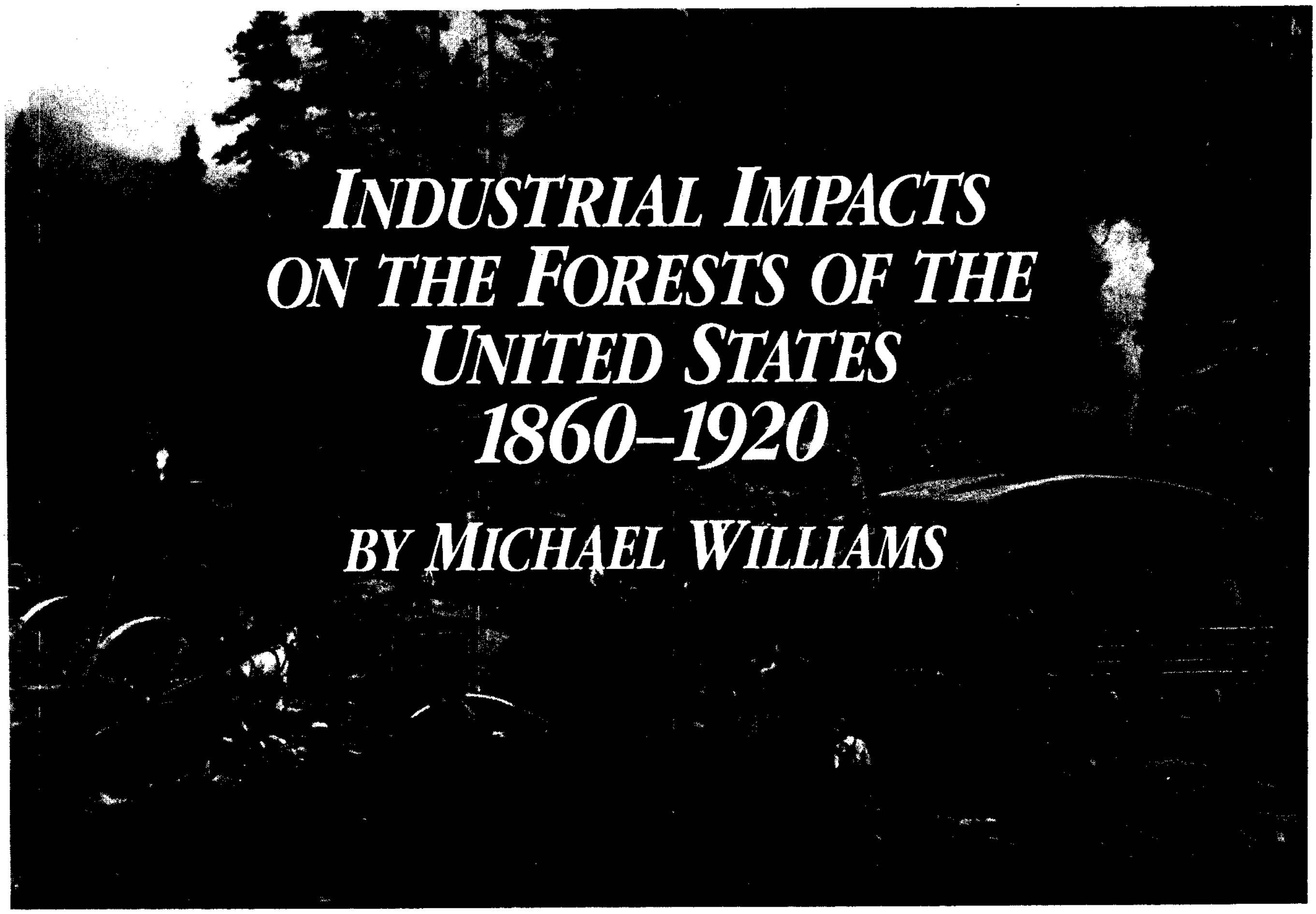

INDUSTRIAL IMPACTS ON THE FORESTS OF THE UNITED STATES 1860–1920

BY MICHAEL WILLIAMS

Painting by Robert Lavin, FHS collection.

> There is no other interest of the country so great as that of the forests,
> considered from the commercial or pecuniary point of view,
> while in other aspects [their] value is altogether beyond computation.
>
> *Nathaniel H. Egleston, U.S. Department of Agriculture Forestry Division, 1884*

The forest was an overwhelmingly important source of raw materials for industry and for fuel in the United States during the latter half of the nineteenth and early years of the twentieth centuries. In 1865 Thomas Starr calculated that wood and its derivatives paid "more than one-half of the entire internal revenue of the United States." Merely thirty years later, Nathaniel Egleston's further elaborate computations led him broadly to the same conclusion: "Our cars and ships are the products of the forests. The thousand tools of our various handicrafts, the machineries of our factories, the conveniences of our warehouse, and the comfort and adornments of our dwellings are largely the product of our forests. Behind all the varied industries and conveniences of life stand the forests as their chief source and support."[1]

The relative importance of industrial wood consumption cannot be measured precisely because the total amount of wood consumed by all users—especially the amount harvested by domestic farmer-producers—is difficult to ascertain. Nevertheless, a reasonable and probably conservative estimate is that total consumption for fuel, lumber, pulp, veneer, poles, and other purposes stood at 3.76 billion cubic feet per annum in 1859, nearly doubled to 6.84 cubic feet in 1879, and very nearly doubled again during the next twenty-seven years to reach 13.38 billion cubic feet in 1907. This figure was never reached again; consumption has hovered between 10 and 11 billion cubic feet per annum throughout the twentieth century.[2]

Figure 1 shows the breakdown of individual uses as a percentage of the whole. Miscellaneous demands on the

1. Thomas Starr, "American Forests: Their Destruction and Preservation," in the U.S. Department of Agriculture *Annual Report for 1865* (Washington, D.C.: GPO, 1866), p. 23; U.S. Department of Agriculture, *Annual Report for 1883* (Washington, D.C.: GPO, 1884), pp. 452–53.

2. Dr. Marion Clawson, Resources for the Future, Washington, D.C., personal communication, 23 October 1980. Data on fuel use are estimates; totals could include fuel for mechanical-energy generation.

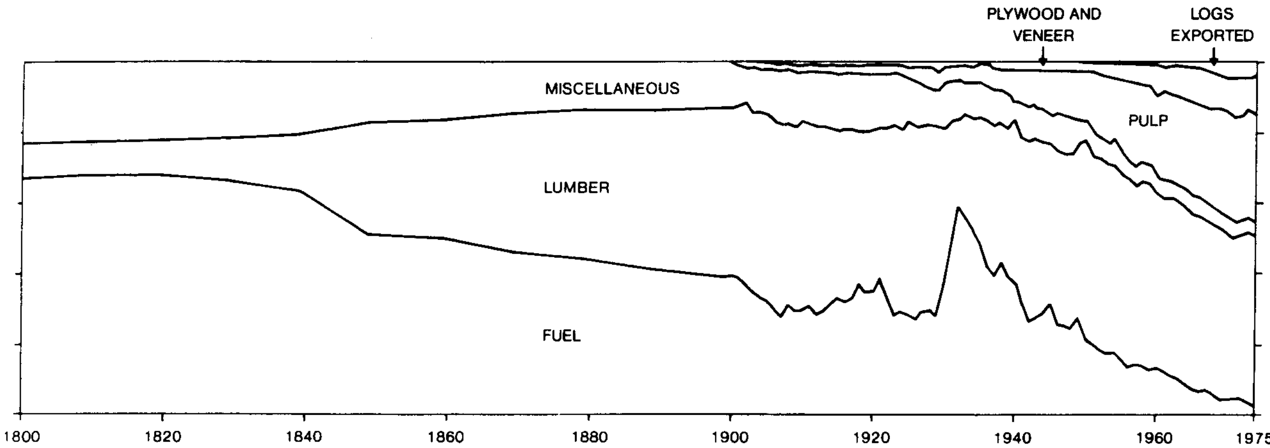

Figure 1. Utilization of wood grown in the United States, by roundwood equivalent, 1800 to 1975. Major uses are expressed as percentages of the total (based on Marion Clawson, personal communication). All figures accompanying this article were provided by the author; see footnotes to text for full source citations.

forests, such as poles and piling, were always important: even such a seemingly trivial item as the wood for lead pencils consumed 110,000 tons of redcedar per annum. The gross volume of lumber did not equal that of fuel until after 1890, and fuel cut for domestic and industrial uses rarely fell below one-third of all timber cut until after 1922. New industrial uses for wood, such as pulp making, began to appear around the turn of the century, so that industrial demand remained important.

The American dependence on wood was overwhelming and ubiquitous. Wood entered into every walk of life. Of its many uses, three are examined here: wood as fuel for warming the home; wood converted to charcoal for use in making iron; and wood consumed by railroads, both as fuel for steam locomotives and as ties in the network of tracks that splayed across the nation and bound its economy together.

Changes in Fuel Use

Fuel for domestic hearths, charcoal-fired iron furnaces, and mechanical and locomotive energy was still an important product of the forest during the closing years of the nineteenth century. Lumber began to outweigh fuel as a percentage of overall forest products only when, between 1880 and 1890, the flow of cheap sawtimber from the South gathered momentum. Although the relative importance of fuelwood was declining in this period, the absolute amount of fuelwood consumed increased in every year up to 1933, with a brief decline in a handful of years during the later 1920s. The availability and cheapness of wood in rural areas made it the ideal fuel, and wood consumption only dropped off when electrification became generally available in rural areas in the mid-1930s.

Of course wood was gradually supplanted by other fuel sources such as coal, oil, and gas during the late nineteenth century, so that fuelwood consumption declined. The total demand for energy experienced a sustained growth and expansion, increasing seventeenfold between 1850 and 1955. The choice of specific fuels depended upon local availability, comparative price, advances in technology of production and utilization, and shifts in consumer preference. Fuelwood accounted for four-fifths of energy as late as 1860, but by the mid-1880s coal overtook it as the principal source. By 1900 fuelwood was probably contributing only one-fifth of the nation's energy needs, and by 1920 a mere 7.5 percent. By this time coal too had passed its peak, and use of oil and natural gas was rising. By 1955 oil and natural gas accounted for nearly two-thirds of total energy consumption (figure 2).[3] Nevertheless, fuelwood's share of 5.4 percent in 1940 was equivalent to nearly 4 billion cubic feet of timber, more than in any year in the nineteenth century except 1899.

Domestic Hearths

Between 1860 and 1910 approximately 151.6 million acres of forestland were cleared, which at the very modest estimate of twenty cords per acre yielded the astronomical figure of over three billion cords of wood. This output could have supplied at least half of the total national consumption of fuelwood during the same years.[4] The shortfall was presumably made up by recutting woodlots and by the waste from lumber production, although as time went on, the mills found increasingly imaginative ways to use every scrap of wood. In addition, pulp production began to consume more and more small timber from lumbering.

Cutting remained a profitable sideline for farmers, who continued to spend up to one-third of their time cutting,

3. Sam H. Schurr and Bruce C. Netschert, *Energy in the American Economy, 1850–1975: an Economic Study of Its History and Prospects* (Baltimore, Maryland: Johns Hopkins University Press for Resources for the Future, Inc., 1960), pp. 36–47.

4. Robert V. Reynolds and Albert H. Pierson, *Fuel Wood Used in the United States, 1630–1930*, U.S. Department of Agriculture Circular 641 (Washington, D.C.: GPO, 1942), pp. 8–10.

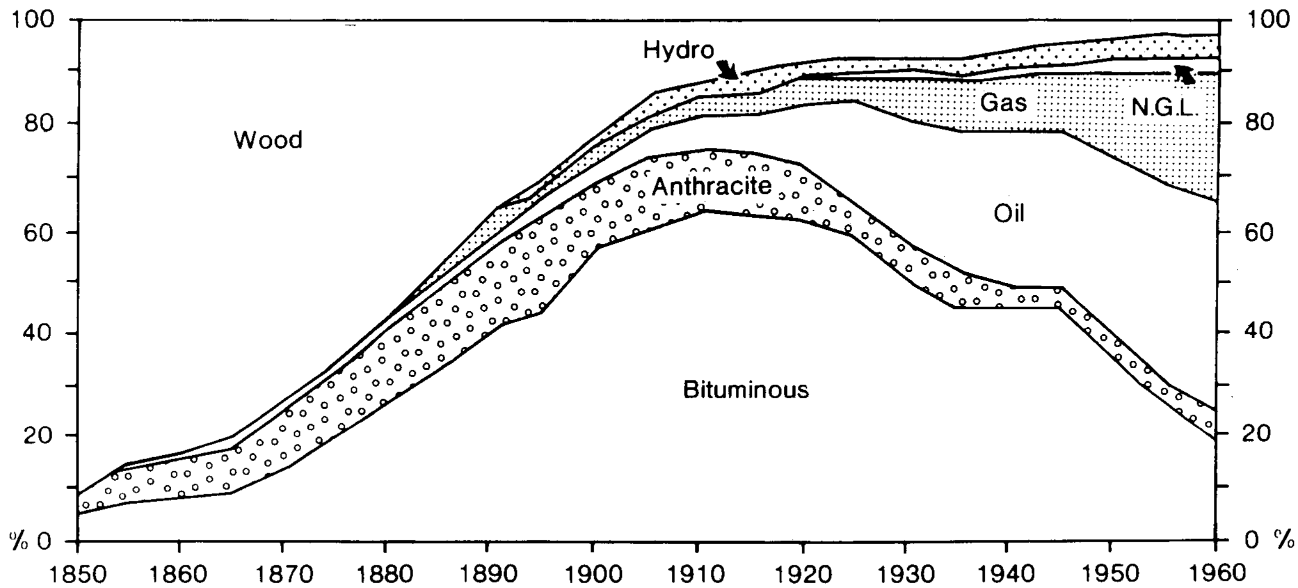

Figure 2. Energy sources in the United States as a percentage of total energy consumption, by five-year periods, 1850–1960 (based on Schurr and Netschert, Energy in the American Economy, *pp. 36–37).*

hauling, and splitting timber, particularly during the winter months when they could do little else. The tenth national census itemizes the number of cords cut on farms only, and also the value of the cut, for the year 1879.[5] This total, 51.4 million cords, falls far short of the total 140.5 million cords of wood that Charles Sargent estimated were consumed in the United States during 1879.[6] Much of the additional wood counted by Sargent must have come from land cleared for new farm holdings and by commercial lumbering, both kinds of activity that did not enter into the census takers' count of small-scale woodcutting on existing farms.

The average American used prodigious amounts of timber to warm himself during the long winter months. Sam Schurr and Bruce Netshert calculate that during the mid-nineteenth century the average family needed 17.5 cords of wood per annum to keep comfortably warm, and Sargent in 1879 put it higher at 22.5 cords per family of five, or 4.56 cords per capita per annum.[7] Whatever the true amount per family—and it surely varied according to location, family size, and type of wood used—locally enormous areas of the forests were stripped clean. John Thomas of New York gave an example of one landholder who had thus transformed "over one hundred acres of land, once densely covered with timber, but now entirely cleared for the sole purpose of supplying his family with firewood during the forty years he had resided there."[8]

Despite the relative abundance and low cost of wood, coal (particularly anthracite) began to supplant wood in the urban areas and near the coalfields. This was partly because wood became scarce near the urban areas after the centuries of clearing around them. More importantly, wood storage was problematic as living space shrank in the cities, especially as wood was still being delivered in the traditional measure of the four-foot cord. Coal weighed less and was less bulky in relation to its energy content than wood—by a factor of as much as one-third or a half again. An additional problem was that the traditional wood measure did not fit easily into the new stoves that were now common in most houses.[9]

During the late 1850s, the invention of central heating—household furnaces in the cellars of urban dwellings for heating the whole or part of the house or apartment—increased the demand for large and reliable quantities of fuel. As early as 1830, shipments of coal from Pennsylvania went up and down the east coast, and urban fuel dealers increasingly changed from "wood" dealers to "coal and wood" dealers. They began to cut firewood into fifteen-inch lengths, which would fit into the new stoves. The increased construction of apartment houses in the cities during the last decades of the century brought further changes. Few, if any, had open fireplaces, both because of the fire risk and because space was too valuable to store wood that would be used only in the cold season. By the

5. U.S. Census Office, *Report on the Production of Agriculture,* vol. 3 of the *Tenth Census of the United States* (Washington, D.C.: GPO, 1883), pp. 251–327.

6. Charles S. Sargent, *Report on the Forests of North America,* vol. 9 of the *Tenth Census of the United States* (Washington, D.C.: GPO, 1884), p. 489.

7. Schurr and Netschert, *Energy in the American Economy,* p. 49; Sargent, *Report on the Forests of North America,* p. 489. Henry S. Graves, *The Use of Wood for Fuel,* U.S. Department of Agriculture Bulletin 753 (Washington, D.C.: GPO, 1919), pp. 2–6, calculates that the consumption was 12.6 cords "per farm."

8. John J. Thomas, "Culture and Management of Forest Trees," in the U.S. Department of Agriculture's *Annual Report for 1864* (Washington, D.C.: GPO, 1865), p. 43.

9. William Hoglund, "Forest Conservation and Stove Inventors, 1750–1850," *Forest History* 5 (Winter 1962): 2–8.

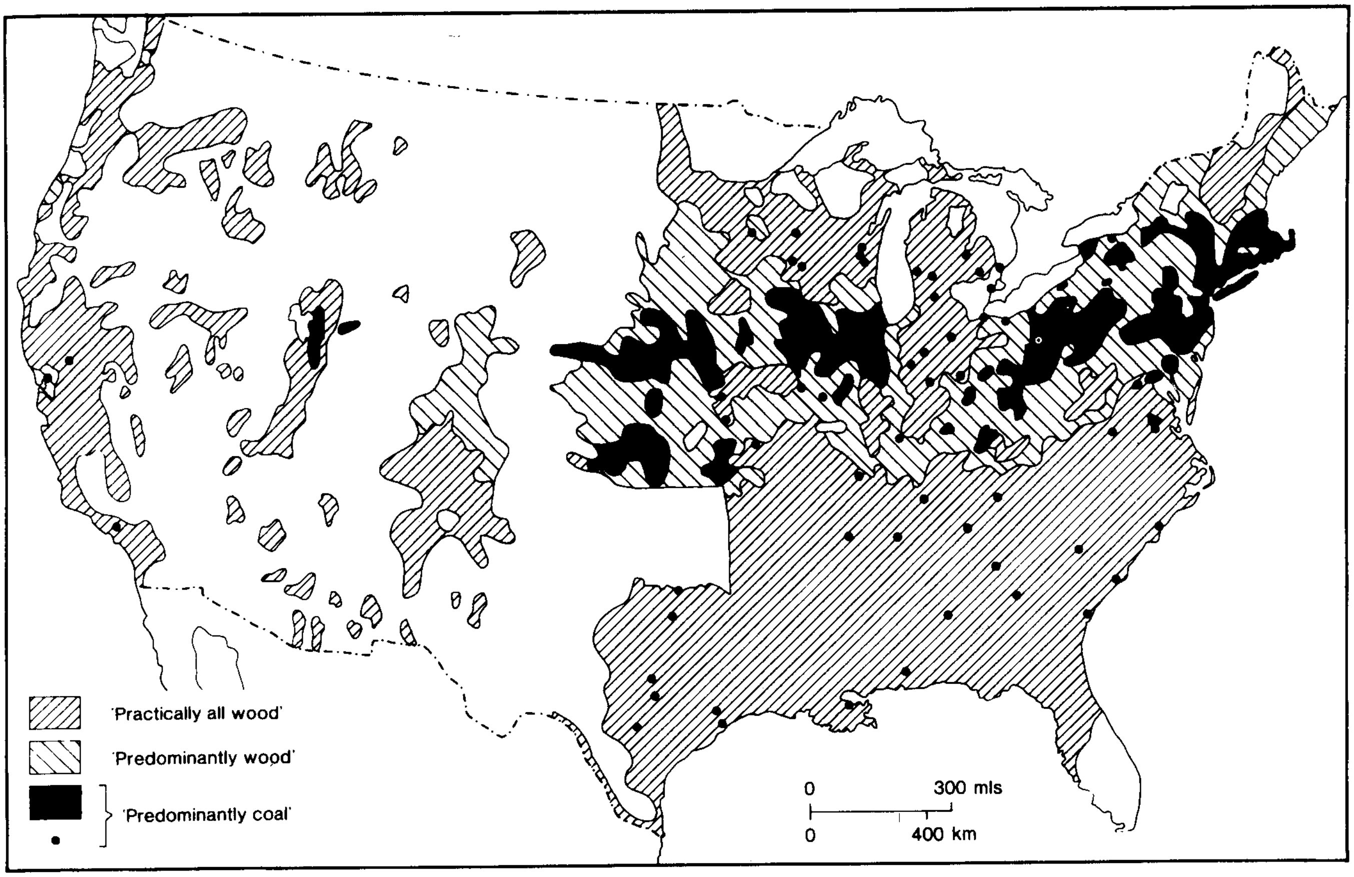

Figure 3. Type of fuel used in the United States, circa 1880 (based on Sargent, Report on the Forests of North America, *pp. 488–89).*

late 1930s fuel dealers along the Atlantic Coast had ceased to handle firewood at all.[10]

The diffusion of coal as a fuel in nineteenth-century America is shown in figure 3, which represents a stage beyond that of initial penetration. By 1880 coal predominated as the main fuel in five main areas: New York and its immediate environs; the Hudson Valley, Massachusetts, and eastern Pennsylvania; western Pennsylvania and eastern Ohio; northern Illinois and western Iowa; and along the Platte and Arkansas rivers in Nebraska and Kansas. In addition, coal was the domestic fuel in nearly every city with a population over fifteen thousand. One example of the local change to coal must stand for many. In Fairfield County in southern Ohio it was said in the early 1880s that "wood is not used for fuel more than half as much as it was eight or ten years ago. Many farmers having timber on their lands find it cheaper and more convenient to buy and burn coal."[11]

Around the core areas of coal use lay a broad belt where coal made some inroads as a fuel but wood still predominated, stretching from eastern Nebraska and Kansas across the continent to New York and Pennsylvania. The rest of the settled portion of the country constituted a third zone where the fuel used was "practically all wood": across the entire South and West, and throughout Wisconsin, Minnesota, Michigan, Indiana, and inland Maine.[12]

The evidence suggests that the picture presented by figure 3 did not alter much during the next few decades. Coal consumption went up and wood consumption dropped slightly, and coal penetrated the intermediate zone across the Northeast and the growing urban areas, wherever they were located. By 1908 consumption of wood may well have dropped to 84.1 million cords, with four-fifths of the consumption being on farms. The weight of farm consumption in proportion to total wood consumption reached nearly 95 percent in the agricultural states of the South and the West, and was as low as 60 percent in the vicinity of the intensely industrial portions of the Northeast.[13]

World War I, however, brought a renewed though short-lived interest in the subject of fuelwood and the management of woodlots by farmers. The war diverted manpower and caused an actual shortage of coal during the winter of 1917–18. Measures to conserve fuel and reduce transportation costs focused attention on the forests that still remained after the great clearing as a source of fuel

10. Arthur H. Cole, "The Mystery of Fuel Wood Marketing in the United States," *Business History Review* 44 (Autumn 1970): 339–59.

11. Ohio State Forestry Association, *Proceedings of the Ohio State Forestry Association Meeting, Columbus, March 28th, 1884, together with a Report Upon the Forest Condition of Ohio* (Columbus: G. J. Brand & Co., State Printers, 1884), p. 166.

12. Sargent, *Report on the Forests of North America*, p. 489.

13. Reynolds and Pierson, *Fuel Wood Used in the United States*, pp. 17–18.

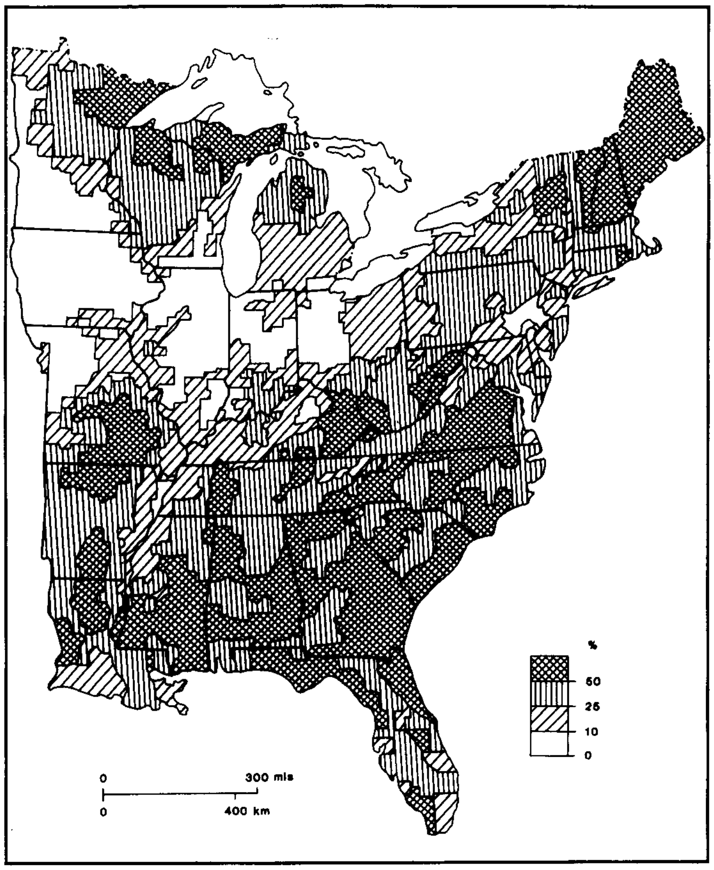

Figure 4. Proportion of farms in the eastern United States covered by woodlot, 1910 (based on Frothingham, The Status and Value of Farm Woodlots in the Eastern United States, *pp. 4–5).*

for the nation. Consumption of fuelwood went up by at least a quarter—from 82.7 million cords to 102.9 million cords in 1917, and wood was seen to be "coming into its own again." The Forest Service and state foresters actively campaigned among farmers, urging them to increase the amount of fuelwood cut as a means of combating a national emergency and as a part of good farm practice.

Coal, however, had penetrated so far into the urban market that there was now little chance of wood winning back a share. The bulk and low energy-to-weight ratio of wood made it too expensive to move overland more than three miles, and wood moved more than five miles simply could not compete with coal on the open market (unless the wood dealer could use sea or river transport to cut his cost of production). Thus farmers could use their wood on their own farms, but could sell it at a profit only in nearby towns and villages. New marketing schemes were suggested to overcome the resistance of fuel merchants to wood, who by now had dealt with coal for so long that they had neither the inclination nor the machinery to deliver fuelwood, especially in the new smaller "handleable" sizes. Proposals included selling wood by weight and not by the confusing measure of volume as of old; setting aside municipal forests as sources of fuel; and establishing municipal woodyards, as actually happened in Mississippi. Virginia took even more positive action and allowed those living outside a city or incorporated town to purchase coal only with a special permit proving that local wood was not available. But all these suggestions and actions had little permanent effect. As soon as the wartime emergency ended, the trend of wood consumption dipped, with a temporary reprieve only during the depths of the Depression years.[14]

Woodlots were a significant portion of the total forest, and by 1910 they covered a staggering total of 143.3 million acres on 4.3 million farms in the eastern United States. Early views about their productivity were pessimistic;[15] but later assessments based on more exact appraisals of their extent and yield were more balanced.[16] The average woodlot contained a little less than thirty acres, although sizes varied from less than five acres on small farms in New England to one hundred fifty acres on partially cleared holdings in northern Minnesota and South Carolina. All in all, the woodlot was a conspicuous feature of the landscape of the eastern United States.

Because woodlots were often a remnant of the original forest left after clearing for agriculture, their area decreased gradually by 15 percent between 1880 and 1900, but there were great regional variations. In New England, woodlots grew as farms were abandoned and reverted to forest. The same happened in the Lake States as settlement extended northward and boosted the area of farm woodlots by incorporating both cutover land and uncleared forest (figure 4).

14. Graves, "The Use of Wood for Fuel," pp. 1, 17–21, 33–37.

15. C. R. Tillotson, "The Woodlot: Its Present Problems and Probable Future Use in the United States," *Proceedings of the Society of American Foresters* 11 (April 1916): 198–208.

16. Earl H. Frothingham, *The Status and Value of Farm Woodlots in the Eastern United States*, U.S. Department of Agriculture Bulletin 481 (Washington, D.C.: GPO, 1919).

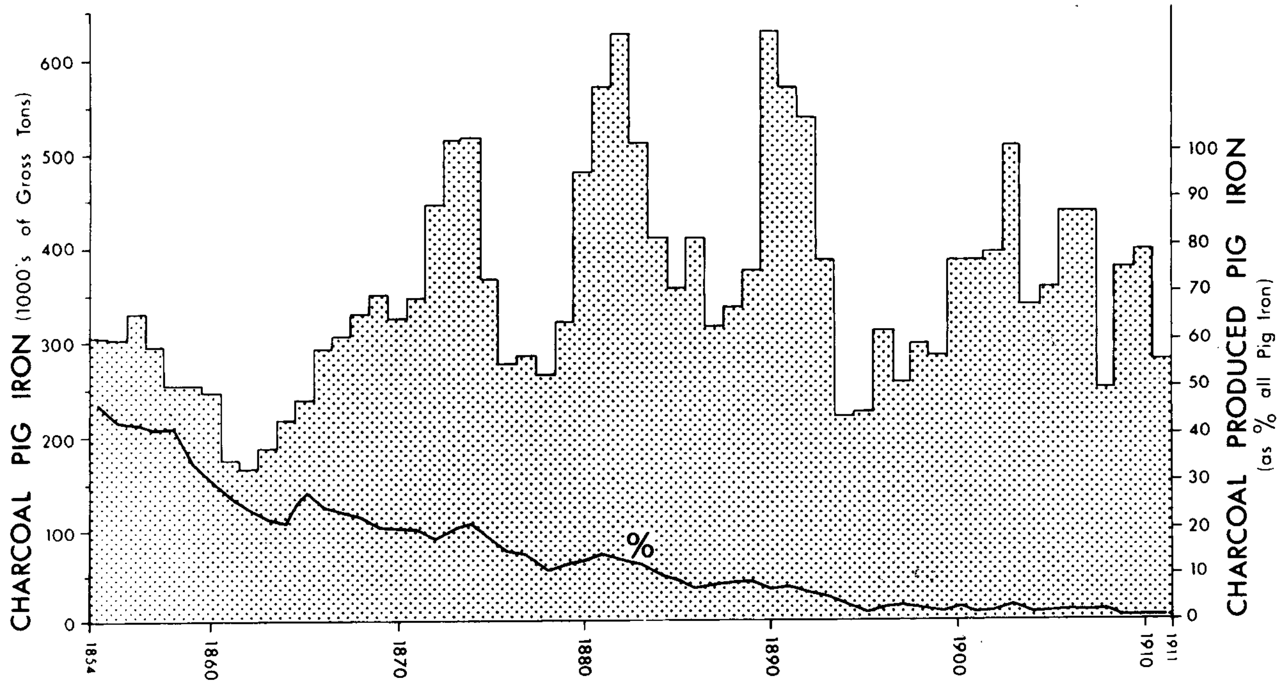

Figure 5. Charcoal pig-iron production, 1854–1911. Annual production is measured in thousands of gross tons; charcoal-produced iron is expressed as a percentage of all iron produced (based on Temin, Iron and Steel in Nineteenth-Century America, *table C-3, pp. 268–69).*

The woodlot had uses other than fuel, some of which directly benefited farmers. They protected livestock during extreme weather, especially if planted as shelterbelts. They contained up to 15 percent of the nation's timber supply. The full value of this lumber was rarely realized, however, because poor management produced stands of widely variable quality and because farmers knew too little about timber grading to get top dollar from wood dealers.

Woodlots were the source of rough construction timber, poles, and fencing, but above all they were a source of fuel, worth some $170 million in 1910, double the total value of either the tobacco or the rye and barley crops combined. In Vermont and New Hampshire woodlot products (mainly fuel) were the second-ranking crop; and in Maine, South Carolina, Georgia, Alabama, Mississippi, and Arkansas they were the third-ranking crop.

As late as 1940, some 7.7 million homes still used wood for heating, a figure that doubled to 14 million homes in the energy-conscious 1970s and early 1980s, underlining the price elasticity of consumers' fuel choices and the abundance of wood.[17]

Charcoal and the Iron Industry

Charcoal, a kind of fuelwood once removed, was replaced by mineral fuels as America moved slowly into the truly industrial age after the Civil War.[18] The proportion of iron smelted by charcoal dropped from 45 percent of all iron in the mid-1850s to 25 percent at the close of the 1860s. However, its decline in percentage was within a rapidly rising total output, which meant that iron smelting by charcoal was not eliminated and fuel gathering in the forests continued. As the economy expanded, the demand for the versatile iron increased consistently; more was produced in nearly every year after 1860 than before, and production reached over half a million tons on eleven occasions during the last couple of decades of the century, only to decline after about 1909 (figure 5).[19]

The number of iron furnaces fell rapidly from 385 in 1859 to a mere 33 in 1920, but this decline in numbers did not necessarily mean a decline in production—while the small preindustrial furnaces with a capacity of less than two thousand tons per annum were eliminated in the older areas of production in Pennsylvania and Ohio, increasingly large (twenty thousand tons capacity or more) furnaces were built in new areas of production farther west, in Michigan, northwestern Wisconsin, Missouri, western Tennessee, northern Alabama, and northwestern Georgia. All of these areas included easily extracted iron ore and extensive forests (figure 6 and table 1).

17. Frothingham, *Status and Value of Farm Woodlots*, pp. 1–3, 11–15, 29–30, 35–43. For later figures see Schurr and Netschert, *Energy in the American Economy*, p. 57.

18. J. Peter Lesley, *The Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States* (New York: John Wiley, 1859), pp. 44–45.

19. Peter Temin, *Iron and Steel in Nineteenth-Century America: An Economic Inquiry* (Cambridge, Massachusetts: MIT Press, 1964), pp. 82–83, 266–67.

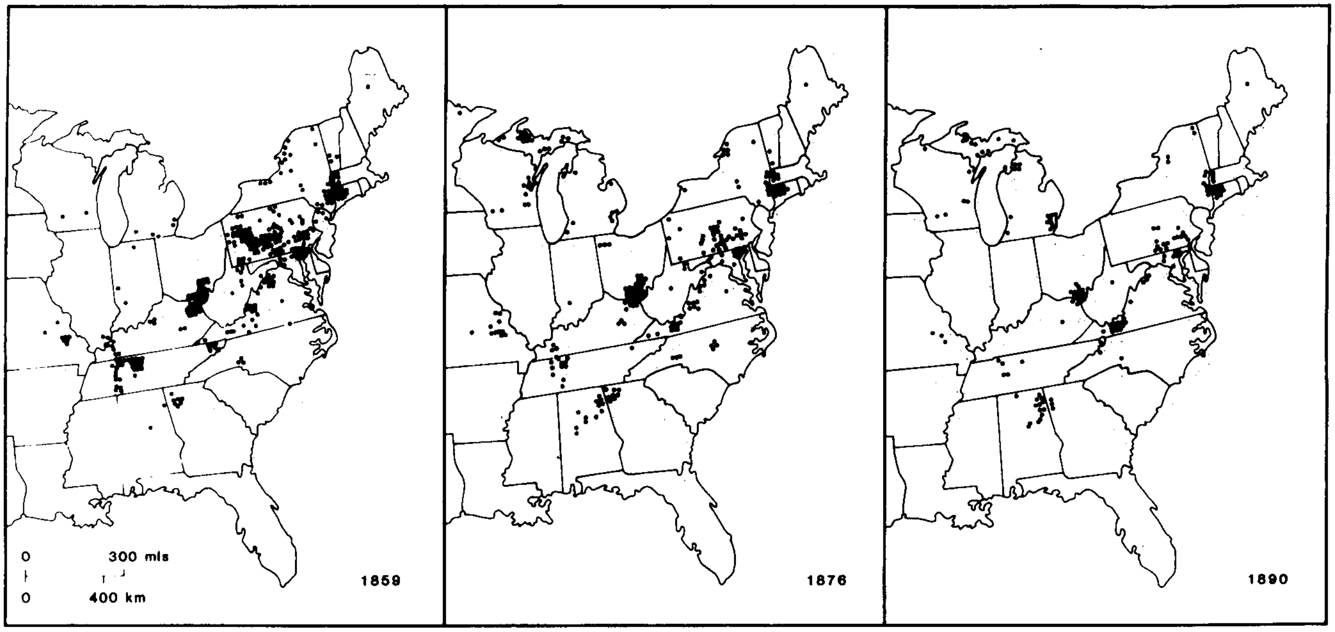

Figure 6. Location of charcoal blast furnaces in 1859, 1876, and 1890 (based on Schallenberg and Ault, "Raw Material Supply and Technological Change in the American Charcoal Iron Industry," pp. 447–49).

The new iron furnaces differed from the old both in appearance and efficiency. The typical, squat (thirty-foot), truncated pyramid of masonry of the preindustrial furnace was slowly replaced by the new, narrow, chimneylike furnace, from fifty-five to sixty feet tall. High-pressure hot blasts could be passed more easily through these furnaces, which used wood fuel much more economically. Hot air was collected from the top of the furnace rather than being allowed to escape as in the old furnaces, and it was pumped at high pressure by a steam engine rather than by a waterwheel.[20] The amount of charcoal needed to smelt a ton of pig iron decreased in consequence. Antebellum furnaces had used between 150 and 250 bushels of charcoal per ton of ore, but the late–nineteenth-century furnace used only between 72 and 120 bushels per ton (the median use of the eighteen furnaces known to be operating between 1881 and 1926 was 91 bushels per ton).[21]

One problem was that the weight of the ore in the more efficient tall furnaces caused the brittle, traditionally made charcoal to crumble. That was overcome by distilling the wood in brick kilns and iron-retort systems, which produced less ash, stronger charcoal, and also valuable and saleable wood-chemical by-products from the condensed gases.[22]

The charcoal industry did not stand still in the face of competition from mineral fuels; it adopted innovations fairly quickly. In fact, because charcoal was inherently more expensive than coal (despite the abundance of timber), the charcoal industry became supercompetitive, hence its very slow death. Charcoal-using furnaces became more like coke-using furnaces and were operated accordingly, some even changing from charcoal to coke and back again depending upon the availability of fuel supplies and the price and demand for different types of iron.

With changes in technique came changes in the organization of production: the old-fashioned iron plantation disappeared with the old-fashioned furnace. The iron master using charcoal became more efficient and aggressively competitive: after about 1860 he reserved his premium product for fine cutting tools, small arms, steam-boiler tubing, crank shafts, axles and gears, and above all, railroad wheels, which consumed the bulk of the output. He left the less-demanding market for rails, horseshoes, and cruder construction bars and rods to the coke iron manufacturer.

After about 1890, however, advances in ferrous metallurgy began to catch up with charcoal iron and erode its few remaining markets. Bessemer converters, and particularly open-hearth steel furnaces, produced large quantities of high-grade steel, and the coke steel strengthened with chrome nickel alloys competed seriously with fine iron as a raw material for specialized products. The railroad wheel, in particular, succumbed to the new strengthened steel because it needed to withstand increasingly greater weights and speeds. As its main markets dried up, the charcoal iron industry began to falter.[23]

Although the impact of the charcoal-using furnaces on their immediate surrounding forest areas was great, nowhere did the devastation become so widespread during

20. Richard H. Schallenberg and David A. Ault, "Raw Material Supply and Technological Change in the American Charcoal Iron Industry," *Technology and Culture* 18 (July 1977), pp. 436–66.

21. Alfred D. Chandler, "Anthracite Coal and the Beginnings of the Industrial Revolution in the United States," *Business History Review* 46 (Summer 1972): 141–81; Temin, *Iron and Steel*, p. 65.

22. Edward H. French and James R. Withrow, "The Hardwood Distillation Industry in America," *Ohio State University Bulletin* no. 19 (Columbus: Ohio State University, 1905), pp. 1–15.

23. Richard H. Schallenburg, "Evolution, Adaptation, and Survival: The Very Slow Death of the American Charcoal Industry," *Annals of Science* 32 (July 1975): 341–58.

Table 1. Charcoal Pig Iron Production, 1866–1910 (to nearest 1,000 tons)

	MA CT NY ME	PA	OH	MD VA	KY TN GA	AL	MI	MO	WI	Total
1866	—	58	88	—	—	—	35	—	—	181
1872	55	45	96	50	77	13	87	46	28	497
1880	64	43	69	47	45	38	154	16	43	519
1885	34	12	18	23	42	78	143	22	20	392
1890	47	18	26	24	64	110	259	34	95	677
1895	17	5	12	—	15	21	102	2	51	225
1900	24	4	9	7	29	65	176	38		352
1910	19	5	1	2	11	40	292	73		443

From Schallenberg and Ault, "Raw Material Supply and Technological Change in the American Charcoal Iron Industry," pp. 461–62.

the pre–Civil War years that the industry died, nor did charcoal become so costly that it was uneconomical to use—both of which are conventional explanations for the shift of the industry to the West.[24] Rather, as Richard Schallenburg and David Ault suggest, the exhaustion of the local iron ore in some cases, and in general the steady progress of the technology of steel production and manufacture, eventually squeezed the charcoal industry out of existence. There is no clear evidence that the price of charcoal was higher in the older settled areas of the East (where demand was greatest) than in the newly settled areas of the West (where supplies were most abundant). Overall, prices may even have decreased as superior techniques of production gave saleable by-products. Charcoal was transported long distances to furnaces sited close to the urban markets for iron instead of near the supplies of fuel in the middle of the forests. River transport and even the railroads were used by many furnace owners, like those near Baltimore or in Virginia.[25] And the number and capacity of furnaces in Michigan during the 1860s and 1870s were nearly as great in the largely nonforested south of the Lower Peninsula as in the densely forested Upper Peninsula. The important and common factor was access to the cheap high-grade ores in the Superior Ranges, which could be moved easily only by lake transport. Fuel, in comparison to iron ore, could be and was transported cheaply overland. Charcoal was supplied over distances of three hundred miles in New England, New York, Pennsylvania, Alabama, and Michigan in specially built railroad wagons.[26] Indeed, transport of fuel was an inevitable accompaniment of increasing furnace capacity; furnaces of thirty to forty thousand tons capacity per annum required that fuel be collected over a greater radius than ever before.

Though wood exhaustion was not the primary reason for either the shift westward or the decline of the charcoal iron industry during the late nineteenth century, large areas of the forests were permanently affected by cutting for charcoal. Depending upon the density of the trees, the amount of land cleared varied from place to place and from time to time. Using a modest estimate of 150 acres of woodland to produce 1,000 tons of pig iron, the number of acres cleared to fire the furnaces must have ranged from 25,000 acres (39 square miles) per annum in a low-production year like 1862 to 94,000 acres (147 square miles) in a high-production year like 1890. Of course, many forests near the furnaces were cut over at intervals of twenty-five to thirty years, and sometimes less. For example, a detailed survey of the 837 square miles of Vinton and Jackson Counties in the Hanging Rock district of southeastern Ohio showed that 60 percent of the forest was clearcut between 1850 and 1860, down to four-inch diameter trees, and that the forests regenerated sufficiently for recutting during the early part of this century. The same was true of neighboring Scioto County, which was "originally well wooded . . . but a large proportion was turned into the charcoal to be used for smelting purposes in the large furnaces." However, here the forests did not regenerate: "After the forests had been cut, nothing was done to ensure their rejuvenescence; cattle were permitted to eat the young trees that came up and to trample over them; in some instances the cleared districts were burned over to secure a better pasture," and consequently some furnaces were abandoned for want of charcoal.[27]

A clue to fuelwood rotations is the amount of woodland reserved by the smelting companies to keep the furnaces going permanently, an estimate that was, of course, linked

24. Temin, *Iron and Steel*, pp. 82–83.

25. Schallenburg and Ault, "Raw Material Supply and Technological Change," pp. 445–46, 450; and John D. Tyler's unpublished master's thesis on "The Charcoal Industry in Decline, 1855–1925" (University of Delaware, 1967).

26. *Journal of the United States Association of Charcoal Iron Workers* 6 (1885): 117–21.

27. Janice C. Beatley, "The Primary Forests of Jackson and Vinton Counties," (Ph.D. diss., Ohio State University, 1953), pp. 96–108; *Proceedings of the Ohio State Forestry Association Meeting, 1884*, p. 218. For other statistics on cutting rotations see Franklin B. Hough, ed., *Report Upon Forestry* (Washington, D.C.: GPO, 1880), 3:65–67. Cutting rotations range from eighteen to forty years, with a median of twenty-five years for the seventy-five cases reported.

to regrowth. The acres of woodland reserved for each ton of iron produced varied enormously, from 2.67 in Kentucky to 37.3 in New York. The median value of eight observations was five acres of woodland per ton of iron. At the Woodstock Iron Company in Calhoun County, Alabama, which produced 6,100 tons of iron per year, it was said that "20,000 acres are sufficient for a permanent supply. Lands cut over are reserved for growing another crop and the furnace now has 4,000 acres of young trees." At the Center Furnace in Clay County, Kentucky, which produced 3,900 tons, it was calculated that "about 10,440 acres would yield a permanent supply if no accident, such as fires, happened to the growing timber. Many furnaces in Kentucky have large tracts of woodland for growing new supplies. They are cut off once in 28–30 years." At the Hamilton Iron Works in Monroe County, Missouri, it took about 8.4 acres of woodland to produce a ton of iron: "The timber being small and of slow growth, 30,000 acres would probably be required to keep a furnace permanently supplied. More than half the land in the region is good for nothing except for growing timber. No second growth has been cut and it would probably require 30 years for it to become large enough for profitable cutting." The Champlain Ore and Iron Company in Essex County, New York, in contrast, needed 60,000 acres of forest to produce a mere 1,600 tons of iron, although of that "30,000 acres are reserved, and a new growth may be cut in from 10 to 20 years."[28] Suffice it to say that the area considered necessary for a reserve stock depended as much on the management of the timber as on the rate of regrowth.

A further and final complication is that the amount of charcoal needed to smelt a ton of pig iron decreased as better smelting and charcoal-making techniques were developed, which lessened the impact of charcoal making on the woodlands as the years progressed. Furnaces during the early nineteenth century consumed well over 200 bushels per ton smelted, but the amount of charcoal needed fell rapidly toward the end of the century. Between 1880 and 1900 it was reduced from an average of 112.3 bushels to 81.6 bushels per ton (table 2).

The only indication of the amount of forest destroyed in the name of charcoal iron production is for particular census years. For example, in 1880 the production of charcoal pig iron was 480,000 tons, smelted by burning 52,910,000 bushels of charcoal. If the charcoal from 150 acres of woodland was required to smelt 1,000 tons, then some 72,000 acres must have been cleared in that year. However, if the common estimate was correct that one acre of woodland could produce between 1,000 and 1,200 bushels of charcoal, then only between 45,000 and 54,000 acres were cleared. Differences in the statistical transformations will clearly lead to differences in the estimates made. An additional complication is that 15.6 million bushels of charcoal went into rolling and steel mills, and forges and bloomeries, which must have meant the clearing of another 13,000 to 15,600 acres.[29]

Table 2. Bushels of Charcoal Used per Ton of Iron Produced, 1880–1900

	Charcoal (bushels)	Pig iron (tons)	Bushels per ton
1880	53,910,000	480,000	112.31
1890	67,672,000	628,000	107.75
1900	31,422,000	385,000	81.61

From U.S. Census Office, *Twelfth Census of the United States* (Washington, D.C.: GPO, 1902), vol. 10, part 4, p. 18.

Because of such variables and uncertainties, one cannot be too dogmatic about the amount of woodland cleared in any one year, or indeed for the whole of the nineteenth century after the Civil War. At best we can calculate roughly that the 20.4 million tons of charcoal iron produced between 1855 and 1910 may have required in toto the forest growth of 4,800 square miles of well-stocked woodland. If we assume a rotation of twenty-five years, that figure drops to about 3,000 square miles. Impressive as that amount is, however, land cleared for iron production was only 1.3 percent of the land cleared for agriculture, and if charcoal for iron came from regrowth or secondary forest, it took a mere 0.8 percent of the forest taken by agricultural settlement.

With this comparative perspective it can be seen that charcoal iron production had relatively little impact on the forests of the country as a whole. However, its impact was out of all proportion to its area because clearing for charcoal was concentrated and thus could be seen, understood, and calculated easily. Unlike agricultural clearing, clearing for iron production was an alien intrusion into the rural landscape and consciousness of post–Civil War America. As such, clearing for charcoal commanded special attention and comment and contributed, perhaps disproportionately, to the heightening awareness about the destruction of the forests during this critical period. Whatever the truth of the situation, most people living in iron-producing districts would have agreed with N. W. Lord's 1884 assessment of what was happening in the Hanging Rock district of Ohio: "The disappearance of the forests under the demands of the furnaces, which is now so apparent throughout the region, increases every year the difficulty of obtaining the necessary fuel, and marks very plainly the fate of the charcoal iron industry."[30]

The Railroads

Of the many industries and activities that depended on the products of the forest, railroad construction and opera-

28. Hough, *Report Upon Forestry* (Washington, D.C.: GPO, 1878), 1:125–27. See also N. W. Lord, "Iron Manufacture of Ohio," in *Economic Geology*, vol. 5 of the *Report of the Geological Survey of Ohio* (Columbus: G. J. Brand and Co., State Printers, 1884), pp. 438–554.

29. James M. Swank, "Iron and Steel Production," in *Report on the Manufacturers of the United States*, vol. 2 of the *Tenth Census of the United States* (Washington, D.C.: GPO, 1883). Note that the capacity of a bushel varied between states. See Hough, *Report Upon Forestry* 3:62–63.

30. Lord, "Iron Manufacture of Ohio," p. 483.

tion had among the greatest impact on North America's forest cover. Lumber was used for railroad ties, trestle bridges, station buildings, telegraph poles, snow fences, and fuel, to mention but the main uses. But in addition to this material impact, there was also a symbolic impact. Some people deplored the railroad as an intruder in the pastoral scene, the harbinger of change and destruction—in short, the "machine in the garden."[31] For others it was the technological culmination of the palaeotechnic age. It caused urban commerce and industry to flourish, and even seemed to promote the formation of the nation by linking the continent together. As an early bulletin of the Forestry Division pointed out in 1888, "the pioneering days are rapidly disappearing before the energetic push and advancement of railroad building and settlements." Earlier on, in 1868, E. F. Palmer had given this symbolism a pictorial representation in his Currier and Ives picture entitled *Westward the Course of Empire Takes Its Way*, in which a railroad crosses the scene and disappears into the distance, splitting the picture diagonally into two worlds, civilization and wilderness.[32]

There was little doubt that the railroad meant change, and in the context of the forest that could mean only one thing—the diminution of the timber stand. In 1866 Andrew S. Fuller noted that "even where railroads have penetrated regions abundantly supplied, we soon find all along its track timber soon becomes scarce. For every railroad in the country requires a continued forest from one end to the other of its lines to supply it with ties, fuel, and lumber for building cars."[33]

Certainly during the 1860s, supplies of fuelwood near railways in the Northeast had become scarce. In southern New England, New York, Pennsylvania, and eastern Ohio, and also around Chicago, the demand of the urban population for firewood, building timber, and charcoal, together with the high value of land in agricultural use, pushed the prices of railroad fuel upward to between seven and eight dollars a cord. The New York Central Railroad ran irregular services during the winter of 1864 because of shortages and problems caused by burning coal in wood-burning locomotives, and then "energetic agents were sent back into the country, and by offering high prices and making great exertions to supply the road, in mid-winter the trains began to resume their regularity." Thomas Starr calculated that the daily consumption of fuelwood by all railroads at that time was 21,555 cords, which would have meant an annual drain on the forests of at least 6.5 million cords, with a total cash value two and one-half times that of the nation's annual coal production.[34]

Nevertheless, all the evidence suggests that wood-burning locomotives began to consume less and less fuel throughout the 1870s and 1880s. In 1878 Franklin B. Hough surveyed thirty-eight railroad companies operating nearly eleven thousand miles of track, and only 254 out of 2,424 locomotives, or a mere 10.5 percent, still burned wood. Nearly half of those few wood burners operated on one line only, the Lake Shore, Michigan Southern Railway (Buffalo to Chicago), but even this line used a mere 87,236 cords of wood compared to 261,719 tons of coal.[35]

Although the demand for fuelwood was falling to almost insignificant levels, the amount of timber needed for railway buildings, stations, telegraph poles, fencing, and particularly crossties, was high and growing proportionately to the expansion in the length of track. Track length more than doubled from thirty-two thousand miles in 1864 to ninety thousand miles in 1875, and it nearly doubled again during each of the next two decades.[36]

The resulting destruction of the forest was enormous and widespread. Ohio, for example, by 1870 lay in the path of many east-west railroads and had over six thousand miles of track, enclosed by over ten thousand miles of wooden fencing, running on more than ten million ties, crossing over sixteen miles of wooden bridges and ten miles of trestles. Locomotives traveling Ohio track consumed about 700,000 cords of fuelwood per year. The average replacement rate for ties was between six and seven years; for bridges, five and one-half years; and for trestles, seven years.

The felling required to keep pace with this rate of construction and even greater rate of decay and replacement made it difficult, concluded Daniel Millikin, to "begin to conceive the demands which this new invention will make upon the woods." By 1876 the railroads were deemed to be making greater inroads than agriculture into the forests, "which were being removed entirely too rapidly." The whole balance of agriculture was being put in jeopardy by "this denuding process."[37]

By 1884 residents in Trumbull County in eastern Ohio noted that their "majestic forests" were "fast disappearing, to aid the rapid strides of public improvements." In Belmont County, three new railroads had created "a special market for lumber to be used for tunnels, ties, bridges, etc.," which caused considerable destruction. In Fairfield, "a vast amount of lumber" had been used in railroad construction; in Tuscarawas, the "railroads have culled the forests . . . to the extent that there is *no first class* or 'heavily wooded lands' " left. In Muskingum, the construction of the new

31. Leo Marx, *The Machine in the Garden: Technology and the Pastoral Ideal in America* (New York: Oxford University Press, 1964).

32. E. F. Palmer, *Westward the Course of Empire Takes Its Way* (1868), print for Currier and Ives.

33. Andrew S. Fuller, *Forest Tree Culturist: A Treatise on the Cultivation of American Forest Trees* (New York: Geo. and F. W. Woodward, 1866), p. 12.

34. Starr, "American Forests," p. 213.

35. Hough, *Report Upon Forestry* 1:112–15.

36. For statistics on track mileage see U.S. Bureau of the Census, *Historical Statistics of the United States from Colonial Times to 1970*, part 2, pp. 727–32, tables Q284–312 and Q321–29; and E. E. Russell Tratman, *Railway Track and Track Work* (New York: The Engineering News Publishing Company, 1901), pp. 1–10 and table 2 in the appendix.

37. Daniel Milliken, "The Best Practical Means of Preserving and Restoring the Forests of Ohio," in the *Twenty-Sixth Annual Report of the Ohio State Board of Agriculture* (Columbus: Nevins and Myers, State Printers, 1871), pp. 319–33; and John H. Klippart, "The Condition of Agriculture in Ohio in 1876," in the *Thirty-first Annual Report of the Ohio State Board of Agriculture* (Columbus: Nevins and Myers, State Printers, 1877), pp. 486–538, especially p. 507.

Baltimore and Ohio line had unleashed "a mania for buying woodland, stripping it of its timber, and then selling it for agricultural purposes." Everywhere, the coming of the railroad meant felling.[38]

But consciousness of timber depletion finally became a real sense of alarm on the largely treeless prairies, where the land-grant railroads such as the Union Pacific, the Central Pacific, the Burlington, and the Santa Fe, used enormous amounts of wood. Speedy construction (up to eight miles a day) in order to beat competitors and to provide a rapid return on investment prompted the railroad companies to use the quickest and cheapest solutions to their engineering problems. Steel, earth, and stone were long-term and costly components for bridges, banks, and tunnels; moreover, their use in construction required skilled labor. Wood, on the other hand, was a familiar, well-tried, and relatively low-cost material that could be improvised, fabricated, and adapted in numerous ways by unskilled labor. Wood could be brought to the site of construction by established means of transportation like rivers, or it could come behind the railroads as they spread across the prairies.

In many areas the laying of the tracks passed almost unnoticed, but the railroad did cut a swath through the forests in many areas of the country. When Charles Sargent published his maps of forest depletion in 1884, showing broad zones of clearing of at least five miles on either side of any railroad, he helped to fix in many minds the simple equation that the railroad equaled forest destruction. As the decade wore on the railroad industry, like the charcoal industry, assumed an emotional and symbolic importance out of all proportion to its actual impact, great as the latter was in places.

Franklin Hough's 1878 inquiry helped to pinpoint how much wood was being used. He noted that railroad lines required between 2,200 and 3,500 ties per mile, the most common number being 2,640. But the timber rotted and decayed as it lay embedded in ballast, so that the ties had to be replaced about every five to six years, with between 15 and 20 percent of the track mileage requiring renewal every year.[39] Hough did not take his observations to their logical conclusion and calculate the amount of forest cut as a result of construction and maintenance, but in 1883 Nathaniel Egleston's annual Forestry Division report estimated that about 3 million acres must have been logged to supply ties for existing track and that 472,400 acres were needed annually (or 12.6 million acres in all) just to maintain the railways. A few years later Egleston adjusted these figures to 567,714 acres annually and 17 million acres in all.[40]

There the matter seemed to rest until the publication in 1887 of the first technical and professional paper by the new Forestry Division on "The Relation of Railroads to Forest Supplies and Forestry." This bulletin thrust the railroad-tie issue into the forefront of the forest-depletion debate that was gaining momentum during the closing years of the century. M. G. Kern of St. Louis, agent for the division and author of the bulletin, posed the question in blunt and uncompromising terms:

> Considering the stupendous amounts of timber already withdrawn from native forests, the annual demands of railways now in operation, and the increase in mileage from year to year, it becomes necessary to take a more accurate survey of the fields of demand and supply, unbiased by the popular delusion of the inexhaustible forest wealth of America. The necessity is no longer either to be ignored or lightly treated as in the past."[41]

Kern calculated that existing tracks and poles consumed 3.1 billion cubic feet and that maintenance and new construction consumed another 0.5 billion cubic feet annually. When due allowance was made for types of timber needed (poles or dimensional timber), and for the density and yield of the forest, the annual drain was nearly 300,000 acres—249,214 acres for the maintenance of tracks and poles, and 47,673 acres for the construction of new track. Kern's figure for the annual cut was less than Egleston's sheer guess a few years earlier, but was no less startling for that. Furthermore, Kern's figure was calculated in a reasonable, precise, and conservative manner, which lent it an authenticity and stature that Egleston's estimates never had.

Whatever the precise figures, the concern over the impact of the railroad industry on the forests was genuine and great. The concern was heightened by the manner of cutting. The railroad owners preferred white oak, and to a lesser extent, other hardwoods like chestnut oak and black locust, which had the requisite strength, elasticity, and resistance to rotting (figure 7). They were convinced that the ties lasted longer if they were taken from young second-growth timber, if they were hewn rather than cut, if the outer sapwood was discarded and only the inner heartwood used, and if they were felled in the winter rather than the spring or summer. The result was the total destruction of substantial stands. As one lumber journal put it: "There is no branch of the lumber industry where there is more waste of raw material. . . . Each tie is split from clear wood, and it takes about 35 feet of clear lumber to make a merchantable tie. . . . When to this is added the percentage of 'culls' that are arbitrarily rejected by the inspectors on behalf of the railroads at the [timber] owner's expense, it will be found that each tie represents about 75 feet

38. *Proceedings of the Ohio State Forestry Association Meeting, 1884*, pp. 138, 153, 166, 96, and 101 respectively.

39. Hough, *Report Upon Forestry* 1:115–16.

40. See the U.S. Department of Agriculture's *Annual Report for 1883*, p. 445, and its *Annual Report for 1885* (Washington, D.C.: GPO, 1886), p. 185. Bernhard E. Fernow estimated that between ten and fifteen million acres of forest were needed to feed the railroads; see his *Consumption of Forest Supplies by Railroads and Practicable Economy in Their Use*, U.S. Department of Agriculture Forestry Division Bulletin 4 (Washington, D.C.: GPO, 1890), pp. 13–14. Other estimates are contained in Franklin B. Hough, "Report on Kinds and Quantities of Timber Used in Railroad Ties," in Nathaniel H. Egleston, ed., *Report Upon Forestry* (Washington, D.C.: GPO, 1884), 4:119–73.

41. M. G. Kern, *The Relation of Railroads to Forest Supplies and Forestry*, U.S. Department of Agriculture Forestry Division Bulletin 1 (Washington, D.C.: GPO, 1887), p. 14.

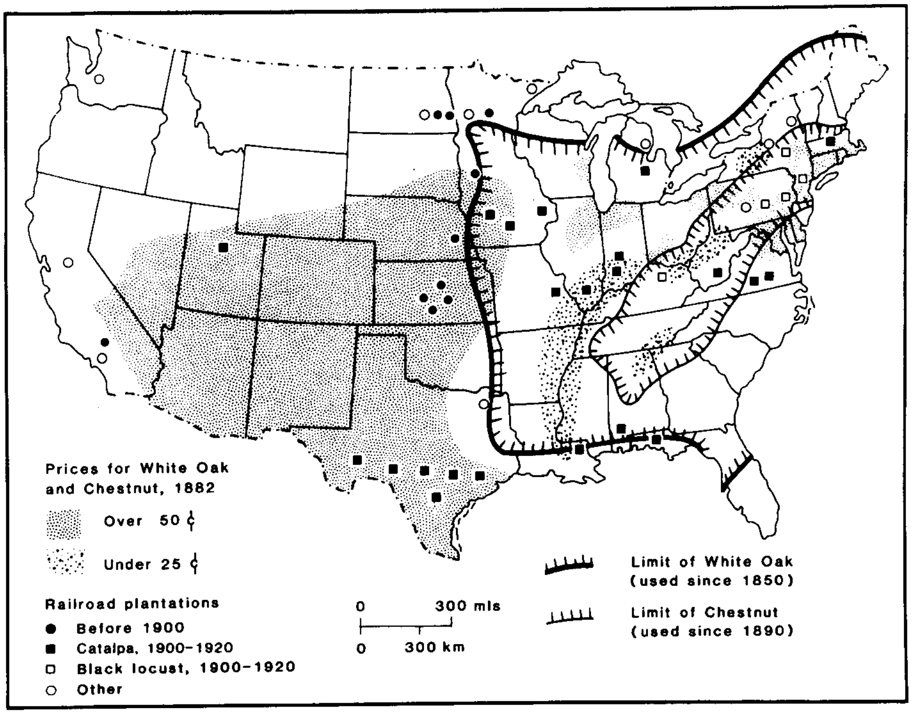

Figure 7. The range of oaks, the hardwood-tie market (1882), and railroad plantations (based on Olson, The Timber Depletion Myth, *pp. 15, 18, 81).*

of good merchantable lumber in the standing timber destroyed for it."[42]

This wasteful exploitation had little scientific basis. A spring or summer felling did not hasten decay because of sap in the outer wood, though a winter felling was incidentally advantageous because the wood had stood for several months when fungi growth was minimal, and the wood was seasoned to a certain extent. Market forces did not check the exploitation, as might be expected. Farmers anywhere near stands of the favored species either cut trees on their own land during their winter off-months or worked for the railroads. Selling ties made an important contribution to farm capital and purchasing power in the least-developed parts of the country. The farmers cut readily and abundantly, oversupplying the railroad companies, who controlled the quantity, quality, and price paid by merely adjusting the freight rate, which effectively lowered the prices of ties. In addition, the ever-increasing spread and integration of long-distance and branch lines throughout the 1870s and 1880s tapped new sources of timber so that the railroads, as consumer, never felt the pinch of higher prices, the specter of scarcity, or the need to economize by using substitute materials. The railroads created and supplied a massive demand with no change in price.

The result was that an immense quantity of tie timber was cut down and delivered to the railroads at prices well below those the same wood would have fetched in eastern or urban markets. "When one locality is exhausted," wrote Kern, "the scene of slaughter of the valuable young timber is simply shifted to another."[43]

The preference for oak and other hardwoods meant that areas that had, on the whole, escaped the worst ravages of commercial lumbering, such as the Appalachians, the Ozarks, southern Wisconsin, Michigan, Illinois, and Indiana, now became major sources of ties. The tributaries of the Ohio flowing off the Appalachians, such as the Tennessee, Cumberland, Green, Kentucky, Licking, and Kanawa, were main lines of production and movement. In Missouri, the oaks of the Ozark plateau fed the railroad network that radiated out from St. Louis in all directions, and indeed, St. Louis became the main crosstie market in the country at about the time of World War I. Although well over 60 percent of the ties were oak and another 5 percent chestnut, the shortfall had to come from other species elsewhere in the country, and the price of oak and chestnut ties was correspondingly high (figure 7). For example, hemlock and tamarack came from the northern areas around the Lake States (3.4 percent), together with red and white cedar (6.8 percent), all of which flowed south through the major lumber market of Chicago to be distributed across the prairies.

Individual Chicago merchants such as Edward Ayer, who controlled two-fifths of the Chicago cedar-tie market, could fill individual orders ranging from 1 to 2.6 million ties for companies like the Burlington and the Santa Fe. For

42. Quoted by Kern, *The Relation of Railroads to Forest Supplies*, pp. 15–16.

43. Sherry H. Olson, *The Depletion Myth: A History of Railroad Use of Timber* (Cambridge, Massachusetts: Harvard University Press, 1971), pp. 28ff; and Kern, *The Relation of Railroads to Forest Supplies*, pp. 19–20.

the first time the eastern slopes of the Rockies became a major source of commercial timber as crossties were floated down the east-flowing rivers to meet the lines advancing westward across the prairies.[44]

For the railroad companies the supply of timber never seemed in doubt throughout the 1880s and 1890s. But the government foresters and the conservation publicists thought otherwise: from Fuller to Hough, and through the succession of personalities such as Egleston, Kern, and particularly Bernhard E. Fernow, the crosstie industry was a central focus in concerns about timber depletion. The railroads were identified as a major cause of the depletion because they had spread into all regions of the country, and moreover their effects on the forests could be calculated precisely from the length of the line and the rate of replacement. In addition, the railroad was a popular target for two kinds of social critics: those who did not like "big business" and those who feared the railroads' disruptive social effects on the countryside.

Bernhard Fernow, who became chief of the Forestry Division after Egleston in 1886, saw the railroad tie question as a new and positive means of promoting forestry interests and the fortunes of his fledgling division. In addition, the issue fitted well into his strategy of reversing forest depletion by convincing large users to use timber rationally and economically. Nearly every annual report of the division under Fernow drew attention to the impending dearth of supplies and the railroads' contribution to that crisis.[45]

Kern also argued that the "reckless system of forest clearing" for ties could not go on indefinitely; the forest supplies would run out. He suggested two remedies: the preservation of timber to prevent rotting, and the planting of new trees to make good the deficiencies.

The impregnation of wood with chemicals had made little headway in the United States, although zinc chloride and creosote had been used in Europe since the beginning of the century. The cost of creosoting was high, and though it had a good effect in maritime conditions, its efficacy had not been proven for ties. One problem with treatment of all kinds was the mistaken idea that fungal growth was a symptom rather than a cause of decay and therefore that treating the outside of a tie could arrest or prevent decay even if fungal growth had already taken hold in the heart of the unseasoned wood. Creosoting worked, as did most impregnating methods, only under intense pressure, and was so expensive that a treated softwood tie of hemlock or cedar might ultimately cost as much as an untreated oak tie but last no longer. Consequently, although information on treatment was available from about 1885 onward, few railroads attempted to preserve their ties. Instead rapid rates of replacement continued throughout the 1890s, and the railroad companies economized by using better purchasing procedures, better stockkeeping of supplies, mergers, and consolidations.

A few railroads did preserve their ties. The Santa Fe established a treatment works at Las Vegas, New Mexico, and the Union Pacific at Omaha, Nebraska, as early as 1881, but these were isolated instances. Preservation plants made little headway until the price of timber rose as supplies dwindled after 1900. Then the ten plants in the country increased rapidly to 70 in the space of a few years and reached 102 at the outbreak of World War I. During and after the war a very substantial proportion of ties of all kinds were treated as methods became more reliable and costs of treatment declined both absolutely and relatively.[46]

Kern's second solution, planting trees, was far less effective than chemical preservatives in combating railroad timber depletion, but was far more attractive and eye-catching. Tree planting was an emotional issue that had already captured the imagination of the settler on the plains west of the ninety-sixth meridian. Arbor Day was proclaimed in 1872, the Timber Culture Act went through Congress a year later, and the rain-making debate was still in full swing during the late 1880s and early 1890s, at the very time the railways were beginning to fire up the timber depletion debate. Andrew Fuller had proposed forest plantations back in 1866 when he pointed out "how simple it would be for the railroad companies to have a few acres of forest trees every few miles all along and contiguous to the line." By 1872 the Burlington and Missouri River Railroad had invested moderately in plantations, as had the St. Paul and Pacific in southern Minnesota—not for timber, it must be stressed, but for snow fences and windbreaks, and as a part of their programs to encourage settlement and expand traffic along their lines.[47]

Perhaps the first serious experiment to grow trees for timber was by H. H. Hunnewell, in 1877 at Farlington in Crawford County, Kansas. Hunnewell, who was president of the Kansas City, Fort Scott, and Gulf Railway, planted about 640 acres of catalpa, which did well and was first thinned out in 1894–95. This, and many similar small projects, attracted enormous attention. Indeed, the Forestry Division bulletins and the general literature on arboriculture give the impression that these insignificant experiments were the main and even the only concern of forestry during these decades. The American Forestry Congress held in Cincinnati and Montreal in 1882 heard papers on catalpa and locust by eminent figures like Hough. The reports were glowing: "These stately blocks of young and thrifty trees, sprung up as if by magic on a treeless plain" was typical prose. Public pressure, combined with price rises for ties between 1895 and 1907 and Forest Service

44. Olson, *The Depletion Myth*, p. 25; Fernow, *Consumption of Forest Supplies*, p. 14; and William H. Wroten, "The Railroad Tie Industry in the Central Rocky Mountain Region, 1867–1900," (Ph.D. diss., University of Colorado, 1956).

45. Andrew Denny Rodgers, *Bernhard Eduard Fernow: A Story of North American Forestry* (Princeton, Princeton University Press, 1951), p. 109; and Fernow, *Consumption of Forest Supplies*, p. 14.

46. Hough, *Report Upon Forestry* 1:116–17; Kern, *Relations of Railroads to Forest Supplies*, p. 20; Olson, *The Depletion Myth*, pp. 57, 63–68, 104–9.

47. Fuller, *Forest Tree Culturist*, p. 12; and Richard C. Overton, *Burlington West: A Colonization History*, pp. 103–105.

predictions for further price increases, caused some companies to plant trees along their tracks.[48]

Yet the plantations were few and insignificant—only about four dozen locations and at most fifteen thousand acres were affected over thirty years. If the trees had all come to maturity and been good merchantable timber, they would have supplied ties for less than ten days at the 1910 rate of consumption (figure 7). The enthusiasm over catalpa, black locust, cottonwood, willow, and eucalypt was largely optimistic. The plantations did not make the money their promoters had forecast and many were located outside the natural limits for the species planted. However justified the plantations were as snow fences, windbreaks, or aesthetic settings for stations, they came nowhere near to filling the timber needs of the railways. By 1915 or thereabouts, the experiment in planting was largely over.[49]

The debate over timber depletion due to the railroads had one other immediate effect. Bernhard Fernow promoted timber savings not only through planting and preservation, but also through substitution and timber science. The first merely promoted the use of steel, stone, and live hedges where wood had been used before.

Timber science offered more complex remedies. Fernow believed that bridges and ties could require 20 to 25 percent less wood if the proper kind of timber was used. Railroads were becoming efficiency-conscious and had access to distant supplies. Fernow reasoned that they could, therefore, select the best timber for the job, unlike farmers who relied on their own woodlots for building materials and fuel. Under Fernow's direction thousands of tests were carried out on the strength and durability of timbers, on air seasoning, on tie preservation, and on every aspect of timber physics. Fernow's tests proved that the formerly despised chestnut oak was perfectly interchangeable with the favored white oak as a tie timber, and that southern pines were all of very similar quality and equalled northern white pine as a bridge timber. Both findings appealed to economy-conscious railroads. Though Fernow's experiments were stopped in 1896 when Congress diverted funds away from material research to tree planting and forest management, the important test centers that arose out of his program became in 1910 the nucleus of the Forest Products Laboratory in Madison, Wisconsin.[50]

What, then, was the impact of the railroads on the forest resources of the country? Kern's figure of nearly 300,000 acres of forest cut over every year was, to a certain extent, lost sight of in the tangled debates and conflicting claims for preservation, planting, substitution, and scientific testing, none of which could significantly diminish the overall impact of the railroad on the forest. In general terms, Kern's calculations corresponded with the 1911 estimates of the Forest Service, which calculated that with an annual average renewal rate of 350 ties per mile of track, and an average cut of 200 ties per forested acre, some 290,000 acres of woods were consumed in 1880 and 445,000 acres in 1890 (table 3).

Table 3. Estimates of Railroad Ties Used and Acres of Forest Cleared, 1870–1910

	Miles of track	Millions of ties renewed annually	Millions of ties used on new construction	Total millions of ties annually	Thousands of acres of forest cleared
1870	60,000	21	18	39	195
1880	107,000	37	21	58	290
1890	200,000	70	19	89	445
1900	259,000	91	—	—	—
1910	357,000	124	—	124	620

From Olson, *The Depletion Myth,* p. 12.

As Sherry Olson has pointed out in her penetrating study of the railroad-tie industry, figures of nearly half a million acres cut annually by the turn of the century must be augmented to take into account wood used for the construction and replacement of buildings, rolling stock, and bridges. Olson does not point out, however, that the mileage of urban electric railways also increased from 1890 onward and added about another thirty thousand miles of track by 1910.[51] The railroads were using one-fourth to one-fifth of the nation's annual timber production during the latter part of the nineteenth century, and the view that the railroad was "the insatiable Juggernaut of the vegetable world," while a little exaggerated, was essentially correct.[52]

Each of the impacts on the forest examined here declined with time. First coal, then electricity and gas were substituted for firewood in heating homes; charcoal gave way to coke for smelting iron; fuelwood was replaced by coal on the steam locomotives. Although nothing has really been a successful subtitute for wooden ties, the number needed has declined as railroads have decreased the miles of track maintained. None of these uses have important impacts on the forest now, but from our contemporary viewpoint it is all too easy to forget that the abundance and widespread availability of wood were probably mainsprings of the country's industrialization during the second half of the nineteenth century. Without its wood America would not be the country it is today. ▲

48. Kern, *The Relation of Railroads to Forest Supplies*, p. 24; Hough, "Tree Planting by Railroads," in Hough, *Report Upon Forestry* 1:118–22; and William L. Hall and Herman von Schrenk, *The Hardy Catalpa*, U.S. Department of Agriculture Forest Service Bulletin 37 (Washington, D.C.: GPO, 1902).

49. Olson, *The Depletion Myth*, pp. 93–95.

50. Fernow, *Consumption of Forest Supplies*, pp. 15–16; Fernow, *Report Upon the Forestry Investigations of the United States Department of Agriculture, 1877–1898* (Washington, D.C.: GPO, 1899), p. 22; Rodgers, *Bernhard Eduard Fernow*, pp. 174–83, 187–91, 239–40. See also E. E. Russell Tratman's *Report on Substitution of Metal for Wood in Railroad Ties*, U.S. Department of Agriculture Forestry Division Bulletin 4 (Washington, D.C.: GPO, 1890); Charles A. Nelson, *A History of the U.S. Forest Products Laboratory (1910–1963)* (Madison, Wisconsin: Forest Products Laboratory, 1971), pp. 25–33.

51. Olson, *The Depletion Myth*, pp. 12–13; and U.S. Bureau of the Census, *Historical Statistics*, part 2, p. 727.

52. Olson, *The Depletion Myth*, p. 14, quoting Howard Miller in *The Forester* 3 (January 1897), p. 6.