6. Land Use Issues

Overview

Land use change and forestry issues are important to national and global inventories of greenhouse gases in two ways:

- Vegetation can "sequester" or remove carbon dioxide from the atmosphere and store it for potentially long periods in above- and below-ground biomass, as well as in soils. Soils, trees, crops, and other plants may make significant contributions to reducing net greenhouse gas emissions by serving as carbon "sinks."
- Humans can alter the biosphere through changes in land use and forest management practices and, in effect, alter the quantities of atmospheric and terrestrial carbon stocks, as well as the natural carbon flux among biomass, soils, and the atmosphere.

Land use issues are of particular interest to the United States because U.S. forests and soils annually sequester large amounts of carbon dioxide. Much of the forest land in the United States was cleared for agriculture, lumber, or fuel in the hundred years prior to 1920. Since then, much agricultural and pasture land has reverted to forest land.

The amount of carbon being sequestered annually is uncertain, in part because of an absence of data and because of difficulties in measuring sequestration. Moreover, in addition to technical uncertainties, there is also policy or accounting ambiguity about which aspects of the biological carbon cycle ought to be included in national inventories as anthropogenic emissions and removals.

The revised guidelines for national emissions inventories published in 1997 by the Intergovernmental Panel on Climate Change (IPCC) include rules to direct the inclusion of carbon sequestration through land use and forestry in national inventories.[127] The U.S. Environmental Protection Agency (EPA), drawing upon the work of U.S. Forest Service researchers Richard Birdsey and Linda Heath, estimates annual U.S. carbon sequestration at 270 million metric tons carbon equivalent (Table 31).[128] Under the IPCC guidelines, this quantity is considered an offset to gross greenhouse gas emissions from other sources, such as the electric power industry. Thus, the 270 million metric tons carbon equivalent sequestered through land use change and forestry practices represents an offset of approximately 17.7 percent of total U.S. anthropogenic carbon dioxide emissions from 1990 through 1999. The total net carbon sequestration resulting from land use and forestry activities declined by approximately 7 percent between 1990 and 1999. The decline resulted in large part from increasing forest harvests and land-use changes, which resulted in lower net sequestration rates for forests.[129]

The EPA's estimates for carbon sequestration in forests are based on carbon stock estimates developed by the U.S. Forest Service, U.S. Department of Agriculture, employing methodologies that are consistent with the 1996 IPCC guidelines. Estimates for sequestration in

Table 31. Net Carbon Dioxide Sequestration from U.S. Land Use Change and Forestry, 1990 and 1995-1999
(Million Metric Tons Carbon Equivalent)

Component	1990	1995	1996	1997	1998	1999
Forests	273	256	257	246	245	247
Agricultural Soils	11	19	19	19	21	21
Landfilled Yard Trimmings	5	3	3	3	2	2
Total	**289**	**278**	**279**	**268**	**268**	**270**

Note: Totals may not equal sum of components due to independent rounding.
Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html, drawing on the work of Richard Birdsey and Linda Heath of the U.S. Forest Service.

[127]Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), web site www.ipcc.ch/pub/guide.htm.
[128]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.
[129]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

agricultural soil involve mineral and organic soil carbon stock changes resulting from agricultural land use and land management, as well as emissions of carbon dioxide resulting from the use of crushed limestone and dolomite on soils. Methodologies drawn from the IPCC guidelines were used to derive all components of changes in agricultural soil carbon stocks. Estimates for yard trimming carbon stocks in landfills were derived using the EPA's method of examining life cycle greenhouse gas emissions and sinks associated with solid waste management.[130] The estimates for carbon fluxes from landfilled yard trimmings trend downward over time, based on EPA estimates.

The EPA's carbon flux estimates for forests and agricultural soils are based on surveys of U.S. forest lands and soils carried out at 5-year intervals by the U.S. Forest Service. Annual estimates of carbon fluxes between survey years are interpolated and, therefore, change little from year to year, except when a new assessment is made. Further, the most current national forest and soil surveys were completed for the year 1997; thus, carbon flux estimates from forests are based in part on model projections.[131]

Total forestry carbon fluxes have fallen from 289 million metric tons carbon equivalent in 1990 to 270 million metric tons carbon equivalent in 1999. The decrease is due mainly to maturation and slowing in the spread of forest cover, as well as a reduction in landfilled yard trimmings. As can be seen from the estimates, the vast majority of the carbon fluxes are from forests (247 million metric tons carbon equivalent or 91.5 percent of total forestry carbon fluxes), followed by agricultural soils (21 million metric tons carbon equivalent or 7.8 percent of total forestry carbon fluxes) and landfilled yard trimmings (2 million metric tons carbon equivalent or 0.7 percent of total forestry carbon fluxes).

To put these figures into perspective, carbon fluxes from forestry offset 18 percent of energy-related carbon dioxide emissions, which totaled 1,500.8 million metric tons carbon equivalent in 1999. The 270 million metric tons carbon equivalent sequestered through land use and forestry activities in 1999 would also act to offset total U.S. emissions of greenhouse gases by 14.2 percent. If the EPA's estimate of 270 million metric tons carbon equivalent holds for 2000, then sequestration will offset approximately 17 percent of the 1,547.4 million metric tons carbon equivalent emitted through the burning of fossil fuels in 2000.

Changes in Forest Carbon Stocks

Worldwide, the most significant anthropogenic activity that affects forest carbon sequestration is deforestation, particularly that of tropical forests. During the 1980s, tropical deforestation is projected to have resulted in approximately 6 billion metric tons of carbon dioxide emissions to the atmosphere annually. This value represents approximately 23 percent of global carbon dioxide emissions resulting from anthropogenic activities during the 1980s. Approximately 7 percent of global carbon dioxide emissions were compensated by carbon sequestration as a result of forest regrowth in the Northern Hemisphere.[132] In the United States, the most significant pressures on the amount of carbon sequestered through forest lands are land management activities and the continuing effects of past changes in land use. These activities directly affect carbon flux by shifting the amount of carbon accumulated in forest ecosystems.[133]

Forests are multifaceted ecosystems with numerous interrelated components, each of which stores carbon. These components include:

- Trees (living trees, dead trees, roots, stems, branches, and foliage)
- Understory vegetation (shrubs and bushes)
- Forest floor (fine woody debris, tree litter, and humus)
- Down dead wood (logging residue and other dead wood on the ground)
- Soil.

As a result of natural biological processes occurring within forests, as well as anthropogenic activities, carbon is constantly cycling through these components and between the forest and the atmosphere. The net change in overall forest carbon may not always be equal to the net flux between forests and the atmosphere, because timber harvests may not necessarily result in an instant return of carbon to the atmosphere. Timber harvesting transfers carbon from one of the seven forest components, or "forest pools" to a "product pool." Once carbon

[130]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.
[131]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.
[132]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.
[133]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

is transferred to a product pool, it is emitted over time as carbon dioxide as the product combusts or decays. Emission rates vary significantly, depending on the type of product pool that houses the carbon. For these reasons, the EPA uses the term "apparent flux" for its estimates.[134]

In the United States, enhanced forest management, regeneration of formerly cleared forest areas, and timber harvesting have resulted in the annual sequestration of carbon throughout the past decade. Since the 1920s, deforestation for agricultural purposes has become a practically nonexistent practice. More recently, managed growth practices have become common in eastern forests, greatly increasing their biomass density over the past 50 years. In the 1970s and 1980s, federally sponsored tree planting and soil conservation programs were embraced. These programs resulted in the reforestation of formerly harvested lands, improvement in timber management activities, soil erosion abatement, and the conversion of cropland to forests. Forest harvests have also affected carbon sequestration. The majority of the timber harvested in the United States is used in wood products. The bulk of the discarded wood products are landfilled; thus, large quantities of the harvested carbon are relocated to long-term storage pools rather than to the atmosphere. The size of wood product landfills has increased over the past century.[135]

According to the EPA (Table 32), between 1990 and 1999, U.S. forest and harvested wood components accounted for an average annual net sequestration of 247 million metric tons carbon equivalent, resulting from domestic forest growth and increases in forested land area. Over the same period, however, increasing harvests and land-use changes have resulted in a decrease of approximately 10 percent in the overall rate of annual sequestration. Table 33 details carbon stock estimates for forests and harvested wood. All carbon stocks increased over time and thus sequestered carbon over the periods examined.

Land Use and International Climate Change Negotiations

In past international negotiations on climate change, the United States and many other countries have maintained that the inclusion of Land Use, Land Use Change and Forestry (LULUCF) activities in a binding agreement that limits greenhouse gas emissions is of the utmost importance; however, the issues of whether and how terrestrial carbon sequestration could be accepted for meeting various commitments and targets have remained the subjects of complex and difficult international negotiations in regard to the issue of climate change.

Many of the countries involved in climate change negotiations have agreed that implementation of LULUCF activities under an international climate change agreement may be complicated by a lack of clear definitions for words such as "reforestation" and "forest." Further, implementation may be hindered by the lack of effective

Table 32. Net Carbon Dioxide Sequestration in U.S. Forests, 1990 and 1995-1999
(Million Metric Tons Carbon Equivalent)

Description	1990	1995	1996	1997	1998	1999
Apparent Forest Flux	**216**	**201**	**201**	**188**	**188**	**188**
Trees	113	105	105	106	106	106
Understory	1	1	1	1	1	1
Forest Floor	16	15	15	14	14	14
Forest Soils	69	62	62	50	50	50
Logging Residues	17	17	17	17	17	17
Apparent Harvested Wood Flux	**57**	**55**	**57**	**58**	**56**	**59**
Apparent Wood Product Flux	13	15	15	16	14	17
Apparent Landfilled Wood Flux	44	41	41	42	42	42
Total Net Flux	**273**	**256**	**257**	**246**	**245**	**247**

Notes: "Apparent" indicates that the estimate is a measure of net change in carbon stocks rather than an actual flux to or from the atmosphere. Total flux is an estimate of the actual flux. Forest values are based on periodic measurements; harvested wood estimates are based on annual surveys. Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

[134]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

[135]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

accounting rules. According to researchers at the Pew Center on Global Climate Change,[136] implementation of LULUCF provisions in an international climate change agreement raises many issues for such activities and/or projects, such as:

- What is a direct human-induced activity?
- What is a forest and what is reforestation?
- How will uncertainty and verifiability be addressed?
- How will the issues of (non) permanence and leakage be addressed?
- Which activities beyond afforestation, reforestation and deforestation (ARD), if any, should be included, and what accounting rules should apply?
- Which carbon pools and which greenhouse gases should be considered?

Uncertainties related to data issues have also slowed international negotiations on climate change.

Land Use Data Issues

Uncertainties in the EPA inventory of U.S. carbon sequestration include sampling and measurement errors inherent to forest carbon estimates. The forest surveys engage a statistical sample that represents the expansive variety of growth conditions over large territories. Although more current inventories are conducted annually in each State, much of the existing data may have been collected over more than one year in any given State. Thus, there may be uncertainty about the year associated with the forest survey data. In addition, the existing forest survey data do not include forest stocks in Alaska, Hawaii, the U.S. Territories, or urban trees (although net carbon fluxes from these stocks are anticipated to be insignificant).[137]

Additional uncertainty results from the derivations of carbon sequestration estimates for forest floor, understory vegetation, and soil from models based on forest ecosystem studies. To extrapolate results of these studies to the forested lands in question, an assumption was made that the studies effectively described regional or national averages. This assumption may result in bias from applying data from studies that improperly represent average forest conditions, from modeling errors, and/or from errors in converting estimates from one reporting unit to another.[138]

Aside from the land use data issues and uncertainties discussed above, which are specific to the methodologies used for the EPA inventory, there is concern about larger and more general uncertainty surrounding estimates of terrestrial carbon sequestration. It is anticipated to be difficult, as well as expensive, to determine carbon stock changes over shorter time periods, such as the 5-year period suggested during international climate change negotiations. This concern is especially problematic if the carbon stocks are large and the stock changes

Table 33. Estimates of U.S. Forest Carbon Stocks, 1987, 1992, 1997, and 2000
(Million Metric Tons Carbon Equivalent)

Description	1987	1992	1997	2000
Forests (Excluding Logging Residues)	**36,251**	**37,243**	**38,160**	**38,672**
Trees	12,709	13,273	13,798	14,115
Understory	557	564	571	574
Forest Floor	3,350	3,428	3,504	3,545
Forest Soils	19,635	19,978	20,287	20,438
Logging Residues	NA	NA	NA	NA
Harvested Wood	**1,920**	**2,198**	**2,479**	**2,651**
Wood Products	1,185	1,245	1,319	1,366
Landfilled Wood	735	953	1,159	1,285

NA = not available.

Note: Excludes forest stocks in Alaska, Hawaii, U.S. territories, and urban trees. Wood product stocks include exports and exclude imports. Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

[136] G. Marland and B. Schlamadinger, *Land Use and Global Climate Change: Forests, Land Management, and the Kyoto Protocol* (Arlington, VA: Pew Center on Global Climate Change, June 2000), p. 5, web site www.pewclimate.org/projects/land_use.cfm.

[137] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

[138] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

are comparatively small.[139] Several countries involved in the negotiations have maintained that the accounting of terrestrial carbon stock changes over a 5-year commitment period fails to account for the differing dynamics of carbon stocks and fluxes over time.

Accounting for carbon sequestration through land use and forestry practices also raises the issues of "permanence" and "leakage." Carbon sequestration occurring at one time and place presents the issue of whether the carbon will be lost at a later time (permanence) or result in offsetting losses elsewhere (leakage). For example, suppose an international climate change agreement is developed in which changes in carbon stocks within a certain commitment period are used to meet targets. If there is a gap between commitment periods, there will be a possibility for unaccounted losses (or gains) in certain countries. A similar possibility of unaccounted losses will arise if countries in one geographic area receive "credits" for carbon that is sequestered in countries in a different geographic area but subsequent carbon losses remain unaccounted.[140]

Leakage is defined as the unexpected loss of expected carbon sequestration benefits when the displacement of activities or market effects leads to carbon losses elsewhere. For example, avoiding deforestation in one geographic location may accelerate the rate of deforestation in another geographic location. Leakage may also occur through the impact of a large reforestation program on timber prices. Increased availability of timber could result in lower prices, which in turn could cause reduced rates of planting in other locations. Reduced timber prices may also result in the conversion of existing forests for agriculture.[141]

In addition to concerns about uncertainty, permanence, and leakage, a recent scientific study published in the science journal *Nature* has raised questions about carbon sequestration through terrestrial sinks.[142] The authors of the study, Dr. John Lichter and Dr. William Schlesinger, concluded that while forests do sequester carbon dioxide from the air and store it in the soil, the majority of the sequestered carbon is ultimately released back into the atmosphere as carbon dioxide when organic soil material decomposes. They maintain that their findings highlight the uncertainty of the role of soils as long-term carbon storage pools and assert that considerable long-term net carbon sequestration in forest soils may be unlikely. Many scientists agree that much work remains to be done on the science surrounding terrestrial carbon sequestration; however, a number of the countries involved in international climate change negotiations assert that the potential for terrestrial carbon sequestration should be embraced, or at the very least, not discounted or overlooked.[143]

Thus, while there are sound estimates of the amount of carbon sequestered through U.S. forests and soils, many uncertainties remain in the accounting methodology and overall conceptual feasibility of carbon sequestration both nationally and globally. For this reason, caution should be employed when accounting for and accepting as fact the amount of carbon sequestered through land use and forestry practices, or when making decisions about the amount of sequestered carbon to be treated as an offset to national carbon dioxide emissions.

Current Global Carbon Sequestration

In August 2000, the U.S. Government submitted its views regarding methodologies related to the handling of LULUCF activities under an international climate change agreement to the UNFCCC. The document, *United States Submission on Land-Use, Land-Use Change and Forestry*, was presented in fulfillment of a request made by the Subsidiary Body for Scientific and Technological Advice (SBSTA). The document includes U.S. estimates of carbon stocks and flux from forest land, cropland, and grazing land. The estimates differ slightly from those in the EPA inventory for two main reasons:

- The SBSTA requested stock and flux estimates for a different set of forest areas and activities than those that are accounted for in national greenhouse gas inventories required under the UNFCCC.
- Both the EPA inventory and the U.S. submission reflect temporary results of forest carbon modeling improvements that are currently underway at the USDA Forest Service.[144]

[139] G. Marland and B. Schlamadinger, *Land Use and Global Climate Change: Forests, Land Management, and the Kyoto Protocol* (Arlington, VA: Pew Center on Global Climate Change, June 2000), p. 31 web site www.pewclimate.org / projects / land_use.cfm.
[140] G. Marland and B. Schlamadinger, *Land Use and Global Climate Change: Forests, Land Management, and the Kyoto Protocol* (Arlington, VA: Pew Center on Global Climate Change, June 2000), p. 31 web site www.pewclimate.org / projects / land_use.cfm.
[141] G. Marland and B. Schlamadinger, *Land Use and Global Climate Change: Forests, Land Management, and the Kyoto Protocol* (Arlington, VA: Pew Center on Global Climate Change, June 2000), p. 32 web site www.pewclimate.org / projects / land_use.cfm.
[142] W.H. Schlesinger and J. Lichter, "Limited Carbon Storage in Soil and Litter of Experimental Forest Plots Under Increased Atmospheric CO_2, *Nature*, No. 6836 (2001), pp. 466-468.
[143] M. MacKinnon, "Canada's Stance on Pollution Debunked," *The Globe and Mail* (June 5, 2001).
[144] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov / globalwarming / publications / emissions / us2001 / index.html.

Further, a separate 2000 report by the IPCC on LULUCF activities provides different values for carbon sequestration. The IPCC maintains that accounting for the amount of carbon being sequestered annually involves a high degree of uncertainty due to lack of data and difficulties in measuring sequestration. Further, there are policy and accounting uncertainties regarding which aspects of the biological carbon cycle should be included in national inventories as anthropogenic emissions and removals. Nevertheless, the IPCC does provide values for carbon sequestration due to LULUCF activities. According to the IPCC, from 1850 to 1998, combined carbon dioxide emissions resulting from fossil fuel burning, industrial processes, and land-use change led to an increase in the atmospheric content of carbon dioxide of 176±10 billion metric tons carbon equivalent. Atmospheric carbon dioxide concentrations increased from approximately 285 to 366 parts per million. About 43 percent of the carbon dioxide emitted from 1850 to 1998 remains in the atmosphere. The remainder, about 230±60 billion metric tons carbon equivalent, has likely been taken up in approximately equal amounts by oceans and terrestrial ecosystems.[145]

The IPCC's 2000 report offers further estimates for future terrestrial carbon sequestration (although it should be noted that different definitions and accounting approaches would result in different estimates of carbon stock changes). The report provides estimates for carbon stock changes resulting from LULUCF activities under IPCC guidelines and, alternatively, under three United Nations Food and Agriculture Organization (FAO) "definitional scenarios." The FAO definitional scenarios are based on different accounting methods, which assume that area conversion rates remain constant and exclude carbon in soils and wood products. All the accounting scenarios provide estimates for sequestration within UNFCCC Annex I countries. The FAO scenarios include the harvest / regeneration cycle, because regeneration is defined as reforestation. Three FAO accounting approaches are distinguished:

- In the FAO *Land-Based I Accounting Scenario*, the stock change over the full commitment period is measured, including stock losses during harvest, as well as delayed emissions from dead organic matter for reforestation. This approach results in estimated Annex I emissions of 333 to 849 million metric tons carbon equivalent per year.

- In the FAO *Land-Based II Accounting Scenario*, the carbon stock change between the beginning of the activity and the end of the commitment period is measured, including decay from harvest. This approach results in estimates for the Annex I countries that range from net sequestration of 205 million metric tons carbon equivalent per year to net emissions of 280 million metric tons carbon equivalent per year.

- In the FAO *Activity-Based Accounting Scenario*, only the accumulation of carbon in new forest stands and new dead organic matter is counted under reforestation. This approach results in estimates for the Annex I countries that range from net sequestration of 483 million metric tons carbon equivalent per year to net emissions of 3 million metric tons carbon equivalent per year.

The IPCC definitional scenario involves transitions between forest and non-forest land uses and assumes that not only planting but also other forms of stand establishment (e.g., natural establishment) are considered to be afforestation or reforestation activities. The IPCC definitional scenario results in estimated Annex I emissions of 44 to 83 million metric tons carbon equivalent per year.[146]

[145]Intergovernmental Panel on Climate Change, *Summary for Policymakers: Land Use, Land-Use Change, and Forestry* (Cambridge, UK: Cambridge University Press, May 2000), p. 4, web site www.ipcc.ch / pub / srlulucf-e.pdf.

[146]Intergovernmental Panel on Climate Change, *Summary for Policymakers: Land Use, Land-Use Change, and Forestry* (Cambridge, UK: Cambridge University Press, May 2000), p. 11, web site www.ipcc.ch / pub / srlulucf-e.pdf. For more information on IPCC estimates of current and future carbon sequestration, see Chapter 6 (pages 68-71) in Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE / EIA-0573(99) (Washington, DC, October 2000).