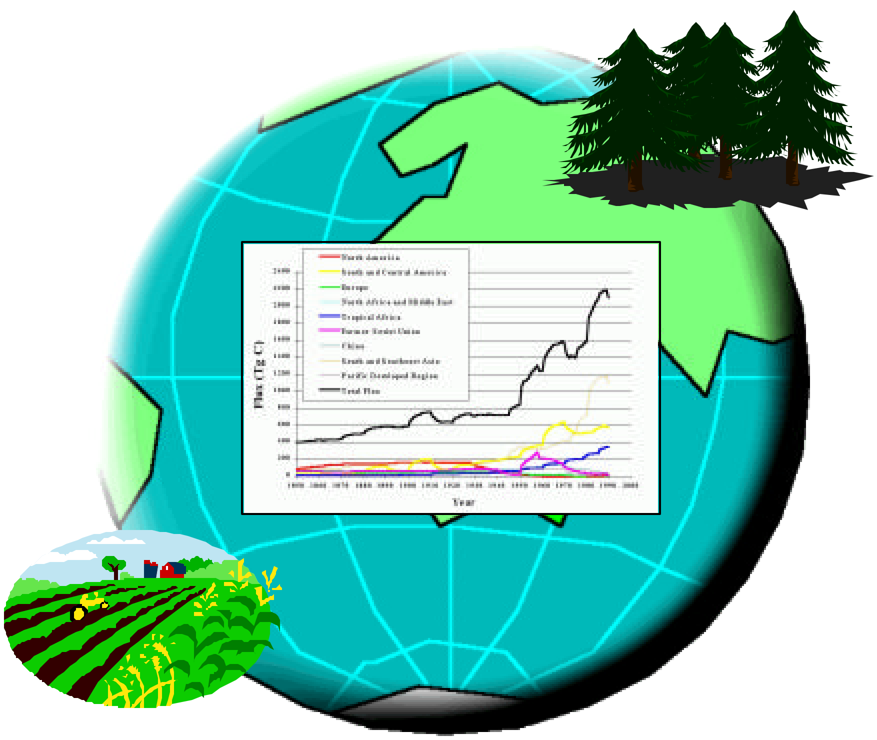
ORNL/CDIAC-131

NDP-050/R1

Carbon Flux to the Atmosphere from Land-Use Changes: 1850 to 1990

Richard A. Houghton
Joseph L. Hackler



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CARBON FLUX TO THE ATMOSPHERE FROM LAND-USE CHANGES: 1850 TO 1990

Contributed by

Richard A. Houghton
Joseph L. Hackler
The Woods Hole Research Center
Woods Hole, Massachusetts

Prepared by

Robert M. Cushman
Carbon Dioxide Information Analysis Center

Environmental Sciences Division
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Prepared by the
Carbon Dioxide Information Analysis Center
Environmental Sciences Division
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6335
managed by
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ABSTRACT

Houghton, R. A., and J. L. Hackler. 2001. *Carbon Flux to the Atmosphere from Land-Use Changes: 1850 to 1990.* ORNL/CDIAC-131, NDP-050/R1 (http://cdiac.esd.ornl.gov/ndps/ndp050.html). Carbon Dioxide Information Analysis Center, U.S. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S.A. 86 pp.

The database documented in this numeric data package, a revision to a database originally published by the Carbon Dioxide Information Analysis Center (CDIAC) in 1995, consists of annual estimates, from 1850 through 1990, of the net flux of carbon between terrestrial ecosystems and the atmosphere resulting from deliberate changes in land cover and land use, especially forest clearing for agriculture and the harvest of wood for wood products or energy. The data are provided on a year-by-year basis for nine regions (North America, South and Central America, Europe, North Africa and the Middle East, Tropical Africa, the Former Soviet Union, China, South and Southeast Asia, and the Pacific Developed Region) and the globe. Some data begin earlier than 1850 (e.g., for six regions, areas of different ecosystems are provided for the year 1700) or extend beyond 1990 (e.g., fuelwood harvest in South and Southeast Asia, by forest type, is provided through 1995).

The global net flux during the period 1850 to 1990 was 124 Pg of carbon (1 petagram = 10^{15} grams). During this period, the greatest regional flux was from South and Southeast Asia (39 Pg of carbon), while the smallest regional flux was from North Africa and the Middle East (3 Pg of carbon). For the year 1990, the global total net flux was estimated to be 2.1 Pg of carbon.

This numeric data package contains a year-by-year regional data set of net flux estimates, a year-by-year data set comparing several estimates of global total net flux, and this documentation file (which includes SAS®[1] and Fortran codes to read the ASCII data files). The data files are provided in both flat ASCII and binary spreadsheet format.

The data files and this documentation are available without charge on a variety of media and via the Internet from CDIAC.

Keywords: agriculture, carbon, deforestation, forests, land cover, land use, pastures, plantations, shifting agriculture, soil, vegetation

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[1]SAS® is a registered trademark of the SAS Institute, Inc., Cary, North Carolina 27511.

1. BACKGROUND INFORMATION

In the attempt to "balance" the global carbon cycle (that is, reconcile the known sources and sinks of carbon), two major unknowns remain: the flux between the atmosphere and the oceans and the flux between the atmosphere and terrestrial ecosystems. To address the latter, several investigators have attempted to estimate the flows of carbon between the atmosphere and both temperate and tropical ecosystems.

Quantification of the role of changing land use in the global cycling of carbon (and, consequently, in controlling atmospheric concentrations of carbon dioxide, the single most important greenhouse gas) requires complete, consistent, and accurate databases of vegetation, land use, and biospheric carbon content. The Carbon Dioxide Information Analysis Center (CDIAC) has previously made available several important quality-assured and documented databases on this topic (Olson et al. 1985, Richards and Flint 1994, Houghton and Hackler 1995, and Brown and Gaston 1996).

This database is a revision to Houghton and Hackler (1995). This revised numeric data package provides and documents the data corresponding to the analysis reported by Houghton (1999). It consists of annual estimates, from 1850 through 1990, of the net flux of carbon between terrestrial ecosystems and the atmosphere resulting from deliberate changes in land cover and land use, especially forest clearing for agriculture and the harvest of wood for wood products or energy. The data are provided on a year-by-year basis for nine regions shown in Figure 1 and specified by country in Table 1 (North America, South and Central America, Europe, North Africa and the Middle East, Tropical Africa, the Former Soviet Union, China, South and Southeast Asia, and the Pacific Developed Region) and the globe. Note that South and Central America, Tropical Africa, and South and Southeast Asia, as used in this database, are called Latin America, Sub-Saharan Africa, and Tropical Asia, respectively, in Houghton (1999). Some data begin earlier than 1850 (e.g., for six regions, areas of different ecosystems are provided for the year 1700) or extend beyond 1990 (e.g., fuelwood harvest in South and Southeast Asia, by forest type, is provided through 1995).

The approach used to derive this time series of flux estimates is described fully in Houghton (1999) and other publications (Houghton et al. 1983, 1987; Houghton and Hackler 1995, 1999). The methodology takes into account not only the initial removal and oxidation of the carbon in the vegetation but also subsequent regrowth and changes in soil carbon. The net flux of carbon to the atmosphere from changes in land use from 1850 to 1990 was modeled as a function of documented land-use change and changes in aboveground and belowground carbon following changes in land use. The changes in carbon, with time, following land-use change are specified by region and ecosystem type.

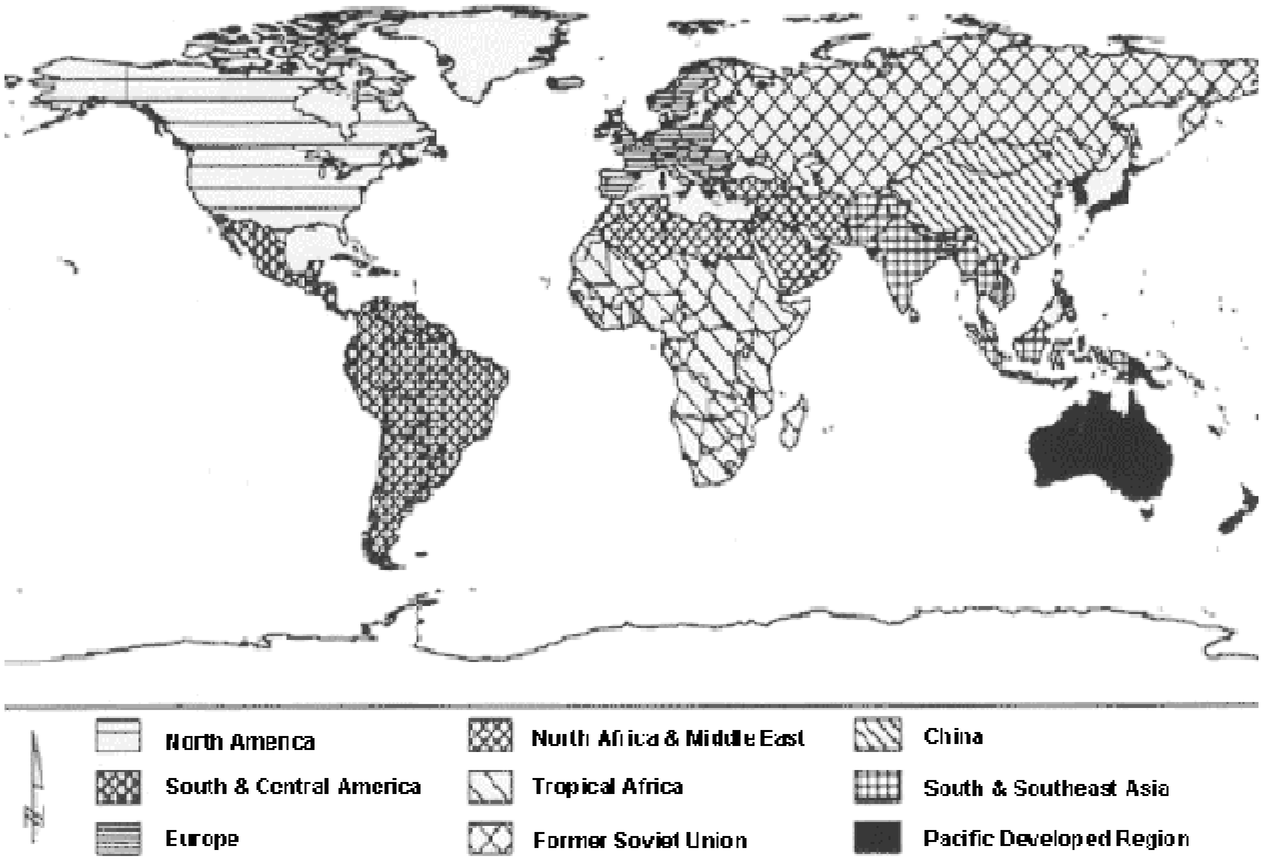

Figure 1. Map of the nine regions covered in this database.

Data on ecosystem areas in each region are listed in Appendix A, which provides areas for the years 1700 (for six of the nine regions), 1850, and 1990, along with the percent change from 1850 to 1990.

Data on changes in land-use and wood harvest are listed in Appendix B, which provides the regional details of fuelwood (nonindustrial logging) and timber (industrial logging) harvest by forest type, changes in area of pasture, forest plantation, afforestation, forest clearing for croplands, and lands in shifting cultivation.

The approach uses a bookkeeping model to track, with an annual time step, changes in aboveground and belowground carbon in different kinds of ecosystems following changes in land use. Annual rates of expansion and contraction of agricultural area (for cropland, pasture, and shifting cultivation) and of wood harvest were used to estimate the types of ecosystem affected and the change in area of each affected ecosystem type. Then, response curves were generated to estimate the changes in carbon, for years to decades, that follow each type of land management or land-use change. All carbon in the affected area is accounted for: live vegetation, soil, slash (woody debris produced during disturbance), and wood products. However, this procedure does not account for all processes that affect ecosystem carbon storage and fluxes (e.g., natural disturbances, fire suppression, and environmental factors, such as CO_2 and climate, that affect vegetation). Furthermore, the analysis ignores fluxes of carbon to or from ecosystems not directly affected by land-use change. Data on land-use change, wood harvest, and carbon in ecosystems were obtained from a number of sources, detailed in Houghton (1999).

Table 1. Countries constituting the nine regions covered in this database

Region	Countries
North America	Canada, United States
South and Central America	Argentina, Bahamas, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Surinam, Trinidad & Tobago, Uruguay, Venezuela
Europe	Albania, Andorra, Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Spain, Switzerland, Yugoslavia
North Africa and the Middle East	Afghanistan, Algeria, Bahrain, Cyprus, Democratic Yemen, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates, Yemen
Tropical Africa	Angola, Benin, Botswana, Burundi, Cabinda, Cameroon, Central African Republic, Chad, Djibouti, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of Congo, Reunion, Rio Muni, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Upper Volta, Western Sahara, Zaire, Zambia, Zimbabwe
Former Soviet Union	Armenia, Azerbaijan, Byelorussia, Estonia, Georgia, Kazakhstan, Kirghistan, Latvia, Lithuania, Moldavia, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
China	People's Republic of China, Mongolia
South and Southeast Asia	Bangladesh, Bhutan, Brunei, Burma, Cambodia, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam
Pacific Developed Region	Australia, Japan, New Zealand, North Korea, Oceania, Papua New Guinea, South Korea, Taiwan

The bookkeeping model partitioned the vegetation after land-use change into three pools: standing live vegetation, dead material left on-site, and woody material removed from the site. The model tracked the return of carbon in the remaining live vegetation to pre-disturbance values. Dead material left on-site and woody material removed from the site (e.g., for timber or firewood) decayed at specified rates. Changes in soil carbon included both post-disturbance losses and eventual recoveries. The coefficients and time constants were specified by region, ecosystem type, and land-use type (see App. C, which provides details of changes in carbon in vegetation and soils with time as a result of land-use change). Finally, changes in on-site carbon pools and carbon in off-site wood products were used to estimate fluxes to and from the atmosphere.

The estimated global total net flux of carbon from changes in land use increased from 397 Tg of carbon (1 teragram = 10^{12} gram) in 1850 to 2187 Tg or 2.2 Pg of carbon (1 petagram = 10^{15} gram) in 1989 and then decreased slightly to 2103 Tg or 2.1 Pg of carbon in 1990 (Fig. 2 and App. D). The global net flux during the period 1850 to1990 was 124 Pg of carbon. During this period, the greatest regional flux was from South and Southeast Asia (39 Pg of carbon), while the smallest regional flux was from North Africa and the Middle East (3 Pg of carbon). For the year 1990, the global total net flux was estimated to be 2.1 Pg of carbon; for comparison, the estimated 1990 carbon flux to the atmosphere from fossil-fuel combustion and cement production has been estimated at 6.1 Pg of carbon (Marland et al. 1999).

This revised database provides estimates for all regions through 1990, whereas Houghton and Hackler (1995) provided estimates for only three regions (South and Central America, Tropical Africa, and South and Southeast Asia) through 1990, for one region (the Former Soviet Union) through 1985, and for the remaining five regions (North America, Europe, North Africa and the Middle East, China, and the Pacific Developed Region) through 1980. For some variables (e.g., fuelwood harvest in South and Southeast Asia, by forest type) the data extend beyond 1990.

The approach used in Houghton (1999) differs from that used in earlier estimates in several respects:

(1) The analysis for South and Southeast Asia has been reconstructed (Houghton and Hackler 1999) to directly assess the effects of logging based on mass of harvested material. This analysis is now methodologically consistent with that for other regions, whereas the approach used in Houghton and Hackler (1995) modeled the region based upon estimated degradation of forest biomass.

(2) The timber harvest rates for China (files chin-rat.* in Houghton and Hackler 1995, App. B in this document) were relabeled to correspond to the correct ecosystem.

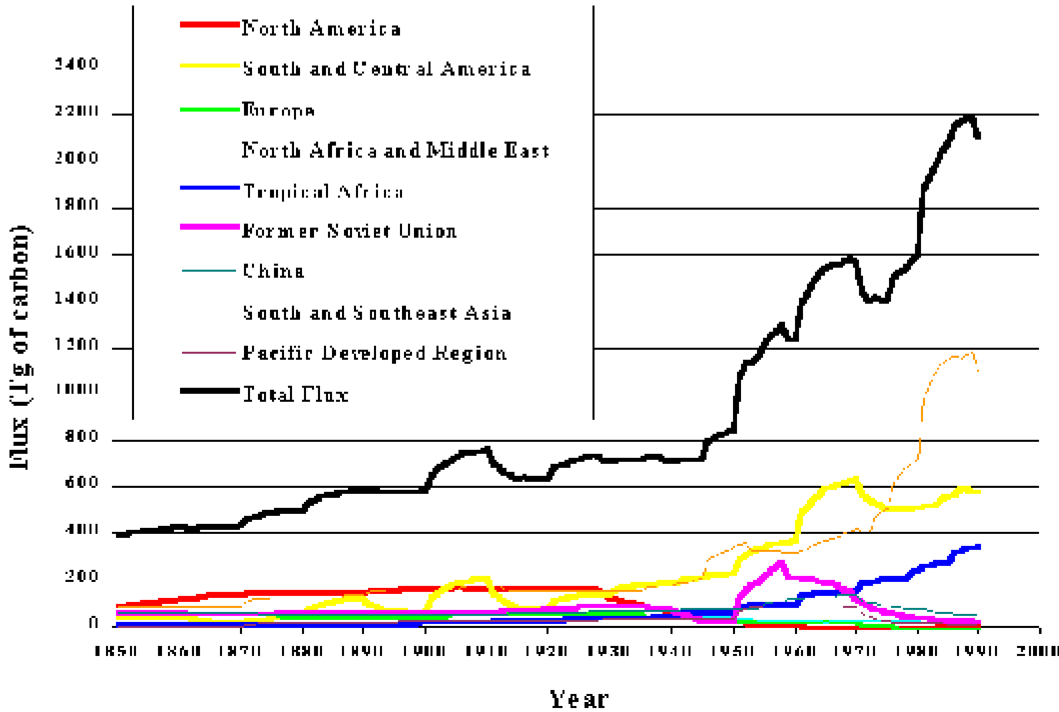

Figure 2. Net flux of carbon to the atmosphere from land-use changes, by region, 1850 to 1990.

(3) The clearing rates and harvest mass for the Former Soviet Union are documented in Melillo et al. (1988), replacing the input rates that had been taken from Houghton et al. (1983) and provided in Houghton and Hackler (1995) as files fsu-rat.* (App. B in this document).

(4) Revised data for South and Central America (Houghton et al. 1991a, 1991b) were used. The earlier data were provided in Houghton and Hackler (1995) as files scam-re.* and scam.rat.*.

(5) Houghton (1999) mentioned three other revisions to the earlier estimates: The residence time of plant debris removed during clearing for agriculture was reduced, forest plantations were considered, and deforestation rates were updated.

2. APPLICATIONS OF THE DATA

This database will be useful for studies of the global carbon cycle, especially focusing on fluxes of carbon between terrestrial ecosystems and the atmosphere. The database will also be useful for studies of land-use change, agriculture, and forestry. The region- and ecosystem-specific parameters provided in Appendix B will be useful for estimating both the recovery of ecosystems following disturbance and the oxidation of carbon in wood products.

3. DATA LIMITATIONS AND RESTRICTIONS

The methodology of Houghton (1999) is limited to deliberate changes in land use (e.g., clearing for agriculture and harvest of forests for timber and fuelwood) and does not account for all processes that affect ecosystem carbon storage and fluxes (e.g., natural disturbances; fire suppression and silvicultural practices; and environmental factors, such as CO_2, nitrogen deposition, acid precipitation, ultraviolet radiation, and climate, that affect vegetation). Furthermore, the analysis ignores fluxes of carbon to or from ecosystems not directly affected by land-use change. In a study of net flux from land-use change in the United States (Houghton et al. 1999), the authors concluded that such environmental factors as climate and increased CO_2 could have accounted for 2 to 4 times as much carbon accumulation as did recovery from previous harvests.

Houghton and Hackler (1999) consider at length the uncertainties associated with estimates of net carbon flux from land-use change. For tropical Asia, they estimate the uncertainty of the long-term flux to be about 30%. The sources of uncertainty are divided into estimating the areas of land affected by change, estimating the biomass of the land (especially in the years before human disturbance), and estimating changes in carbon stocks over time.

Houghton (1999) addresses the simplifications, approximations, and assumptions that are inherent in the estimation of carbon fluxes based on available data, such as estimation of time series of wood harvest or area of cropland by extrapolating from population time series and single-year per capita data.

Additional, region-specific, data limitations are mentioned in Houghton (1999):

(1) In China, Europe, North Africa and the Middle East, North America, the Pacific Developed Region, and South and Central America, harvest of timber was not distinguished from harvest of fuelwood, even though they have different carbon oxidation rates.

(2) Only in South and Central America and in South and Southeast Asia was shifting cultivation considered.

(3) In the Former Soviet Union, the effects of grazing and peat drainage were not considered.

(4) In South and Central America, carbon flux from an increase in degraded lands was excluded.

(5) In South and Southeast Asia, the extraction of fuelwood during the early years may have been underestimated, because of an inverse relationship between per capita extraction and population density.

(6) In Tropical Africa, harvest of wood and shifting cultivation were not included.

The estimates of annual net carbon flux on a global total basis, derived from this database and reported by Houghton (1999), vary somewhat from estimates reported previously (e.g., Houghton et al. 1983, Houghton and Skole 1990, Houghton and Hackler 1995) [Fig. 3 and App. E; but note that the data for the period 1850 to 1859 attributed in Fig. 3 and App. E to Houghton et al. (1983) were not actually presented in that publication but are present in the data used in that publication]. According to the data presented in this numeric data package, the total flux over the period 1850 to 1980 was 103 Pg of carbon (corrected from the 109 Pg of carbon estimate reported in Houghton 1999). This estimate is considerably lower than that found in Houghton et al. (1983) for the (shorter) period 1860 to 1980, 180 Pg of carbon, which has been characterized (Houghton 1999) as an overestimate for three reasons: (1) The amount of soil carbon lost with cultivation was overestimated, because an observed 50% loss of carbon in the upper 20 to 30 cm of the soil column was applied to the top 1 m of soil; (2) estimates of forest biomass in Latin America and Africa were too high; and (3) there was no distinction between harvests of fuelwood and timber despite their very different efficiencies of wood removal. The estimate of global total net flux over the period 1850 to 1980 derived from the data in this numeric data package (103 Pg of carbon) is closer to the more recent estimate in Houghton and Skole (1990): A value of 110 Pg of carbon is reported in that paper, although the authors (personal communication) have noted that the methodology and data described in the paper actually yield a total of 118 Pg of carbon. It is also closer to the estimate of 106 Pg of carbon in Houghton (1993) and to the estimate of 99 Pg of carbon in Houghton and Hackler (1995).

4. DATA CHECKS AND PROCESSING PERFORMED BY CDIAC

An important part of the data-packaging process at CDIAC involves the quality assurance (QA) of data before distribution. To guarantee data of the highest possible quality, CDIAC performs extensive

QA checks, examining the data for completeness, reasonableness, and accuracy, through close cooperation with the data contributor.

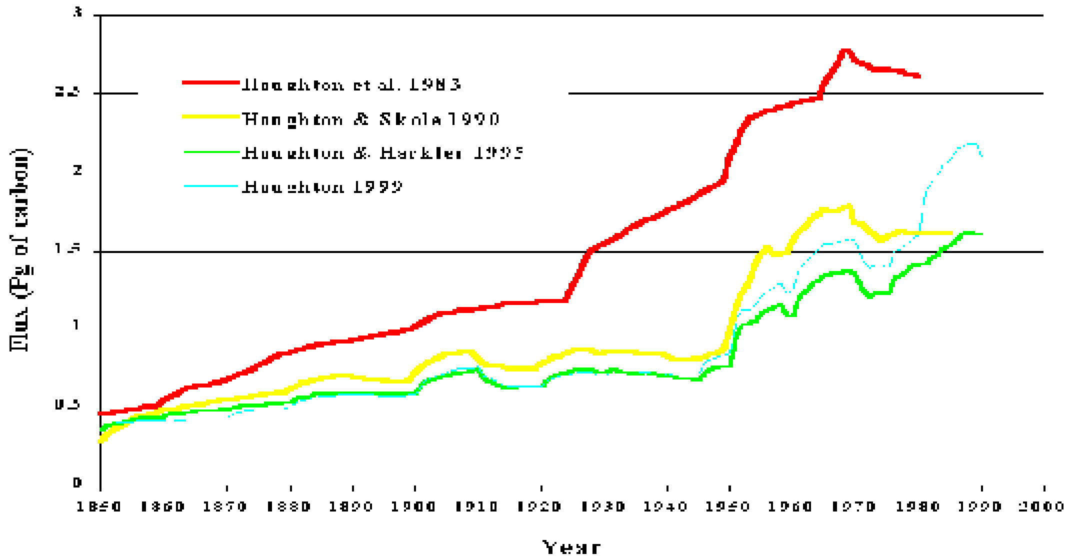

Figure 3. Comparison of estimates of net flux of carbon to the atmosphere from land-use changes, 1850 to 1990.

CDIAC did not attempt to run the bookkeeping model to validate the estimates presented in Houghton (1999). Rather, CDIAC focused its QA efforts on the format and consistency of the datasets and on comparing the values in the database with the corresponding values specified in Houghton (1999).

The annual net flux estimates by region for the period 1850 to 1990 were graphed and visually compared with Figure 5 in Houghton (1999), and the annual global total estimates for the period 1850 to 1990 were graphed and visually compared with Figure 6 in Houghton (1999).

The global total net flux estimates, derived from this database, for the periods 1850 to 1980 (103 Pg of carbon) and 1850 to 1990 (124 Pg of carbon) were compared with the corresponding totals reported in Table 3 of Houghton (1999). While the 1850 to 1990 estimates were identical, the 1850 to 1980 total derived from this database differed from the value of 109 Pg of carbon reported in Houghton (1999). This was determined to be an error in Houghton (1999) rather than an error in the database.

Regional total net flux estimates, derived from this database, for the period 1850 to 1990 and the average annual flux for the 1980s were compared with the corresponding totals reported in Table 2 of Houghton (1999). They all agreed, with the exception of the estimate of the 1850 to 1990 total for the Former Soviet Union, which is 10.7 Pg of carbon according to this database but 10.4 Pg of carbon according to Houghton (1999). This discrepancy is attributed to the current explicit specification of *volume* of timber and fuelwood harvest in the data input and modeling process (as opposed to the previous use of *area* harvested as a surrogate for the volume of harvest).

Equivalent files **compare.dat** and **compare.wk1** list the year-by-year estimates of global total net flux plotted in Figure 6 of Houghton (1999), corresponding to the estimates presented in Houghton et al. (1983), Houghton and Skole (1990, as corrected), Houghton and Hackler (1995), and Houghton (1999, as corrected).

5. INSTRUCTIONS FOR OBTAINING THE DATA AND DOCUMENTATION

This database (NDP-050/R1) is available free of charge from CDIAC. The files are available via the Internet, from CDIAC's World Wide Web site (**http://cdiac.esd.ornl.gov**), or from CDIAC's anonymous file transfer protocol (FTP) area (**cdiac.esd.ornl.gov**) as follows:

1. FTP to cdiac.esd.ornl.gov (128.219.24.36).
2. Enter "ftp" as the user id.
3. Enter your electronic mail address as the password (e.g., fred@zulu.org).
4. Change to the directory "pub/ndp050" (i.e., use the command "cd pub/ndp050").
5. Set ftp to get ASCII files by using the ftp "ascii" command.
6. Retrieve the ASCII database documentation file by using the ftp "get ndp050.txt" command.
7. Retrieve the ASCII data files by using the ftp "mget *.dat" command.
8. Set ftp to get binary files by using the ftp "binary" command.
9. Retrieve the binary spreadsheet files by using the ftp "mget *.wk1" command.
10. Exit the system by using the ftp "quit" command.
11. Uncompress the files on your computer if they are obtained in compressed format.

For non-Internet data acquisitions (e.g., diskette or CD-ROM) or for additional information, contact:

Information Services
Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6335, U.S.A.

Telephone: 1-865-574-3645
Telefax: 1-865-574-2232
E-mail: cdiac@ornl.gov

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7. LISTING OF FILES PROVIDED

The database consists of five files (see Table 2), including this documentation file. The data files (**ndp050.*** and **compare.***) are available in two formats: as flat ASCII files and as binary spreadsheet files (in Lotus 1-2-3® format, but readable by other spreadsheet programs).

Table 2. Files in the database

File number	File name	File size (kB)	File type	File description
1	**ndp050.txt**	137	ASCII text	Documentation file
2	**ndp050.dat**	16	ASCII text	Data file
3	**ndp050.wk1**	26	Binary spreadsheet	Data file
4	**compare.dat**	10	ASCII text	Data file
5	**compare.wk1**	13	Binary spreadsheet	Data file

8. DESCRIPTION OF THE DOCUMENTATION FILE

The **ndp050.txt (File 1)** file is an ASCII text equivalent of this document.

9. DESCRIPTION, FORMAT, AND PARTIAL LISTINGS OF THE ASCII DATA FILES

Table 3 describes the format and contents of the ASCII data file **ndp050.dat (File 2)** distributed with this numeric data package. Table 3 also indicates the column in the corresponding spreadsheet file **ndp050.wk1** in which each variable is found. There are no missing values in these two files.

Table 3. Contents and format of ndp050.dat (File 2)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition and comments
YEAR	Integer	4	5	8	year	A	Year
NAM	Real	6	11	16	1000 Mg C	B	Net flux for North America
SCAM	Real	6	22	27	1000 Mg C	C	Net flux for South and Central America
EUROPE	Real	6	31	36	1000 Mg C	D	Net flux for Europe
NAFRME	Real	5	45	49	1000 Mg C	E	Net flux for North Africa and the Middle East
TRAFR	Real	6	54	59	1000 Mg C	F	Net flux for Tropical Africa
FSU	Real	6	64	69	1000 Mg C	G	Net flux for the Former Soviet Union
CHINA	Real	6	74	79	1000 Mg C	H	Net flux for China
SSEASIA	Real	7	84	90	1000 Mg C	I	Net flux for South and Southeast Asia
PACDR	Real	5	97	101	1000 Mg C	J	Net flux for the Pacific Developed Region
TOTAL	Real	8	104	111	1000 Mg C	K	Net global flux

First two data records:

```
1850   87.28      42.48   55.04        3.98      5.61     58.56     56.52      85.63       2.05   397.145
1851   87.22      42.18   55.02        3.98      6.47     58.55     56.50      85.20       2.04   397.164
```

Last two data records:

```
1989    9.47     579.12  -18.42       22.47    337.54     21.19     49.85    1180.05       5.29  2186.550
```

```
1990   12.42     577.16   -18.08        23.24    341.50     20.11     48.69    1094.39       3.92  2103.342
```

Table 4 describes the format and contents of the ASCII data file **compare.dat (File 4)** distributed with this numeric data package. Table 4 also indicates the column in the corresponding spreadsheet file **compare.wk1** in which each variable is found. The missing-value indicator in the ascii file is !9.999 (in the spreadsheet file, cells representing missing values are simply left blank).

Table 4. Contents and format of compare.dat (File 4)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition and comments
YEAR	Integer	4	1	4	year	A	Year
HETAL83	Real	6	13	18	1000 Mg C	B	Global total net flux, from Houghton et al. (1983)
HS90	Real	6	31	36	1000 Mg C	C	Global total net flux, from Houghton and Skole (1990), as corrected
HH95	Real	5	51	55	1000 Mg C	D	Global total net flux, from Houghton and Hackler (1995)
H99	Real	5	63	67	1000 Mg C	E	Global total net flux, from Houghton (1999)

First two data records:

```
1850          0.458              0.278                 0.352        0.397
1851          0.464              0.319                 0.383        0.397
```

Last two data records:

```
1989         -9.999             -9.999                 1.611        2.187
1990         -9.999             -9.999                 1.614        2.103
```

10. DESCRIPTION AND FORMAT OF THE LOTUS 1-2-3® BINARY SPREADSHEET FILES

Lotus 1-2-3® binary spreadsheet file **ndp050.wk1 (File 3)** contains the same information as the corresponding ASCII file **ndp050.dat (File 2)**, and Lotus 1-2-3® binary spreadsheet file **compare.wk1 (File 5)** contains the same information as the corresponding ASCII file **compare.dat (File 4)**

Table 3, which describes the contents and format of **ndp050.dat**, also indicates the column of **ndp050.wk1** in which each variable is found, and Table 4, which describes the contents and format of **compare.dat**, also indicates the column of **compare.wk1** in which each variable is found.

11. SAS® AND FORTRAN CODES TO ACCESS THE DATA

The following is SAS® code to read file **ndp050.dat**.

```
/*** SAS code to read ndp050.dat ***/
data ndp050;
infile 'ndp050.dat' firstobs=10;
input YEAR 5-8 NAM 11-16 SCAM 22-27 EUROPE 31-36 NAFRME 45-49
      TRAFR 54-59 FSU 64-69 CHINA 74-79 SSEASIA 84-90 PACDR 97-101
      TOTAL 104-111;
run;
```

The following is Fortran code to read file **ndp050.dat**.

```
C *** Fortran program to read the file "ndp050.dat"
C *** from Houghton's CDIAC NDP-050 that corresponds
C *** with the 1999 Tellus article.
C
      INTEGER YEAR
      REAL NAM, SCAM, EUROPE, NAFRME, TRAFR, FSU, CHINA,
     +     SSEASIA, PACDR, TOTAL
C
      OPEN (UNIT=1, FILE='ndp050.dat')
C
C *** SKIP OVER HEADER INFO.
    9 READ (1,100)
  100 FORMAT (////////)
C *** READ DATA
   10 READ (1,101,END=99) YEAR, NAM, SCAM, EUROPE, NAFRME,
     + TRAFR, FSU, CHINA, SSEASIA, PACDR, TOTAL
  101 FORMAT (4X,I4,2X,F6.2,5X,F6.2,3X,F6.2,8X,F5.2,4X,
     + F6.2,4X,F6.2,4X,F6.2,4X,F7.2,6X,F5.2,2X,F8.3)
C
      GO TO 10
   99 CLOSE (UNIT=1)
      STOP
      END
```

The following is SAS® code to read file **compare.dat**.

```
/*** SAS code to read compare.dat ***/
data compare;
infile 'compare.dat' firstobs=14;
input YEAR 1-4 HETAL83 13-18 HS90 31-36 HH95 51-55 H99 63-67;
run;
```

The following is Fortran code to read file **compare.dat**.

```
C *** Fortran program to read the file "compare.dat"
C *** from Houghton's CDIAC NDP-050 that corresponds
C *** with the 1999 Tellus article.
C
      INTEGER YEAR
      REAL HETAL83, HS90, HH95, H99
C
      OPEN (UNIT=1, FILE='compare.dat')
C *** SKIP OVER HEADER INFORMATION
    9 READ (1,100)
  100 FORMAT (////////////)
```

```
C *** READ DATA
   10 READ (1,101,END=99) YEAR, HETAL83, HS90, HH95, H99
  101 FORMAT (I4,8X,F6.3,12X,F6.3,14X,F5.3,7X,F5.3)
C
      GO TO 10
   99 CLOSE (UNIT=1)
      STOP
      END
```

APPENDIX A. ECOSYSTEM AREA BY REGION

This listing indicates the area (in units of 10^6 hectare) in different ecosystems for the nine regions in this database, for the years 1700, 1850, and 1990, along with the percent change from 1850 to 1990. The values in this listing replace the values in files areas.* in Houghton and Hackler (1995), the previous version of this database. Missing values are denoted by !9999.

	1700	1850	1990	% Change 1850-1990
North America				
Temperate evergreen forest	236	222	215	-0.03
Temperate deciduous forest	157	125	118	-0.06
Boreal forest	325	325	322	-0.01
Temperate woodland/shrubland	302	302	292	-0.03
Temperate grassland	568	481	172	-0.64
South and Central America				
Tropical evergreen forest	-9999	310	299	-0.03
Tropical seasonal forest	-9999	756	604	-0.20
Tropical open forest	-9999	427	287	-0.33
Temperate evergreen forest	-9999	67	57	-0.15
Temperate seasonal forest	-9999	58	56	-0.03
Europe				
Temperate evergreen forest	85	66	72	0.10
Temperate deciduous forest	65	56	56	-0.01
Boreal forest	35	28	27	0.00
Temperate woodland/shrubland	45	45	45	0.00
Temperate grassland	88	42	27	-0.36
North Africa and the Middle East				
Temperate evergreen forest	17.7	16	7	-0.56
Tropical moist forest	2.1	2	2	0.00
Tropical grassland	90	86	44	-0.49
Desert scrub	979	961	793	-0.17
Tropical woodland/shrubland	32.4	31	19	-0.40
Tropical Africa				
Closed forest	-9999	605	553	-0.09
Open forest	-9999	198	105	-0.47
Former Soviet Union				
Temperate evergreen forest	88	88	88	0.00
Temperate deciduous forest	121	78	54	-0.31
Boreal forest	613	613	613	0.00
Temperate woodland/shrubland	186	186	186	0.00
Temperate grassland	175	144	31	-0.78

	1700	1850	1990	% Change 1850-1990
China				
Temperate evergreen forest	122	49	82	0.66
Temperate deciduous forest	103	76	48	-0.38
Temperate grassland	723	586	439	-0.25
Tropical moist forest	18	14	8	-0.43
South and Southeast Asia				
Tropical moist forest	-9999	177	94	-0.47
Tropical seasonal forest	-9999	179	89	-0.50
Tropical open forest	-9999	52	40	-0.23
Tropical grassland	-9999	55	36	-0.35
Pacific Developed Region				
Temperate evergreen forest	14	14	14	0.00
Temperate deciduous forest	14	14	14	0.00
Tropical moist forest	72	72	64	-0.12
Tropical grassland	497	496	70	-0.86
Tropical woodland/shrubland	120	120	106	-0.11

APPENDIX B. REGIONAL LAND-USE CHANGE AND WOOD HARVEST DATA

The following listing provides the regional details of fuelwood (nonindustrial logging) and timber (industrial logging) harvest by forest type, changes in area of pasture, forest plantation, afforestation, forest clearing for croplands, and lands in shifting cultivation. The values in this listing replace the values in the indicated ascii and binary spreadsheet files in Houghton and Hackler (1995), the previous version of this database.

South and Southeast Asia

The following values replace the data in files asia-rat.* in Houghton and Hackler (1995).

South and Southeast Asia — Fuelwood Harvest (10^6 Mg C per year):

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1751	8.58	10.50	4.50
1752	8.58	10.50	4.50
1753	8.58	10.50	4.50
1754	8.58	10.50	4.50
1755	8.58	10.50	4.50
1756	8.58	10.50	4.50
1757	8.58	10.50	4.50
1758	8.58	10.50	4.50
1759	8.58	10.50	4.50
1760	8.58	10.50	4.50
1761	8.58	10.50	4.50
1762	8.58	10.50	4.50
1763	8.58	10.50	4.50
1764	8.58	10.50	4.50
1765	8.58	10.50	4.50
1766	8.58	10.50	4.50
1767	8.58	10.50	4.50
1768	8.58	10.50	4.50
1769	8.58	10.50	4.50
1770	8.58	10.50	4.50
1771	8.58	10.50	4.50
1772	8.58	10.50	4.50
1773	8.58	10.50	4.50
1774	8.58	10.50	4.50
1775	8.58	10.50	4.50
1776	8.58	10.50	4.50
1777	8.58	10.50	4.50
1778	8.58	10.50	4.50
1779	8.58	10.50	4.50
1780	8.58	10.50	4.50
Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1781	8.58	10.50	4.50
1782	8.58	10.50	4.50
1783	8.58	10.50	4.50
1784	8.58	10.50	4.50
1785	8.58	10.50	4.50
1786	8.58	10.50	4.50
1787	8.58	10.50	4.50
1788	8.58	10.50	4.50
1789	8.58	10.50	4.50
1790	8.58	10.50	4.50
1791	8.58	10.50	4.50
1792	8.58	10.50	4.50
1793	8.58	10.50	4.50
1794	8.58	10.50	4.50
1795	8.58	10.50	4.50
1796	8.58	10.50	4.50
1797	8.58	10.50	4.50
1798	8.58	10.50	4.50
1799	8.58	10.50	4.50
1800	8.58	10.50	4.50

1801	8.58	10.50	4.50
1802	8.62	10.55	4.52
1803	8.66	10.60	4.54
1804	8.70	10.65	4.56
1805	8.74	10.70	4.59
1806	8.78	10.75	4.61
1807	8.82	10.80	4.63
1808	8.86	10.85	4.65
1809	8.90	10.90	4.67
1810	8.94	10.95	4.69

South and Southeast Asia — Fuelwood Harvest (continued)

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1811	8.98	11.00	4.71
1812	9.03	11.05	4.74
1813	9.07	11.10	4.76
1814	9.11	11.15	4.78
1815	9.15	11.20	4.80
1816	9.19	11.25	4.82
1817	9.23	11.30	4.84
1818	9.27	11.35	4.86
1819	9.31	11.40	4.89
1820	9.35	11.45	4.91
1821	9.39	11.50	4.93
1822	9.43	11.55	4.95
1823	9.47	11.60	4.97
1824	9.52	11.65	4.99
1825	9.56	11.70	5.01
1826	9.60	11.75	5.04
1827	9.64	11.80	5.06
1828	9.68	11.85	5.08
1829	9.72	11.90	5.10
1830	9.76	11.95	5.12
1831	9.80	12.00	5.14
1832	9.84	12.05	5.16
1833	9.88	12.10	5.19
1834	9.92	12.15	5.21
1835	9.96	12.20	5.23
1836	10.01	12.25	5.25
1837	10.05	12.30	5.27
1838	10.09	12.35	5.29
1839	10.13	12.40	5.31
1840	10.17	12.45	5.34
1841	10.21	12.50	5.36
1842	10.25	12.55	5.38
1843	10.29	12.60	5.40
1844	10.33	12.65	5.42
1845	10.37	12.70	5.44
1846	10.41	12.75	5.46
1847	10.45	12.80	5.49
1848	10.50	12.85	5.51
1849	10.54	12.90	5.53
1850	10.58	12.95	5.55
1851	10.66	13.05	5.59
1852	10.74	13.15	5.63
1853	10.82	13.24	5.68
1854	10.90	13.34	5.72
1855	10.98	13.44	5.76
1856	11.06	13.54	5.80
1857	11.14	13.64	5.84

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1858	11.22	13.73	5.89
1859	11.30	13.83	5.93
1860	11.38	13.93	5.97
1861	11.46	14.03	6.01
1862	11.54	14.13	6.05
1863	11.62	14.22	6.10
1864	11.70	14.32	6.14
1865	11.78	14.42	6.18
1866	11.86	14.52	6.22
1867	11.94	14.62	6.26
1868	12.02	14.71	6.31
1869	12.10	14.81	6.35
1870	12.18	14.91	6.39
1871	12.26	15.01	6.43
1872	12.34	15.11	6.47

1873	12.42	15.20	6.52
1874	12.50	15.30	6.56
1875	12.58	15.40	6.60
1876	12.66	15.50	6.64
1877	12.74	15.60	6.68
1878	12.82	15.69	6.73
1879	12.90	15.79	6.77
1880	12.98	15.89	6.81
1881	13.06	15.99	6.85
1882	13.14	16.09	6.89
1883	13.22	16.18	6.94
1884	13.30	16.28	6.98
1885	13.38	16.38	7.02
1886	13.46	16.48	7.06
1887	13.54	16.58	7.10
1888	13.62	16.67	7.15
1889	13.70	16.77	7.19
1890	13.78	16.87	7.23
1891	13.86	16.97	7.27
1892	13.94	17.07	7.31
1893	14.02	17.16	7.36
1894	14.10	17.26	7.40
1895	14.18	17.36	7.44
1896	14.26	17.46	7.48
1897	14.34	17.56	7.52
1898	14.42	17.65	7.57
1899	14.50	17.75	7.61
1900	14.58	17.85	7.65
1901	14.69	17.99	7.71
1902	14.81	18.13	7.77
1903	14.92	18.27	7.83
1904	15.04	18.41	7.89

South and Southeast Asia — Fuelwood Harvest (continued)

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1905	15.15	18.55	7.95
1906	15.27	18.69	8.01
1907	15.38	18.83	8.07
1908	15.49	18.97	8.13
1909	15.61	19.11	8.19
1910	15.72	19.25	8.25
1911	15.84	19.39	8.31
1912	15.95	19.53	8.37
1913	16.07	19.67	8.43
1914	16.18	19.81	8.49
1915	16.29	19.95	8.55
1916	16.41	20.09	8.61
1917	16.52	20.23	8.67
1918	16.64	20.37	8.73
1919	16.75	20.51	8.79
1920	16.87	20.65	8.85
1921	16.98	20.79	8.91
1922	17.10	20.93	8.97
1923	17.21	21.07	9.03
1924	17.32	21.21	9.09
1925	17.44	21.35	9.15
1926	17.71	21.69	9.29

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1927	17.99	22.02	9.44
1928	18.26	22.36	9.58
1929	18.54	22.69	9.73
1930	18.81	23.03	9.87
1931	19.08	23.37	10.01
1932	19.36	23.70	10.16
1933	19.63	24.04	10.30
1934	19.91	24.37	10.45
1935	20.18	24.71	10.59
1936	20.46	25.05	10.73
1937	20.73	25.38	10.88
1938	21.01	25.72	11.02
1939	21.28	26.05	11.17
1940	21.55	26.39	11.31
1941	21.83	26.73	11.45
1942	22.10	27.06	11.60
1943	22.38	27.40	11.74
1944	22.65	27.73	11.89
1945	22.93	28.07	12.03
1946	23.20	28.41	12.17
1947	23.48	28.74	12.32
1948	23.75	29.08	12.46
1949	24.02	29.41	12.61
1950	24.30	29.75	12.75
1951	25.04	30.66	13.14
1952	25.79	31.57	13.53
1953	26.53	32.48	13.92
1954	27.27	33.39	14.31
1955	28.02	34.30	14.70
1956	28.76	35.21	15.09
1957	29.50	36.12	15.48
1958	30.25	37.03	15.87
1959	30.99	37.94	16.26
1960	31.73	38.85	16.65
1961	32.47	39.76	17.04
1962	33.17	40.67	17.43
1963	33.86	41.58	17.82
1964	34.63	42.49	18.21
1965	35.48	43.40	18.60
1966	36.32	44.31	18.99
1967	37.29	45.22	19.38
1968	38.31	46.13	19.77
1969	39.41	47.04	20.16
1970	40.50	47.95	20.55
1971	41.75	48.86	20.94
1972	42.92	49.77	21.33
1973	43.94	50.68	21.72
1974	45.51	51.59	22.11
1975	47.22	52.50	22.50
1976	48.17	53.76	23.04
1977	49.03	55.02	23.58
1978	49.89	56.28	24.12
1979	50.76	57.54	24.66
1980	51.82	58.80	25.20
1981	53.04	60.13	25.77
1982	54.11	61.46	26.34
1983	55.23	62.79	26.91
1984	56.46	64.12	27.48
1985	57.79	65.45	28.05
1986	58.93	66.78	28.62
1987	59.95	68.11	29.19
1988	61.04	69.44	29.76
1989	62.21	70.77	30.33
1990	63.59	72.10	30.90
1991	64.61	72.10	30.90
1992	67.58	72.10	30.90
1993	70.94	72.10	30.90
1994	74.01	72.10	30.90
1995	77.04	72.10	30.90

South and Southeast Asia — Timber Harvest (10^6 Mg C per year):

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1750	1.26	0.80	0.00
1751	1.27	0.80	0.00
1752	1.27	0.80	0.00
1753	1.28	0.81	0.00
1754	1.29	0.81	0.00
1755	1.29	0.81	0.00
1756	1.30	0.81	0.00
1757	1.30	0.81	0.00
1758	1.31	0.82	0.00
1759	1.31	0.82	0.00
1760	1.32	0.82	0.00
1761	1.32	0.82	0.00
1762	1.33	0.82	0.00
1763	1.33	0.83	0.00
1764	1.34	0.83	0.00
1765	1.34	0.83	0.00
1766	1.35	0.83	0.00
1767	1.35	0.83	0.00
1768	1.36	0.84	0.00
1769	1.37	0.84	0.00
1770	1.37	0.84	0.00
1771	1.38	0.84	0.00
1772	1.38	0.84	0.00
1773	1.39	0.85	0.00
1774	1.39	0.85	0.00
1775	1.40	0.85	0.00
1776	1.40	0.85	0.00
1777	1.41	0.85	0.00
1778	1.41	0.86	0.00
1779	1.42	0.86	0.00
1780	1.42	0.86	0.00
1781	1.43	0.86	0.00
1782	1.44	0.86	0.00
1783	1.44	0.87	0.00
1784	1.45	0.87	0.00
1785	1.45	0.87	0.00
1786	1.46	0.87	0.00
1787	1.46	0.87	0.00
1788	1.47	0.88	0.00
1789	1.47	0.88	0.00
1790	1.48	0.88	0.00
1791	1.48	0.88	0.00
1792	1.49	0.88	0.00
1793	1.49	0.89	0.00
1794	1.50	0.89	0.00
1795	1.51	0.89	0.00
1796	1.51	0.89	0.00

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1797	1.52	0.89	0.00
1798	1.52	0.90	0.00
1799	1.53	0.90	0.00
1800	1.53	0.90	0.00
1801	1.54	0.90	0.00
1802	1.54	0.90	0.00
1803	1.55	0.91	0.00
1804	1.55	0.91	0.00
1805	1.56	0.91	0.00
1806	1.56	0.91	0.00
1807	1.57	0.91	0.00
1808	1.58	0.92	0.00
1809	1.58	0.92	0.00
1810	1.59	0.92	0.00
1811	1.59	0.92	0.00
1812	1.60	0.92	0.00
1813	1.60	0.93	0.00
1814	1.61	0.93	0.00
1815	1.61	0.93	0.00
1816	1.62	0.93	0.00
1817	1.62	0.93	0.00
1818	1.63	0.94	0.00
1819	1.63	0.94	0.00
1820	1.64	0.94	0.00
1821	1.64	0.94	0.00
1822	1.65	0.94	0.00
1823	1.66	0.95	0.00
1824	1.66	0.95	0.00
1825	1.67	0.95	0.00
1826	1.67	0.95	0.00
1827	1.68	0.95	0.00
1828	1.68	0.96	0.00
1829	1.69	0.96	0.00
1830	1.69	0.96	0.00
1831	1.70	0.96	0.00
1832	1.70	0.96	0.00
1833	1.71	0.97	0.00

1834	1.71	0.97	0.00
1835	1.72	0.97	0.00
1836	1.73	0.97	0.00
1837	1.73	0.97	0.00
1838	1.74	0.98	0.00
1839	1.74	0.98	0.00
1840	1.75	0.98	0.00
1841	1.75	0.98	0.00
1842	1.76	0.98	0.00
1843	1.76	0.99	0.00

South and Southeast Asia — Timber Harvest (continued)

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1844	1.77	0.99	0.00
1845	1.77	0.99	0.00
1846	1.78	0.99	0.00
1847	1.78	0.99	0.00
1848	1.79	1.00	0.00
1849	1.80	1.00	0.00
1850	1.80	1.00	0.00
1851	1.81	1.01	0.00
1852	1.82	1.02	0.00
1853	1.82	1.02	0.00
1854	1.83	1.03	0.00
1855	1.84	1.04	0.00
1856	1.85	1.05	0.00
1857	1.86	1.06	0.00
1858	1.86	1.06	0.00
1859	1.87	1.07	0.00
1860	1.88	1.08	0.00
1861	1.89	1.09	0.00
1862	1.90	1.10	0.00
1863	1.90	1.10	0.00
1864	1.91	1.11	0.00
1865	1.92	1.12	0.00
1866	1.93	1.13	0.00
1867	1.94	1.14	0.00
1868	1.94	1.14	0.00
1869	1.95	1.15	0.00
1870	1.96	1.16	0.00
1871	1.97	1.17	0.00
1872	1.98	1.18	0.00
1873	1.98	1.18	0.00
1874	1.99	1.19	0.00
1875	2.00	1.20	0.00
1876	2.02	1.21	0.00
1877	2.04	1.22	0.00
1878	2.06	1.24	0.00
1879	2.08	1.25	0.00
1880	2.10	1.26	0.00
1881	2.12	1.27	0.00
1882	2.14	1.28	0.00
1883	2.16	1.30	0.00
1884	2.18	1.31	0.00
1885	2.20	1.32	0.00
1886	2.22	1.33	0.00
1887	2.24	1.34	0.00
1888	2.26	1.36	0.00
1889	2.28	1.37	0.00
1890	2.30	1.38	0.00

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1891	2.32	1.39	0.00
1892	2.34	1.40	0.00
1893	2.36	1.42	0.00
1894	2.38	1.43	0.00
1895	2.40	1.44	0.00
1896	2.42	1.45	0.00
1897	2.44	1.46	0.00
1898	2.46	1.48	0.00
1899	2.48	1.49	0.00
1900	2.50	1.50	0.00
1901	2.52	1.51	0.00
1902	2.54	1.52	0.00
1903	2.56	1.52	0.00
1904	2.58	1.53	0.00
1905	2.60	1.54	0.00

1906	2.62	1.55	0.00
1907	2.64	1.56	0.00
1908	2.66	1.56	0.00
1909	2.68	1.57	0.00
1910	2.70	1.58	0.00
1911	2.72	1.59	0.00
1912	2.74	1.60	0.00
1913	2.76	1.60	0.00
1914	2.78	1.61	0.00
1915	2.80	1.62	0.00
1916	2.82	1.63	0.00
1917	2.84	1.64	0.00
1918	2.86	1.64	0.00
1919	2.88	1.65	0.00
1920	2.90	1.66	0.00
1921	2.92	1.67	0.00
1922	2.94	1.68	0.00
1923	2.96	1.68	0.00
1924	2.98	1.69	0.00
1925	3.00	1.70	0.00
1926	3.04	1.71	0.00
1927	3.08	1.72	0.00
1928	3.12	1.74	0.00
1929	3.16	1.75	0.00
1930	3.20	1.76	0.00
1931	3.24	1.77	0.00
1932	3.28	1.78	0.00
1933	3.32	1.80	0.00
1934	3.36	1.81	0.00
1935	3.40	1.82	0.00
1936	3.44	1.83	0.00
1937	3.48	1.84	0.00

South and Southeast Asia — Timber Harvest (continued)

Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1938	3.52	1.86	0.00
1939	3.56	1.87	0.00
1940	3.60	1.88	0.00
1941	3.64	1.89	0.00
1942	3.68	1.90	0.00
1943	3.72	1.92	0.00
1944	3.76	1.93	0.00
1945	3.80	1.94	0.00
1946	3.84	1.95	0.00
1947	3.88	1.96	0.00
1948	3.92	1.98	0.00
1949	3.96	1.99	0.00
1950	4.00	2.00	0.00
1951	4.50	2.25	0.00
1952	5.00	2.50	0.00
1953	5.50	2.75	0.00
1954	6.00	3.00	0.00
1955	6.50	3.25	0.00
1956	7.00	3.50	0.00
1957	7.50	3.75	0.00
1958	8.00	4.00	0.00
1959	8.50	4.25	0.00

1960	9.00	4.50	0.00
1961	9.70	4.65	0.00
1962	10.40	4.80	0.00
1963	11.10	4.95	0.00
1964	11.80	5.10	0.00
1965	12.50	5.25	0.00
1966	13.20	5.40	0.00
1967	13.90	5.55	0.00
1968	14.60	5.70	0.00
1969	15.30	5.85	0.00
1970	16.00	6.00	0.00
1971	16.50	6.30	0.00
1972	17.00	6.60	0.00
1973	17.50	6.90	0.00
1974	18.00	7.20	0.00
1975	18.50	7.50	0.00
1976	19.00	7.80	0.00
1977	19.50	8.10	0.00
1978	20.00	8.40	0.00
1979	20.50	8.70	0.00
1980	21.00	9.00	0.00
1981	21.83	9.37	0.00
1982	22.67	9.73	0.00
1983	23.50	10.10	0.00
1984	24.33	10.47	0.00
Year	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1985	25.17	10.83	0.00
1986	26.00	11.20	0.00
1987	26.83	11.57	0.00
1988	27.67	11.93	0.00
1989	28.50	12.30	0.00
1990	28.50	12.30	0.00
1991	31.22	13.47	0.00
1992	32.00	13.81	0.00
1993	30.02	12.95	0.00
1994	28.68	12.38	0.00
1995	28.49	12.29	0.00

South and Southeast Asia — Forest Clearing for Croplands (stepped changes between dates) (10^6 hectares per year):

	Tropical moist	Tropical seasonal	Tropical open

Years	forest	forest	forest
1750-1799	0.000	0.000	0.000
1800-1809	0.008	0.272	0.000
1810-1829	0.027	0.268	0.000
1830-1849	0.038	0.459	0.000
1850-1869	0.040	0.450	0.000
1870-1889	0.081	0.626	0.000
1890-1904	0.136	0.702	0.040
1905-1911	0.178	0.708	0.070
1912-1914	0.178	0.468	0.070
1915-1924	0.238	0.446	0.060
1925-1934	0.230	0.409	0.058
1935-1944	0.227	0.630	0.007
1945-1947	0.347	1.194	0.157
1948-1951	0.347	1.184	0.157
1952-1956	0.357	0.576	0.123
1957-1961	0.160	0.804	0.240
1962-1966	0.293	0.676	0.187
1967-1969	0.360	0.597	0.263
1970-1971	0.360	0.417	0.263
1972-1974	0.576	0.780	0.184
1975-1979	1.200	0.860	0.103
1980-1985	2.711	1.035	0.207
1986-1990	2.721	0.765	0.206
1991-1995	2.271	0.639	0.172

South and Southeast Asia — Lands in Shifting Cultivation Cycle (linear change between dates) (10^6 hectares per year):

Years	Tropical moist forest	Tropical seasonal forest	Tropical open forest
1750-1801	3.73	0.00	0.35
1802-1939	3.73	0.00	0.35
1940-1944	3.85	0.00	0.36
1945-1949	3.93	0.00	0.36
1950-1954	4.09	0.00	0.37
1955-1959	4.17	0.00	0.38
1960-1964	4.35	0.00	0.39
1965-1969	4.63	0.00	0.40
1970-1974	4.85	0.00	0.40
1975-1979	5.25	0.00	0.42
1980-1985	5.69	0.00	0.42
1986-1990	6.15	0.00	0.44
1991-1995	6.25	0.00	0.44

China

The following values replace the data in files chin-rat.* in Houghton and Hackler (1995).

China — Clearing for Croplands (10^6 hectares per year):

Years	Temperate evergreen forest	Temperate deciduous forest	Tropical moist forest	Temperate grassland
1700-1701	0.000	0.000	0.000	0.000
1702-1872	0.046	0.182	0.030	0.046
1873-1912	0.038	0.152	0.025	0.038
1913-1932	0.055	0.220	0.037	0.055
1933-1953	0.000	0.300	0.049	0.150
1954-1964	0.000	0.470	0.112	0.540
1965-1969	0.000	0.480	0.097	0.390
1970-1979	0.000	0.000	0.065	0.590
1980-1990	0.000	0.000	0.000	0.000

China — Afforestation (10^6 hectares per year):

Years	Temperate evergreen forest
1700-1710	0.00
1951-1970	1.40
1971-1980	2.40
1981-1990	0.38

China — Wood Harvest (10^6 Mg C per year):

Years	Tropical moist forest	Temperate evergreen forest	Temperate deciduous forest
1700-1859	0.8	3.7	4.6
1860-1874	2.0	10.0	12.0
1875-1899	2.0	10.0	12.0
1900-1924	2.0	11.0	13.0
1925-1949	3.0	12.0	15.0
1950-1969	3.0	13.0	16.0
1970-1979	5.0	22.0	27.0
1980-1980	5.0	25.0	31.0
1981-1990	6.7	31.7	38.6

China — Lands in Pasture (10^6 hectares per year):

Years	Temperate grassland
1700-1701	1.0
1702-1780	0.9
1781-1860	0.6
1861-1875	0.6
1876-1900	0.8
1901-1925	0.8
1926-1950	2.1
1951-1970	0.8
1971-1980	0.4
1981-1990	0.0

Europe

The following values replace the data in files euro-rat.* in Houghton and Hackler (1995).

Europe — Clearing for Croplands (10^6 hectares per year):

Years	Temperate evergreen forest	Temperate deciduous forest	Boreal forest	Temperate grassland
1700-1701	0.0600	0.0600	0.0500	0.2600
1702-1869	0.0600	0.0600	0.0500	0.2600
1870-1959	0.0200	0.0200	0.0170	0.0860
1960-1961	0.0000	0.0000	0.0000	0.0000
1962-1969	0.0000	0.0000	0.0000	0.0000
1970-1974	-0.2000	-0.2000	-0.2000	-0.2000
1975-1980	-0.2000	-0.2000	-0.2000	-0.2000
1981-1990	-0.0506	-0.0506	-0.0506	-0.0506

Europe — Afforestation (10^6 hectares per year):

Years	Temperate evergreen forest
1700-1710	0.00
1711-1711	0.00
1712-1800	0.00
1801-1849	0.02
1850-1875	0.02
1876-1900	0.03
1901-1925	0.05
1926-1950	0.08
1951-1980	0.08
1981-1990	0.08

Europe — Wood Harvest (10^6 Mg C per year):

Year	Temperate evergreen forest	Temperate deciduous forest	Boreal forest
1700	12.0	10.0	2.0
1860	26.0	22.0	5.0
1875	29.0	24.0	5.0
1900	35.0	30.0	6.0
1925	44.0	37.0	8.0

1950	41.0	35.0	7.0
1970	49.0	41.0	8.0
1980	44.0	38.0	8.0
1981-1990	51.8	43.9	9.1

Europe — Lands in Pasture (10^6 hectares per year):

Years	Temperate grassland
1700-1701	0.05
1702-1780	0.05
1781-1860	0.05
1861-1875	0.05
1876-1900	0.05
1901-1925	0.05
1926-1950	0.00
1951-1970	0.00
1971-1980	0.00
1981-1990	0.00

Former Soviet Union

The following values replace the data in files fsu-rat.* in Houghton and Hackler (1995).

Former Soviet Union — Clearing for Croplands (10^6 hectares per year):

Years	Temperate deciduous forest	Temperate grassland
1700-1860	0.288	0.206
1861-1911	0.098	0.588
1912-1939	0.148	1.111
1940-1949	-0.333	-0.111
1950-1957	1.429	5.714
1958-1968	0.364	0.636
1969-1970	-0.065	-0.065
1971-1974	-0.065	-0.065
1975-1976	0.038	0.038
1977-1980	0.038	0.038
1981-1984	0.022	0.022
1985-1990	-0.072	-0.409

Former Soviet Union — Timber Harvest (10^6 Mg C per year):

Years	Temperate deciduous forest	Boreal forest
1700-1701	0.00	0.00
1702-1850	0.36	1.44
1851-1919	3.72	14.88
1914-1932	9.88	39.52
1933-1945	10.10	40.40
1946-1960	22.18	88.72
1961-1970	23.10	92.40
1971-1975	22.26	89.04
1976-1980	21.42	85.68
1981-1985	21.42	85.68
1986-1990	23.96	95.84

Former Soviet Union — Fuelwood Harvest (10^6 Mg C per year):

Years	Temperate deciduous forest	Boreal forest
1700-1701	0.000	0.000
1702-1850	14.364	23.436
1851-1919	26.448	43.152
1914-1932	25.422	41.478
1933-1945	15.960	26.040
1946-1960	4.560	7.440
1961-1970	4.218	6.882
1971-1975	3.990	6.510
1976-1980	3.762	6.138
1981-1990	3.762	6.138

North Africa and the Middle East

The following values replace the data in files nafm-rat.* in Houghton and Hackler (1995).

North Africa and the Middle East — Clearing for Croplands (10^6 hectares per year):

Years	Temperate evergreen forest	Tropical grassland	Desert scrub	Tropical woodland/ shrubland
1700-1701	0.000	0.000	0.000	0.000
1702-1859	0.014	0.024	0.000	0.010
1860-1899	0.066	0.111	0.000	0.044

1900-1924	0.091	0.151	0.000	0.060
1925-1949	0.150	0.410	0.100	0.170
1950-1964	0.000	0.640	0.510	0.130
1965-1979	0.000	0.730	0.590	0.150
1980-1990	0.000	0.297	0.238	0.061

North Africa and the Middle East — Wood Harvest (10^6 Mg C per year):

Year	Temperate evergreen forest	Tropical moist forest
1700	0.90	0.50
1860	1.00	1.00
1875	1.00	1.00
1900	2.00	1.00
1925	2.00	1.00
1950	3.00	2.00
1970	6.00	3.00
1980	7.00	4.00
1990	10.94	6.25

North Africa and the Middle East — Lands in Pasture (10^6 hectares per year):

Years	Desert scrub
1700-1701	0.1
1702-1780	0.1
1781-1860	0.2
1861-1875	0.5
1876-1900	0.7
1901-1925	1.5
1926-1950	2.1
1951-1970	1.3
1971-1990	0.5

North America

The following values replace the data in files nam-rat.* in Houghton and Hackler (1995).

North America — Clearing for Croplands (10^6 hectares per year):

	Temperate forest		Temperate forest (abandonment)			Temperate	
Years	evergreen	deciduous	evergreen	deciduous	Boreal forest	woodland/ shrubland	Temperate grassland
1700-1701	0.135	0.315	-0.045	-0.105	0.00	0.000	0.000
1702-1849	0.135	0.315	-0.045	-0.105	0.00	0.000	0.000

Houghton & Hackler 2001, CDIAC NDP-050/R1 (http://cdiac.esd.ornl.gov/ndps/ndp050.html)

1850-1889	0.135	0.135	-0.045	-0.045	0.03	0.090	1.200
1890-1927	0.210	0.210	-0.070	-0.070	0.05	0.140	1.810
1928-1949	0.045	0.045	-0.015	-0.015	0.01	0.030	0.400
1950-1969	0.010	0.010	-0.010	-0.010	0.00	0.000	0.000
1970-1979	0.010	0.010	-0.100	-0.100	0.00	0.000	-0.020
1980-1990	-0.122	-0.122	0.000	0.000	0.00	0.000	-0.027

North America — Wood Harvest (10^6 Mg C per year):

Year	Temperate evergreen forest	Temperate deciduous forest	Boreal forest
1700	1.4	1.2	2.3
1860	30.0	26.0	51.0
1875	37.0	31.0	62.0
1900	36.0	31.0	61.0
1925	38.0	32.0	64.0
1950	33.0	28.0	55.0
1970	38.0	32.0	63.0
1980	41.0	35.0	69.0
1990	55.1	46.8	92.5

North America — Lands in Pasture (10^6 hectares per year):

Years	Temperate grassland
1700-1701	0.3
1702-1780	0.6
1781-1860	0.9
1861-1875	1.8
1876-1900	3.6
1901-1925	1.6
1926-1950	0.1
1951-1970	0.0
1971-1990	0.0

Pacific Developed Region

The following values replace the data in files pcdv-rat.* in Houghton and Hackler (1995).

Pacific Developed Region — Clearing for Croplands (10^6 hectares per year):

Years	Tropical moist forest	Tropical grassland	Tropical woodland/ shrubland
1700-1869	0.001	0.004	0.002
1870-1949	0.038	0.152	0.064
1950-1969	0.220	0.860	0.360
1970-1979	0.030	0.120	0.050

Houghton & Hackler 2001, CDIAC NDP-050/R1 (http://cdiac.esd.ornl.gov/ndps/ndp050.html)

1980-1990	0.051	2.000	0.084

Pacific Developed Region — Wood Harvest (10^6 Mg C per year):

Years	Temperate evergreen forest	Temperate deciduous forest	Tropical moist forest
1700-1701	3.8	4.5	1.2
1702-1859	5.0	6.0	1.0
1860-1874	5.0	6.0	2.0
1875-1899	7.0	8.0	2.0
1900-1924	9.0	11.0	3.0
1925-1949	12.0	14.0	4.0
1950-1969	12.0	13.0	3.0
1970-1979	10.0	12.0	3.0
1980-1990	6.9	8.2	2.1

Pacific Developed Region — Lands in Pasture (10^6 hectares per year):

Years	Tropical grassland	Desert scrub
1700-1701	0.0	0.0
1702-1780	0.0	0.0
1781-1860	0.0	0.0
1861-1875	0.0	0.0
1876-1900	0.0	0.0
1901-1925	8.0	2.6
1926-1950	7.8	1.7
1951-1970	0.6	0.2
1971-1990	0.6	0.2

South and Central America

The following values replace the data in files scam-rat.* in Houghton and Hackler (1995).

South and Central America — Lands in Forest Plantation (10^6 hectares per year):

Years	Tropical seasonal forest
1800-1948	0.000
1949-1954	0.040
1955-1957	0.040
1958-1962	0.079
1963-1967	0.127
1968-1977	0.228

1978-1982	0.410
1983-1990	0.535

South and Central America — Clearing for Croplands (10^6 hectares per year):

Years	Tropical equatorial forest	Tropical seasonal forest	Tropical woodland	Warm coniferous forest	Temperate broadleaf forest	Grassland	Desert scrub
1800-1849	0.0037	0.0267	0.0147	0.0037	0.0009	0.0414	0.0009
1850-1859	0.0037	0.0267	0.0147	0.0037	0.0009	0.0414	0.0009
1860-1869	0.0082	0.0595	0.0328	0.0082	0.0021	0.0923	0.0021
1870-1879	0.0082	0.0595	0.0328	0.0082	0.0021	0.0923	0.0021
1880-1889	0.0264	0.1910	0.1056	0.0264	0.0066	0.2970	0.0066
1890-1899	0.0240	0.1740	0.0960	0.0240	0.0060	0.2700	0.0060
1900-1909	0.0864	0.6260	0.3456	0.0864	0.0216	0.9720	0.0216
1910-1919	-0.0032	-0.0232	-0.0128	-0.0032	-0.0008	-0.0360	-0.0008
1920-1929	0.0616	0.4470	0.2464	0.0616	0.0154	0.6930	0.0154
1930-1939	0.0572	0.4150	0.2288	0.0572	0.0143	0.6440	0.0143
1940-1949	0.0292	0.2120	0.1168	0.0292	0.0073	0.3280	0.0073
1950-1959	0.0660	0.4780	0.2640	0.0660	0.0165	0.7420	0.0165
1960-1969	0.1740	1.2640	0.6976	0.1744	0.0436	1.9620	0.0436
1970-1979	0.1010	0.7310	0.4032	0.1008	0.0252	1.1340	0.0252
1980-1982	0.0460	0.3310	1.2480	0.0460	0.0110	0.5130	0.0110
1983-1984	0.0460	0.3310	1.2620	0.0460	0.0110	0.5130	0.0110
1986-1987	0.0460	0.3310	1.2860	0.0460	0.0110	0.5130	0.0110
1988-1989	0.0460	0.3310	0.9940	0.0460	0.0110	0.5130	0.0110
1990	0.0460	0.3310	0.7000	0.0460	0.0110	0.5130	0.0110

South and Central America — Lands in Pasture (10^6 hectares per year):

Years	Tropical equatorial forest	Tropical seasonal forest	Tropical woodland	Warm coniferous forest	Temperate broadleaf forest	Grassland	Desert scrub
1800-1859	0.000	0.000	0.735	0.000	0.000	1.323	0.042
1860-1869	0.005	0.090	-0.210	0.005	0.000	-0.378	-0.012
1870-1879	0.000	0.000	0.525	0.000	0.000	0.945	0.030
1880-1889	0.005	0.090	1.330	0.005	0.000	2.394	0.076
1890-1899	0.005	0.090	0.000	0.005	0.000	0.000	0.000
1900-1909	0.005	0.090	0.770	0.005	0.000	1.386	0.044
1910-1919	0.015	0.270	0.420	0.015	0.000	0.756	0.024
1920-1929	0.015	0.270	-0.280	0.015	0.000	-0.504	-0.016
1930-1939	0.020	0.360	0.665	0.020	0.000	1.197	0.038
1940-1949	0.025	0.450	1.820	0.025	0.000	3.276	0.104
1950-1959	0.045	0.810	1.715	0.045	0.000	3.087	0.098
1960-1969	0.055	0.990	2.415	0.055	0.000	4.347	0.138

1970-1979	0.075	1.350	0.210	0.075	0.000	0.378	0.012
1980-1982	0.060	1.752	0.000	0.060	0.000	0.000	0.000
1983-1985	0.060	2.259	0.000	0.060	0.000	0.000	0.000
1986-1987	0.060	2.660	0.000	0.060	0.000	0.000	0.000
1988-1989	0.060	2.480	0.000	0.060	0.000	0.000	0.000
1990	0.060	2.039	0.000	0.060	0.000	0.000	0.000

South and Central America — Wood Harvest (10^6 Mg C per year):

Years	Tropical seasonal forest	Warm coniferous forest
1800-1801	0.416	0.301
1802-1874	0.518	0.378
1875-1899	0.832	0.602
1900-1924	1.978	1.428
1925-1949	3.953	2.860
1950-1974	12.080	8.720
1975-1979	18.720	13.540
1980-1984	21.420	15.500
1985-1990	21.420	15.500

South and Central America — Lands in Shifting Cultivation (10^6 hectares per year):

Years	Tropical seasonal forest	Tropical woodland
1800-1939	5.1176	9.3333
1940-1944	5.1376	9.3333
1945-1949	5.2976	9.3533
1950-1954	5.4176	9.4333
1955-1959	5.5376	9.4933
1960-1964	5.6376	9.5133
1965-1969	5.8176	9.5333
1970-1974	6.0776	9.5533
1975-1979	6.3376	9.5733
1980-1984	6.6556	9.5933
1985-1999	6.6556	9.5933

Tropical Africa

The following values replace the data in files taf-rat.* in Houghton and Hackler (1995).

Tropical Africa — Forest Clearing (10^6 hectares per year):

Years	Closed forest	Open forest
1800-1824	0.021	0.037
1825-1849	0.029	0.051
1850-1859	0.036	0.064
1860-1874	0.045	0.080
1875-1887	0.054	0.096
1885-1899	0.065	0.115
1900-1909	0.090	0.160
1910-1919	0.126	0.224
1920-1929	0.162	0.288
1930-1939	0.198	0.352
1940-1949	0.324	0.576
1950-1959	0.504	0.896
1960-1969	0.792	1.408
1970-1977	1.080	1.920
1978-1979	1.324	2.354
1980-1984	1.440	2.560
1985-1989	1.836	3.264
1990	2.160	3.840

APPENDIX C. REGIONAL CARBON-CHANGE COEFFICIENTS

The following listing provides the regional values and coefficients associated with oxidation and recovery of carbon in vegetation, soils, and forest products. The values in this listing replace the values in the indicated ascii files and binary spreadsheet files in Houghton and Hackler (1995), the previous version of this database.

The values for five kinds of response curve are provided herein: *clearing response curve* (changes in the carbon in vegetation and soils resulting from the clearing of natural ecosystems for croplands), *pasture response curve* (changes in the carbon in vegetation and soils resulting from the clearing of natural ecosystems for pasture), *forest plantation response curve* (changes in carbon in vegetation and soils following the clearing of forests for plantations), *shifting cultivation response curve* (changes in the carbon in vegetation and soils following the clearing of natural ecosystems for shifting cultivation), and *logging response curve* (changes in the carbon in vegetation following the harvest of forests and recovery; the amount of carbon in soils was assumed to be unchanged).

The following values are provided in this appendix:

Carbon in undisturbed vegetation (Mg C/ha): Carbon content of live vegetation *before* land-use change (or harvest)

Carbon in crops (Mg C/ha): Carbon content of vegetation remaining in the ecosystem during the period of land-use change

Carbon in disturbed vegetation (Mg C/ha): Carbon content of live vegetation, *after* land-use change (or harvest) but *before* initial recovery

Carbon in recovered vegetation (Mg C/ha): Carbon content of live vegetation, *after* land-use change (or harvest) and initial recovery, but *before* it has returned to initial level

Carbon in slash (Mg C/ha): Carbon content of dead vegetation left on-site during land-use change (or harvest)

Carbon in undisturbed soil (Mg C/ha): Carbon content of soil before land-use change (or harvest)

Carbon in recovered soil (Mg C/ha): Carbon content of soil, after initial oxidation and subsequent recovery, but *before* it has returned to initial level

Soil carbon after initial rapid change (Mg C/ha): Carbon content of soil after initial oxidation resulting from land-use change

Minimum soil carbon (Mg C/ha): Carbon content of soil following both initial (fast) oxidation and subsequent (slow) oxidation

Time for vegetation to return from disturbed to recovered state (year): Length of time, in years, required for carbon content of vegetation, after land-use change (or harvest), to *partially* return to initial level

Time for vegetation to return from recovered to primary state (year): Length of time, in years, required for carbon content of vegetation, after land-use change (or harvest) and partial recovery, to complete the *full* return to initial level

Time for vegetation to return from disturbed to primary state (year): Length of time, in years, required for carbon content of vegetation, after land-use change (or harvest), to *fully* return to initial level

Duration of initial rapid change (year): Length of time, in years, required for initial rapid oxidation of soil carbon after land-use change (or harvest)

Time to minimum soil carbon (year): Length of time, in years, following initial rapid oxidation of soil carbon, until lowest level of soil carbon is achieved

Time for soil carbon to return from minimum to recovered state (year): Length of time, in years, for carbon content of soil to *partially* return to initial level from lowest level

Time for soil carbon to return from recovered to primary state (year): Length of time, in years, for carbon content of soil to complete *full* return to initial level

Time for soil carbon to return from minimum to primary state (year): Length of time, in years, for carbon content of soil to *fully* return to initial level from lowest level

Fraction of harvested vegetation assigned to decay pools (1-year, 10-year, 100-year, and 1000-year): Fraction of carbon in live vegetation removed from site that is oxidized with decay constants of 1 yr^{-1} (fuelwood), 0.1 yr^{-1} (pulp and paper products), 0.01 yr^{-1} (sawn wood, plywood, panels, and lumber), and 0.001 yr^{-1} (elemental carbon from burning), respectively.

Fraction of harvested vegetation left to decay on-site: Fraction of carbon in vegetation that is killed and left on-site (i.e., slash)

Rate constant for on-site decay (per year): Fraction of remaining carbon in dead vegetation left on-site (i.e., slash) that oxidizes in each year following land-use change (or harvest)

In some cases, the specific meaning of a term will change according to the context (type of ecosystem, land use, or land-use change involved). Thus, "recovery" in the case of clearing for agriculture is measured from time of abandonment. In the case of shifting cultivation it is measured from the onset of the fallow period, and in a logged forest it is measured following the initial harvest. In the case of logging, a "recovered" system is a secondary forest that can be harvested again, and "crop" represents wood harvested. In the case of shifting cultivation, the "disturbed" state refers to the beginning of the fallow cycle, and the "recovered" state refers to the end of the fallow cycle; the "time for vegetation to return from disturbed to recovered state" represents the length of the fallow cycle.

South and Southeast Asia (the following values replace the data in files asia-re.* and asia-sh.* in Houghton and Hackler 1995)

South and Southeast Asia — Clearing Response Curve:

	Tropical moist forest	Tropical seasonal forest	Tropical open forest
Carbon in undisturbed vegetation (Mg C/ha)	250	150	60
Carbon in recovered vegetation (Mg C/ha)	175	105	42
Carbon in crops (Mg C/ha)	5	5	5
Time for vegetation to return from disturbed to recovered state (yr)	37	29	12
Time for vegetation to return from recovered to primary state (yr)	40	30	40
Carbon in undisturbed soil (Mg C/ha)	120	80	50
Carbon in recovered soil (Mg C/ha)	120	80	50
Soil carbon after initial rapid change (Mg C/ha)	96	64	40
Minimum soil carbon (Mg C/ha)	84	56	37
Duration of initial rapid change (yr)	5	5	5
Time to minimum soil carbon (yr)	5	5	5
Time for soil carbon to return from minimum to recovered state (yr)	40	29	12
Fraction of harvested vegetation assigned to decay pools:			
1-yr	0.4	0.4	0.4
10-yr	0.1	0.1	0.1
100-yr	0.0	0.0	0.0
1000-yr	0.0	0.0	0.0
Fraction of harvested vegetation left to decay on-site	0.5	0.5	0.5
Rate constant for on-site decay (per yr)	0.5	0.4	0.3

South and Southeast Asia — Shifting Cultivation Response Curve:

	Tropical moist forest	Tropical open forest
Carbon in undisturbed vegetation(Mg C/ha)	250	60
Carbon in recovered vegetation (Mg C/ha)	90	35
Carbon in crops (Mg C/ha)	15	5
Time for vegetation to return from disturbed to recovered state (yr)	15	10
Time for vegetation to return from recovered to primary state (yr)	22	2
Carbon in undisturbed soil (Mg C/ha)	120	50
Carbon in recovered soil (Mg C/ha)	108	45
Soil carbon after initial rapid change (Mg C/ha)	90	38
Minimum soil carbon (Mg C/ha)	90	38
Duration of initial rapid change (yr)	2	2
Time to minimum soil carbon (yr)	2	2
Time for soil carbon to return from minimum to recovered state (yr)	15	10
Time for soil carbon to return from recovered to primary state (yr)	22	2
Fraction of harvested vegetation assigned to decay pools:		
1-yr	0.38	0.41
10-yr	0.07	0.10
100-yr	0.00	0.00
1000-yr	0.02	0.02
Fraction of harvested vegetation left to decay on-site	0.53	0.47
Rate constant for on-site decay (per year)	0.50	0.30

South and Southeast Asia — Logging Response Curve:

	Tropical moist forest	Tropical seasonal forest
Carbon in undisturbed vegetation (Mg C/ha)	250	150
Carbon in recovered vegetation (Mg C/ha)	175	105
Carbon in disturbed vegetation (Mg C/ha)	110	60
Time for vegetation to return from disturbed to recovered state (yr)	20	20
Carbon in undisturbed soil (Mg C/ha)	120	80
Carbon in recovered soil (Mg C/ha)	120	80
Minimum soil carbon (Mg C/ha)	120	80
Carbon in crops (Mg C/ha)	27	16
Carbon in slash (Mg C/ha)	219	131
Fraction of harvested vegetation assigned to decay pools:		

1-yr	0.0162	0.0162
10-yr	0.0088	0.0088
100-yr	0.1000	0.1000
Fraction of harvested vegetation left to decay on-site	0.8750	0.8750
Rate constant for on-site decay (per year)	0.5000	0.3000

Former Soviet Union (the following values replace the data in files fsu-re.* and fsulogpt.* in Houghton and Hackler 1995)

Former Soviet Union — Clearing Response Curve:

	Temperate grassland	Temperate deciduous forest	Boreal forest
Carbon in undisturbed vegetation (Mg C/ha)	10	135	90
Carbon in recovered vegetation (Mg C/ha)	10	108	72
Carbon in crops (Mg C/ha)	5	5	5
Time for vegetation to return from disturbed to recovered state (yr)	10	40	80
Time for vegetation to return from recovered to primary state (yr)	5	21	43
Carbon in undisturbed soil (Mg C/ha)	189	134	206
Carbon in recovered soil (Mg C/ha)	189	134	206
Soil carbon after initial rapid change (Mg C/ha)	161	114	175
Minimum soil carbon (Mg C/ha)	151	107	165
Duration of initial rapid change (yr)	15	10	15
Time to minimum soil carbon (yr)	30	30	65
Time for soil carbon to return from minimum to recovered state (yr)	45	40	80
Time for soil carbon to return from recovered to primary state (yr)	5	21	43
Fraction of harvested vegetation assigned to decay pools:			
1-yr	0.4	0.48	0.48
10-yr	0.1	0.24	0.24
100-yr	0.0	0.08	0.08
1000-yr	0.0	0.00	0.00
Fraction of harvested vegetation left to decay on-site	0.5	0.20	0.20
Rate constant for on-site decay (per year)	0.5	0.04	0.05

Former Soviet Union — Logging Response Curve:

	Fuelwood Harvest		Timber Harvest	
	Temperate deciduous forest	Boreal forest	Temperate deciduous forest	Boreal forest
Carbon in undisturbed vegetation (Mg C/ha)	135	90	135	90

Carbon in recovered vegetation (Mg C/ha)	108	72	108	72
Carbon in disturbed vegetation (Mg C/ha)	97	46	0	0
Time for vegetation to return from disturbed to recovered state (yr)	14	29	40	80
Time for vegetation to return from recovered to primary state (yr)	20	24	20	24
Carbon in undisturbed soil (Mg C/ha)	134	206	134	206
Fraction of harvested vegetation left to decay on-site	0.20	0.21	0.37	0.30
Rate constant for on-site decay (per year)	0.04	0.05	0.04	0.05

Former Soviet Union — Partitioning of logging products into decay pools by harvest type, ecosystem type, and year:

Fuelwood harvest

Temperate deciduous forest

	Years				
Decay pool	1700-1944	1945-1959	1960-1974	1975-1979	1980-1990
1-yr	0.71132	0.73342	0.59211	0.65211	0.64737
10-yr	0.00000	0.00000	0.00000	0.00000	0.00000
100-yr	0.07816	0.05605	0.19737	0.13737	0.14211
1000-yr	0.00000	0.00000	0.00000	0.00000	0.00000

Boreal forest

	Years				
Decay pool	1700-1944	1945-1959	1960-1974	1975-1979	1980-1990
1-yr	0.71670	0.73898	0.59659	0.65705	0.65227
10-yr	0.00000	0.00000	0.00000	0.00000	0.00000
100-yr	0.07875	0.05648	0.19886	0.13841	0.14318
1000-yr	0.00000	0.00000	0.00000	0.00000	0.00000

Timber harvest

Temperate deciduous forest

	Year				
Decay pool	1700	1945	1960	1975	1990
1-yr	0.21407	0.40296	0.18259	0.11333	0.09444
10-yr	0.00000	0.00000	0.00000	0.00000	0.00000
100-yr	0.41556	0.22667	0.44704	0.51630	0.53519
1000-yr	0.00000	0.00000	0.00000	0.00000	0.00000

Boreal forest

	Year				
Decay pool	1700	1945	1960	1975	1990
1-yr	0.23611	0.44444	0.20139	0.12500	0.10417
10-yr	0.00000	0.00000	0.00000	0.00000	0.00000
100-yr	0.45833	0.25000	0.49306	0.56944	0.59028
1000-yr	0.00000	0.00000	0.00000	0.00000	0.00000

South and Central America (the following values replace the data in files scam_re.* in Houghton and Hackler 1995)

South and Central America — Clearing Response Curve:

	Tropical equatorial forest	Tropical seasonal forest	Tropical woodland	Warm coniferous forest
Carbon in undisturbed vegetation (Mg C/ha)	200	140	55	168
Carbon in recovered vegetation (Mg C/ha)	200	140	55	168
Carbon in crops (Mg C/ha)	5	5	5	5
Time for vegetation to return from disturbed to primary state (yr)	40	35	18	42
Carbon in undisturbed soil (Mg C/ha)	98	98	69	134
Soil carbon after initial rapid change (Mg C/ha)	78	78	55	107
Duration of initial rapid change (yr)	5	5	5	5
Minimum soil carbon (Mg C/ha)	74	74	52	100
Time to minimum soil carbon (yr)	20	20	20	20
Time for soil carbon to return from minimum to primary state (yr)	40	35	18	42
Fraction of harvested vegetation assigned to decay pools:				
1-yr	0.30	0.30	0.30	0.30
10-yr	0.35	0.35	0.30	0.35
100-yr	0.00	0.00	0.00	0.00
1000-yr	0.02	0.02	0.02	0.02
Fraction of harvested vegetation left to decay on-site	0.33	0.33	0.38	0.33
Rate constant for on-site decay (per year)	0.50	0.40	0.30	0.30

	Temperate broadleaf forest	Grassland	Desert scrub
Carbon in undisturbed vegetation (Mg C/ha)	100	10	6
Carbon in recovered vegetation (Mg C/ha)	100	10	6
Carbon in crops (Mg C/ha)	5	5	6
Time for vegetation to return from disturbed to primary state (yr)	25	2	1
Carbon in undisturbed soil (Mg C/ha)	134	42	58
Soil carbon after initial rapid change (Mg C/ha)	107	34	46
Duration of initial rapid change (yr)	5	5	5
Minimum soil carbon (Mg C/ha)	100	32	44
Time to minimum soil carbon (yr)	20	20	20
Time for soil carbon to return from minimum to primary state (yr)	40	18	40
Fraction of harvested vegetation assigned to decay pools:			

1-yr	0.30	0.48	0.48
10-yr	0.35	0.00	0.00
100-yr	0.00	0.00	0.00
1000-yr	0.02	0.02	0.02
Fraction of harvested vegetation left to decay on-site	0.33	0.50	0.50
Rate constant for on-site decay (per year)	0.50	0.30	0.20

South and Central America — Pasture Response Curve:

	Tropical equatorial forest	Tropical seasonal forest	Tropical woodland	Warm coniferous forest
Carbon in undisturbed vegetation (Mg C/ha)	200	140	55	168
Carbon in disturbed vegetation (Mg C/ha)	10	10	28	10
Time for vegetation to return from disturbed to primary state (yr)	40	35	18	42
Carbon in undisturbed soil (Mg C/ha)	98	98	69	134
Minimum soil carbon (Mg C/ha)	87	87	69	118
Time to minimum soil carbon (yr)	20	20	20	20
Time for soil carbon to return from minimum to primary state (yr)	40	35	18	42
Fraction of harvested vegetation assigned to decay pools:				
1-yr	0.30	0.30	0.30	0.30
10-yr	0.35	0.35	0.30	0.35
100-yr	0.00	0.00	0.00	0.00
1000-yr	0.02	0.02	0.02	0.02
Fraction of harvested vegetation left to decay on-site	0.33	0.33	0.38	0.33
Rate constant for on-site decay (per year)	0.50	0.40	0.30	0.30

	Temperate broadleaf forest	Grassland	Desert scrub
Carbon in undisturbed vegetation (Mg C/ha)	100	10	6
Carbon in disturbed vegetation (Mg C/ha)	10	10	6
Time for vegetation to return from disturbed to primary state (yr)	25	2	2
Carbon in undisturbed soil (Mg C/ha)	134	42	58
Minimum soil carbon (Mg C/ha)	118	42	58
Time to minimum soil carbon (yr)	20	20	20
Time for soil carbon to return from minimum to primary state (yr)	40	18	40
Fraction of harvested vegetation assigned to decay pools:			
1-yr	0.30	0.48	0.48
10-yr	0.35	0.00	0.00
100-yr	0.00	0.00	0.00
1000-yr	0.02	0.02	0.02

Fraction of harvested vegetation left to decay on-site	0.33	0.50	0.50
Rate constant for on-site decay (per year)	0.50	0.40	0.30

South and Central America — Shifting Cultivation Response Curve:

	Tropical seasonal forest	Tropical woodland
Carbon in undisturbed vegetation (Mg C/ha)	140	55
Carbon in disturbed vegetation (Mg C/ha)	15	5
Carbon in recovered vegetation (Mg C/ha)	65	20
Time for vegetation to return from disturbed to recovered state (yr)	17	6
Carbon in undisturbed soil (Mg C/ha)	98	69
Minimum soil carbon (Mg C/ha)	83	59
Time to minimum soil carbon (yr)	2	2
Carbon in recovered soil (Mg C/ha)	91	64
Fraction of harvested vegetation assigned to decay pools:		
1-yr	0.30	0.30
10-yr	0.35	0.35
100-yr	0.00	0.00
1000-yr	0.02	0.02
Fraction of harvested vegetation left to decay on-site	0.33	0.33
Rate constant for on-site decay (per year)	0.40	0.30

South and Central America — Logging Response Curve:

	Tropical seasonal forest	Warm coniferous forest
Carbon in undisturbed vegetation (Mg C/ha)	140	168
Carbon in crops (Mg C/ha)	3	15
Carbon in slash (Mg C/ha)	15	25
Carbon in disturbed vegetation (Mg C/ha)	122	128
Time for vegetation to return from disturbed to primary state (yr)	6	13
Fraction of harvested vegetation assigned to decay pools:		
1-yr	0.0	0.0
10-yr	0.0	0.1
100-yr	1.0	0.9
1000-yr	0.0	0.0
Rate constant for on-site decay (per year)	0.4	0.4

South and Central America — Forest Plantation Response Curve:

	Tropical seasonal forest
Carbon in undisturbed vegetation (Mg C/ha)	140
Carbon in disturbed vegetation (Mg C/ha)	10
Carbon in undisturbed soil (Mg C/ha)	98
Minimum soil carbon (Mg C/ha)	87
Time to minimum soil carbon (yr)	2
Fraction of harvested vegetation assigned to decay pools:	
1-yr	0
10-yr	0
100-yr	0
1000-yr	0
Fraction of harvested vegetation left to decay on-site	1
Rate constant for on-site decay (per year)	0.4

*Tropical Africa (*the following values replace the data in files taf_re.* in Houghton and Hackler 1995)

Tropical Africa — Clearing response curve:

	Closed Forest	Open forest
Carbon in undisturbed vegetation (Mg C/ha)	136	30
Carbon in recovered vegetation (Mg C/ha)	136	30
Carbon in crops (Mg C/ha)	15	15
Time for vegetation to return from disturbed to recovered state (yr)	30	30
Carbon in undisturbed soil (Mg C/ha)	100	50
Carbon in recovered soil (Mg C/ha)	100	50
Soil carbon after initial rapid change (Mg C/ha)	80	40
Minimum soil carbon (Mg C/ha)	75	37
Duration of initial rapid change (yr)	1	1
Time to minimum soil carbon (yr)	5	5
Time for soil carbon to return from minimum to recovered state (yr)	30	30
Fraction of harvested vegetation assigned to decay pools:		
1-yr	0.40	0.40
10-yr	0.27	0.27
100-yr	0.00	0.00
1000-yr	0.00	0.00
Fraction of harvested vegetation left to decay on-site	0.33	0.33
Rate constant for on-site decay (per year)	0.50	0.30

North America, China, Europe, Pacific Developed Region, and North Africa and the Middle East *(*the following values replace the data in files tem_re.* in Houghton and Hackler 1995)

North America, China, Europe, Pacific Developed Region, and North Africa and the Middle East — Clearing Response Curve:

	Tropical moist forest	Tropical seasonal forest	Temperate evergreen forest	Temperate deciduous forest	Boreal forest
Carbon in undisturbed vegetation (Mg C/ha)	200	160	160	135	90
Carbon in recovered vegetation (Mg C/ha)	150	120	120	100	68
Carbon in crops (Mg C/ha)	5	5	5	5	5
Time for vegetation to return from disturbed to recovered state (yr)	50	50	50	50	50
Carbon in undisturbed soil (Mg C/ha)	117	117	134	134	206
Carbon in recovered soil (Mg C/ha)	103	103	127	127	185
Soil carbon after initial rapid change (Mg C/ha)	94	94	107	107	164
Minimum soil carbon (Mg C/ha)	88	88	101	101	155
Duration of initial rapid change (yr)	3	3	15	15	50
Time to minimum soil carbon (yr)	15	15	30	30	50
Time for soil carbon to return from minimum to recovered state (yr)	15	15	40	40	35
Fraction of harvested vegetation assigned to decay pools:					
1-yr	0.40	0.40	0.40	0.40	0.40
10-yr	0.27	0.27	0.20	0.20	0.20
100-yr	0.00	0.00	0.07	0.07	0.07
1000-yr	0.00	0.00	0.00	0.00	0.00
Fraction of harvested vegetation left to decay on-site	0.33	0.33	0.33	0.33	0.33

North America, China, Europe, Pacific Developed Region, and North Africa and the Middle East — Clearing Response Curve (continued)

	Tropical woodland/ shrubland	Temperate woodland/ shrubland	Tropical grassland	Temperate grassland	Desert scrub
Carbon in undisturbed vegetation (Mg C/ha)	27	27	18	7	3
Carbon in recovered vegetation (Mg C/ha)	27	27	18	7	3
Carbon in crops (Mg C/ha)	5	5	5	3	1
Time for vegetation to return from disturbed to recovered state (yr)	25	50	5	10	10
Carbon in undisturbed soil (Mg C/ha)	69	69	42	189	58
Carbon in recovered soil (Mg C/ha)	69	69	42	189	58
Soil carbon after initial rapid change (Mg C/ha)	55	55	34	151	80
Minimum soil carbon (Mg C/ha)	52	52	32	142	87
Duration of initial rapid change (yr)	3	15	3	15	5
Time to minimum soil carbon (yr)	15	30	15	30	10
Time for soil carbon to return from minimum to recovered state (yr)	15	45	15	45	10
Fraction of harvested vegetation assigned to decay pools:					
1-yr	0.40	0.40	0.50	0.50	0.50
10-yr	0.10	0.10	0.00	0.00	0.00
100-yr	0.00	0.00	0.00	0.00	0.00
1000-yr	0.00	0.00	0.00	0.00	0.00
Fraction of harvested vegetation left to decay on-site	0.50	0.50	0.50	0.50	0.50

North America, China, Europe, Pacific Developed Region, and North Africa and the Middle East — Logging Response Curve:

	Tropical moist forest	Temperate evergreen forest	Temperate deciduous forest	Boreal forest
Carbon in undisturbed vegetation (Mg C/ha)	200	160	135	90
Carbon in recovered vegetation (Mg C/ha)	150	120	100	68
Carbon in disturbed vegetation (Mg C/ha)	0	0	0	0
Time for vegetation to return from disturbed to recovered state (yr)	50	50	50	50
Carbon in undisturbed soil (Mg C/ha)	117	134	134	206
Carbon in recovered soil (Mg C/ha)	103	127	127	185
Minimum soil carbon (Mg C/ha)	76	108	108	165
Carbon in crops (Mg C/ha)	73	42	51	17
Carbon in slash (Mg C/ha)	127	118	84	73

Time to minimum soil carbon (yr)	5	10	10	15
Time for soil carbon to return from minimum to recovered state (yr)	45	40	40	35

Partitioning of logging products (from all ecosystem types) into decay pools by region and year:

China

	Year					
Decay pool	1700	1875	1900	1925	1950	1980
1-yr	0.90	0.90	0.90	0.86	0.80	0.75
10-yr	0.04	0.04	0.04	0.06	0.08	0.10
100-yr	0.06	0.06	0.06	0.08	0.12	0.15
1000-yr	0.00	0.00	0.00	0.00	0.00	0.00

Europe

	Year					
Decay pool	1700	1875	1900	1925	1950	1980
1-yr	0.50	0.50	0.50	0.48	0.42	0.18
10-yr	0.20	0.20	0.20	0.21	0.23	0.33
100-yr	0.30	0.30	0.30	0.31	0.35	0.49
1000-yr	0.00	0.00	0.00	0.00	0.00	0.00

North Africa and the Middle East

	Year					
Decay pool	1700	1875	1900	1925	1950	1980
1-yr	0.90	0.90	0.90	0.87	0.75	0.63
10-yr	0.04	0.04	0.04	0.05	0.10	0.15
100-yr	0.06	0.06	0.06	0.08	0.15	0.22
1000-yr	0.00	0.00	0.00	0.00	0.00	0.00

North America

	Year					
Decay pool	1700	1875	1900	1925	1950	1980
1-yr	0.50	0.44	0.40	0.30	0.20	0.04
10-yr	0.20	0.22	0.24	0.28	0.32	0.38
100-yr	0.30	0.34	0.36	0.42	0.48	0.58
1000-yr	0.00	0.00	0.00	0.00	0.00	0.00

Pacific Developed Region

	Year					
Decay pool	1700	1875	1900	1925	1950	1980
1-yr	0.81	0.81	0.81	0.81	0.42	0.27
10-yr	0.08	0.08	0.08	0.08	0.23	0.29
100-yr	0.11	0.11	0.11	0.11	0.35	0.44
1000-yr	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX D. FULL LISTING OF NDP050.DAT (FILE 2)

The following is a full listing of ascii file ndp050.dat (File 2), which is also provided, in binary spreadsheet format, as file ndp050.wk1 (File 3). This file lists the estimated net flux of carbon, in units of 1000 Mg of carbon (1 megagram = 10^6 g), to the atmosphere from land-use change, from 1850 through 1990, by year and by region, along with the global totals. The values in this listing replace the values in files netflux.* in Houghton and Hackler (1995), the previous version of this database.

Year	North America	South and Central America	Europe	North Africa and Middle East	Tropical Africa	Former Soviet Union	China	South and Southeast Asia	Pacific Developed Region	TOTAL FLUX
1850	87.28	42.48	55.04	3.98	5.61	58.56	56.52	85.63	2.05	397.145
1851	87.22	42.18	55.02	3.98	6.47	58.55	56.50	85.20	2.04	397.164
1852	90.37	41.90	54.99	3.98	6.60	58.88	56.48	85.25	2.04	400.492
1853	93.38	41.66	54.96	3.98	6.69	59.22	56.47	85.33	2.03	403.713
1854	96.28	41.44	54.93	3.98	6.77	59.58	56.45	85.42	2.03	406.877
1855	99.12	41.24	54.90	3.98	6.82	59.96	56.43	85.53	2.03	410.017
1856	101.93	41.06	54.87	3.98	6.86	60.34	56.42	85.65	2.02	413.137
1857	104.72	40.91	54.84	3.98	6.88	60.72	56.40	85.77	2.02	416.250
1858	107.50	40.77	54.81	3.98	6.90	61.10	56.39	85.90	2.01	419.363
1859	110.27	40.64	54.78	3.98	6.92	61.48	56.37	86.02	2.01	422.481
1860	113.06	38.09	54.75	3.98	6.93	61.85	56.36	86.14	2.01	423.171
1861	116.34	32.46	54.79	9.01	8.02	62.22	56.25	86.26	2.08	427.422
1862	119.70	29.66	54.86	9.96	8.18	53.69	56.13	86.38	2.18	420.740
1863	123.16	26.89	54.96	10.82	8.31	53.75	55.99	86.49	2.30	422.672
1864	126.70	24.20	55.06	11.25	8.41	53.80	55.85	86.61	2.43	424.303
1865	130.31	21.57	55.18	11.64	8.49	53.86	55.71	86.71	2.56	426.033
1866	131.46	20.62	55.31	11.99	8.53	53.74	55.55	86.82	2.70	426.713
1867	132.67	19.74	55.46	12.31	8.57	53.62	55.39	86.91	2.83	427.495
1868	133.95	18.90	55.61	12.61	8.59	53.51	55.23	87.01	2.96	428.377
1869	135.30	18.11	55.78	12.89	8.62	53.41	55.06	87.10	3.09	429.350
1870	136.72	19.79	55.95	13.15	8.64	53.32	54.88	87.18	3.21	432.843
1871	138.16	23.97	50.48	13.40	8.66	53.23	54.70	108.79	9.87	461.264
1872	139.64	25.66	49.60	13.64	8.67	53.49	54.53	113.96	11.93	471.118
1873	141.14	27.32	48.75	13.87	8.69	53.75	54.35	117.71	13.66	479.236
1874	142.67	28.92	47.95	14.09	8.70	54.01	51.69	120.51	14.33	482.862
1875	144.23	30.47	47.17	14.30	8.71	54.27	51.15	122.69	14.87	487.850
1876	144.64	30.66	46.53	14.47	9.79	54.94	50.74	124.08	15.35	491.204
1877	144.91	31.36	45.94	14.63	9.96	55.04	50.41	125.23	15.76	493.231
1878	145.05	32.02	45.39	14.79	10.08	55.13	50.11	126.23	16.12	494.901
1879	145.06	32.63	44.87	14.93	10.18	55.21	49.84	127.11	16.44	496.273
1880	144.94	33.22	44.39	15.07	10.26	55.30	49.59	127.91	16.75	497.425
1881	144.70	70.55	43.94	15.21	10.30	55.40	49.35	128.27	17.05	534.771
1882	144.34	82.30	43.52	15.35	10.33	55.51	49.14	128.59	17.34	546.421
1883	143.86	92.24	43.12	15.49	10.36	55.63	48.94	128.87	17.64	556.158
1884	143.27	100.88	42.74	15.63	10.39	55.76	48.75	129.13	17.94	564.499
1885	142.58	108.58	42.39	15.77	10.41	55.90	48.58	129.37	18.24	571.807
1886	141.82	112.04	42.56	15.90	11.71	56.03	48.42	129.59	18.54	576.593
1887	141.00	114.43	42.73	16.03	11.91	56.17	48.26	129.79	18.83	579.162
1888	140.14	116.44	42.92	16.16	12.06	56.30	48.11	129.98	19.12	581.235

Year	North America	South and Central America	Europe	North Africa and Middle East	Tropical Africa	Former Soviet Union	China	South and Southeast Asia	Pacific Developed Region	TOTAL FLUX
1889	139.21	118.15	43.11	16.29	12.18	56.44	48.04	130.16	19.36	582.940
1890	138.09	119.63	43.31	16.42	12.28	56.57	47.97	130.32	19.60	584.180
1891	148.45	92.35	43.51	16.54	12.34	56.70	47.90	146.76	19.83	584.388
1892	150.16	84.19	43.72	16.66	12.38	56.83	47.84	150.78	20.06	582.620
1893	151.73	77.09	43.91	16.78	12.42	56.96	47.79	153.67	20.28	580.630
1894	153.18	70.78	44.11	16.90	12.45	57.08	47.75	155.83	20.50	578.581
1895	154.55	65.05	44.31	17.01	12.47	57.21	47.70	157.53	20.72	576.549
1896	155.52	63.60	44.50	17.12	12.50	57.33	47.66	158.61	20.93	577.764
1897	156.43	62.47	44.68	17.23	12.52	57.45	47.63	159.49	21.14	579.038
1898	157.30	61.59	44.86	17.34	12.53	57.57	47.60	160.22	21.35	580.364
1899	158.14	60.90	45.03	17.45	12.55	57.68	47.57	160.87	21.55	581.740
1900	158.92	60.36	45.19	17.55	12.56	57.79	47.54	161.44	21.75	583.112
1901	159.83	124.92	45.44	20.07	15.57	57.90	47.62	161.69	22.03	655.075
1902	160.75	144.42	45.70	20.58	16.02	58.05	47.72	161.98	22.34	677.559
1903	161.70	160.67	45.98	21.04	16.35	58.19	47.84	162.24	22.65	696.656
1904	162.67	174.59	46.28	21.29	16.61	58.33	47.96	162.47	22.97	713.179
1905	163.67	186.84	46.60	21.52	16.82	58.47	48.11	162.67	23.30	727.993
1906	163.10	191.39	46.93	21.72	16.93	58.59	48.25	170.77	23.62	741.299
1907	162.56	195.05	47.27	21.89	17.02	58.59	48.40	172.83	23.94	747.540
1908	162.04	198.06	47.62	22.05	17.10	58.58	48.55	174.30	24.25	752.540
1909	161.56	200.56	47.98	22.20	17.16	58.56	48.70	175.40	24.56	756.671
1910	161.10	202.27	48.35	22.33	17.21	58.54	48.85	176.27	24.87	759.791
1911	160.68	140.60	48.72	22.48	21.53	58.53	49.01	176.84	25.15	703.522
1912	160.30	122.37	49.10	22.59	22.20	58.51	49.16	177.30	25.41	686.940
1913	159.97	107.21	49.47	22.69	22.69	63.68	49.30	156.93	25.67	657.631
1914	159.68	94.19	49.85	22.79	23.08	65.23	55.07	152.36	25.91	648.173
1915	159.44	82.67	50.23	22.88	23.40	66.59	56.06	149.05	26.16	636.474
1916	159.22	78.80	50.66	22.93	23.57	67.89	56.94	153.45	26.39	639.850
1917	159.03	75.71	51.09	22.97	23.71	69.21	57.66	153.09	26.62	639.076
1918	158.88	73.19	51.51	23.01	23.82	70.49	58.32	152.93	26.84	638.978
1919	158.76	71.09	51.92	23.03	23.92	71.76	58.95	152.69	27.05	639.181
1920	158.68	66.46	52.32	23.05	24.00	73.06	59.55	152.43	27.26	636.822
1921	158.64	104.94	52.77	23.06	28.35	74.38	60.11	152.08	27.57	681.924
1922	158.64	114.93	53.20	23.07	29.04	75.75	60.66	151.74	27.79	694.822
1923	158.67	122.76	53.62	23.08	29.56	77.06	61.17	151.80	28.00	705.725
1924	158.75	129.12	54.03	23.09	29.97	78.40	61.61	151.87	28.18	715.011
1925	158.85	134.47	54.42	23.09	30.30	79.78	62.10	151.96	28.35	723.319
1926	158.29	135.88	54.08	31.70	30.49	81.20	62.42	147.46	28.57	730.099
1927	157.65	136.87	53.62	33.63	30.64	82.53	62.72	146.83	28.81	733.300
1928	157.22	137.47	53.05	35.36	30.77	83.10	62.98	146.53	29.05	735.537
1929	131.20	137.78	52.36	35.79	30.87	83.70	63.09	146.44	29.30	710.527
1930	124.19	141.11	51.56	36.12	30.97	84.30	63.17	146.47	29.54	707.444
1931	117.44	157.80	50.66	36.74	35.33	84.91	63.25	146.66	29.79	722.578
1932	110.89	163.27	49.66	37.31	36.02	85.52	63.31	146.89	30.04	722.897
1933	104.46	167.92	48.56	37.82	36.55	86.15	63.36	147.15	30.28	722.256
1934	98.14	171.97	47.36	38.30	36.96	84.55	67.10	147.42	30.53	722.339
1935	91.89	175.55	46.08	38.75	37.30	82.80	67.92	147.70	30.78	718.768
1936	85.51	177.38	44.76	39.18	37.49	80.90	68.63	165.10	31.02	729.964
1937	79.19	179.58	43.40	39.59	37.65	78.84	69.19	169.48	31.26	728.172
1938	72.92	181.57	42.01	39.98	37.78	76.69	69.70	172.75	31.50	724.900
1939	66.67	183.40	40.59	40.35	37.89	74.51	70.17	175.29	31.73	720.611
1940	60.51	185.09	39.15	40.71	37.99	71.15	70.61	177.32	31.96	714.481
1941	54.31	194.01	37.69	41.03	53.04	54.42	71.04	182.27	32.19	719.998
1942	48.15	198.34	36.23	41.35	55.30	47.51	71.44	187.87	32.41	718.624
1943	42.05	202.54	34.77	41.65	56.99	40.84	71.84	193.64	32.63	716.943
1944	39.63	206.70	33.31	41.89	58.30	34.35	72.21	199.44	32.84	718.664
1945	37.25	210.70	31.86	42.13	59.36	28.04	72.58	205.19	33.04	720.135
1946	34.91	214.35	30.40	42.35	59.93	24.03	72.93	281.30	33.24	793.441
1947	32.61	217.62	28.96	42.56	60.38	20.43	73.28	302.11	33.44	811.378

1948	30.35	221.01	27.52	42.77	60.75	17.18	73.62	318.01	33.63	824.833
1949	28.13	224.51	26.08	42.97	61.06	14.31	73.67	329.78	33.82	834.320
1950	25.97	229.84	24.66	43.16	61.33	13.08	73.72	340.01	34.00	845.773
1951	18.23	286.38	23.53	34.40	82.95	126.91	74.65	349.78	67.51	1064.327
1952	15.04	304.72	22.55	32.64	86.28	149.64	75.60	362.04	76.88	1125.376
1953	12.12	319.58	21.71	30.83	88.76	171.48	76.56	322.62	84.52	1128.181
1954	9.44	331.78	21.01	28.61	90.71	192.67	77.52	323.13	86.59	1161.448
1955	6.97	342.05	20.44	26.39	92.29	213.75	97.76	326.78	87.92	1214.345
1956	4.71	348.10	20.00	25.71	93.16	236.15	102.65	326.49	88.76	1245.711
1957	2.63	353.04	19.68	25.04	93.86	258.25	107.01	326.34	89.26	1275.109
1958	0.72	357.15	19.48	24.41	94.43	279.95	110.54	320.70	89.52	1296.919
1959	-1.02	362.41	19.40	23.79	94.92	208.34	113.79	320.51	89.62	1231.770
1960	-2.61	366.65	19.44	23.21	95.34	210.89	116.84	321.34	89.59	1240.677
1961	-4.09	481.93	16.70	22.64	129.92	205.22	119.69	325.96	89.48	1387.432
1962	-5.48	517.55	16.32	22.08	135.24	201.87	122.35	332.01	89.30	1431.247
1963	-6.76	546.07	16.01	21.55	139.22	198.82	124.84	347.12	89.09	1475.961
1964	-7.96	572.04	15.78	21.03	142.32	196.18	127.34	356.56	88.83	1512.116
1965	-9.08	593.94	15.61	20.52	144.85	192.92	129.51	365.27	88.56	1542.088
1966	-9.07	603.87	15.48	21.63	146.24	181.17	129.61	374.12	88.25	1551.292
1967	-9.03	612.03	15.39	21.82	147.36	169.52	130.71	382.93	87.94	1558.677
1968	-8.97	619.05	15.35	21.96	148.28	157.92	131.78	397.51	87.61	1570.492
1969	-8.87	629.61	15.33	21.73	149.06	147.84	132.89	407.46	87.04	1582.089
1970	-9.26	638.01	13.57	21.48	149.73	114.46	132.78	416.75	86.46	1563.981
1971	-9.53	567.12	11.18	21.52	184.52	100.10	104.98	407.73	50.23	1437.845
1972	-9.76	547.71	8.64	21.57	190.04	85.37	101.07	410.06	39.11	1393.820
1973	-9.93	531.05	5.96	21.62	194.18	71.25	97.25	474.68	29.74	1415.799
1974	-9.56	516.35	3.15	21.66	197.43	64.85	93.70	492.08	26.12	1405.787
1975	-9.15	503.09	0.21	21.71	200.09	58.78	90.12	505.73	23.24	1393.830
1976	-8.74	501.64	-2.64	21.75	201.60	55.92	86.52	619.65	20.85	1496.554

Year	North America	South and Central America	Europe	North Africa and Middle East	Tropical Africa	Former Soviet Union	China	South and Southeast Asia	Pacific Developed Region	TOTAL FLUX
1977	-8.32	500.90	-5.64	21.78	202.82	50.36	82.85	655.90	18.78	1519.441
1978	-7.99	500.34	-8.79	21.81	203.84	44.82	79.10	682.44	16.94	1532.511
1979	-7.48	507.58	-12.08	21.84	233.70	39.50	75.22	703.56	15.26	1577.084
1980	-7.09	511.59	-14.09	21.85	238.69	35.44	73.78	721.19	13.69	1595.045
1981	-7.01	516.39	-15.34	17.00	256.24	33.41	73.42	979.87	15.58	1869.544
1982	-5.80	517.03	-16.39	16.56	261.24	30.73	63.74	1046.49	14.94	1928.539
1983	-4.30	516.74	-17.23	16.44	265.19	28.82	60.42	1092.35	14.13	1972.563
1984	-2.55	552.39	-17.88	18.04	267.79	27.16	57.65	1126.06	12.75	2041.413
1985	-0.55	563.87	-18.34	19.80	269.92	25.77	55.55	1152.18	11.29	2079.482
1986	1.67	567.57	-18.62	20.37	318.45	23.36	53.90	1173.82	9.77	2150.284
1987	4.08	592.06	-18.72	21.02	326.58	22.57	52.43	1154.87	8.22	2163.104
1988	6.69	596.17	-18.65	21.72	332.71	21.85	51.09	1166.73	6.65	2184.948
1989	9.47	579.12	-18.42	22.47	337.54	21.19	49.85	1180.05	5.29	2186.550
1990	12.42	577.16	-18.08	23.24	341.50	20.11	48.69	1094.39	3.92	2103.342

APPENDIX E. FULL LISTING OF COMPARE.DAT (FILE 4)

The following is a full listing of ascii file compare.dat (File 4), which is also provided, in binary spreadsheet format, as file compare.wk1 (File 5). This file compares the estimated global total net flux of carbon to the atmosphere from land-use change, from 1850 to 1990, by year, for this database (Houghton 1999) and three earlier publications (Houghton et al. 1983, Houghton and Skole 1990, and Houghton and Hackler 1995). Note that the data for the period 1850 through 1859 attributed below to Houghton et al. (1983) were not actually presented in that publication but are present in the data used in that publication.

Units = Pg of carbon (1 petagram = 10^{15} grams); ! 9.999 denotes missing value

Year	Houghton et al. 1983	Houghton & Skole 1990	Houghton & Hackler 1995	Houghton 1999
1850	0.458	0.278	0.352	0.397
1851	0.464	0.319	0.383	0.397
1852	0.469	0.353	0.397	0.400
1853	0.475	0.379	0.408	0.404
1854	0.480	0.393	0.417	0.407
1855	0.486	0.424	0.424	0.410
1856	0.492	0.439	0.430	0.413
1857	0.497	0.452	0.435	0.416
1858	0.503	0.464	0.439	0.419
1859	0.509	0.475	0.443	0.422
1860	0.539	0.492	0.446	0.423
1861	0.563	0.485	0.457	0.427
1862	0.587	0.492	0.463	0.421
1863	0.612	0.500	0.468	0.423
1864	0.623	0.508	0.474	0.424
1865	0.634	0.516	0.479	0.426
1866	0.641	0.522	0.481	0.427
1867	0.649	0.528	0.484	0.427
1868	0.656	0.534	0.486	0.428
1869	0.665	0.541	0.489	0.429
1870	0.684	0.544	0.492	0.433
1871	0.701	0.553	0.501	0.461
1872	0.717	0.562	0.507	0.471
1873	0.731	0.566	0.512	0.479
1874	0.744	0.572	0.513	0.483
1875	0.771	0.579	0.517	0.488
1876	0.792	0.585	0.521	0.491
1877	0.813	0.589	0.524	0.493
1878	0.834	0.592	0.526	0.495
1879	0.846	0.594	0.528	0.496
1880	0.857	0.621	0.529	0.497

1881	0.868	0.639	0.560	0.535
1882	0.878	0.658	0.569	0.546
1883	0.888	0.669	0.576	0.556
1884	0.897	0.679	0.582	0.564
1885	0.905	0.686	0.586	0.572

Year	Houghton et al. 1983	Houghton & Skole 1990	Houghton & Hackler 1995	Houghton 1999
1886	0.910	0.692	0.590	0.577
1887	0.915	0.696	0.592	0.579
1888	0.919	0.700	0.593	0.581
1889	0.923	0.702	0.594	0.583
1890	0.936	0.701	0.593	0.584
1891	0.944	0.694	0.597	0.584
1892	0.951	0.688	0.597	0.583
1893	0.959	0.683	0.597	0.581
1894	0.966	0.679	0.597	0.579
1895	0.973	0.676	0.597	0.577
1896	0.979	0.673	0.597	0.578
1897	0.985	0.672	0.596	0.579
1898	0.991	0.674	0.596	0.580
1899	0.997	0.676	0.595	0.582
1900	1.027	0.732	0.596	0.583
1901	1.048	0.765	0.660	0.655
1902	1.070	0.791	0.678	0.678
1903	1.092	0.811	0.693	0.697
1904	1.100	0.828	0.705	0.713
1905	1.108	0.844	0.716	0.728
1906	1.113	0.851	0.726	0.741
1907	1.117	0.856	0.731	0.748
1908	1.122	0.860	0.735	0.753
1909	1.126	0.862	0.738	0.757
1910	1.133	0.815	0.740	0.760
1911	1.138	0.788	0.686	0.704
1912	1.143	0.762	0.670	0.687
1913	1.153	0.762	0.646	0.658
1914	1.158	0.758	0.639	0.648
1915	1.164	0.750	0.630	0.636
1916	1.167	0.750	0.634	0.640
1917	1.170	0.749	0.635	0.639
1918	1.173	0.750	0.637	0.639
1919	1.175	0.751	0.639	0.639
1920	1.177	0.789	0.641	0.637
1921	1.179	0.808	0.691	0.682
1922	1.181	0.823	0.707	0.695
1923	1.182	0.836	0.722	0.706
1924	1.184	0.842	0.734	0.715

1925	1.281	0.866	0.745	0.723
1926	1.360	0.875	0.753	0.730
1927	1.441	0.883	0.755	0.733
1928	1.507	0.866	0.757	0.736
1929	1.527	0.844	0.736	0.711
1930	1.548	0.856	0.730	0.707
1931	1.569	0.861	0.740	0.723
1932	1.591	0.862	0.737	0.723
1933	1.614	0.860	0.732	0.722
1934	1.637	0.857	0.730	0.722

Year	Houghton et al. 1983	Houghton & Skole 1990	Houghton & Hackler 1995	Houghton 1999
1935	1.660	0.852	0.724	0.719
1936	1.683	0.850	0.729	0.730
1937	1.705	0.849	0.727	0.728
1938	1.717	0.849	0.719	0.725
1939	1.736	0.850	0.715	0.721
1940	1.756	0.839	0.707	0.714
1941	1.773	0.810	0.702	0.720
1942	1.791	0.808	0.695	0.719
1943	1.808	0.808	0.688	0.717
1944	1.832	0.812	0.685	0.719
1945	1.856	0.820	0.682	0.720
1946	1.880	0.830	0.736	0.793
1947	1.904	0.844	0.751	0.811
1948	1.927	0.861	0.761	0.825
1949	1.950	0.878	0.767	0.834
1950	2.101	0.990	0.774	0.846
1951	2.186	1.150	0.986	1.064
1952	2.265	1.234	1.037	1.125
1953	2.340	1.294	1.045	1.128
1954	2.360	1.418	1.068	1.161
1955	2.374	1.482	1.109	1.214
1956	2.390	1.528	1.128	1.246
1957	2.405	1.478	1.146	1.275
1958	2.417	1.483	1.156	1.297
1959	2.429	1.488	1.084	1.232
1960	2.437	1.573	1.084	1.241
1961	2.447	1.625	1.217	1.387
1962	2.455	1.663	1.255	1.431
1963	2.463	1.700	1.293	1.476
1964	2.469	1.735	1.322	1.512
1965	2.562	1.768	1.348	1.542
1966	2.632	1.747	1.355	1.551

1967	2.700	1.758	1.360	1.559
1968	2.768	1.775	1.368	1.570
1969	2.776	1.783	1.377	1.582
1970	2.721	1.684	1.357	1.564
1971	2.699	1.669	1.250	1.438
1972	2.677	1.632	1.215	1.394
1973	2.655	1.609	1.232	1.416
1974	2.653	1.567	1.233	1.406
1975	2.650	1.595	1.234	1.394
1976	2.646	1.611	1.324	1.497
1977	2.640	1.631	1.350	1.519
1978	2.633	1.616	1.367	1.533
1979	2.624	1.609	1.413	1.577
1980	2.613	1.608	1.423	1.595
1981	-9.999	1.608	1.420	1.870
1982	-9.999	1.608	1.450	1.929
1983	-9.999	1.608	1.470	1.973

Year	Houghton et al. 1983	Houghton & Skole 1990	Houghton & Hackler 1995	Houghton 1999
1984	-9.999	1.608	1.519	2.041
1985	-9.999	1.608	1.539	2.079
1986	-9.999	-9.999	1.574	2.150
1987	-9.999	-9.999	1.605	2.163
1988	-9.999	-9.999	1.619	2.185
1989	-9.999	-9.999	1.611	2.187
1990	-9.999	-9.999	1.614	2.103