

CHAPTER Cf

Geography and the Environment

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NATURAL RESOURCES AND THE ENVIRONMENT

Gavin Wright

The United States has long been rich in natural resources, an abundance that has had a profound influence on the country's prosperity and economic preeminence in the world. What is perhaps less well appreciated is that natural resources have a history. Territorial expansion as a feature of nineteenth-century American history is well known; but even within U.S. political jurisdiction, the economic meaning and significance of a given land area depended on settlement, ownership, transportation, the application of technologies, and the state of knowledge, to offer only a partial list of contributing factors. Although the temperate-zone regions of the country were blessed with naturally fertile soils, expansion of cropland throughout the nineteenth century required an arduous struggle to clear these lands of their original forest. Further extensions of agriculture during the twentieth century have been possible only with the aid of artificial irrigation and other forms of human intervention.

In this chapter, the term "natural resources" encompasses land, water, the environment, and climate. Information on resource-based economic activity in mining, energy, forestry, and fisheries may be found in Chapter Db, on natural resource industries. The attention given to these subjects by observers and reformers has varied widely through American history, as national priorities have evolved from resource development in the nineteenth century to conservation in the twentieth, and increasingly to the quality of life in the twenty-first. Partly as a consequence of these changing foci, the availability of data on particular topics varies considerably. Because competing resources have interacted historically, and interpretive themes often overlap, readers are encouraged to consult more than one of the essays and their associated groups of tables.

Acknowledgments

The preparation of data for the tables on land and water was partly supported by a grant from the National Institute of Child Health and Human Development.

Gavin Wright and Scott Farrow would like to thank Carroll Curtis for her substantial assistance on numerous environmental tables. Her work was made possible by funding from the Office of Environmental Information, U.S. Environmental Protection Agency, and from the Council on Environmental Quality.

Land Area and the Public Domain

The United States is by no means a "natural" geographic unit; instead, the country's size and boundaries have been shaped by historical events and forces dating back to the eighteenth century, continuing even into the mid-twentieth century when Alaska and Hawai'i became states in 1959. These noncontiguous states are the most obvious deviations from purely geographic logic, but regional divisions dictated by waterways, mountain ranges, or differences in soil and climate could readily have formed the basis for smaller national units. For that matter, an even larger American national entity is not difficult to imagine, but for limits set by military or diplomatic exigencies at particular historical junctures.

Each one of the events that led to an expansion of the American domain may appear to have been inevitable in retrospect, and indeed it would be hard to claim that any of them were mere "historical accidents." But to say that territorial expansion reflected powerful historical forces is not the same as saying that the breadth of the country as we know it was geographically inevitable. The original thirteen colonies were only a subset of British North America, a potentially larger national unit that until that time had functioned in many respects as an integrated economy. After independence, the country's western boundary was commonly shown as a line marking the area closed to settlement and reserved by treaty for Indians. The westward movement of this boundary was ultimately driven by military pressures. Perhaps the clearest example of historical contingency is provided by the Civil War, in which one major section of the country – distinguished by geographic as well as institutional features – attempted to secede and form a new national entity. Thus, when we review the quantitative record of America's land and resources, we are viewing the outcomes of a rich and complex set of historical events and developments, not a simple count of the bounties of nature.

Territorial Expansion: The Continental United States

Table Cf1 lists the major additions to U.S. land area after 1790, and Map Cf-A depicts the territorial expansion of the United States

The preparation of data for the tables on weather was partly supported by a grant from the National Institute of Child Health and Human Development. Myron P. Gutmann, Christie S. Wilson, and Timothy G. F. Kittel are grateful to J. Andrew Royle and Nan A. Rosenbloom for the work done to prepare these data. The data described as drawn from the VEMAP2 source are from the Vegetation/Ecosystem Modeling and Analysis Project, with support from the National Aeronautics and Space Administration, the Electric Power Research Institute, and the U.S. Department of Agriculture Forest Service.



MAP Cf-A Territorial expansion of the United States: 1783–1898

Source

Charles O. Paullin, *Atlas of the Historical Geography of the United States* (Carnegie Institution of Washington, 1932), plate 46C; see also plates 46B and 89–101.

Documentation

The area shown for the original thirteen states depicts their western boundaries as established by the Ordinance of 1784. Note that this region also includes the area that would become the state of Vermont (1791). The northern and eastern boundaries of what would become Maine (which was part of Massachusetts at the time) and the northern boundary of New Hampshire were not finalized with Great Britain until 1842. The modern boundaries are shown here.

The Western Country was recognized as the territory of the United States by the Treaty of Paris (1783). The western boundary between the Lake of the Woods and the headwaters of the Mississippi River is ambiguous because of misconceptions about the locations of the lake and the course of the river

from 1783 to 1898. The vehicles of expansion ranged from outright purchase to military conquest.

In 1803 President Thomas Jefferson secured the new country's status as a continental power by purchasing from the French Republic the Louisiana Territory comprising the entire river basin west of the Mississippi River. The price was 60 million francs, about \$15 million; \$11,250,000 was paid directly. The U.S. assumption of the French debts to American citizens covered the balance. Napoleon Bonaparte had acquired the territory from Spain only in 1800. But after the French loss of Hispaniola, when Haitian slaves led by Toussaint L'Ouverture seized power in 1801, Napoleon abandoned his vision of a vast French empire in the New World. Facing a war with Great Britain, he could not spare the troops to defend the territory and he needed funds to support his European

with respect to the 49th parallel. Ongoing boundary negotiations with Great Britain became moot with the Louisiana Purchase.

The northern boundary of the Louisiana Purchase, originally defined by the drainage of the Mississippi and Missouri Rivers, was formally established with Great Britain as the 49th Parallel running westward from the Lake of the Woods in 1818. The western boundary north of the 42nd Parallel was the continental divide. The United States claimed all of the land westward to the Rio Grande. Spain, however, disputed both the legitimacy of the purchase and the western boundary. As part of the larger settlement with Spain in 1819 (ratified in 1821), which ceded East and West Florida to the United States, the western boundary was established as shown.

The Texas–Mexico boundary was agreed upon in 1848, following the Mexican–American War. The United States acquired the Mexican Cession at the same time.

campaigns. Accordingly, in April 1803 he offered to sell Louisiana to the United States.

The purchase set the precedent for territorial expansion even though the Constitution did not specifically grant this power to the federal government. The newly acquired land became part of the general territory mentioned in the Constitution and might be admitted as one or more states at the discretion of Congress. The principle was established that Congress has powers in the territories that it may not exercise in the states, and that the constitutional limitations of power are applicable only to the area within the states.¹

¹ See Ogg (1904) for a history of the Louisiana Purchase and the early political history of the territory.

Spain had never recognized the validity of the French sale of Louisiana, which they deemed to have been prohibited by the treaty wherein Spain had transferred the territory to France. Spain, however, was soon distracted by the South American wars of liberation led by Simón Bolívar in the North and José de San Martín in the South. In 1818 Andrew Jackson, then the American military commander in the South, invaded East Florida under the pretext that Florida had become a haven for escaped American slaves. The next year Spain agreed to cede both Floridas to the United States and to relinquish any claim it may have had on the Oregon Territory in exchange for establishing the western boundary of the Louisiana Purchase (delineating it from Texas). The so-called “Transcontinental Treaty” was ratified in 1821.

In 1836 Anglo-Texans, unhappy with the Mexican government’s attempt to discourage further immigration of Americans and to prohibit the importation of slaves, proclaimed the independence of Texas from Mexico. In 1844 the further westward expansion of the country became a political issue when Democrats linked the southern interest in the annexation of Texas – as a slave state – with the assertion of U.S. claims to the Oregon Territory, including the area north of the Columbia River as far north as the Russian boundary of Alaska, which had been ruled for decades by the British Hudson’s Bay Company. The claim to “all of Oregon” – presumably as territory free of slaves – had political appeal in the North. In 1845, Texas, bypassing territorial status, was admitted to the Union. The boundary between Texas and Mexico was, however, still very much in dispute.

The next year, using the boundary issue as a pretext, the United States declared war on Mexico. Military victories on Mexican soil, the collapse of the Mexican government in California, and the capture of Mexico City by General Winfield Scott led Mexico to agree to the Treaty of Guadalupe Hidalgo, which offered Mexico essentially the same terms the United States was prepared to offer before the war. For \$15 million and the assumption of Mexican debts to American citizens, Mexico gave up California and New Mexico, and it agreed to the Rio Grande as the Texas–Mexican boundary. The treaty was ratified in 1848.

Meanwhile, another treaty ratified in the same year settled the dispute with Great Britain over the Oregon Territory by establishing the 49th parallel as the boundary between the two countries (rather than the line of 54° 40’) and by giving British Canada all of Vancouver Island.

Gold was discovered in California in 1848 simultaneously with the Mexican cession of that territory. The discovery spurred the great Gold Rush of 1849 and hastened the admission of California as a state in 1850 as part of the famous Compromise of 1850. In 1853, to secure a favorable railroad right-of-way for a southern route for a transcontinental railroad, the government purchased a strip of land from Mexico along the border between New Mexico Territory and Mexico for \$10 million. The land was named for the American railroad entrepreneur and diplomat James Gadsden. The purchase also clarified a misunderstanding arising from the Treaty of Guadalupe Hidalgo, which defined the border between Mexico and the United States on the basis of an inaccurate map. The Southern Pacific Railroad was eventually built through the region.

Territorial Expansion: Outlying Areas

With the Gadsden Purchase, the territorial boundaries of the 48 contiguous states were essentially complete. Subsequently, a series

of acquisitions added a diverse set of possessions in outlying areas.

In 1856 Congress passed the Guano Act, which authorized the President to claim any uninhabited and unclaimed island valuable for its deposits of guano, which was highly prized as a natural fertilizer in the era before chemical fertilizers were developed. More than 100 islands, reefs, banks, and cays were claimed in the Pacific and the Caribbean during the next three years. Midway Island in the Pacific was occupied in 1867 under the provisions of the Guano Act.

That same year, 1867, the United States purchased Alaska from the Russian czar for \$7.2 million despite the lack of public enthusiasm.

In 1893, American business interests engineered a coup in the Hawaiian Islands against the native queen. The reluctance of President Cleveland to act thwarted the attempts to annex the Islands immediately.

In 1895, the Cuban Revolution against Spain broke out. With the issue of slavery removed from both the American and Cuban agendas, there was strong national support for the revolutionary side and even calls for America to intervene against Spain. The issue did not come to a head, however, until the Spanish instituted a brutal program of repression against the revolutionaries. When the U.S. battleship *Maine* exploded in Havana Harbor in Cuba many Americans assumed the Spanish were responsible. Congress declared war against Spain in 1898. The American Pacific fleet demolished the Spanish in the Battle of Manila Bay, Philippines, and the Atlantic squadron systematically destroyed the Spanish ships in Santiago Harbor, Cuba. The Spanish possessions of Puerto Rico and Guam fell to the Americans without any real resistance. Within months, Spain conceded and signed a treaty of peace. Spain relinquished Cuba, Puerto Rico, the Philippines, and Guam. The United States annexed the last three named territories and incorporated Hawai’i, Wake Island, and Palmyra Atoll into the list of territories at the same time. Cuba was occupied and became a U.S. protectorate in 1903, a state of affairs that lasted until 1934. An insurrection arose against U.S. rule in the Philippines that dragged on until 1901.

In the 1890s, the British, German, and American governments all vied for political domination of the Samoan Islands. After an American attempt to take the Islands by a show of force was thwarted by a typhoon, an 1899 treaty in which Germany and the United States divided the Samoan archipelago settled the international rivalries. The United States formally occupied its portion – a smaller group of eastern islands – the following year.

The Virgin Islands were purchased in 1917 from Denmark for \$25 million.

Following the defeat of Japan in World War II, the United Nations established the Trust Territory of the Pacific Islands under U.S. stewardship. It was composed of the former Japanese mandates of the Marshall Islands, the Northern Mariana Islands, Palau, and the four islands of Kosrae, Ponape (now Pohnpei), Truk (now Chuuk), and Yap. In 1986 the Northern Mariana Islands became a commonwealth in political union with the United States. The Marshall Islands, Palau, and the Federated States of Micronesia (Kosrae, Pohnpei, Chuuk, and Yap) became independent in free association with the United States.

The Philippines were granted their independence in 1946. The Corn Islands were ceded to Nicaragua in 1971 and the U.S. lease on the Swan Islands from Honduras was terminated that same year.

Guano banks were ceded to Colombia in 1972. The Phoenix and Line Islands and a number of atolls in the Ellice Islands (also claimed under the Guano Act) were transferred to Kiribati and Tuvalu in 1979. In 1980 guano atolls were transferred to Tokelau, New Zealand, and the Cook Islands. Pursuant to an agreement reached in 1977 the Panama Canal Zone was transferred to Panama in 1999.

This sequence of events left the United States with five major possessions (Puerto Rico, Guam, American Samoa, the U.S. Virgin Islands, and the Northern Mariana Islands), an entity known as the United States Minor Outlying Islands (none of which have indigenous inhabitants), and three states in free association (Marshall Islands, Palau, and the Federated States of Micronesia). In almost all cases the outlying areas are not included in the national totals reported here. As always, users are cautioned to examine the documentation for the series of interest to determine whether and in which time periods various outlying areas are included in the national aggregates.²

The Public Domain

The fact that the United States acquired sovereignty over an area does not mean that the federal government thereby gained title to that land. Only land that was not retained by individual states and their political subdivisions, or by private owners, is included under the heading "public domain." Comparison of series Cf65 with series Cf8 shows that the share of the public domain in total national land area peaked at more than 40 percent in 1850, declining to less than 15 percent a century later. During this period the federal government relinquished title to approximately 800 million acres, primarily through a series of active "privatization" measures that permeated national politics in the nineteenth century. Today the unclaimed or "vacant" public domain is still very substantial (242 million acres as shown in series Cf71), but most of this is remote and of low market value.

The first phase of liberalized land policy is depicted in Table Cf79–82, which records annual data on public land sales between 1800 and 1860. These numbers may be compared to those in Table Cf83–87, which represent the more active uses of federal land to promote westward settlement and economic development, through support for what were known as "internal improvements": wagon roads, canals, river improvements, and railroads. The tables show that prior to the Civil War, the largest shares of lands were released through sales to private buyers. After survey, these lands were offered at auction, with a minimum price (\$2.00 per acre from 1796 to 1820, \$1.25 per acre thereafter) and a minimum required acreage (which declined from 640 acres in 1796 to 40 acres after 1832). Schoene (1981) shows that the great majority of sales were "private" or post-auction sales, generally at the minimum price. Land was often occupied prior to purchase, a practice known as "squatting" that was legitimated by a series of special "preemption" acts between 1801 and 1841, at which point preemption became standard.³

² Chapter Ef, on outlying areas, treats the statistical history of the remaining five insular possessions, the three states in free association, as well as Alaska, Hawai'i, the Canal Zone, and the Philippines during the period these last four were territories.

³ These legal changes are conveniently summarized in Davis, Easterlin, et al. (1972), pp. 104–5.

Legal changes notwithstanding, the marked cyclical fluctuation in the volume of land sales has been used to argue that the pace of westward settlement was driven by economic forces, because the major surges (of 1815–1818, 1833–1836, and 1853–1855) were associated with peaks in commodity prices (North 1961). During these periods, competitive bidding sometimes drove average land prices well above the minimum. Prior to the Civil War, revenues from these sales represented a substantial share of federal revenues, peaking at nearly 50 percent of the total in 1836 (see series Cf82 and Table Ea588–593). But the political pressures toward more generous land distribution policies were inexorable, culminating in the Homestead Act of 1862, and effectively reducing land sales to a minor revenue role. The Homestead Act did not abolish earlier measures, however, and throughout the nineteenth century land was released to private hands under any number of prior or subsequent laws.

Table Cf83–87 does confirm, however, that the Civil War era marked a major watershed in policies regarding the public domain and economic development. The Republican Party was formed in the 1850s in opposition to the extension of slavery into the territories, but also in favor of homestead legislation and activist policies to promote railroad construction in the West. When southern representatives walked out at the time of the secession crisis, the Republican Congress was free to pursue this agenda, through the Homestead Act and the Pacific Railway Act of 1862, in addition to tariff legislation and other measures. Series Cf84 shows the surge in acreage granted to aid in construction of railroads, more than 100 million acres in total, between 1863 and 1871. Whereas the railroad land grants were concentrated in that one decade, acreage released under the Homestead Act continued to rise throughout the nineteenth century, beginning its historical descent only after World War I. This pattern may be seen in series Cf76–78.

Neither of these sets of acreage figures should be taken as straightforward measures of the federal contribution. Grants of public land to railroads were only a part of a much broader program, which included bond subsidies, construction financing, and other forms of assistance. The measure of the *value* of the land grant subsidy is itself subject to ambiguity and debate, because rising land values were one of the anticipated consequences of railroad building. Support in the form of land grants could be viewed therefore as an incentive scheme, whereby railroads internalized much of the return to the enterprise as appreciated land value. In response, transcontinental railroads engaged in extensive efforts to recruit settlers and facilitate migration, sometimes even engaging in research on farming techniques and livestock varieties. Also, the typical pattern was for the federal government to provide alternate sections along the right-of-way, doubling the minimum price on the remainder in hopes that the government would also share in these gains. Although the land-grant program may be rationalized in these ways, it is also clear that vast individual fortunes were made in the course of federally supported railroad construction, and that corruption was not infrequent. The economic effects of the program, and the returns to society and to private entrepreneurs, have been extensively debated by economic historians (see Gates 1954; Fleisig 1975; and Mercer 1982).

The Homestead Act is also subject to interpretation and debate. Although the Act was clearly a response to the long-standing demand for free farmland in family-size units, by the 1860s the frontier of settlement had passed the point where the size specified (160 acres) was commercially viable. Even by the 1850s, the

cost of acquiring the land itself was only a small part of the total costs of setting up a working commercial farm. Thus large numbers of “original” Homestead entries were recorded, but less than half of these ultimately resulted in a transfer of title under the terms of the Act. Nonetheless, vast acreages did pass into private hands by means of the Homestead Act, one way or another. A key provision of the Act allowed a homestead to be “commuted” (i.e., converted into clear title through payment of the statutory minimum price) after only six months of residence. Very often the purpose of commutation was to sell to a cattle rancher, lumber company, or mining firm.⁴

The total acreage disposed, as recorded in series Cf73, includes not just Homestead land but also land claimed under several other statutes. The major acts were: the Timber Culture Act (1873), which offered 160 acres free to settlers who cultivated trees on one quarter of the plot (reduced to one sixteenth in 1878); the Desert Land Act (1877), which offered 640 acres at \$1.25 per acre, on condition that the land be irrigated within three years; and the Enlarged Homestead Act (1909) and the Stock-Raising Homestead Act (1916), both of which offered land in larger sizes in semiarid areas suitable only for grazing. These incentives were often ineffective, or observed only with the aid of fraud. But on the whole, the system was not ineffective in encouraging rapid settlement.

Land Utilization

Around the turn of the twentieth century, attention turned from territorial expansion to the balance in allocations of land among alternative uses. Tracking land utilization historically is hazardous, however, because the country has not maintained a national land inventory on a consistent basis over any extended stretch of history. The Census of 1850 may be considered the first attempt, when land on farms was divided into “improved” and “unimproved” acreage. The Census of Agriculture continued to be responsible for land utilization figures, but the farm-based series reported in Table Cf101–118 became less and less informative over time; hence the thoroughly revised set of categories found in Table Cf119–134, which have been extended back to 1945 by the U.S. Department of Agriculture’s (USDA’s) Economic Research Service. Yet another categorization appears in Table Cf135–144, in which major uses are listed separately, according to whether the land is owned by private parties or by public agencies (federal, state, and local). Any comprehensive account of the history of land utilization will have to make use of each one of these frameworks, which themselves reflect changes in public attention and concerns.

Despite problems of comparability, the broad impression that these tables convey is that patterns of American land utilization have been surprisingly stable across the twentieth century. The “big three” land uses in terms of area have continued to be cropland, grazing land, and forest. Total cropland acreage has declined only modestly from its peak in 1930 (series Cf103 and Cf120). The area actually “used for crops” (series Cf121) has fallen by perhaps ten percent, but this largely reflects a decline in intensity of use, as acreage has been shifted into cover crops (series Cf122). Contrary to popular impression, the amounts of both public and private

forest acreage have actually been rising since World War II (series Cf138 and Cf143), as land that had been cut over and abandoned has regenerated its forests. The only change that stands out as discontinuous is the addition of Alaska in 1959; this is perhaps more an accounting measure than a new development in land utilization, but that one state is large enough to have a notable impact on total area (series Cf101 and Cf119), “other land uses” (series Cf134), and total public land (series Cf140).

Perhaps the surprise is that urban land still looms so small as a share of the total (series Cf130). Although the acreage classified as “urban” quadrupled between 1945 and 1992, this still only came to 2.6 percent of the nation’s land area in that year. One can justifiably conclude that the country is still land-rich by world standards. But it would be unjustified to argue as a result that urban land-use issues are of minor importance. The *value* of urban land clearly exceeds the value of most rural American land, an indication that well-located property does indeed have scarcity value. As a result, conversion of farmland to urban uses is a lively issue in many localities, but not one to be evaluated with national aggregate data.

The aggregate data do, however, allow us to dismiss the fear that agricultural production has been or will be severely constrained by a shortage of cropland. As noted, acreage harvested is well below its historic peak. The U.S. Conservation Service estimates that for every hundred acres presently in cropland, there are thirty-six acres of potential cropland of roughly comparable quality. Earlier analyses of the dangers of soil erosion are now known to have exaggerated the magnitude of the losses, while underestimating the recuperative powers of the soil. As yields per acre have risen steadily since the 1930s – through greater attention to soils, improved hybrid strains, and increased use of fertilizer – production has been limited much more by export demand than by land availability.⁵

Despite these successes, fears about the sustainability of the country’s agricultural path deserve to be taken seriously. A particular concern is the supply of water, a scarce resource that in many parts of the country has long been priced below its true social cost. Enthusiasm for public water projects was high after World War II, expanding the area of irrigated farmland by more than 25 million acres in the western states (series Cf153). But such projects largely ceased after 1980, as the reality of limits has become more fully appreciated. Series Cf158 shows that consumption of groundwater in irrigation grew rapidly until that year, but has since declined. In California and elsewhere, rising salinity levels and land subsidence threaten not only agriculture, but also supplies of water for urban uses.⁶

The impact of public opinion is discernible elsewhere in the tables. The Department of the Interior has long been criticized for allowing private grazing on the public domain. Lacking incentives to conserve, grazers have often been accused of exploitative practices on public range land. Tables Cf95–100 and Cf135–144 show that grazing on the public domain, particularly by sheep and goats, has greatly declined since the 1970s. Against this, the area allocated to rural parks and wildlife area has expanded (series Cf129), and recreational use of these areas continues to climb (see series Db402 for data on visitor-days to national forests). A major challenge

⁵ For a more thorough discussion of these issues, see Crosson (1991).

⁶ Annual updates on California water quality may be found at the U.S. Geological Survey Internet site, “Water Resources of California,” part of the National Water Data System.

⁴ The social and economic consequences of the Homestead Act are discussed in Shannon (1945).

facing the Forest Service is balancing these recreational demands against the environmentalist pressure to conserve and preserve ecological relationships in wooded and wilderness areas.

Environmental Indicators

Information on the “environment,” broadly defined, is scattered throughout these volumes. Examples include land utilization, forests, fisheries, crop yields, nutrition and public health, and many others. Missing from coverage under other headings tend to be data on the unwanted byproducts of human activity, such as pollution of air, land, and water, as well as the effects of such byproducts on wildlife habitats and the preservation of the nation’s natural heritage – in short, the state of the “environment” as it has come to be defined as a policy objective in recent decades. Tables Cf168–285 address these topics.

Unfortunately, there are few long national series on measures of environmental quality. Most of the systematic evidence dates only from the rise of the modern environmental movement in the 1960s, much of it collected by the Council on Environmental Quality, the Environmental Protection Agency, the National Oceanic and Atmospheric Agency (all created in 1970), and other relatively recent federal monitoring agencies. To be sure, many of the issues – water pollution, air quality, wildlife preservation – have a much longer history. But until recent times, pollution policies were considered to be primarily a local responsibility. Some local series extending over longer periods have been assembled.⁷ At the national level, however, most data on environmental indicators is available only for the period since World War II, sometimes only for the years since the 1960s or even later.

Even within this constricted historical range of observation, the evidence shows the remarkable expansion in the scope of federal involvement in environmental policy since 1970 and, broadly speaking, the effectiveness of these policies in arresting previous trends toward environmental deterioration. Table Cf177–182 shows the expansion of expenditures for the implementation of environmental regulations, the largest percentage increase being federal spending, of which the Environmental Protection Agency accounts for only about half (series Cf178–179). The table also shows that the majority of environmental expenditures are private rather than public, but these too represent the effects of federally mandated standards (series Cf182). Table Cf168–176 demonstrates that this intensified compliance has not been concentrated on any one form of pollution or environmental medium. Chemicals, water, land, air, and radiation all received substantial increases in compliance expenditures between 1972 and 1999.

Trends in Air and Water Quality

Have these expenditures been effective in improving the environment? The most readily observable trend reversal is in emissions of air pollutants, for which annual data go back to 1940, and estimates have been extended back to 1900 by the Environmental Protection

Agency (EPA).⁸ Almost all of the major criteria pollutants – sulfur dioxide, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead – show a rising trend until 1970, after which they have declined, or (in the case of nitrogen oxides) at least stopped rising (see Table Cf203–210 and Figure Cf-B).⁹ The timing suggests that the decisive steps were taken in 1970, when a series of amendments to the Clean Air Act of 1963 created the EPA and charged it with developing three sets of standards: National Ambient Air Quality Standards (NAAQS); motor vehicle emission standards; and new source performance standards (NSPS). Because on-road vehicles have been significant contributors to rising levels of nearly all of these pollutants (with the exception of sulfur dioxide), it is notable that these improvements have occurred despite substantial increases in vehicle miles traveled, along with population and national per-person income. The most dramatic change has been in emissions of lead, which steadily declined after 1972 as the result of EPA mandates progressively reducing the lead content of gasoline, culminating in a complete ban as of 1996 (series Cf204). In 1998, on-road vehicles accounted for less than 1 percent of national lead emissions, down from 82 percent in 1980.

Monitoring of air concentrations of these pollutants by the Office of Air Quality and Standards dates only from 1977 (Table Cf197–202). Even across this relatively brief span, the data show striking reductions in air pollutant levels for sulfur dioxide, carbon monoxide, ozone, nitrogen dioxide, PM-10 particulates, and lead, averaged over hundreds of monitoring sites.

Another side effect of fossil fuel consumption is the acidification of rain, as sulfur dioxide and nitrous oxide emissions are transformed into sulfuric and nitric acid, which inflict damage on trees, lakes, rivers, fish, crops, soils, and buildings. Although these effects have been observed since the nineteenth century, both monitoring and regulations targeted at acid rain were long delayed by a combination of skepticism among scientists and political conflicts arising from the interstate and international (U.S.–Canadian) character of the problem. A major breakthrough occurred with the 1990 amendments to the Clean Air Act, which mandated specific reductions in sulfur dioxide and nitrous oxide emissions. A noteworthy policy initiative was the introduction of a system of “tradable pollution permits,” allowing power companies to buy and sell sulfur dioxide emission allowances each year. Observations on these programs are still relatively early, but suggest some success in acid rain reduction, at least in the eastern region of the country (Table Cf183–196).¹⁰

A partial exception to this generally optimistic picture is the long-term trend in emissions of carbon dioxide, the byproduct of the consumption of fossil fuels. Series Cf209 shows that aggregate national emissions of carbon dioxide grew steadily from 1940 through the 1970s (extending a much longer trend); after a brief hiatus in the 1980s, expansion resumed in the 1990s, setting new all-time records every year. The United States is easily the world’s largest source of fossil fuel–related carbon dioxide emissions, more than 50 percent larger than the People’s Republic of China, which is in second place. Per capita emissions are also highest in the United

⁷ See, for example, the water quality data in the Storage and Retrieval System for Water and Biological Monitoring Data (STORET); air quality data in the Aerometric Information Retrieval System (AIRS); the data of the Ohio River Valley Water Sanitation Commission (ORSANCO); and individual studies such as Davidson (1979).

⁸ See *National Air Pollutant Emission Trends, 1900–1998*.

⁹ The much earlier peak for particulate (PM-10) emissions is attributable to state air pollution statutes enacted in the 1950s, aimed at controlling smoke and particulates from both residential and industrial sources.

¹⁰ For evidence of the effectiveness of the program in reducing regulated emissions, see Schmalensee, Joskow, et al. (1998) and Stavins (1998).

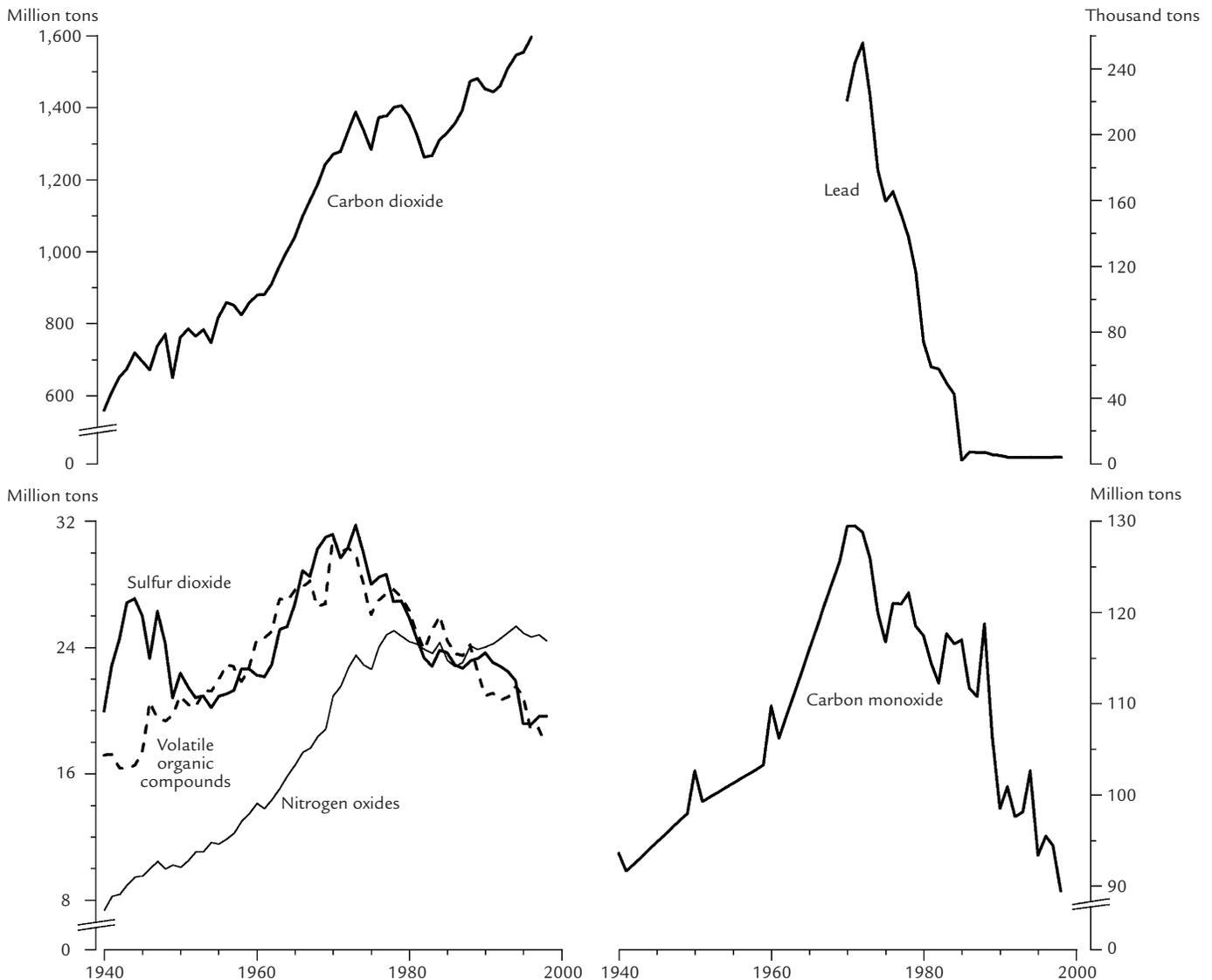


FIGURE Cf-B Emissions of air pollutants – sulfur dioxide, volatile organic compounds, and nitrogen oxides: 1940–1998

Sources

Series Cf205-206 and Cf208.

States, but in the 1990s were still somewhat below the peaks of the 1970s (see Marland, Boden, et al. 2002). The proximate reason for the absence of further progress on this front was apparently the decline in the relative prices of petroleum and coal between the 1970s and the 1990s.

National data on water quality are much more limited, even though the techniques and sophistication of water quality indicators have a much longer history. Municipalities began to employ scientists and engineers to analyze sewage-polluted waters in the mid-nineteenth century. In 1912, Congress assigned the Public Health Service (PHS) the task of investigating “the diseases of man and conditions influencing the propagation and spread thereof, including sanitation and sewage and the pollution, either directly or indirectly, of the navigable streams and lakes of the United States.” The PHS investigations were especially important in improving understanding of the comparative effects of both sewage and organic wastes on stream quality, the natural assimilative characteristics of

streams, and the measurement of stream pollution. In conjunction with various editions of the Standard Methods of Water Analysis formulated by the American Public Health Association, the PHS standards came to define basic measures of water quality throughout the nation. In the 1960s, partially stimulated by the publication of Rachel Carson’s *Silent Spring* (1962), concern over the environmental effects of insecticides and pesticides accelerated, leading to monitoring for various trace elements and toxics that could not be identified in the past. The data presented in Table Cf223–227 suggest that violation rates for such pollutants as dissolved oxygen, phosphorus, cadmium, and lead had fallen to insignificance by the 1990s.

Municipal Solid Waste Disposal

Along with sewage, the growth of economic activity and population generates unwanted byproducts in the form of solid waste.

Although solid waste disposal is an inherently local issue, the emergence of the EPA has made it possible to monitor national trends in municipal solid waste (MSW) generation and disposal. The EPA also plays an active role in shaping waste disposal policies. Local choices are of course constrained by federal and state environmental regulations, and the volume of waste generation is influenced by efforts at “source reduction” strategies that are often implemented at higher governmental levels – package designs, recyclability of products or packaging, product durability, and so forth. The evidence presented in Table Cf211–216 suggests that heightened environmental concerns have had a major impact on the nation’s way of handling its garbage.

The table distinguishes “gross discards” from “net discards,” the former being the volume of waste generated by business and residential activity, the latter being the portion of that waste remaining after recycling and compost recovery. This net figure is then further divided into a portion that is burned and a remainder discarded in landfills. Gross discards nearly tripled between 1960 and 1990, but show only slow growth during the 1990s, as per capita MSW generation has largely stabilized at around 4.5 pounds per person per day (series Cf211). Series Cf212–213 show the remarkable expansion of recycling and composting, from less than 10 percent of MSW in 1980 to nearly 30 percent in 1998. Because the combustion levels have been relatively stable, the result has been an absolute decline in the tonnage of MSW discarded to landfills (series Cf216). The number of landfills in the country declined from 8,000 in 1988 to 2,314 in 1998, although their average size has increased. In 1998, there were more than 9,300 curbside recycling programs, and approximately 3,800 yard trimmings composting programs in the United States. These trends are now closely monitored by the Municipal and Industrial Solid Waste Division of the EPA, whose annual reports may be found at the EPA Internet site.

Wildlife Preservation

Hunting enthusiasts, concerned about the decline in wildlife populations, were one of the organized forces behind the creation of national forests and national parks in the late nineteenth and early twentieth centuries. Early legislative achievements of this campaign include the Lacey Act (1900), regulating imports of, and interstate commerce in, birds and mammals; the Norbeck–Andresen Migratory-Bird Conservation Act (1929), which provided for a system of national refuges; and legislation of 1934 and 1937 taxing hunters of migratory fowl, the funds to be used for wildlife preservation programs. The U.S. Wildlife Refuge System was established in 1940 and is administered by the Fish and Wildlife Service of the Department of the Interior. By far the most numerous are the waterfowl refuges, which supply breeding areas, wintering areas, and rest and feeding areas along major flyways during migration. Refuges have also been established by private individuals and societies, such as the Nature Conservancy and the Audubon Society.

As part of the trend toward environmental consciousness in recent decades, the hunters were joined by an increasing sentiment in favor of the appreciative or “nongame” protection of wildlife in the 1960s and 1970s, confirmed by public opinion polls. Their impact was reflected in the passage of the Endangered Species

Acts of 1966, 1969, 1973, 1978, 1982, and 1988, constructing an elaborate set of restrictions and procedures to be followed when proposed projects may have an impact on wildlife habitat. Wildlife preservation has thus made its way onto the agenda of any number of federal agencies, and monitoring responsibilities are widely dispersed. The tables presented here are only a small sampling of recent trends, and they are not necessarily representative. The number of threatened and endangered species has increased steadily since 1980.¹¹ On the other hand, populations of ospreys, bald eagles, and peregrine falcons have recovered robustly since the ban on dichlorodiphenyltrichloroethane (DDT) in 1972.

Table Cf263–268 presents evidence of major gains in North American goose and swan populations between 1970 and the 1990s. Estimates of North American duck populations show a more mixed trend (Table Cf269–280). The number of pintails declined from more than 10 million in 1956 to fewer than 2 million in 1991, with some recovery in the 1990s. The numbers of scaups and widgons drifted downward in the 1990s, while the number of black ducks has steadily declined on both the Atlantic and Mississippi flyways. Populations of all other major duck varieties are either stable or substantially increased since the 1950s.

Not all wildlife preservation policies take the direct form of refuge maintenance. Of equal importance is the preservation of natural habitats threatened by the encroachment of human settlements or by air and water pollution. One measure of progress in this area is the number of closures of shellfish beds, recorded by the Strategic Environmental Assessments Division of the National Oceanic and Atmospheric Administration (Table Cf228–235). The table shows that between 1966 and 1990, the number and rate of bed closures significantly increased in both the North Atlantic and Gulf of Mexico regions, followed by improvements in the 1990s. In the South Atlantic and Pacific Coast regions, the number of closures steadily declined after 1971. One should note, however, that water contamination is only one of several possible reasons for prohibiting shellfish harvests in a locality.

Another index of habitat conditions is the contamination of herring gull eggs in the Great Lakes, monitored by the Canadian Wildlife Service. Table Cf238–262 records remarkable improvements between 1974 and 1999, for all contaminants on every one of the Great Lakes.

Possibly the most infamous human assaults on wildlife have been the major spills of oil in environmentally sensitive areas; the largest was the Exxon Valdez, which spilled 11 million gallons in Prince William Sound, Alaska, in 1989. In fact, hundreds of such spills occur every year, from pipelines and storage tanks as well as from oil-carrying vessels. Since the 1970s, oil polluting incidents have been monitored by the U.S. Coast Guard. The evidence in Table Cf236–237 shows that although the average annual number of such incidents has not declined, the volume of oil spillage has fallen to a tiny fraction of what was common in the 1970s. The decline in the early 1990s is attributable to increased attention to the issue on the part of companies, in the wake of the Exxon Valdez incident, as well as increased audit and inspection activity. Another response to the same incident was the Oil Pollution Act of 1990,

¹¹ Fish and Wildlife Service, *Endangered Species Bulletin*, bimonthly.

which mandated a phase-in of double hulls on oil-carrying vessels, beginning in 1995.¹²

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¹² For a full review, see Commission on Engineering and Technical Systems of the National Academy of Sciences (1998).

WEATHER

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Weather Research and Climatological Data

The data in Tables Cf286-569 represent a microscopic portion of the vast amount of data collected and preserved in the service of understanding and predicting the weather of the United States. The quantity and quality of the data have grown and improved over the past two centuries, thereby advancing knowledge of weather processes achieved by American and other scientists. The double goal of meteorologists and climatologists has been to understand current weather and climate, and to predict future weather and climate, for general scientific purposes and to contribute to the

overall social, economic, and political good of the United States. The mass of data that have accumulated are the consequence in large part of an institutional commitment by the U.S. government to support weather forecasting and science to ensure the quality of life of many Americans, including parents planning school day clothing for their children; farmers planning planting, irrigation, and harvest; and NASA planning its operations in space.¹

The early history of climatological recording in the United States was marked largely by guesswork and nonstandardized analytical techniques, although several trends in the nineteenth century helped to transform observation from casual study into the highly useful and practical science of meteorology. During those years, American settlers moving west in search of fertile farming territory relied increasingly on information about the weather in making decisions about where to settle. Although such information remained hit-or-miss for many decades, this process established a link between accurate weather data and successful farms.

In the United States, 1814 was the first watershed year in weather observation, as the U.S. Army Medical Department, in coordination with a small group of academics, began recording data at military posts. Previously such activity had been restricted to hobbyists and expeditioners such as Lewis and Clark. Thanks to increased interest from scientific communities and the government, by the middle of the century every state in the Great Plains and Western United States had at least one weather observation site.

In 1847, the Smithsonian Institution began a meteorological project that extended a network of observation across North America. This project, whose existence was catalyzed by leading meteorologists such as Elias Loomis and James Pollard Espy as well as Smithsonian director Joseph Henry, had long been a dream of scientists who surmised that weather observation could move drastically forward only through the work of a geographically broad and well-organized association of data recorders. With hundreds of observers, the Smithsonian network represented just such an organization, and indeed dominated weather data collection for nearly twenty years. Unfortunately, the Civil War and a building fire eventually ravaged the network irreparably. To the dismay of many scientists, in 1873 the U.S. Army Signal Office assumed control of the work the Smithsonian had previously done.

Despite increased scholarly and governmental attention to monitoring weather and understanding climatological issues, farmers and settlers remained generally uninformed. Folklore persistently acted as a crucial means of predicting and reacting to weather. The climatic volatility of the central and western United States further complicated this problem. Storms, floods, and freezing temperatures alternated with extended periods of drought and heat. Some scholars have even asserted that the mid-nineteenth century was a "little ice age," during which typically dry regions experienced increased precipitation and cooler temperatures. While more rain aided travelers along the Oregon Trail, it also contributed to widespread confusion about the nature of climate in the Western states. The inadequate work of the Signal Office led to misinformation and inaccurate forecasts. The scientific community criticized

¹ This review of the early history of American meteorology draws upon Whitnah (1961), Hughes (1970), and Fleming (1990).