad	4.468	5
15	Chota Nagpur	7.964	6
	Total Bihar, India	17.388	17
16	Alluvial Plain	5.233	9
17	24 Parganas-Calcutta	1.471	1
18	Malda-W. Dinajpur	0.892	2
19	Darjeeling	0.308	1
20	West Bengal Terai	0.963	2
	Total West Bengal, India	8.866	15
21	Sikkim, India	0.730	1
22	Assam, India	7.852	10
23	Meghalaya	2.249	1
24	Tripura	1.048	1
25	Mizoram	2.109	1
26	Manipur	2.236	1
27	Nagaland	1.653	1
	Total NE Hill States, India	9.294	5
28	Arunachal Pradesh, India	8.358	5
	Total northern India	87.095	117
29	Western Districts	5.279	8
30	Meghna Districts	4.441	4
31	Sundarbans	2.362	2
32	Coastal Bangladesh	1.396	2
33	Chittagong Hill Tracts	1.319	1
	Total Bangladesh	14.797	17
34	Chin-Arakan Divisions	7.280	2
35	Northern Burma	18.367	2
36	Dry Zone	8.184	2
37	Shan-Karen-Kayah	19.791	4
38	Burma Delta	8.471	3
39	Tenasserim-Mon	5.564	2
	Total Burma	67.657	15
	Total study region	169.549	149

NOTE: Zones are grouped by state or larger region within India and are also aggregated for each nation in the study region.

tropical moist forest vegetation (3, 86, 166). Early Burmese records (11th–13th centuries) indicate that population and agriculture, as in India, were concentrated in relatively dry parts of the country (205). As recently as the 19th century, some of the lowland moist forests of the Gangetic and Brahmaputra plains (136, 181, 182, 26) and the Irrawaddy

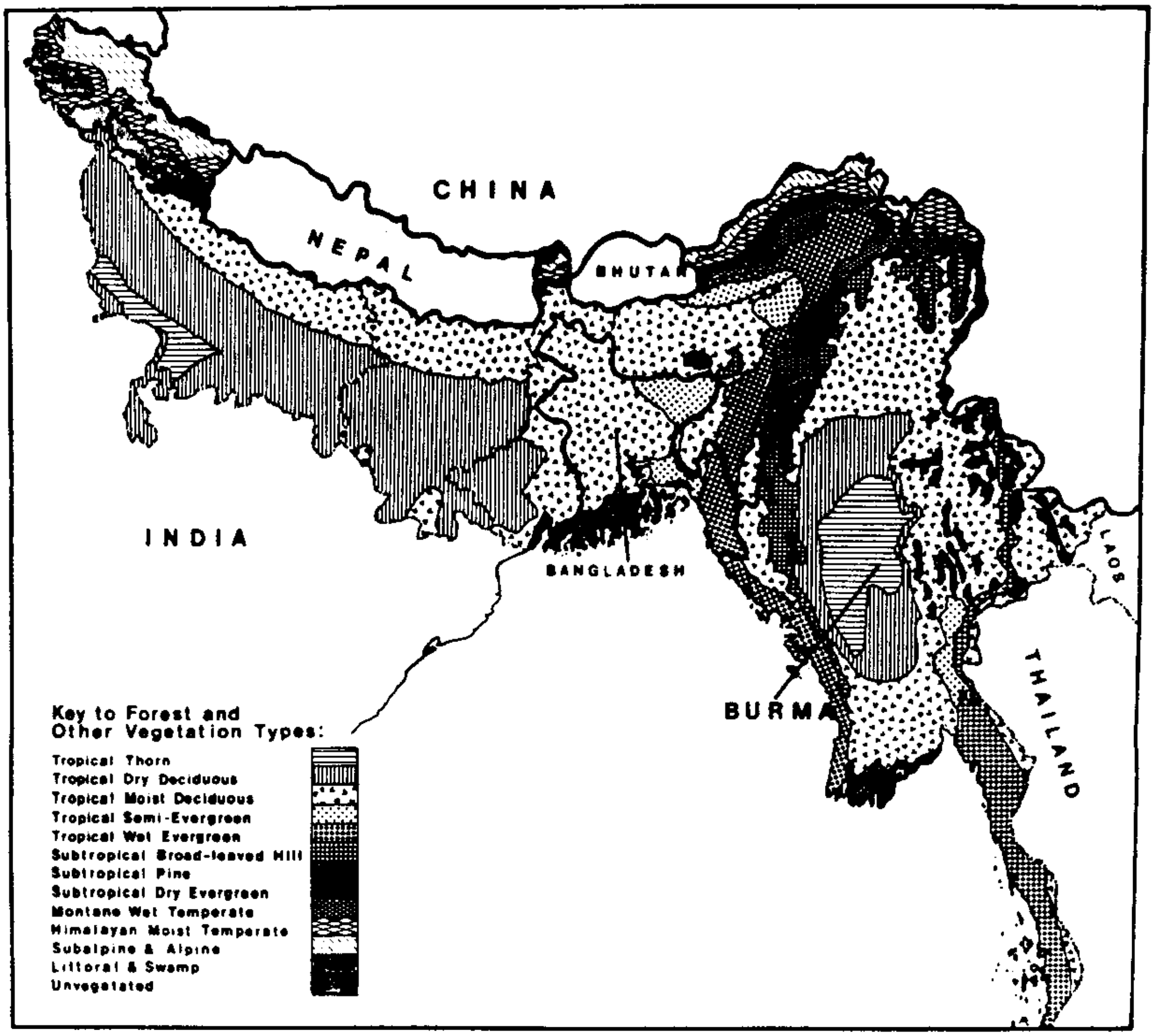

FIG. 2. Map of study area showing its expected natural vegetation under current climatic conditions. This map uses the vegetation classification of Champion and Seth (45), but includes information from a number of other sources (42, 46, 56, 59, 123, 130, 139, 155, 193).

Delta (1, 61) still represented an open frontier for the expansion of agriculture. Thus, our study region reflects a wide range of intensity of human use and historical experience (4, 195, 5, 126). Considerable variations in population density from 1880 to 1980 at the national level can be seen in Table 2, and a much greater spread (from 0.02 to 2.82 persons/ha in 1880 and 0.05 to 9.55 persons/ha in 1980) is noted in smaller, more ecologically homogenous zones. Over the entire study region, the human population increased by 19% from 1880 to 1920, by 38% from 1920 to 1950, and by 93% from 1950 to 1980.

Methodology: historical sources

The entire study area fell within the sphere of influence of the British Empire through the end of the second world war. Most of modern-day India, Bangladesh, and Burma was under direct colonial management; the remainder consisted of princely states subject to indirect British political control. The colonial governments, and those of the adjacent semi-independent states, both relied on taxation of land as a major source of revenue. Careful revenue records were maintained for agricultural land, which was taxed annually at a rate proportional to its economic productivity (7, 23, 167, 170).

Colonial governments also asserted ownership over most forest land and hired professional foresters to manage it for maximum long-term yields of timber and other forest resources (28, 171, 44, 212). During the colonial period, foresters throughout the region followed a common tradition established by European foresters transplanted to south and southeast Asia in the mid 19th century (140, 196–198, 118, 21). Management practices and classification systems developed within this tradition are important components of current forest policy, not only in India (121) and Bangladesh (118), but also in socialist Burma (33). Throughout the region, the state (whether colonial or independent) has faced a conflict in land-use policy between two needs: forest clearance for agriculture a versus forest preservation to ensure a sustained future supply of wood products and to protect watersheds (173, 209).

State economic interests thus provided strong incentives for frequent cadastral and forest surveys of all but the least-

TABLE 2. Total human population and density, from 1880 to 1980, for each nation in the study region

	Total human population (millions)				Population density (persons/ha)			
	1880	1920	1950	1980	1880	1920	1950	1980
N. India	90.03	99.57	141.30	267.34	1.03	1.14	1.62	3.07
Bangladesh	24.89	33.43	41.88	86.97	1.68	2.26	2.83	5.88
Burma	7.59	13.20	18.79	35.04	0.11	0.20	0.28	0.52
Total study region	122.51	146.20	201.97	389.35	0.72	0.86	1.19	2.30

accessible territory. Beginning in 1884, the land-use data generated by such surveys were published as part of the Agricultural Statistics of British India (100). As the statistics were annually updated, increasingly large percentages of the colonial territory and the princely states were included within the reporting network (7, 101, 96, 97). This system continued throughout the colonial period for all parts of British India (16) and was maintained after independence by the newly formed governments of India, Bangladesh, and Burma (106–108, 146, 11, 13, 35, 36, 37). Thus, continuous long-term series of systematically collected annual land-use data are available for most of the study region.

The lowest level of resolution for these data (and therefore in our work) is the district in India and Bangladesh and the division (an aggregation of several districts) in Burma. Our data represent 134 districts (mean area 0.76×10^6 ha) in northern India and Bangladesh, plus 15 Burmese divisions (mean area 4.51×10^6 ha). Official land-use statistics for the entire region used the same classification system throughout the century. The total area was officially divided (16) into five major land-use categories: Net Sown (including all land in temporary or permanent crops); Fallow land; Culturable Waste (including pasture and all other land judged potentially useful for agriculture); Forest (all lands classed or administered as forest, whether state owned or private); and Not Available for Cultivation (land environmentally unsuitable for crops, like desert or tundra, land underwater, plus settled and built-up areas). Some temporal and regional variations in definitions of categories occur (e.g., adjustments of the legal definition of forest and changes in the number of years of abandonment required to shift Fallow land into the Culturable Waste class), but overall the system is surprisingly consistent.

Methodology: choice of land-use categories

The categories used for official land-use statistics were developed for administrative use and so do not accurately represent vegetation cover and carbon content of a given land area. They are not directly comparable to land-use classifications used in other parts of the world. Therefore, we developed a set of globally applicable, ecologically based, land-use classes and a system for translating information from its original format to these ecological classes. Our classification was adapted from that used by Olson et al. (144) to map carbon in world ecosystem complexes at the half-degree scale. We used eight major classes: (*i*) net cultivated area, which is subdivided into temporary and permanent crops; (*ii*) settled–built-up area, which includes land under settlements, roads and railways, mines, etc; (*iii*) forest–woodland, which includes all forms of natural and plantation forest with 30% or greater crown cover (to increase the accuracy of carbon estimates, we compiled local information on the areas of land in four subcategories: tropical moist forest, tropical dry forest, temperate broad-leaved forest, and coniferous forest); (*iv*) interrupted woods, which is vegetation with some arboreal component, but mean crown cover below 30% (this category includes thorn woodland, degraded or scrub forest, bamboo, tree savanna, and related vegetation types with biomass significantly lower than that of forest–woodland; it is derived from, but not identical with, the category of the same name as defined by Olson et al. (144)); (*v*) grass-shrub complexes, which include grasslands, forb communities, and shrub land; (*vi*) barren - sparsely vegetated class, which includes tundra, desert, semidesert scrub, and all unvegetated land (rock, sand, ice); (*vii*) the wetlands class, which comprises all vegetation subject to inundation by either fresh or salt water (we compile data separately within this category for herbaceous wetlands, freshwater swamp forest, and tidal (mostly mangrove) forest); (*viii*) the surface water class, which comprises areas permanently underwater (rivers, estuaries, canals, lakes, irrigation tanks, etc.).

Methodology: spreadsheet operation

The logic involved in developing our time series of land-use data and carbon-stock estimates is embodied in a sequential series of modular Lotus 1-2-3[2] spreadsheets. The flowchart in Fig. 3 summarizes the construction and aggregation of spreadsheets used to evaluate land use and carbon content. Our analysis involves three sequential spreadsheets. Spreadsheet A compiles data for administrative units that represent the lowest level of aggregation. Output from one or more A spreadsheets is then fed into spreadsheet B for further analysis at a higher level of aggregation. The combination of A and B embodies our bookkeeping model of land use. Output of B becomes the initial input for spreadsheet C, which is the bookkeeping model of change in standing stock of carbon in live vegetation. Our system design allows alteration of input data at any point in the process. (The operation of the spreadsheets, briefly described in the following section, is documented in detail in a technical manuscript, forthcoming from Oak Ridge National Laboratories (Oak Ridge TN) in 1990.)

Land-use spreadsheets

The first step in preparation of a time series of land-use data is entry of input data into the A spreadsheet for a given district or division. Data for areas of land in each official category are drawn from the agricultural statistics series

[2]Registered trademark of Lotus Development Corp., Cambridge, MA.

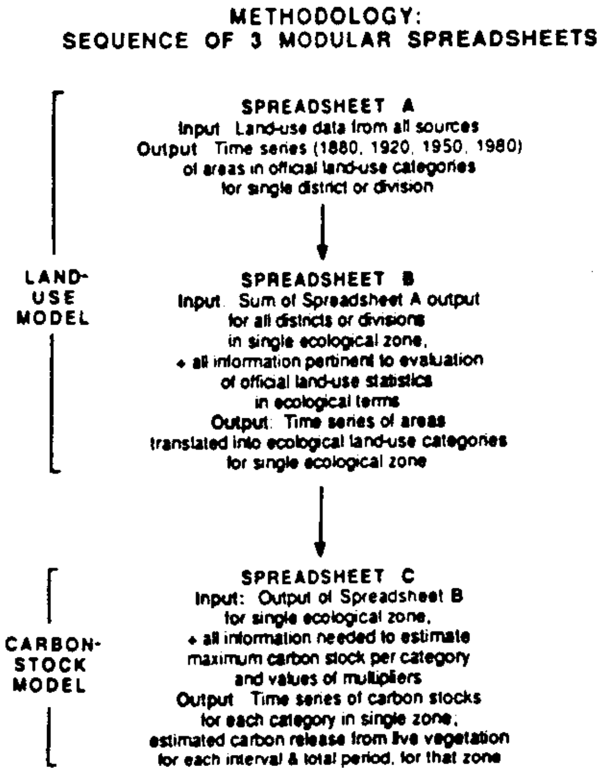

FIG. 3. Flow sheet illustrating spreadsheet methodology used in analysis of changes in land use and carbon stocks in study area.

described earlier. Missing data are supplemented by consulting revenue records, particularly settlement survey reports (e.g., 48, 113), and from regional and local gazetteers (15, 95, 178). Typically these sources contain both land-use statistics and detailed descriptions of land in each official category. Additional information on the extent of forest cover, the condition and legal status of forests, and local vegetation types is taken from forest administration reports (18, 58, 98, 99, 115), working plans (78, 191), and other forestry publications (20, 33, 88, 102, 105, 125, 141, 210). Data are also drawn from a geographically indexed bibliography of over 4200 botanical, agricultural, ecological, geographical, and historical studies pertaining to land use in south Asia (62), which was prepared in conjunction with this study. We evaluate all available vegetation maps, particularly those from older forestry sources (52, 71) and those that indicate both vegetation types and land use (200, 22, 73–77, 131). We also examine all available forest cover data sets developed using remote sensing sources (63, 67, 109, 174, 214). We consult census data to determine the human population of each administrative unit at each date. Censuses in India, published decennially from 1872 through 1981 (16, 112, 145), included Burma until 1931 and Bangladesh until 1941. (Modern population data for Burma were compiled from references 34-38; for Bangladesh, from 12, 14, 15, and 147.) Livestock censuses (103, 104) and other sources (13, 37, 213) provide information on livestock numbers.

Spreadsheet A automatically adjusts for missing data and boundary changes, allows manual overrides for unusual circumstances, and provides a section for documentation of these adjustments. The final spreadsheet output is a data set that allocates, for each date, 100% of the district area to the five official administrative categories mentioned earlier. When all of the A spreadsheets for a nation are completed, we aggregate the output for contiguous and ecologically similar districts or divisions at the higher level of the ecological zone. Here, we aggregate data from 149 smaller administrative units into the 39 ecological zones listed in Table 1. Some zones include only a single district; others include as many as 11. Mean areas of our ecological zones in India, Bangladesh, and Burma are 3.11×10^6, 2.96×10^6, and 11.28×10^6 ha, respectively.

The aggregated land-use data for an ecological zone constitute the input to spreadsheet B. The primary purpose of spreadsheet B is translation of the land-use data from the official categories used in spreadsheet A to the ecological classes that form the basis for our estimation of carbon content. One class at a time, we allocate all land area in each administrative class to ecological categories. This conversion is made in the context of the full multidisciplinary range of sources for all districts or division in the zone. Land areas are finally summed for each ecological category to produce the output data set of spreadsheet B: a time series for the zone showing the areas in each ecological land-use category, for the dates 1880, 1920, 1950 and 1980.

Carbon spreadsheet

As shown in the flowchart (Fig. 3), the output of B forms the initial input for spreadsheet C, which embodies our carbon bookkeeping model. Operating at the level of the ecological zone, spreadsheet C standardizes the process of estimation of carbon content in live vegetation in each ecological category at each date. Use of this spreadsheet requires examination of all biomass data applicable to each ecological category for vegetation from all locations comparable to the ecological zone under consideration. In addition to the global forest biomass reviews of Cannell (39, 40), which contain considerable quantities of south and southeast Asian data, we found the following south and southeast Asian sources particularly useful: 54, 158, 164, 189, and 202 for forests; 53, 187, 188, and 215 for grasslands and savanna; 79 and 80 for wetlands; 133, 160, 203, and 204 for successional vegetation in tropical moist forests; 64, 65, and 135 for cropland. (Additional literature on biomass of south Asian vegetation used in developing our analyses, too extensive to cite in this publication, can be accessed using the indexed bibliography (62) of Flint and Richards.) Carbon values are used directly when available (e.g., 190), but generally must be calculated from biomass, using a 50% conversion factor (29).

Almost all direct measurements of vegetation biomass and carbon content are modern. Therefore, estimation of carbon content of vegetation at earlier dates requires systematic evaluation of all quantitative and descriptive information relevant to assessment of factors that influenced the actual carbon stock at each date within the zone. (Particularly important is time-specific information pertaining to forest volume.) Formulas built into spreadsheet C standardize the procedure for estimation of carbon content (t/ha) for each ecological land-use category at each date. Then the land area of each category (ha) is multiplied by the carbon content (t/ha) to calculate total carbon stock for the category. Output of spreadsheet C includes both the area and the estimated carbon content for each land-use category as of

1880, 1920, 1950, and 1980. Spreadsheet C also calculates carbon release or uptake, for each category and for the total area, for intervals between each successive pair of dates, and for the entire century.

We estimate carbon release from live vegetation in this model as the difference in total carbon content between two given dates. Our bookkeeping model does not assess the partitioning of carbon into various decay pools, and therefore does not directly address the time course of the release. It calculates carbon stock at each point in time for each ecological category in the zone, using [1].

Method for time-specific estimation of carbon content in vegetation of each ecological category

To estimate the actual carbon stock per hectare (CPH) for a single category at one point in time, we use the formula

[1] $CPH = M(ED)$

where M is the maximum carbon stock (t/ha) in live vegetation theoretically possible under optimal conditions and E and D are fractional multipliers that quantify the estimated reduction of M by abiotic and biotic factors, respectively.

M is estimated for each ecological category, for a relatively large area (often several ecological zones), after compiling all applicable biomass data for undisturbed vegetation in the class. It represents the maximum carbon content (t/ha) of undisturbed live vegetation in that class, under optimal conditions, that would be expected for a substantial area. M values for forest-woodland are generally consistent in magnitude with biomass extrapolated from volume data from mature, undisturbed stands of major commercial species on top-quality sites. Although all published forest biomass data are considered in the estimation of forest-woodland M values, we avoid overreliance on isolated instances of extremely high biomass representing extreme outliers of the total forested area.

E, the environmental limitation multiplier, expresses the degree to which abiotic factors (climate, soil chemistry and structure, topography, etc.) reduce carbon content below the maximum value, M. For woody vegetation, we developed a set of multipliers based on the strong correlations between forest site quality and yield. Site quality was an important variable used by south Asian foresters in their construction of yield tables that predict crop volume from top height of trees at given stand ages (196–198, 121). Their procedures applied the traditional European methods (8) to tropical forests and involved similar assumptions concerning the strong dependency of crop volume in even-aged stands upon site quality. For each species of commercial value, site-quality curves were constructed that allowed professional foresters to assess site quality of local stands on a relative scale from I (the best) to V (the worst, generally not commercially exploitable) and therefore to predict the merchantable volume of those stands without immediate harvest. Using the methodology of Brown et al. (29–31), we developed tables quantifying the relationship between site quality and predicted biomass of mature stands for most of the major commercial species (broadleaf and conifer) in the region. To prepare these, we used volume data in yield and stand tables published for commercial species of the study region by S. H. Howard (1921-1926), H. G. Champion et al. (1929–1934), I. D. Mahendru (1932-1933), S. K. Seth et al. (1957–1960), S. N. Dabral et al. (1960–1969), A. N. Chaturvedi et al. (1971-1980), R. P. Sharma et al. (1977-1981), and S. P. Singh et al. (1979-1985). (Refer to Flint and Richards (62) for citations.) We then applied data on specific gravity of each species (49, 50, 69, 124, 152, 156, 157, 163) and information on biomass partitioning and expansion factors (29-31, 39, 40, 54, 117, 134, 189) to extrapolate biomass from volume. A survey of our completed tables indicated that estimated stand biomass of each site quality, expressed as percentages of the quality I biomass, ranged from 70-80% for quality II; 40-60% (generally about 50%) for quality III; 30-40% for quality IV; and 20% or less for quality V. The ranges of percentages indicate the extent of interspecific and regional variation in the relative volumes expected from the lower site quality classes.

Especially for early dates, location-specific site-quality estimates (e.g., 41, 207) are our best surrogate for firsthand measurements of forest biomass. For common and gregarious species like sal (*Shorea robusta* Gaertn. f.) and chir pine (*Pinus longifolia* Roxb.), site-quality estimates based on performance of single species are often applicable to relatively large areas. Some forestry sources also assign overall site-quality ratings to mixed-species forests. In either situation, the site-quality rating effectively integrates the abiotic environmental factors that affect biomass accumulation. We estimate site quality for forests lacking such data by comparing all forest vegetation descriptions (particularly those including height, girth, and density estimates) and environmental data (precipitation, temperature, soil type, etc.) with equivalent information available for the nearest comparable sites for which site quality has been officially assessed. A wide selection of such descriptions is available (e.g., 17, 24, 25, 81, 154, 180, 183, 206; see 62 for further references).

Data from working plans indicate the mean site quality, even in the best state-controlled forests, seldom exceeds quality III, and top-quality forest rarely exceeds 1 or 2% of the total (191). As a result, our environmental limitation multiplier for the forest of an entire zone typically reduces estimated carbon content to 50% or less of the regional maximum, M, even before factoring in the degradation multiplier.

Site-quality classes are not applicable to nonwoody vegetation, so our environmental limitation multiplier for other vegetation is based primarily on relationships between mean annual rainfall and biomass of herbaceous communities, as documented in the regional literature (187, 53, 215).

D, the degradation multiplier, expresses the extent of reduction in carbon content due to biomass removal by humans and livestock. For each zone, degradation multipliers for woody vegetation are based on the density of humans, who are directly responsible for most wood removal. (It is of interest here to note that one authority estimates that 90% of the wood taken from Indian forests ca. 1980 is firewood (27), with all other uses relegated to the remaining 10%.) Magnitude of multipliers was empirically derived from published comparisons of biomass in undisturbed forest and forest degraded by human activity of various types and intensities (63, 67, 189, 204). Our overall biomass estimates at the regional scale were cross-checked against published local (e.g., 83), regional (20, 210, 68, 185), and national estimates of commercial and noncommercial volume of various forest types (66, 67).

For nonwoody vegetation, virtually all of which is grazed, our degradation multipliers reflect livestock density per hect-

TABLE 3. Area of each major land-use category, from 1880 to 1980, for the study region (northern India, Bangladesh, and Burma)

Land-use category	Area (10^6 ha) of each category			
	1880	1920	1950	1980
Net cultivated area	40.34	42.97	47.77	53.55
Temporary crops	38.72	41.03	45.55	51.05
Permanent crops	1.62	1.94	2.22	2.50
Settled-built-up area	1.81	2.26	3.03	5.29
Forest-woodland	47.30	40.99	36.34	30.00
Interrupted woods	34.06	31.88	30.70	28.41
Grass-shrub complexes	25.67	31.97	33.47	34.89
Barren - sparsely vegetated	7.76	7.99	8.00	7.81
Wetlands	6.75	5.72	4.58	3.40
Surface water	5.86	5.76	5.64	5.73
Total area	169.55	169.55	169.55	169.55

are of natural vegetation. Their magnitude is based on regional literature relating vegetation biomass to grazing pressure (53, 188).

The system employed here to analyze land use and carbon stock of vegetation in south and southeast Asia can be extended to other world regions. The ecological categories are globally applicable. The bookkeeping approach adjusts readily to any choice of time periods or divisions of area. Context-sensitive use of both statistical and narrative data from many sources is facilitated by the procedures for systematic input and translation of data. Most importantly, the hierarchical, summed data sets lend themselves to a continuing process of refinement and correction.

Results and discussion

Changes in land use

Table 3 summarizes the area of land in each major ecological category in 1880, 1920, 1950, and 1980, for the entire study region. In terms of the area affected, the most important change in land use was deforestation, i.e., the conversion of land originally classified as either forest-woodland or interrupted woods to categories of lower biomass. Over 37% of the area bearing forest-woodland vegetation in 1880 (equivalent to 10% of the entire study area), plus 17% of the interrupted woods, was converted to vegetation types of lower biomass. Much, but not all, of this loss was associated with a second important trend, the 33% expansion of net cultivated area. Also notable was a 50% reduction in the area occupied by vegetation in the wetland categories. Forest not replaced by cropland or settled area (which increased by 193%) tended to degrade to the category of grass-shrub complexes, which increased in area by 36%. The area classified as barren - sparsely vegetated showed little change.

The rates of these changes were not constant among the three intervals 1880–1920, 1920–1950, and 1950–1980. For example, reduction in forest-woodland occurred at an average rate of 15 000–16 000 km^2/decade through 1950, accelerating thereafter to 21 100 km^2/decade. Cultivated area increased relatively slowly (6600 km^2/decade) before 1920 and more rapidly thereafter (16 000 and 19 300 km^2/decade for the intervals 1920–1950 and 1950–1980, respectively). However, arable expansion cannot be maintained at these rates, because most of the available land that can support agriculture is already in crops. The wetlands depletion rate, which averaged 2100 km^2/decade in the first interval, rose to 3800 and then 3900 km^2/decade during the next two intervals.

Changes in carbon content of vegetation at the level of the entire study region

Table 4 shows changes in the total carbon stock of the study area from 1880 to 1980. Carbon content of live vegetation dropped progressively throughout the century. From 1880 to 1980, for the entire 1.7 × 10^6 km^2 study area, we estimate that carbon release from live vegetation totaled 2.63 Gt. This represents a 43% depletion of the estimated 1880 carbon stock. Carbon release in each interval was considerable: 911 Mt from 1880 to 1920, 750 Mt from 1920 to 1950, and 964 Mt from 1950 to 1980. The rate of release, expressed in average values per decade, increased in each succeeding interval: from 228 to 250 to 321 Mt/decade.

The forest-woodland class contained more carbon than all other categories combined, but the proportion of total carbon in this class progressively declined throughout the century, from 73% in 1880 to 63% in 1980 (Table 5). This was due to both contraction of forest-woodland area (from 28 to 18% of the regional total) and reduction of its mean carbon stock (from 94 to 74 t/ha). The percentage of total carbon in wetlands also decreased. Proportions of the total carbon in the cultivated, interrupted woods, and grass-shrub categories increased.

The overall carbon release had two major components: (*i*) transfer of area from classes of high to classes of lower biomass and (*ii*) reduction in the mean biomass of vegetation within classes (carbon content of course directly followed the biomass trends). We compared the relative importance of changes between and within categories in the carbon release estimates by running the carbon-stock bookkeeping model at the level of the study area with two different assumptions.

If we assume that carbon content per hectare remained stable within each ecological category at the 1880 value, and the degradation multiplier is held constant, the estimated total carbon release from 1880 to 1980 is 1.8 Gt. But when we assume that reduction of carbon content within categories occurred in synchrony with increases in human or livestock density and we apply successively smaller degradation multipliers at later dates, the estimated carbon release rises to 2.6 Gt for the century. Thus, the adjustments associated with degradation within categories increased our estimated carbon release by 49%.

Figure 4 illustrates, for the entire study area, the pattern of carbon release and uptake by category. In every interval, the forest-woodland class lost the most carbon. Carbon lost from this class (Table 6) equaled 85% of the total release for the century. Smaller, but still significant, quantities of carbon were released from vegetation in the interrupted woods and wetland categories. There was little net change in carbon stock of grass-shrub vegetation, as early uptake was offset by later release. Change in carbon content of the barren - sparsely vegetated category was minimal. The limited carbon uptake that occurred was concentrated in cultivated and settled classes, and three-quarters of it was associated with expansion of the area in temporary crops.

It is important to recognize that even by 1880 human activ-

TABLE 4. Estimated carbon content of vegetation in each land-use category, from 1880 to 1980, for the study region

Land-use category	Estimated carbon content of vegetation (Mt)			
	1880	1920	1950	1980
Net cultivated area	252.9	286.2	320.2	365.4
Temporary crops	227.0	253.5	280.9	319.7
Permanent crops	25.9	32.7	39.3	45.7
Settled-built-up area	4.6	6.0	8.3	14.0
Forest-woodland	4435.4	3654.8	3021.4	2209.6
Interrupted woods	835.5	729.9	657.5	546.2
Grass-shrub complexes	221.1	258.3	253.5	232.3
Barren - sparsely vegetated	8.7	8.1	7.0	5.9
Wetlands	354.4	257.6	182.7	112.8
Surface water	0.6	0.6	0.6	0.6
Total all categories	6113.1	5201.6	4451.1	3486.8

TABLE 5. Changes in percentages of total carbon in vegetation of each land-use category, from 1880 to 1980, for the study region

Land-use category	Percentage of total carbon			
	1880	1920	1950	1980
Net cultivated area	4.1	5.5	7.2	10.5
Temporary crops	3.7	4.9	6.3	9.2
Permanent crops	0.4	0.6	0.9	1.3
Settled-built-up area	0.1	0.1	0.2	0.4
Forest-woodland	72.6	70.3	67.9	63.4
Interrupted woods	13.7	14.0	14.8	15.7
Grass-shrub complexes	3.6	5.0	5.7	6.7
Barren - sparsely vegetated	0.1	0.2	0.2	0.2
Wetlands	5.8	5.0	4.1	3.2
Surface water	0.0	0.0	0.0	0.0
Total all categories	100.0	100.0	100.0	100.0

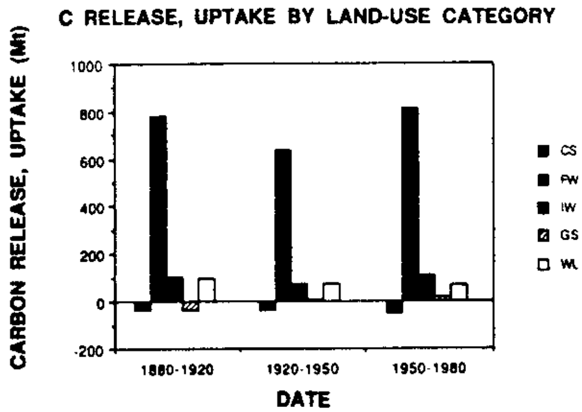

FIG. 4. Graph illustrating carbon release and uptake in the study area, during each of three time intervals, for five land-use categories. Each bar represents carbon release or uptake (Mt) in one land-use category during one interval. Bars extending above the zero line represent carbon release; bars extending below it show uptake. Key to bars: CS, cultivated or settled; FW, forest-woodland; IW, interrupted woods; GS, grass-shrub complexes; WL, wetlands. Net changes in the barren - sparsely vegetated and surface water categories were too small to register on the graph, so they have been omitted.

ity had reduced both forest cover and biomass in the study region. Even at this point in time the proportion of the region bearing forest-woodland vegetation was clearly lower than the total area potentially capable (Fig. 2) of supporting climax forest vegetation in the absence of human activity. Many forests had been converted to agricultural land. In addition, much land still officially described as forest as of 1880 bore vegetation in which the arboreal component was discontinuous, depauperate, or absent. We allocated such land to the interrupted woods and even grass-shrub complexes. Thus, our 1880 estimate of forest-woodland cover for the region does not represent a predisturbance state. Furthermore, careful scrutiny of a wide variety of historical sources indicates that much of the vegetation that met our criteria for classification as forest-woodland in 1880 was also significantly degraded. This is reflected in the relatively low estimate of initial carbon content of the vegetation in the forest-woodland class. For most of south and southeast Asia, a predisturbance or pristine landscape did not exist in the 19th century. Therefore, assumptions that preindustrial forests bore climax vegetation of high carbon content should be modified for south and southeast Asia, and reevaluated for every world region.

Regional comparisons

At present, 51% of the study area is in northern India, 9% in Bangladesh, and 40% in Burma. Neither the present nor the past distributions of the various land-use categories among the three nations are directly proportional to their overall areal representation in the study area. Most categories are very disproportionately distributed among nations. For example, throughout the century, close to 60% of the total forest-woodland (Table 7) was in Burma, and less than 2% in Bangladesh. In contrast, 29% of total wetland area occurs in Bangladesh. Differences in proportions of total cultivated and settled area among the three nations reflect their differing national histories and population densities. Population density (persons/ha) in 1980 for Bangladesh was 5.9; for northern India, 3.1; for Burma, 0.5. As of 1980, the area of cultivated land in Bangladesh was still slightly higher than that of Burma, which is more than four times its size.

Accordingly, total carbon stocks of the three nations have never been proportional to their share of the area (Table 8). Over the entire century, about half the total carbon content of vegetation in the study area has been located in

TABLE 6. Estimated carbon release (negative values) and uptake (positive values) for each land-use category during three intervals, and for total period, for the study region

Land-use category	Total carbon release and uptake (Mt) 1880–1920	1920–1950	1950–1980	1880–1980	% carbon release and uptake* 1880–1920	1920–1950	1950–1980	1880–1980
Net cultivated area	33.4	34.0	45.1	112.5	3.7	4.5	4.7	4.3
Temporary crops	26.6	27.3	38.8	92.7	2.9	3.6	4.0	3.5
Permanent crops	6.8	6.6	6.3	19.8	0.7	0.9	0.7	0.8
Settled, built-up area	1.5	2.3	5.7	9.4	0.2	0.3	0.6	0.4
Forest-woodland	−780.6	−633.5	−811.8	−2225.8	−85.6	−84.4	−84.2	−84.8
Interrupted woods	−105.6	−72.4	−111.3	−289.3	−11.6	−9.7	−11.5	−11.0
Grass-shrub complexes	37.2	−4.8	−21.2	11.2	4.1	−0.6	−2.2	0.4
Barren - sparsely vegetated	−0.5	−1.2	−1.0	−2.7	−0.1	−0.2	−0.1	−0.1
Wetlands	−96.9	−74.9	−69.9	−241.6	−10.6	−10.0	−7.2	−9.2
Surface water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total all categories	−911.5	−750.5	−964.4	−2626.3	−100.0	−100.0	−100.0	−100.0

*Percentage of total release.

TABLE 7. Percentages of total area in selected land-use categories, from 1880 to 1980, in each nation in the study region, compared with percentage of the total study region represented by each nation

	Area of nation as % of regional total	% of total forest-woodland area 1880	1920	1950	1980	% of total cultivated + settled area 1880	1920	1950	1980	% of total wetland area 1880	1920	1950	1980
N. India	51.4	40.6	42.2	41.3	38.3	74.8	67.8	69.6	68.8	33.0	36.6	37.7	35.6
Bangladesh	8.7	1.4	1.3	1.3	1.0	17.8	17.3	17.5	15.7	25.8	29.4	28.2	29.0
Burma	39.9	58.0	56.5	57.4	60.7	7.4	14.9	12.9	15.5	41.2	34.0	34.1	35.4
Total study region	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Burma. This is consistent with the high representation of forest-woodland (the category with highest mean carbon content) in that country. India has been slightly under-represented, and Bangladesh deficient in carbon stock.

Each nation's pattern of carbon release and uptake over time has been distinctive (Table 9). In Burma, the highest rate of carbon release occurred in the first interval, with a drop-off after 1920. Carbon released from the forest-woodland class amounted to 87% of the total. Two factors contributed to the release: a 33% reduction in forest-woodland area and reduction of carbon content within the category from an estimated 84 t/ha in 1880 to 66 t/ha in 1980. These estimates may seem low, but the zones in Burma with rainfall sufficient to support high rain forest were significantly degraded before 1880. The Tenasserim dipterocarp forests (93) were significantly damaged by commercial extraction of teak before 1850 (196); while those of Arakan include much secondary growth due to long-term shifting cultivation (179, 193). The remainder of the carbon release in Burma came from interrupted woods and wetlands vegetation, both of which also showed significant reductions in area and carbon content per hectare. The modest carbon uptake was limited to the cultivated and grass-shrub classes. Total carbon release from Burma for the century is estimated as 1.28 Gt. A recent estimate (92) of the 1980 release from Burma suggests that the rate of carbon release from this nation continues to increase.

Bangladesh, with carbon release less than a tenth of Burma's (0.10 Gt), showed a different pattern of carbon stock dynamics. The mean rate of release per decade increased in each succeeding interval. Wetland vegetation accounted for 47% of the total release, almost all of it from the Sundarbans mangrove and tidal forest (66, 180). Contributing to this release were a 43% reduction in wetland area and an estimated decline in its carbon content from 40 to 22 t/ha over the course of the century. Another 35% of the total release came from forest-woodland vegetation, primarily due to the effects of logging, shifting cultivation, and dam construction on the tropical humid forests in the Chittagong Hill Tracts and Coastal zones (6, 199). Much of the rest of Bangladesh was deforested before 1880 (110) and, thus, contributed little to the forest-woodland release. However, carbon was also released from vegetation in the interrupted woods and even the grass-shrub complex categories. The effects of degradation within land-use categories are particularly severe in this nation (6) because of the extremely high densities of both people (Table 1) and livestock (Table 10). Bangladesh is disproportionately over-endowed, and Burma underendowed, with both two- and four-legged consumers. The limited carbon uptake that occurred in the cultivated sector was due to expansion of the area in that class, rather than to changes in mean carbon content of temporary crops. Current carbon release from Bangladesh is relatively low (92), because most of its area had already been transformed from high-carbon forested to low-carbon nonforested systems before 1880.

In northern India, the rate of carbon release rose with each succeeding interval (78, 123, and 183 Mt/decade). Total release for the century (1.23 Gt) was comparable to that of Burma. By one recent calculation (92), the annual carbon

TABLE 8. Area and total carbon in vegetation, from 1880 to 1980, for each nation in the study region

	Area (10^6 ha)	Total carbon content in vegetation (Mt)				Area of nation as % of regional total	% of total carbon in vegetation			
		1880	1920	1950	1980		1880	1920	1950	1980
N. India	87.10	2736	2423	2054	1504	51.4	44.8	46.7	46.2	43.3
Bangladesh	14.80	212	177	148	109	8.7	3.5	3.4	3.3	3.1
Burma	67.66	3158	2592	2244	1872	39.9	51.7	49.9	50.5	53.7
Total study region	169.55	6104	5193	4446	3485	100.0	100.0	100.0	100.0	100.0

release from Burma now exceeds that of the entire nation of India, a trend consistent with the comparative time courses of carbon release observed here. Carbon release in northern India was particularly concentrated in the forest-woodland class, which lost carbon equivalent to 89% of the total release. As elsewhere, reduction in both area (52%) and mean carbon content per hectare of forest (from 108 to 88 t/ha) contributed to this release. Mean carbon content of northern Indian forests is somewhat higher than that of Burma because a relatively high proportion of the surviving forest-woodland in the former consists of high-biomass forest types (in relatively inaccessible Arunachal Pradesh and the reserved forests of the Himalayan districts of Uttar Pradesh). Interrupted woods, wetlands, and grass-shrub vegetation were the other sources of carbon release in northern India. Overgrazing has significantly reduced the carbon content per hectare of nonforest vegetation. The number of livestock doubled from 1880 to 1980 (Table 10), while that of people almost tripled (Table 1). Carbon uptake in cultivated land, associated with increased area in this category, was minimal in context of the total release.

Table 11 compares the relative contributions of seven states or aggregations of states to the total northern Indian area and carbon stock. With less than 10% of the total area, Arunachal Pradesh contained an estimated 31% of the carbon stock in 1880, and 42% in 1980. Its relative inaccessibility, rugged mountain terrain, and sparse population prevented rapid deforestation (201). Uttar Pradesh, with one-third of the total area, has accounted for about 20% of the carbon stock. This is concentrated in the forests of the Himalayan districts (85, 185). Most of the carbon in the other zones of Uttar Pradesh in contained in the vegetation of the cultivated land, which has dominated their land-use patterns throughout the century (43, 57, 127, 148). The carbon contents of the Northeast Hill States, Assam, Sikkim, and Himachal Pradesh, are roughly proportional to their area. Heavily agricultural Bihar (2) and West Bengal (136, 181) have been proportionally underrepresented in carbon terms throughout the century.

Case studies of deforestation

The regional and temporal heterogeneity in our carbon-stock estimates results from juxtaposition of many different patterns of land use at smaller spatial scales. In each zone we see complex and localized interactions of environmental and historical factors. We will examine three case studies at the level of the ecological zone that illustrate different processes of deforestation.

Case study 1: agricultural expansion in the Burma Delta

A classic case of deforestation driven largely by agricultural expansion occurred in the Burma Delta zone (Fig. 2, zone 38, comprising the modern Irrawaddy and Pegu divisions and Rangoon) following its annexation by the British in 1852. Rice cultivation was already established in parts of the upper Irrawaddy River delta. Colonial administrators valued the remaining forest vegetation, because these mixed tropical moist deciduous forests contained economically significant quantities of teak (*Tectona grandis* L. f.), pyinkado (*Xylia dolabriformis* Benth.), and other desirable trees (196). Government controls to prevent depletion of these species by commercial loggers were applied as early as 1858, and much of the remaining forest land of this type had been legally reserved by 1880 (17, 21).

However, the extensive tidal and mangrove forests of the lower delta, which were relatively untouched before the advent of the British, were not regarded as worthy of conservation. As late as 1948, one British authority dismissed the tidal forests as "horrible places fit only for the snakes and crabs that inhabit them, feet deep in mud" (9, p. 480). Colonial administrators rewrote old trade laws, structured new land tenure and taxation systems to favor forest clearance and rice planting by peasant migrants, subsidized embankment construction to protect the paddy crop, and built roads to provide market access, all with the intent of establishing a rice export economy (1, 172). When the Suez Canal was opened in 1869, the foreign market became even stronger (129), and the influx of land-hungry peasants to the lower Irrawaddy Delta increased.

The initial phase of agricultural expansion was concentrated in fallow land, secondary vegetation, and herbaceous wetlands dominated by kaing grass (*Saccharum spontaneum* L.), which immigrants found relatively easy to clear. Such land was in short supply by 1880. Thereafter, the virgin wetland forests of lower Burma were preferentially sacrificed to provide more land for commercial cultivation of rice (1). Inland tidal forests dominated by large kanazo (*Heritiera Jomes* Buch.) trees were particularly attractive to cultivators because they were less saline and less vulnerable to severe floods. Soon, however, even the most frequently flooded and salt-tolerant mangrove swamps were being converted to rice paddies, and dense stands of *Rhizophora*, *Sonneratia*, and *Ceriops* spp. were destroyed.

Table 12 illustrates the changes in land use and carbon content in the Burma Delta zone. From 1880 to 1920, the net sown area increased by 142%, at the expense of 47% of the 1880 wetland forest area. As a result, the Delta, with only 12.5% of the area in Burma, accounted for 32% of its total carbon release from 1880 to 1920. The magnitude of this release is explained by the large areas cleared and the relatively high biomass of the vegetation that was

TABLE 9. Changes in carbon content of live vegetation in each land-use category, for each nation in the study region, during three intervals, and for total period (negative values indicate release; positive values indicate uptake)

	Carbon release and uptake (Mt)											
	Northern India				Bangladesh				Burma			
Land-use category	1880-1920	1920-1950	1950-1980	1880-1980	1880-1920	1920-1950	1950-1980	1880-1980	1880-1920	1920-1950	1950-1980	1880-1980
Net cultivated area	-1.2	28.7	23.7	51.2	2.0	5.3	0.2	7.5	34.3	-0.4	21.4	55.3
Temporary crops	-2.9	25.4	20.4	42.9	1.6	5.5	0.2	7.3	28.9	-3.7	18.4	43.7
Permanent crops	1.8	3.3	3.2	8.3	0.4	-0.2	0.0	0.2	5.4	3.3	3.0	11.7
Settled-built-up area	0.5	1.3	3.0	4.9	0.4	0.3	1.3	2.0	0.6	0.6	1.4	2.5
Forest-woodland	-278.7	-326.9	-487.5	-1093.1	-13.8	-9.7	-15.7	-39.2	-488.2	-296.9	-308.5	-1093.6
Interrupted woods	-22.6	-24.4	-56.7	-103.7	-7.2	-4.8	-5.0	-17.0	-76.0	-42.2	-49.0	-167.3
Grass-shrub complexes	7.7	-23.4	-10.1	-25.9	-3.2	-3.6	-3.4	-10.2	32.2	22.2	-7.8	46.5
Barren - sparsely vegetated	-0.5	-1.1	-0.9	-2.5	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2
Wetlands	-18.0	-23.6	-21.4	-63.0	-14.0	-17.0	-16.5	-47.5	-66.8	-31.2	-28.8	-126.8
Surface water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total all categories	-312.7	-369.5	-549.9	-1232.1	-35.8	-29.4	-39.1	-104.2	-563.9	-348.0	-371.6	-1283.5

replaced by rice: kanazo trees in the tidal forests were known to reach heights of 45 m, and shorter stands were characterized by high stem density (194). Additional carbon release occurred when unprotected lowland stands of tropical moist forests were converted to rice land and logging depleted the biomass in teak-bearing reserved forests (197), but the enormous expansion of cultivated area was clearly the major cause of carbon release in this zone before 1920. It was recognized that by this time most of the area suitable for rice production was occupied (129). From 1920 to 1950, both the net cultivated area and the forest-woodland area declined (by 15 and 16%, respectively). The primary causal factor here was the Japanese invasion of Burma during the second world war (44). The area in wetlands also declined. Further reductions of 13% in forest-woodland area and 28% in wetland area between 1950 and 1980 were probably linked to both a 38% expansion of the cultivated area and new techniques for commercial exploitation of woody species in both the tropical moist and tidal forests. Overall, however, the primary factor driving deforestation in this area has clearly been conversion to arable land.

Case study 2: commercial overfelling in Chamba, Himachal Pradesh

A contrasting pattern is seen in the mountainous Chamba ecological zone in the Indian Himalayas (Fig. 2, zone 1). Here, throughout the century, the primary agent of deforestation was commercial extraction of timber from forests, with subsistence use of wood as an aggravating factor after 1950. Extant 10th century deeds suggest that sedentary agriculture was well established in Chamba valleys at that time, and human settlement in the area apparently dates back to the 1st century A.D. (47). However, until the British gained political control over the northwestern Himalayas in the early 19th century, the mountain forests of Chamba were relatively undisturbed (208, 209). During that period, travelers to this Himalayan state (coextensive with the modern district and our ecological zone) described supposedly inexhaustible forests of deodar (*Cedrus deodara* L.) (196). This conifer was particularly valuable because of its great size (trees over 70 m tall were still standing in the western Himalayas in 1920) and the resistance of its wood to rot and insect attack (207, 208). It is believed that some trees were cut as building timber for export to the Lahore market before the 19th century (78).

However, the recorded history of deodar exploitation in Chamba begins after 1850. By this date, the accessible northern Indian forests of sal (*Shorea robusta*), the only other species north of the Ganges equally desirable for construction and railway sleepers (151), had been depleted (189). Private timber contractors aware of the needs of the colonial government then turned their attentions to the forest estate of the Rajah of Chamba, which was known to contain stands of quality I deodar. They did so with such energy that this resource was reported as near exhaustion by 1864 (51). The actual proportion of deodar in these forests was considerably lower than that initially estimated, since deodar is limited in its elevational range and it often grows intermixed with other species, notably blue pine (*Pinus excelsa* Wall.) and ban oak (*Quercus incana* Roxb.) (72, 81, 128, 138, 161). The Rajah, who had effectively lost control of his reserved forests, leased them to the British Forest Department, and forest conservancy was introduced (78, 196, 197).

An official program of forest management slowed but did not halt the contraction of the forest area, because railway expansion generated an enormous demand (209) throughout the rest of the 19th century, rendering economically feasible the exploitation of formerly remote deodar stands. By 1905, technological changes made commercial logging of blue pine economically remunerative (78). Formerly uncommercial forests dominated by this species now came under the axe, as deodar became increasingly scarce, so the forest area of Chamba continued to contract. As wood preservation technology improved, the remaining coniferous species of the Himalayas were gradually reclassified as economically useful. Many of these were overfelled during both the first and second world wars (198, 44) in response to military demands for wood. When the princely state of Chamba was integrated into Himachal Pradesh after independence, the Indian Forest Service took full control of forests (138), which were by now badly depleted. Commercial logging, although subjected to some controls, continued at levels exceeding maximum sustained yield.

After 1950, accelerated subsistence use of oaks for firewood and browse by an exploding farm population (189) deforested large areas of temperate broad-leaved trees that had hitherto been relatively unmolested. Sedentary agriculture as practiced in the western and central Indian Himalayas requires such extensive energy subsidies from forests (150) that adjacent forests of up to four times the cultivated area are needed to maintain the system (111). As elsewhere in the Himachal Pradesh and Uttar Pradesh Himalayas (149), the depredations of itinerant pastoralists (19) further degraded the forests.

Table 13 illustrates the process of deforestation in Chamba. In 1 century, this zone lost 64% of its forest-woodland area. Some land went into permanent cultivation and now bears temporary crops or orchards (186), but this amounted to less than 15% of the deforested area. Most of the remainder was degraded to scrub or pasture. Because over 90% of the 1880 carbon stock of Chamba was in the forest-woodland class, almost all of the carbon release in this zone came from the forest vegetation. Reduction in forest area was the primary factor, but depletion of biomass in the remaining forests was also involved; estimated carbon content of the Chamba forest-woodland declined from 127 to 94 t/ha, primarily as a result of selective commercial removal of the largest trees.

Case study 3: shifting cultivation in Meghalaya

A very different process of deforestation is represented by the indigenous practice of shifting cultivation in the humid hill country of northeastern India and adjacent parts of Burma. Tribal peoples have developed a variety of agricultural subsistence strategies, collectively known as jhum (211). Typically, a family of five or six members clear-cuts a forest plot of 2 to 2.5 ha on sloping land, allows the slash to dry during the winter season, burns it in March or April, and plants a mixture of up to 30 species of cereals, legumes, tuber crops, vegetables, and fruits (70, 159). The plot is abandoned after 1 or 2 years of cultivation and (under optimal conditions) left fallow for 25-35 years to allow forest regrowth (70, 203, 204). Considerable information on the ecology of jhum (133, 159, 160, 203, 204) is available from the northeast Indian state of Meghalaya (Fig. 2, zone 23), where tribesmen have practiced it for generations (84, 153). In the absence of human intervention, the natural vegetation of the Meghalaya hills (87) would be dominated by tropical evergreen forest (*Mesua ferrea* L., *Castanopsis indica* A.DC.; *Dysoxylum*, *Terminalia*, and *Elaeocarpus* spp., etc.), tropical semievergreen forest (characterized by species of *Elaeocarpus* and *Dillenia*, among others), moist temperate forests (*Quercus* and *Castanopsis* spp., *Schima khasiana* Dyer, etc.), and islands of subtropical coniferous (*Pinus khasya* Royle) forest.

Colonial foresters and botanists working not only in Meghalaya but also throughout northeastern India, the Bangladesh Chittagong Hills, and Burma, deplored shifting agriculture as wasteful of timber. Dietrich Brandis, the founder of the Indian Forest Service did adapt it in Burma to develop the taungya method of regenerating teak (28). But as a rule the Forest Service strongly discouraged shifting cultivation in reserved forests. Meghalaya was included in this policy, although significant areas of deciduous forest (which in some ways are more economically desirable than the evergreen types) appear to have been established in the past as a result of jhum fires (87). Indeed, at low population densities, shifting-cultivation systems theoretically possess long-term sustainability (159). This is particularly true where tribes (as is customary in Meghalaya) avoid old-growth tropical forest and concentrate their slash and burn operations on the more manageable secondary forest (159, 203). However, the critical variable determining sustainability is the length of time allowed for regrowth of arboreal vegetation. A stable system can only be maintained if the ratio of persons to land permits a fallow interval of at least 20 years, and optimally 30 years after each planting. Early

TABLE 10. Livestock populations, from 1880 to 1980, for each nation in the study region

	Livestock population (millions)			
	1880	1920	1950	1980
N. India	67.29	78.81	109.77	134.71
Bangladesh	15.49	21.38	19.03	36.07
Burma	2.69	6.93	8.35	15.39
Total study region	85.47	107.11	137.15	186.18

TABLE 11. Area and total carbon content of vegetation, from 1880 to 1980, for state or aggregations of states in northern India, expressed as percentages of the total northern India area and carbon content, respectively

State or aggregation of states	Area, as % of total area	Carbon content, as % of total northern India carbon			
		1880	1920	1950	1980
Himachal Pradesh	6.2	7.6	7.3	6.8	5.2
Uttar Pradesh	33.6	21.7	20.8	20.0	18.2
Bihar	20.0	8.4	7.5	6.9	7.0
West Bengal	10.2	4.9	4.8	4.0	3.7
Sikkim	0.8	0.9	0.9	1.0	0.9
Assam	9.0	10.6	9.6	9.6	9.3
Arunachal Pradesh	9.6	31.0	34.6	38.0	41.9
Northeast Hill States	10.7	15.0	14.4	13.7	13.8
Total	100.0	100.0	100.0	100.0	100.0

TABLE 12. Changes in land use and carbon content in the Burma Delta zone from 1880 to 1980

	Area (10^3 ha)				Estimated carbon content (kt)			
Land-use category	1880	1920	1950	1980	1880	1920	1950	1980
Net cultivated area	1147	2777	2363	3255	12 014	29 385	25 630	34 165
Temporary crops	1111	2669	2229	3147	11 110	26 687	22 295	31 472
Permanent crops	36	108	133	108	904	2 698	3 335	2 693
Settled-built-up area	56	108	160	291	224	434	639	1 165
Forest-woodland	3314	2344	1975	1720	347 998	210 919	162 954	116 118
Interrupted woods	1758	1279	1103	1011	55 369	34 528	27 304	20 466
Grass-shrub complexes	636	916	2002	1428	8 903	10 987	24 019	12 850
Barren - sparsely vegetated	61	65	70	78	214	196	210	175
Wetlands	1101	585	400	290	82 227	37 426	23 713	13 929
Surface water	398	398	398	398	40	40	40	40
Total area	8471	8471	8471	8471	506 988	323 915	264 509	198 910

TABLE 13. Changes in land use and carbon content in the Chamba zone from 1880 to 1980

	Area (10^3 ha)				Estimated carbon content (kt)			
Land-use category	1880	1920	1950	1980	1880	1920	1950	1980
Net cultivated area	29.9	34.7	33.2	40.9	196	228	218	286
Temporary crops	29.7	34.5	33.0	38.6	193	224	215	251
Permanent crops	0.2	0.2	0.2	2.3	3	4	3	35
Settled-built-up area	1.7	2.0	2.8	3.6	5	6	9	11
Forest-woodland	125.6	104.6	82.7	45.9	16 010	12 045	8370	4341
Interrupted woods	11.8	13.4	15.3	8.8	452	462	464	249
Grass-shrub complexes	202.3	216.2	236.3	267.2	667	648	638	641
Barren - sparsely vegetated	273.3	273.8	274.3	278.2	150	137	123	111
Wetlands	0.0	0.0	0.0	0.0	0	0	0	0
Surface water	6.9	6.9	6.9	6.9	1	1	1	1
Total area	651.5	651.5	651.5	651.5	17 483	13 527	9823	5641

descriptions of agricultural practices and vegetation (94, 122, 153) suggest that population density in parts of the northeastern Himalayas locally exceeded this limit well before the 20th century. Travelers' descriptions of Cherrapunji station in the wettest part of Meghalaya (82, 90) indicate that considerable areas of rain forest had been permanently converted to grassland before 1850.

What was once only a local problem is now regional; explosive growth of population since 1950 (119% in Meghalaya) has forced virtually all northeast Indian shifting cultivators to progressively shorten the length of the fallow period between cycles of clearing and burning from 30 years to as little as 5 years (204). Ten- and 15-year cycles allow some forest regrowth, but repeated short cycles cause exotic herbaceous weeds such as *Eupatorium adenophorum* Spreng. and *Imperata cylindrica* (L.) Beauv. to permanently replace the forest. Infestations of these species were observed in northeastern India before 1920 (184). Land infested with these species cannot be economically returned to cultivation and is permanently relegated to the grass-shrub category. In extreme cases, shortened jhum cycles can cause erosion and total loss of vegetation (160).

Our data for Meghalaya state (Table 14) indicate a 56% reduction in the forest-woodland vegetation between 1880 and 1980. The deforestation rate increased in each successive interval. Cultivated area increased by 168%, but this accounted for only a quarter of the lost forest area. Some land has been converted to sedentary agriculture, and much remains in jhum fields. But most of the deforested land has been degraded to the grass-shrub complex category, the typical end point of degradation induced by excessively short jhum cycles (70). Overall, the carbon content of live vegetation in this zone decreased by 52%, with the greatest rate of loss occurring in the final interval. Forest-woodland systems lost carbon equivalent to 62% of the total release. Reduction in area and degradation within category were both significant components of the release. Estimated carbon content per hectare for forest-woodland in Meghalaya dropped from 88 to 68 t/ha. Interrupted woods vegetation also released a significant amount of carbon. The carbon content of the grass-shrub category increased because the area in this category rose by over 250%.

Implications of comparison of the case studies

The three case studies described show that in each ecological zone the single concept of deforestation is underlain by a unique mosaic of land-use changes. Remarkably different economic activities caused dramatic transformations on the land, and large reductions in the carbon content of vegetation, in the three case studies. In some cases (e.g., Meghalaya) these processes were driven primarily by local events, but in others (notably the Burma Delta), global economic and political factors significantly affected the patterns of land-use change. Such diversity is characteristics of human activity in every part of the world during the past 2 centuries (172). Attempts to model past land-use

TABLE 14. Changes in land use and carbon content in the Meghalaya zone from 1880 to 1980

	Area (10^3 ha)				Estimated carbon content (kt)			
Land-use category	1880	1920	1950	1980	1880	1920	1950	1980
Net cultivated area	72	92	138	193	674	874	1 321	1 809
Temporary crops	68	85	126	181	612	767	1 130	1 629
Permanent crops	4	7	13	12	62	107	191	180
Settled-built-up area	4	6	9	20	17	25	36	80
Forest-woodland	852	687	529	378	74 763	55 666	39 252	25 488
Interrupted woods	1119	1185	1188	1028	29 456	28 799	26 474	20 813
Grass-shrub complexes	166	244	353	595	1 660	2 199	3 178	4 759
Barren - sparsely vegetated	11	11	11	22	28	25	25	45
Wetlands	22	20	18	11	1 359	1 117	946	532
Surface water	2	2	2	2	0	0	0	0
Total area	2249	2249	2249	2249	107 956	88 706	71 232	53 526

change must recognize and consider the variability of these processes among different time periods and societies.

General conclusions

Our study, based on a surprising depth of source material for what are today considered Third World nations, has generated time series of land-use data and carbon stock estimates for 1.7×10^6 km^2 of south and southeast Asia. During the century under review, major shifts in the area covered by major land-use classes have occurred. Forests and woodlands declined by 17.3×10^6 ha (37%); net cultivated area grew by 13.2×10^6 ha (33%). Human numbers in this region more than tripled between 1880 and 1980. Lands in this region have become more productive from the standpoint of certain human needs (in particular, food production). But, at the same time, much of their vegetative cover has been converted from categories of high biomass to categories of low biomass. Such conversions, particularly the felling and clearing of forests and woodlands, have released an estimated 1.8 Gt of carbon into the atmosphere.

Since 1880, recurring human exploitation of the land has depleted the vegetation within each land-use category. Intensifying human pressures have reduced the standing stock of live vegetation at an accelerating rate. This process of depletion must be quantified to arrive at a credible value for carbon releases. By our calculations, degradation within land-use categories contributed an additional 47% (0.8 Gt) to the regional carbon release between 1880 and 1980.

In summary, our data reveal a dynamic picture of dramatic changes in land use and the carbon content of live vegetation over the century in this tropical and subtropical region. Intensified forest clearance for both permanent and swidden agriculture, timber extraction, and exploitation of fodder and other forest produce have all contributed to deforestation and consequent release of carbon to the atmosphere. Similar documentation of long-term land-use change in other world regions can reduce uncertainties in estimates of biotic release as a component of the global carbon cycle.

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