Historical Perspective on the Relationship between Demand and Forest Productivity in the US South

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Global Wood & Fiber Supply Chain Experts

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Forest2Market's mission is to empower participants in the global forest, wood products, paper products, biochemical and bioenergy industries to make exponentially better decisions through the strategic application of industry expertise and unique datasets.

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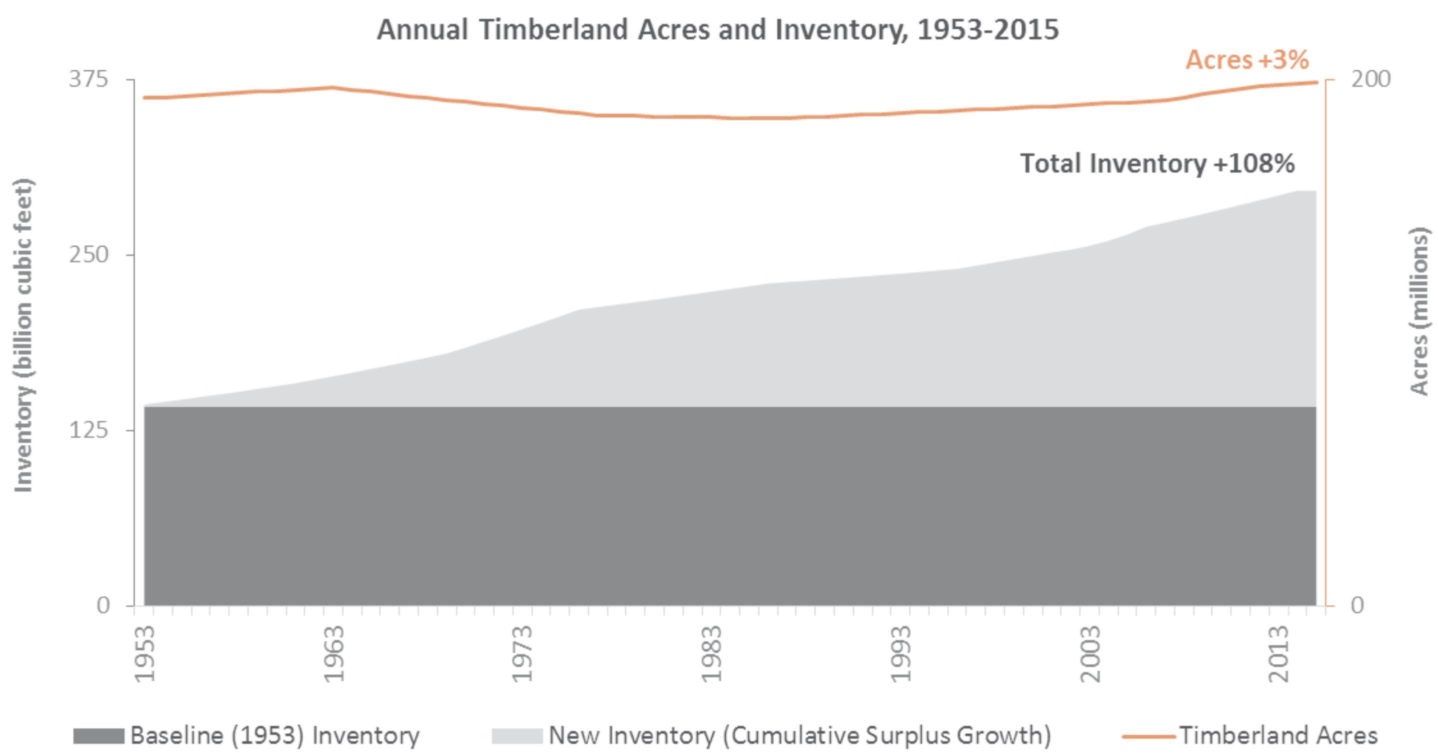
Increased demand for wood did not deplete forests in the US South; instead, it encouraged landowners to invest in productivity improvements that dramatically increased the amount of wood fiber, and therefore the amount of carbon, contained in the South's forests.

Since the middle of the twentieth century, the amount of timberland—unreserved, productive forest land—in the US South has remained stable, increasing by about 3 percent between 1953 and 2015. During this period, economic growth and increased construction spurred consumer demand for forest products, which led timber harvests—or removals—to increase 57 percent. Yet over this same period, the amount of wood fiber—or inventory—stored in Southern forests increased 108 percent.

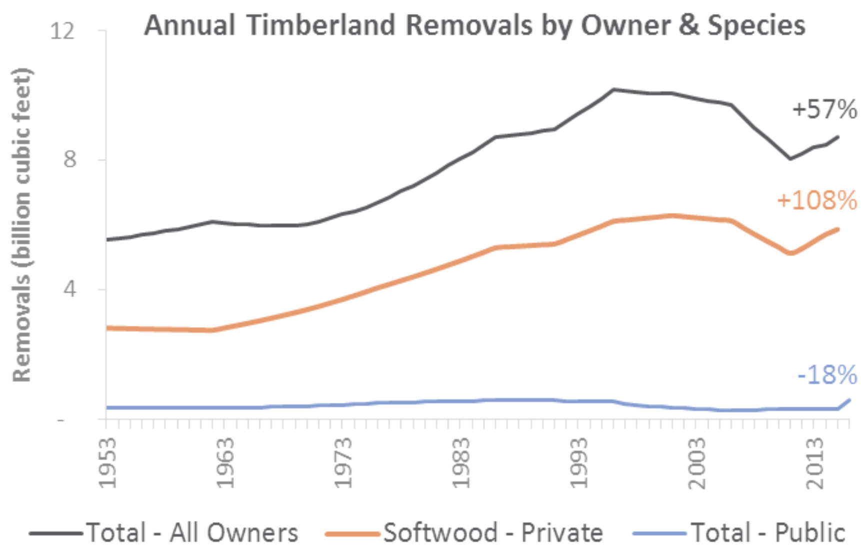
Forest2Market's in-depth analysis of historical data over the past six decades documents the link between increased demand and increased inventory. Further, it explains that the dramatic increase in forest inventory was made possible by even more remarkable increases in productivity, especially on privately-owned timberlands. Encouraged by strong demand from the forest products industry, landowners made the long-term investments that were necessary to significantly improve forest productivity and increase inventory on a stable land base.



Rising Demand for Forest Products Increased Removals from Timberlands

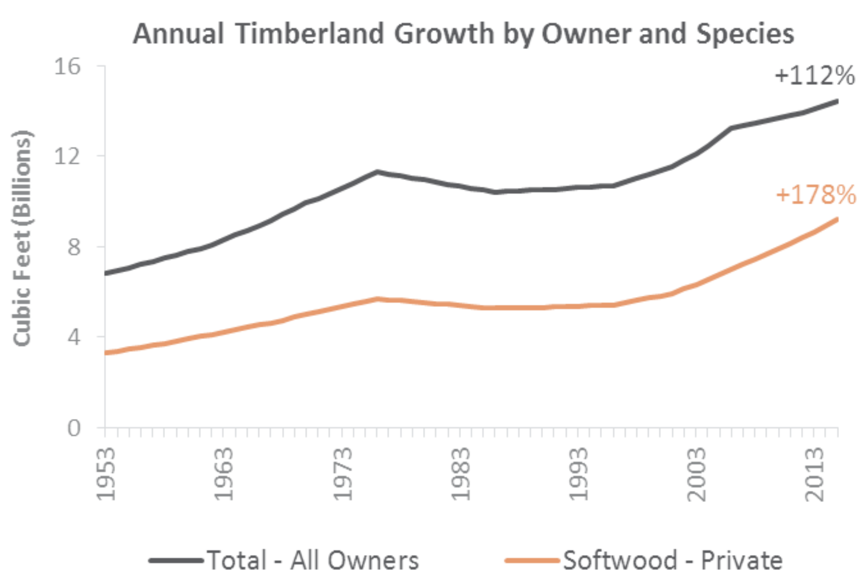
During the latter half of the twentieth century, demand for forest products expanded significantly as the US population and Gross Domestic Product (GDP) increased. Americans built more and larger homes and, until the dawn of the digital era in the 1990s and 2000s, consumed more and more paper to conduct their business and supply their homes. All of this fueled demand for timber to make the many forest products Americans use daily; as a result, timber removals nearly doubled from 5.5 billion cubic feet in 1953 to a peak of 10.2 billion cubic feet in 1996.

Around the turn of the century, technological improvements reduced demand for printing and writing papers, and increasing imports reduced demand for domestically-produced lumber and panels. The housing bubble of the mid-2000s buoyed domestic lumber and panel production until the Great Recession dramatically reduced housing starts and demand for these products. Today, timber removals, which have recovered due to improving housing markets, increased demand for personal hygiene and packaging products and new demand from emerging bioenergy markets, are still below their 1990s peak, but they are 57 percent higher than they were in 1953—due largely to increased removals from private softwood stands.



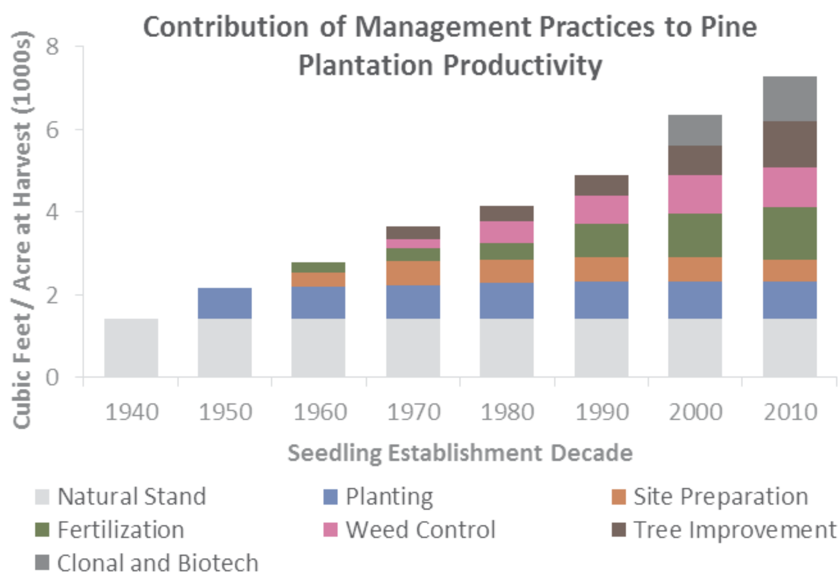
The Forest Products Industry and Landowners Responded by Increasing Forest Productivity

By the 1950s, the pulp and paper industry migrated south to take advantage of fast-growing southern yellow pine in the region's second-growth forests. Feedstock came from local landowners' and company-owned lands. As the companies and the timber on their lands grew, some diversified into supplying local sawmills, and some became vertically integrated and owned their own sawmills. In this model, lower-value small-diameter trees (i.e., pulpwood) were directed to the companies' pulp or paper mills while higher-value larger-diameter trees (i.e., sawtimber) were used by their sawmills to produce lumber or plywood.



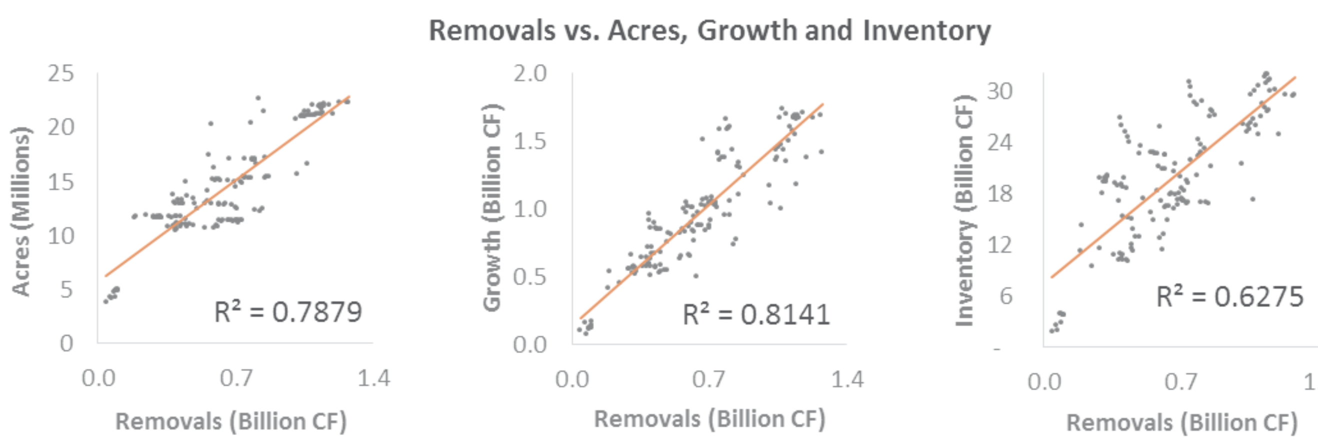
In order to ensure that their mills would have a stable, high-quality source of supply, forest products companies invested heavily in research to promote forest productivity. This research, which was conducted in partnership with the US Forest Service, university forestry departments, state agencies and industry partners, resulted in fact-based improvements to forest management practices, including site preparation, fertilization, weed control and thinning. These efforts also enhanced the quality and survival of seedlings.

The result was an astounding almost fourfold increase in the amount of growth achievable for seedlings established in the 2000s compared to seedlings established in the 1950s. Largely because of the implementation of these practices on privately-owned lands, total annual timberland growth increased 112 percent between 1953 and 2015, and growth exceeded removals by 38 percent on average. Healthy demand made it easy for corporate and family landowners to take a long-term view, investing in more expensive management practices up front for greater returns in the future.



The Evidence Is Clear: Increased Demand for Forest Products Is Associated with More, Not Less, Productive Forests

Demand from the forest products industry has not resulted in dramatic losses to the South's timberlands. Quite the opposite is true, in fact, as shown by both the historical data, which documents increases in timberland removals, acres, growth and inventory, and Forest2Market's independent statistical analyses. Statistical analyses show that increased demand in the US South is associated with *more* acres, *better* growth and *larger* inventories. These relationships are strong and statistically significant.



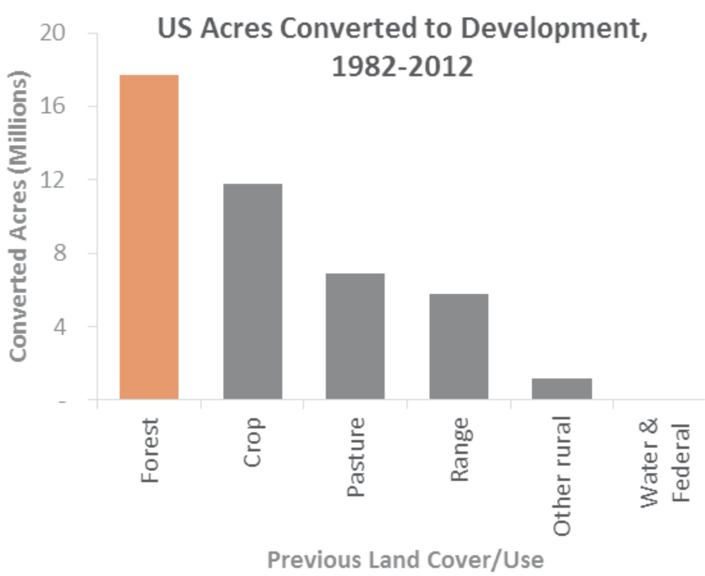
These results also bear out in Forest2Market's case study analyses of local wood basins surrounding Flint River, Georgia and St. Joe, Florida from the 1970s to today. These local wood basins tended to follow larger Southwide trends despite the fact that Flint River experienced the opening (in 1981) and St. Joe experienced the closing (in 1998) of a pulpwood-consuming mill. In both areas, sawtimber and pulpwood inventories increased alongside increased removals because annual growth outpaced annual removals. Further, the case studies show that markets and forests were not defined by changes in demand from a single mill, but rather market-wide shifts in the demand for all wood products. However, the case studies also show that when these basins had an active, centrally-located pulpwood-consuming mill, plantation acres increased more quickly, which helped retain total timberland acres in the face of declining naturally-regenerated timberlands.

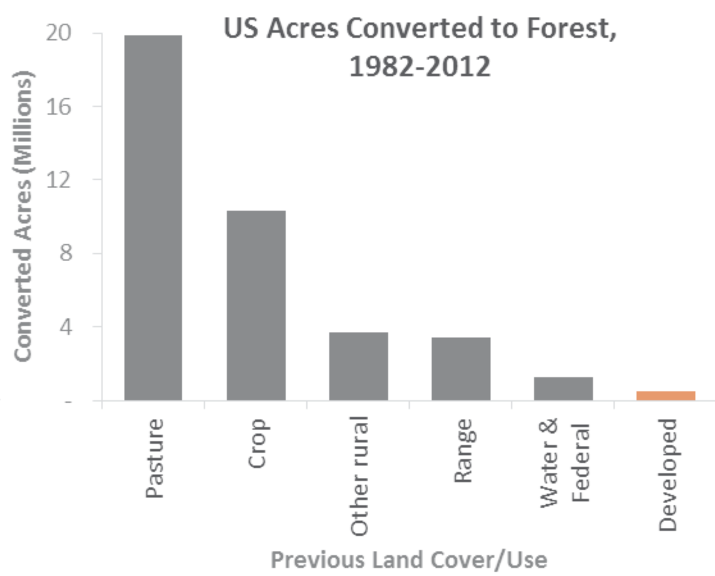
Percent Change in Annual Removals, Growth and Inventory by Basin and Product, 1970s-2015

Basin	Measure	Sawtimber	Pulpwood	Basin	Measure	Sawtimber	Pulpwood
Flint River, Georgia	Removals	▲ +17%	▲ +178%	St. Joe, Florida	Removals	▲ +164%	▲ +478%
	Growth	▲ +46%	▲ +41%		Growth	▲ +164%	▲ +159%
	Inventory	▲ **+70%**	▲ **+22%**		**Inventory**	▲ **+167%**	▲ **+122%**

The Biggest Threat to Forests Is Urbanization, Not the Forest Products Industry

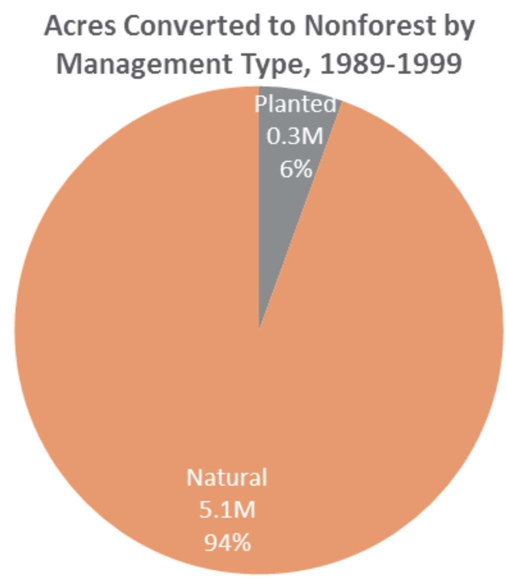
As with the total area of Southern timberland, the total amount of forest land in the United States has been stable in recent years according to US Department of Agriculture data. However, while total acreage has remained stable, US forests have not been impervious to change. National land cover/use data show that approximately 36 million acres of forestland converted to other land cover/use types between 1982 and 2012. Of these converted acres, 17.7 million acres (49 percent) were lost to development, more than any other single land cover/use type. While forest land converted to other uses, other land use types also converted to forest, resulting in a 0.7 percent net increase in forest acres. However, of the 39 million acres of land that converted to forest during this same period, only 0.5 million acres, or 1.2 percent, were previously developed; most were previously pasture or cropland.





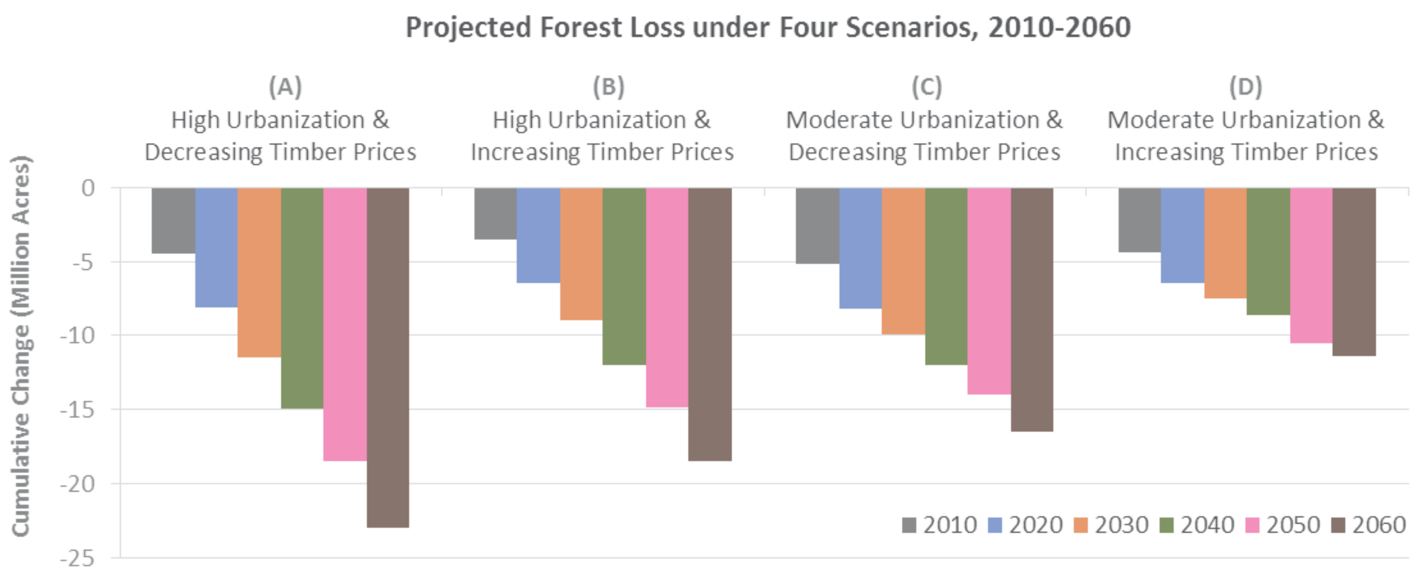
These data show that developed land uses, which expanded by 58.7 percent between 1982 and 2012, place undeniable pressure on forests. Further, once developed, land rarely ever reverts back to forests. Urbanization, not the production of forest products, is the single biggest threat facing forests today. While landowners harvest timber from their lands, they typically also regenerate that timber and keep forests forested, especially if they can find readily accessible, healthy markets for their timber.

Healthy Demand for Forest Products Mitigates Forest Loss



Demand from the forest products industry helps protect forests. For example, planted stands, which are some of the most productive, have been the least likely to succumb to the pressures of conversion. Between 1989 and 1999—the only period available for this kind of analysis—5.4 million acres of stocked timberlands in the US South were converted to nonforest uses. Of these lost acres, the overwhelming majority (94 percent) were naturally-regenerated forests, not planted stands. Not only does demand for forest products increase the productivity of forests and provide an incentive for landowners to continue growing trees, it also helps counter factors—like development—that *irrevocably* destroy this natural resource.

While timberlands in the US South have been stable to increasing since the 1950s, the pressures of urbanization are projected to result in forest loss over the coming decades. While forest loss to development is projected to continue, healthy markets for timber products are expected to mitigate, not exacerbate, the losses. One analysis by the US Forest Service modelled shifts in non-Federal forestland under four different scenarios, which varied in the amount of urbanization projected to occur and shifts in the future value of timber. Their results predicted that higher urbanization and decreasing prices for timber—Scenario A—resulted in the most forest land loss. Moderate urbanization and increasing prices for timber—Scenario D—resulted in the least forest land loss.



As with almost any product, high demand encourages producers to increase, not decrease, supply; demand for forest products is no different. As Forest2Market's comprehensive analysis of the South's forests since the 1950s shows, strong demand for forest products incentivizes landowners to maintain their timberlands and invest in forest productivity in order to increase supply, which resulted in more wood growing on trees in the South's forests. In the future, healthy markets for timber will continue to be, as they have been over the last six decades, key to keeping forested lands forested and to diminishing the threat of urbanization.

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1 EXECUTIVE SUMMARY

The project sponsors contracted Forest2Market, Inc. to analyze the relationship between demand and forest productivity. Both in terms of standing inventory and annual removals, the US South is the most productive timber-producing region in the United States. Therefore, our analysis focuses on the US South.

Our analysis showed the following:

1. **As demand for forest products has increased, timberlands in the US South have become increasingly productive.** Between 1953 and 2015, annual removals—driven by demand—increased 57 percent from 5.5 to 8.7 billion cubic feet. Simultaneously, annual growth increased 112 percent from 6.8 to 14.4 billion cubic feet.
2. **Increased demand for wood has not depleted forests.** The amount of timberland—unreserved, productive forest land—in the US South has remained stable, increasing by about 3 percent. Because annual growth has outpaced annual removals by an average of 38 percent (GRR=1.38), inventory increased 108 percent from 142.1 to 296.1 billion cubic feet.
3. **Removals increased as consumer demand for wood products grew.** Population growth, higher real Gross Domestic Product and greater utilization of wood for housing construction during periods of economic expansion spurred demand for forest products, including lumber, wood panels, pulp and paper products.
4. **Landowners responded to greater demand by investing in the future growth of their forests.** The forest products industry played a critical role in promoting increases in forest productivity by funding public-private research projects to improve tree genetics and update silvicultural practices, which increased growth and yield, especially on plantation stands. Consistent and increasing demand for forest products assured other private landowners that engaging in more active (and expensive) management practices would provide financial dividends, which ensured more widespread adoption of improved management practices.
5. **The evidence is clear: Increases in removals are associated with more timberland acres, better growth and larger inventories.** Removals have strong, positive, statistically significant correlations with acres, inventory and growth. Regression models that use removals to predict these measures of forest productivity are statistically significant and explain from 65 to 90 percent of the variance in acres, inventory and growth.
6. **Case study evidence confirms that increased removals are associated with increased inventory not only at a regional scale, but also in local wood basins.** Further, they demonstrate that the markets in local wood basins are defined not by changes in demand from a single mill, but rather market-wide shifts in the demand for all wood products, especially sawtimber. However, the case studies also show that when these basins had an active, centrally-located pulpwood-consuming mill, plantation acres increased more quickly, which helped retain total timberland acres in the face of declining naturally-regenerated timberlands.
7. **Today, the biggest threat to forests is urbanization, but this threat can be mitigated by healthy markets for forest products, especially for products from highly-productive plantations.** Nationwide, between 1982 and 2012, development was responsible for almost half (49.2 percent or 17.7 million acres) of all forest land that converted to other land uses.[1] Conversely, forests reclaimed very little (1.2 percent or 0.5 million acres) from developed areas. In the US South, the most productive plantation stands are best protected against conversion: Between 1989 and 1999, 5.4 million acres of stocked timberlands converted to nonforest uses. Of those that did, the overwhelming majority (94 percent) were naturally-regenerated forests, not planted stands.

[1] Total forested acres in the United States increased despite this loss to development only because pastureland, cropland and other land use types converted to forest.

1.1 Key Findings

1.1.1 Key Finding #1

As demand for forest products has increased, timberlands[2] in the US South have become increasingly productive. Between 1953 and 2015, annual removals—driven by demand—increased 57 percent from 5.5 to 8.7 billion cubic feet (Figure 1-1-A). Simultaneously, annual growth increased 112 percent from 6.8 to 14.4 billion cubic feet (Figure 1-1-B).

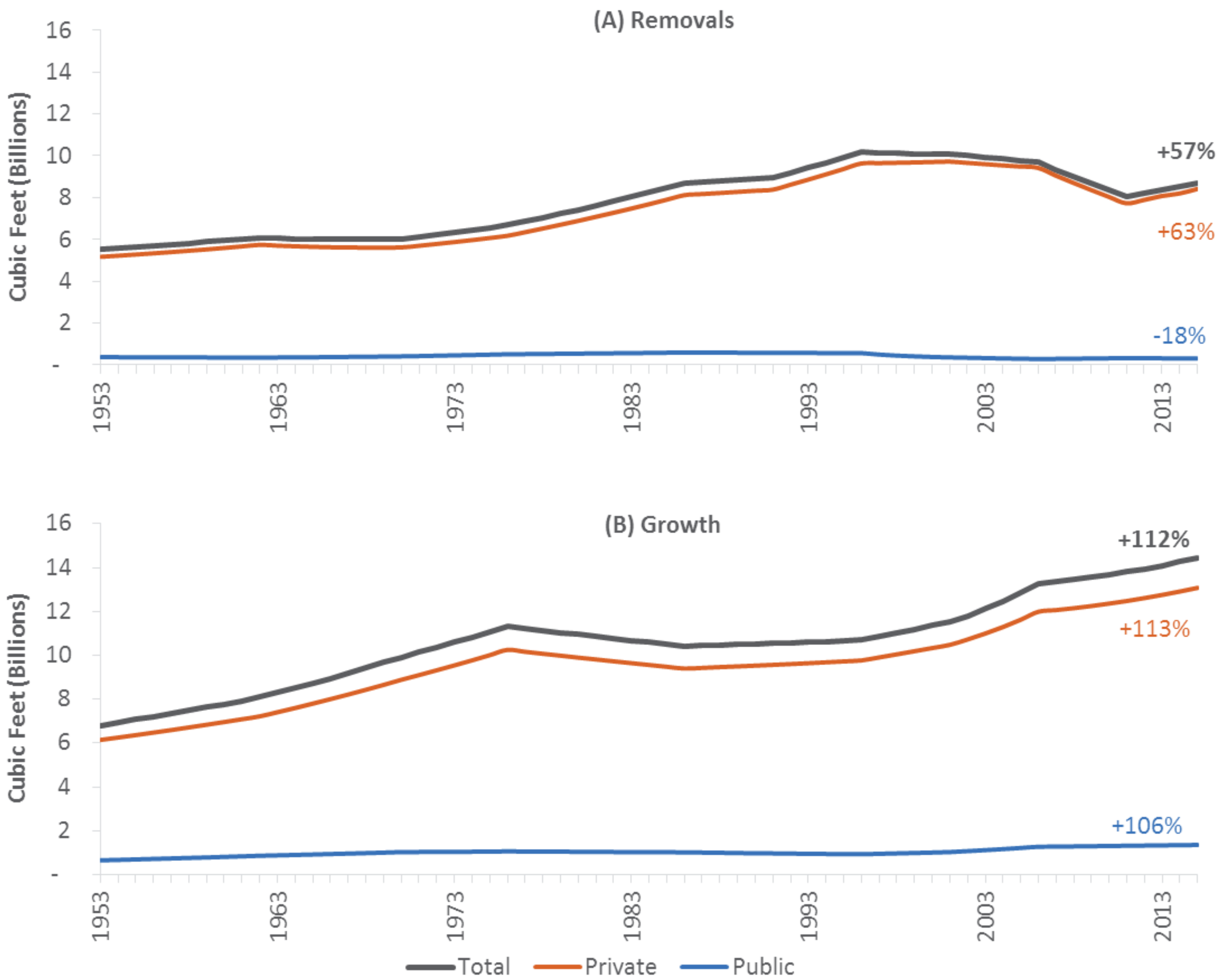

Figure 1-1 Annual Growing-Stock Removals and Growth by Ownership, 1953-2015 – US South
(Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.[3])

[2] Timberland, as used by the FIA, is a subset of forest land defined as "Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing at least 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)"
[3] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market proprietary transaction data. Growth and removals data include Kentucky.

- Annual removals increased from 5.5 billion cubic feet (BCF) in 1953 to a peak of 10.2 BCF in 1996 driven by increased demand for solid wood, pulp and paper products to support the growing population and economy (Figure 1-1-A). Removals remained at around 10.0 BCF through the late 1990s when technological improvements and increased imports reduced demand for domestically-produced wood products. The Great Recession of 2007 to 2009 caused further declines in wood fiber demand, especially in the solid wood and panel sector, which had previously been buoyed by rapid increases in housing starts during the early 2000s. In response, removals had sunk to around 8.0 BCF by the early 2010s. While removals increased to 8.7 BCF in 2015, they still have not reached pre-Recession levels.
- Annual growth increased at a rate of 1.2 percent annually from 6.8 BCF in 1953 to 14.4 BCF in 2015 in response to improved silvicultural practices and management on private timberlands and declining harvests on public timberlands (Figure 1-1-B). Private, corporate owners realized the biggest productivity improvements as the forest products industry sought to ensure a stable wood supply to support its manufacturing operations, and, after divestiture, financial management organizations sought to maximize the financial return on their timberland investments. Because of their efforts, annual growth increased 259 percent from approximately 1.5 BCF in 1953 to 5.3 BCF in 2015 on corporately-owned timberlands.

1.1.2 Key Finding #2

Increased demand for wood has not depleted forests. Between 1953 and 2012, timberland acreage in the US South has been generally stable and is trending upwards. The amount of timberland—unreserved, productive forest land—in the US South has remained stable, increasing by about 3 percent. Because annual growth has outpaced annual removals by an average of 38 percent (GRR=1.38), inventory increased 108 percent from 142.1 to 296.1 billion cubic feet.

- After increasing from 193.0 million in 1953 to 197.1 million acres in 1963, timberland acreage decreased to 185.3 million acres by 1987 and has since been on an increasing trend (Figure 1-2). By 2012, timberland acreage had reached 197.8 million acres, surpassing its previous 1963 peak. Current timberland acreage in the US South is an estimated 198.9 million acres, a net increase of 5.8 million acres (3 percent) since 1953.
- A decrease of 18.6 million acres (14 percent) in the amount of timberland owned by private, non-corporate owners was offset by a 14.0 million acre (31 percent) increase in corporately-owned[4] timberland and a 10.4 million acre (62 percent) increase in publicly-owned timberland (Figure 1-3).

[4] Until the mid-2000s, the US Forest Service reported private forest ownership under two categories: forest products industry and non-industrial private forest landowners (NIPF). Until this time, land held by Timberland Investment Management Organizations (TIMOs) or Real Estate Investment Trusts (REITs) was classified under the NIPF ownership category. Following the divestiture of many forest products industry lands to TIMOs and REITs in the late 1990s and 2000s, the Forest Service began grouping land held by these management entities together with the remaining lands held by the forest products industry in a new “corporate” category, largely to protect the confidentiality of forest industry owners. For more information on timberland ownership, refer to Section 5.1.

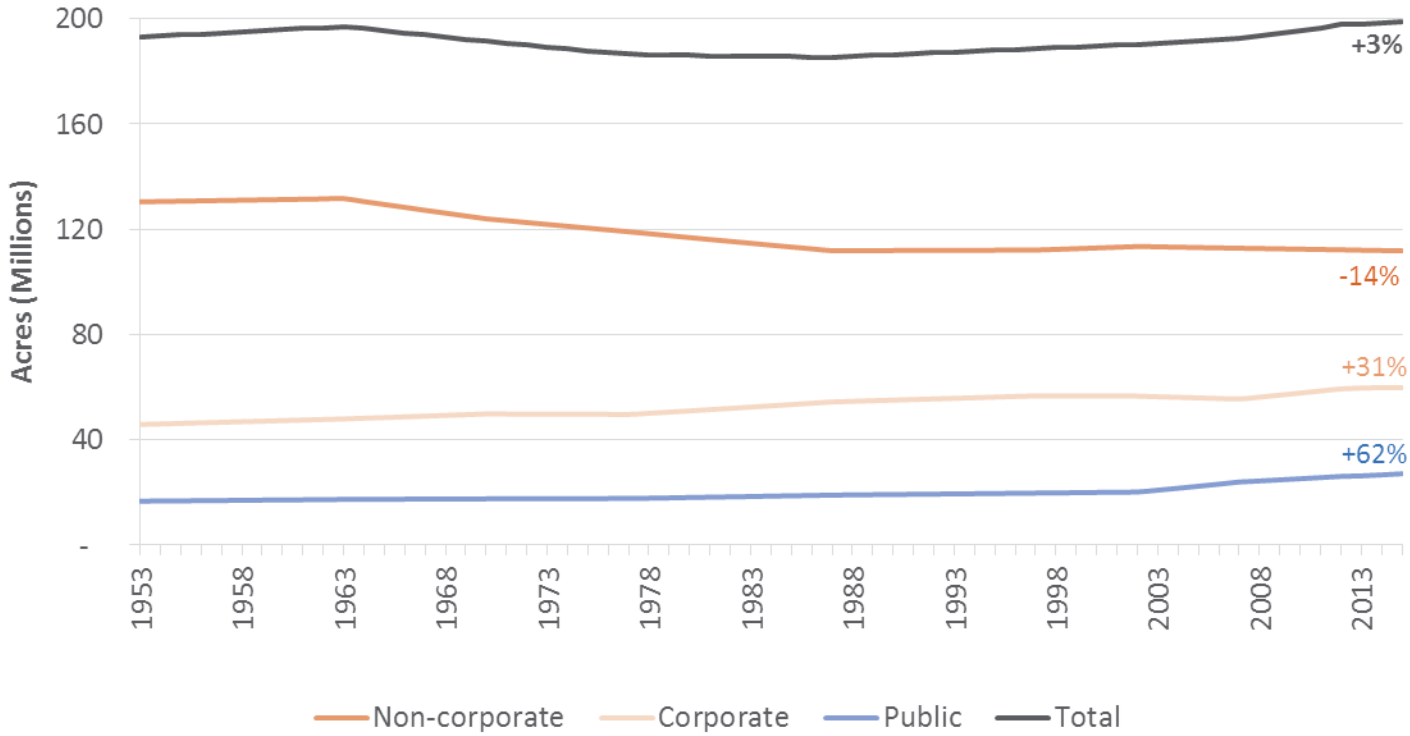

Figure 1-2 Timberland Acres by Ownership Group, 1953-2015
(Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.[5])

- On average, growth has exceeded removals on US South timberlands by 38 percent since 1953 (Figure 1-3).

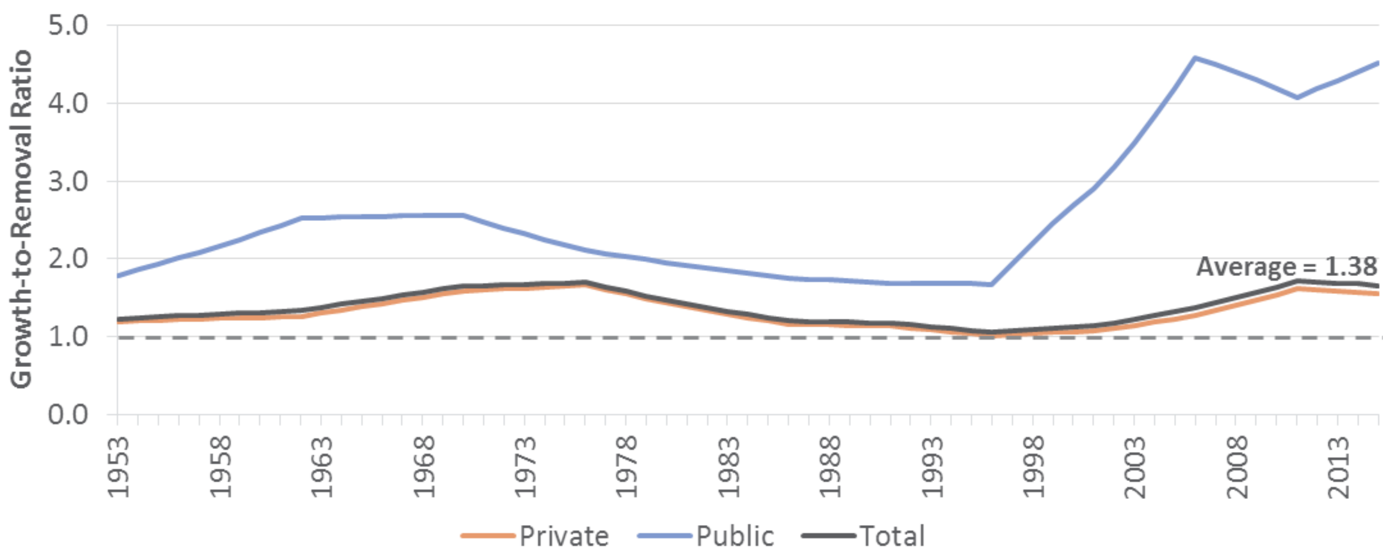

Figure 1-3 Annual Growing Stock Growth-to-Removal Ratios by Ownership, 1953-2015
(Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.[6])

[5] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market assumptions. Data exclude Kentucky. Also see Section 2.1.

- Because growth predominantly exceeded removals, the forest inventory of the US South continuously increased and more than doubled from 142.1 BCF in 1953 to 296.1 BCF in 2015 (Figure 1-4).

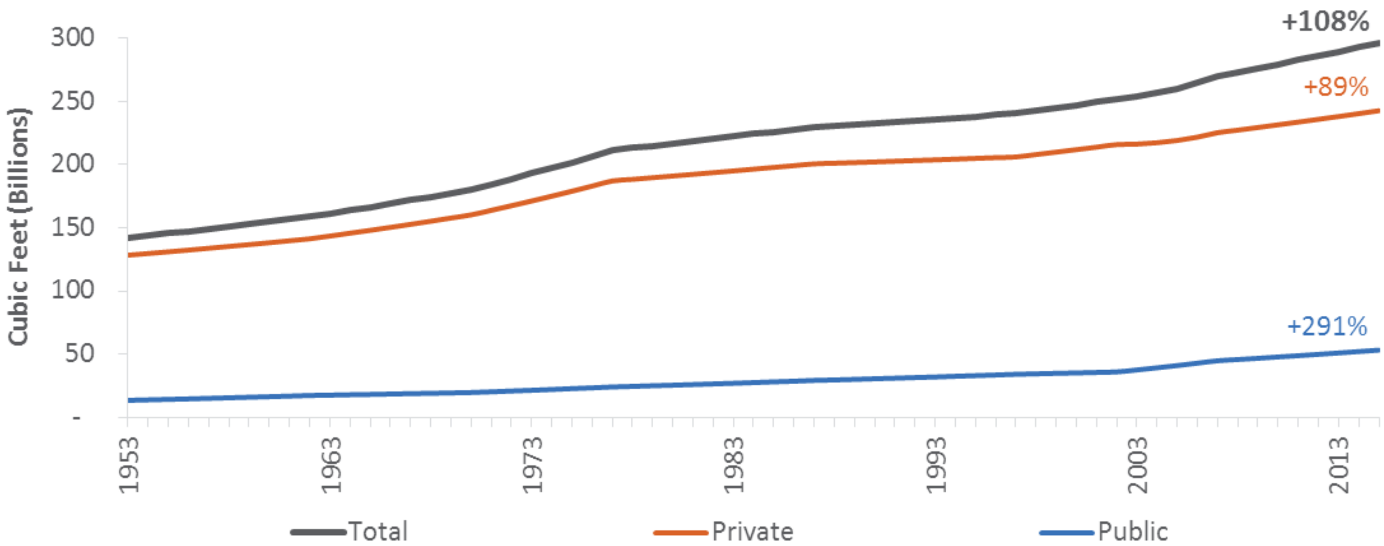

Figure 1-4 Annual Growing-Stock Inventory by Ownership, 1953-2015 – US South
(Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.[7])

1.1.3 Key Finding #3

Removals increased as consumer demand for wood products grew. Increased demand for wood products is the result of population growth, higher real Gross Domestic Product and greater utilization of wood for housing construction during periods of economic expansion. Increased removals since the 1950s were driven by increased demand for wood products, including sawnwood (i.e., lumber), panels (i.e., plywood, particle board), pulp and paper products.

- From 1953 to 2015, US population more than doubled from 159.0 to 321.4 million people, and real GDP increased over six-fold from $2.6 to $16.4 trillion dollars (Figure 1-5-A). These shifts increased the utilization of forest products, including paper, lumber and wood panels.
- While periods of economic expansion and recession caused annual housing starts to fluctuate in the United States, an average of 1.5 million private housing units were started annually between 1959 and 2006 (Figure 1-5-B), a steep increase over the meager 360,000 started annually[8] in the 1930s and 1940s. Homes also became larger: The average size of a single-family home increased from 1,498 square feet in 1965 to 2,687 square feet in 2015 (Figure 1-5-C). Together, these changes increased demand for lumber, plywood and particle board, the staples of American home construction.

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[6] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market proprietary transaction data. Data include Kentucky.

[7] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market proprietary transaction data. Inventory data exclude Kentucky.

[8] Source: Fedkiw 1989.

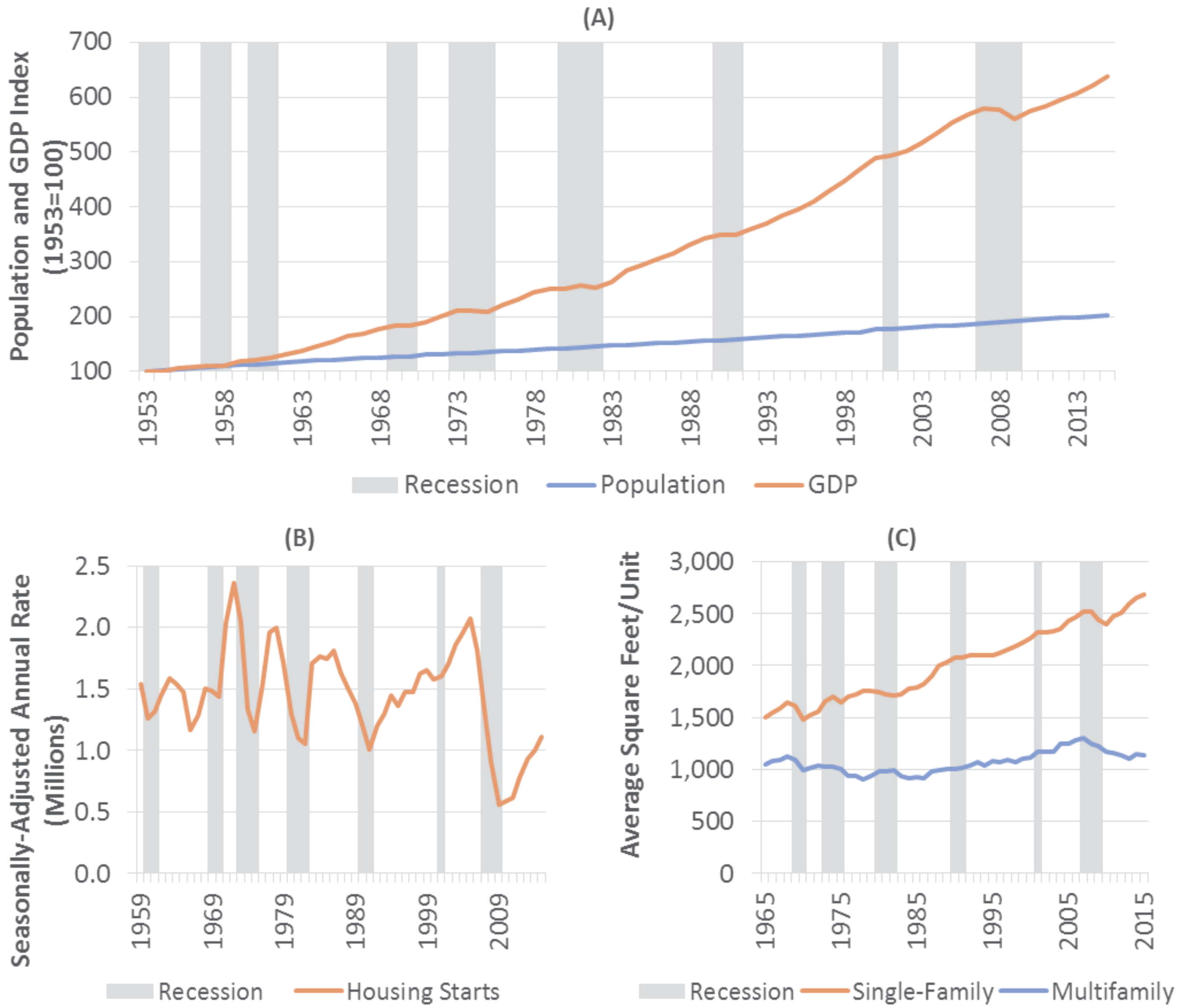

Figure 1-5 Changes in US Population, GDP, Housing Starts and Dwelling Unit Size, 1953-2015
(Sources: US Bureau of Economic Analysis 2016b, US Census Bureau [including data quoted in Howard and Jones 2016], National Bureau of Economic Research.)

- Pulp production peaked in 1994 at 58.4 million metric tonnes, 189 percent above 1961 production. Paper product production increased 237 percent to its peak of 127.6 million metric tonnes in 2007. Sawnwood production increased 67 percent through its peak of 97.0 cubic meters in 2005. Plywood and particle board production increased 321 percent to its peak of 38.5 cubic meters in 1999 (Figure 1-6).

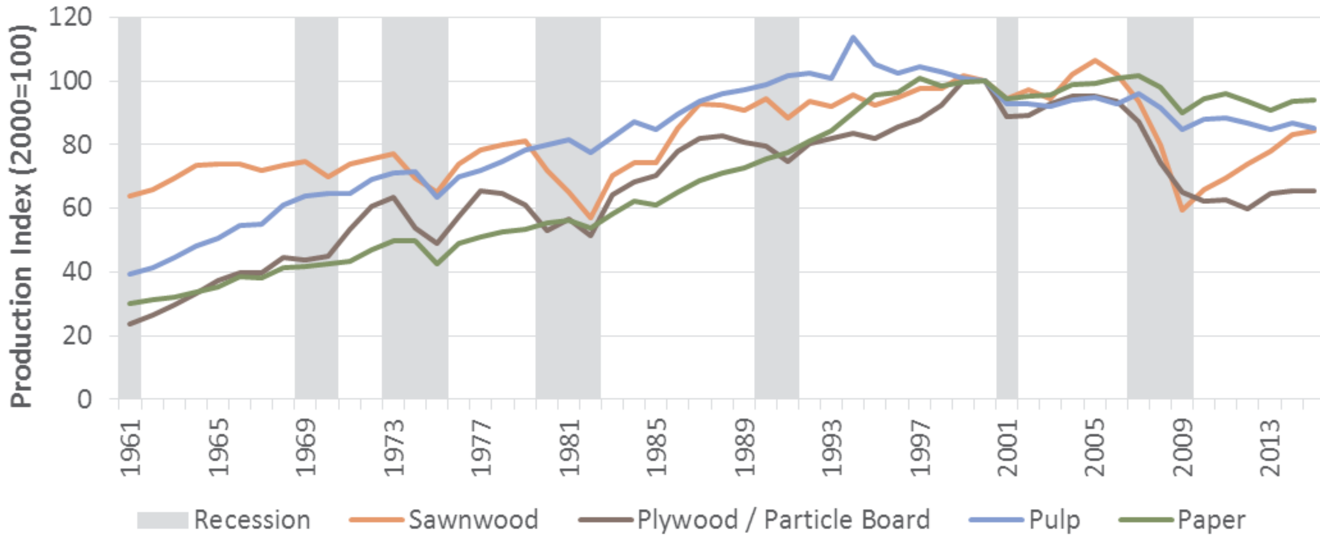

Figure 1-6 US Sawnwood, Panel, Pulp and Paper Production Indices (2000=100) and Economic Recessions, 1961-2015
(Sources: FAO 2016, National Bureau of Economic Research.)

- The Great Recession had a severe negative impact on the forest products industry, especially sawnwood and panel production, which decreased 44 and 35 percent, respectively, between 2005 and 2009 (Figure 1-6, Figure 1-7). Production is gradually improving but has not yet attained pre-Recession levels.

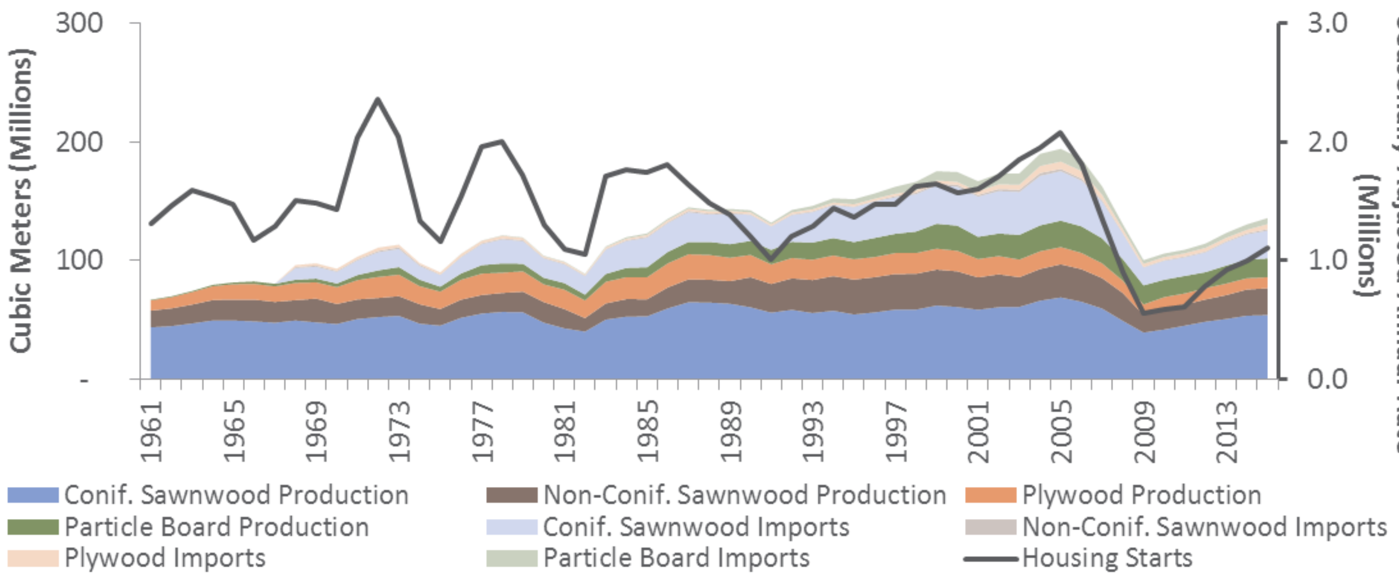

Figure 1-7 US Solid Wood and Panel Production Output and Imports vs. Housing Starts, 1961-2015
(Sources: FAO 2016, US Census Bureau.[9])

- While industrial wood pellet production in the United States has increased dramatically since 2009, its rate of growth has moderated and remains dwarfed by pulp and paper production (Figure 1-8).

[9] FAO import data is unavailable prior to 1968. Note: Particle board includes Oriented Strand Board (OSB).

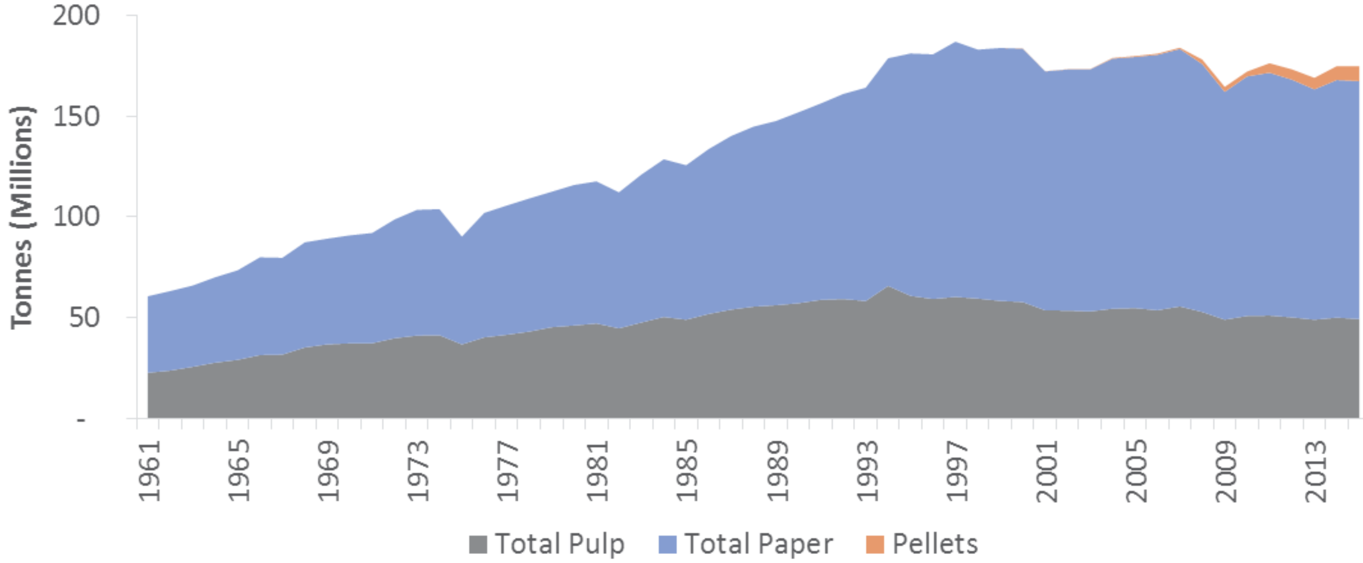

Figure 1-8 Total US Pulp, Paper and Pellet Production, 1961-2015
(Sources: FAO 2016, Forest2Market data and estimates.)

1.1.4 Key Finding #4

Landowners responded to greater demand by investing in the future growth of their forests. The forest products industry played a critical role in promoting increases in forest productivity by funding public-private research projects to improve tree genetics and update silvicultural practices, which increased growth and yield, especially on plantation stands. Consistent and increasing demand for forest products assured other private landowners that engaging in more active (and expensive) management practices would provide financial dividends, which ensured more widespread adoption of improved management practices.

- The rapid increases in Southern inventory since the 1950s coincided with consistent increases in forest products demand and removals through the mid-2000s. This increase in inventory alongside increasing removals on a relatively stable base of timberland acres could not have occurred without larger increases in growth.
- Private landowners have held an average of 90 percent of Southern timberland since 1953. Private owners' actions, therefore, are largely responsible for changes in forest productivity.
- To ensure stable and increasing supplies of raw material, the forest products industry made significant investments in timber production. Throughout the latter half of the twentieth century, the industry invested in collaborative public-private research programs to promote forest productivity.
- As a result of improved silvicultural practices, the output of plantations increased almost fourfold from 90 cubic feet per acre per year in the 1950s and 1960s to 350 cubic feet per acre per year in the 2000s (Figure 1-9).
- New knowledge and technology related to forest management and silvicultural practices were then passed on to non-industrial private landowners via landowner assistance programs. Government policies also promoted the retention and expansion of privately-owned timberland through land conservation policies, most notably the Soil Bank Act of 1956, which established the Conservation Reserve Program, and the 1985 Farm Bill, which reinstated it.

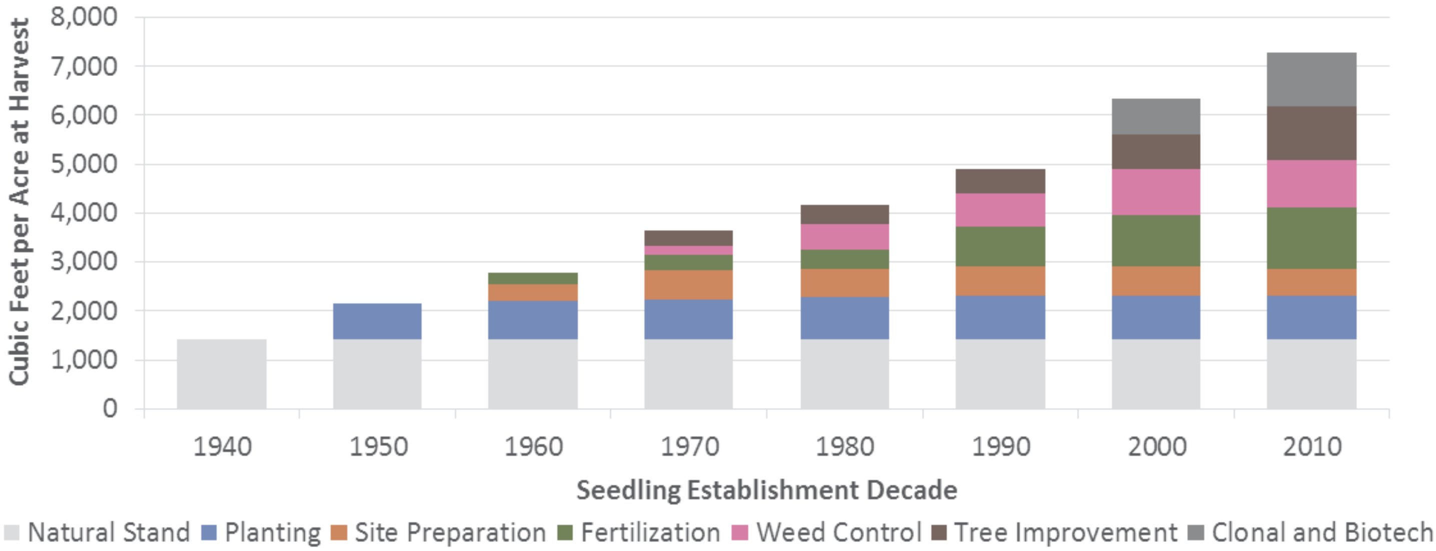

Figure 1-9 Estimated Contributions of Intensive Management Practices to Productivity in Pine Plantations in the US South, 1940-2010
(Source: Fox, Jokela and Allen 2004.[10])

- In total, growth per acre on private stands increased 118 percent from 35 cubic feet per acre in 1953 to 76 cubic feet per acre in 2015. In contrast, growth per acre on public stands increased just 27 percent from 39 to 50 cubic feet per acre (Figure 1-10).

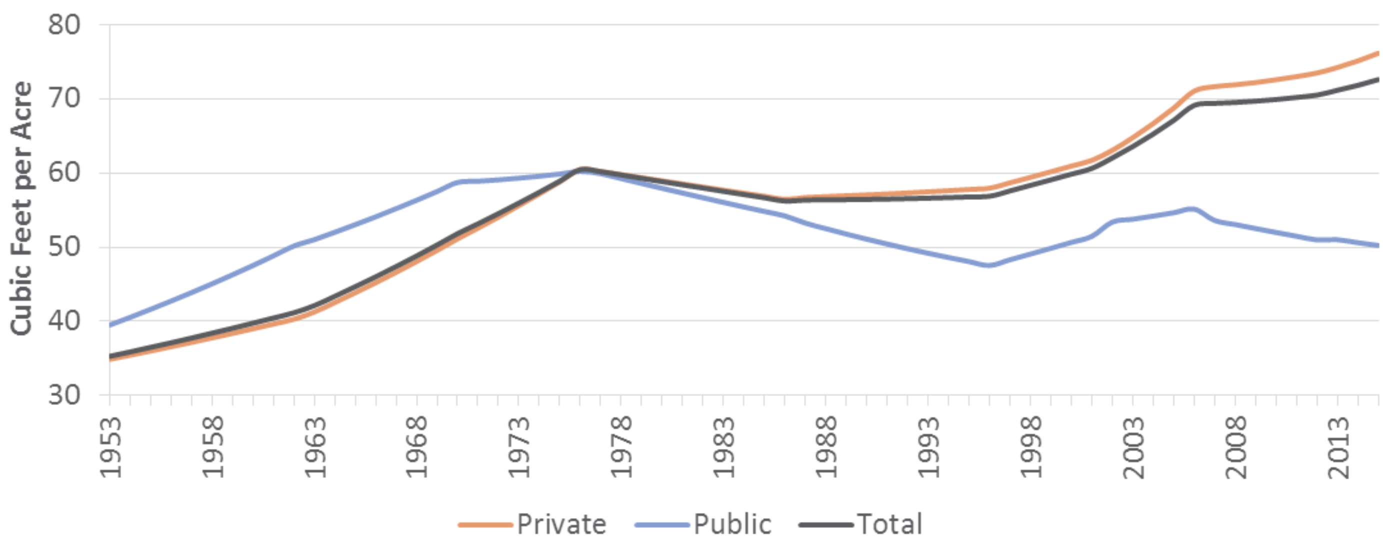

Figure 1-10 Annual Growing Stock Growth per Acre on Timberland by Ownership, 1953-2015
(Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.[11])

[10] Notes: Adapted from Figure 8.3 of original source. Data in the chart are approximated and may not be perfectly to scale. Approximate tons were converted to cubic feet using a conversion factor of 1 ton ≈ 34.48276 cubic feet. Data in the chart correspond to total harvest and are different than the annual yield data reported in text: Dividing totals in the chart by 15 would approximate the average annual productivity of plantations established at different times assuming a 15-year rotation.

- Driven by the desire to maximize productivity and government policies that encouraged planting, landowners—especially private landowners—increased their utilization of plantation pine management types (Figure 1-11). As a result, planted pine increased from 1 percent of timberland acreage in 1953 to 19 percent in 2010.
- The amount of timberland in hardwood management types increased by 6.3 million acres between 1953 and 2010; a decrease of 5.9 million acres of lowland hardwood timberlands was offset by an increase of 12.3 million acres of upland hardwood timberlands.[12]

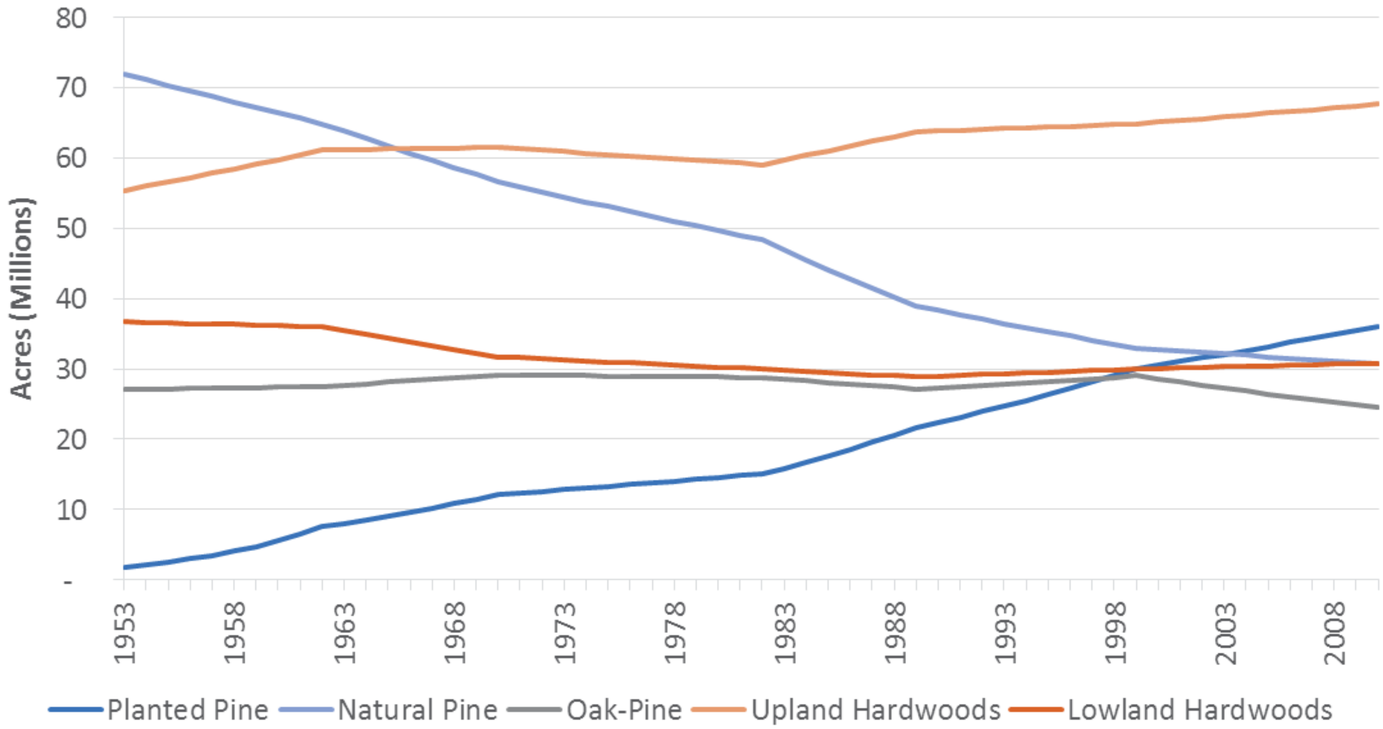

Figure 1-11 Annual Timberland Acres by Forest Management Type, 1953-2010 – All Ownerships
(Sources: Conner and Hartsell 2002, Hartsell and Conner 2013, Forest2Market estimates.[13])

[11] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market assumptions. Growth data include Kentucky; acreage data exclude Kentucky.

[12] May not sum to total due to rounding.

[13] Data for 1953, 1962, 1970, 1982, 1989, 1999 and 2010 from Conner and Hartsell 2002 and Hartsell and Conner 2013. Data for intervening years are derived by Forest2Market using annual rates of change between available data years. Data are for all ownerships and exclude nonstocked stands and Kentucky acreage. Also see Section 2.1.

- Neither all of the gain in plantation pine stands, nor all of the loss in natural stands can be attributed to conversion from natural to plantation management. While it is true that some naturally-regenerated stands are being converted to plantations, it is also true that nonforested stands are being converted to plantations and that natural stands are being converted to nonforested uses. Forest management data from 1989 to 1999 show that forest management practices are largely stable over the medium-term and that shifts in management types over time are more nuanced (Table 1-1).

Table 1-1 Ten-Year Trends in Forest Management Types on Areas that were Timberland in 1989
(Source: Conner and Hartsell 2002)

Status in 1989		Status in 1999						
Forest Management Type	Total Acres (Thousands)	Remained Plantation	Remained Natural	Remained Nonstocked	Became Plantation	Became Natural	Became Nonstocked	Became Nonforest
Planted Pine/Oak-Pine	24,798	89%				10%	0.1%	1%
Natural Pine	40,104		88%		8%		0.1%	3%
Natural Oak-Pine	23,850		92%		5%		0.0%	3%
Upland Hardwood	65,906		91%		6%		0.1%	3%
Lowland Hardwood	29,817		95%		2%		0.1%	3%
Nonstocked	75			29%	40%	21%		9%

1.1.5 Key Finding #5

The evidence is clear: Increases in removals are associated with more timberland acres, better growth and larger inventories. Analyses of privately-owned timberland in Southern states show that the observed historical relationships between Southwide demand and productivity are statistically significant.[14] Removals have strong, statistically significant, positive correlations with acres, inventory and growth, especially for softwood species (Table 1-2). Models that use removals to predict acres, inventory and growth are also statistically significant and explain between 65 and 90 percent of the variance in acres, inventory and growth (Figure 1-12).

- Removals are strongly and significantly positively correlated with timberland acres on a same-species basis (r=0.93 for softwood and r=0.81 for hardwood). Private softwood removals describe approximately 87 percent of the variance in private softwood acres. Hardwood removals explain less of the variance (66 percent) in hardwood acres.
- The strong, significant, positive correlations between removals and inventory are even stronger than those observed between removals and acres for softwood species: Softwood removals have an almost perfect positive correlation (r=.95) with softwood inventory. Private softwood removals describe approximately 90 percent of the variance in private softwood inventory. While somewhat smaller, hardwood removals still have a strong positive correlation (r=.80) with hardwood inventory. Hardwood removals explain approximately 65 percent of the variance in hardwood inventory, less than the variance in softwood inventory explained by softwood removals.

[14] In order to maintain consistency with published US Forest Service reports, this report used Southwide historical removals, inventory, growth and acres information sourced primarily from US Forest Service Resources Planning Act (RPA) reports, which are published every five to ten years. While some state-level data are available in the RPA reports, most forest metrics are based on the entire Southern region. Attempting statistical analyses on the regional RPA data would have limited the analysis to fewer, region-level data points. By analyzing individual inventory years of state-level data from the US Forest Service Forest Inventory and Analysis dataset, we were able to build a much more robust dataset for analysis. It should be noted that each point in the scatterplots that appears in corresponds to a single year of state-level inventory data and does not bear any direct relationship to the historical Southwide totals. For more information about the data source and methodology for the statistical analyses, see the introduction to Section 6.

- Removals are strongly and significantly positively correlated with growth on a same-species basis (r=0.91 for softwood and r=0.84 for hardwood). Private softwood removals explain approximately 84 percent of the variance in softwood growth. Hardwood removals explain a lower percentage of the variance (71 percent) in hardwood growth.
- There are several reasons why softwood removals bear a stronger relationship to acres, growth and inventory. First, plantations, which largely occur on softwood stands, typically are managed to maximize output to produce a steady supply of wood and/or to promote predictable financial returns; other objectives, such as recreation and wildlife habitat may be secondary. Plantation stands require more upfront financial investment (i.e., stand preparation, planting and upkeep costs), but they are also associated with high growth and more regular harvesting. Second, softwood species also have shorter harvest rotations than hardwood species. Third, hardwood stands, especially those owned by non-industrial private landowners, may be managed with more diverse management objectives, and timber output may not be the landowner's primary goal.

Table 1-2 Pearson Correlations between Removals and Acres, Inventory and Growth by Species, 1968-2015
(Sources: US Forest Service Forest Inventory and Analysis database, Forest2Market calculations.)

Pearson Correlations (p-values)								
Softwood Removals			Hardwood Removals			Total Removals		
Softwood Acres	0.93056	(p<.0001)	Hardwood Acres	0.81413	(p<.0001)	Total Acres	0.88763	(p<.0001)
Softwood Inventory	0.95007	(p<.0001)	Hardwood Inventory	0.80486	(p<.0001)	Total Inventory	0.79217	(p<.0001)
Softwood Growth	0.91452	(p<.0001)	Hardwood Growth	0.84462	(p<.0001)	Total Growth	0.90229	(p<.0001)

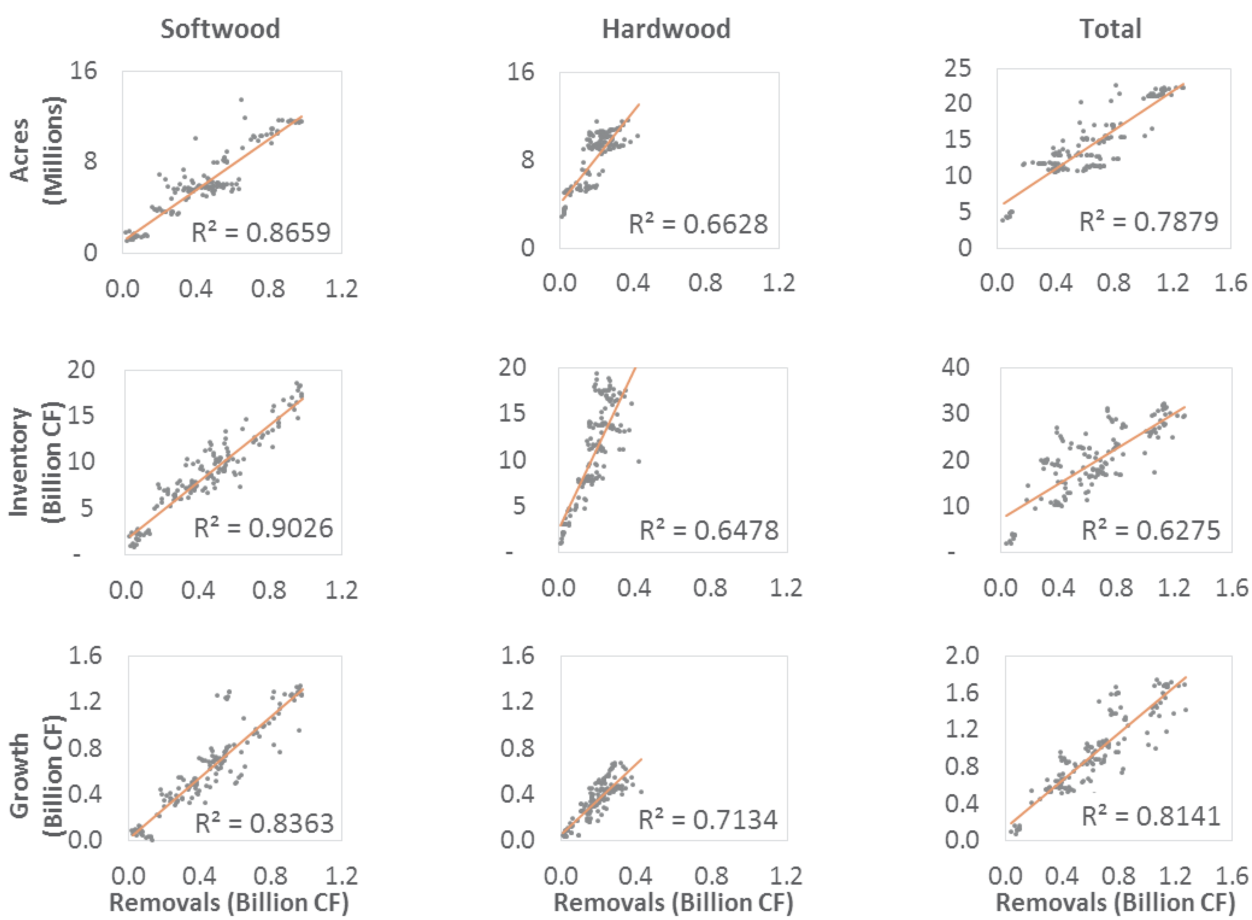

Figure 1-12 Private Removals vs. Acres, Inventory and Growth by Species, 1968-2015
(Sources: US Forest Service Forest Inventory and Analysis database, Forest2Market calculations.)

1.1.6 Key Finding #6

Case study evidence confirms that increased removals are associated with increased inventory not only at a regional scale, but also in local wood basins. Further, they demonstrate that the markets in local wood basins are defined not by changes in demand from a single mill, but rather market-wide shifts in the demand for all wood products. In particular, shifts in demand for larger and more valuable sawtimber had a greater impact on case study forests and markets than did changes in demand associated with individual pulpwood-consuming mills. However, the case studies also show that when these basins had an active, centrally-located pulpwood-consuming mill, plantation acres increased more quickly, which helped retain total timberland acres in the face of declining naturally-regenerated timberlands.

- Case studies of wood basins surrounding the Flint River, Georgia and St. Joe, Florida areas from the 1970s to 2015 show that these local wood basins tended to follow larger Southwide trends despite the fact that Flint River experienced the opening (in 1981) and St. Joe experienced the closing (in 1998) of a pulpwood-consuming mill. In both areas, removals, growth and inventory associated with both sawtimber and pulpwood increased over the study period (Figure 1-13). These localized findings are consistent with Southwide historical trends and statistical results linking increased removals to increased inventory.

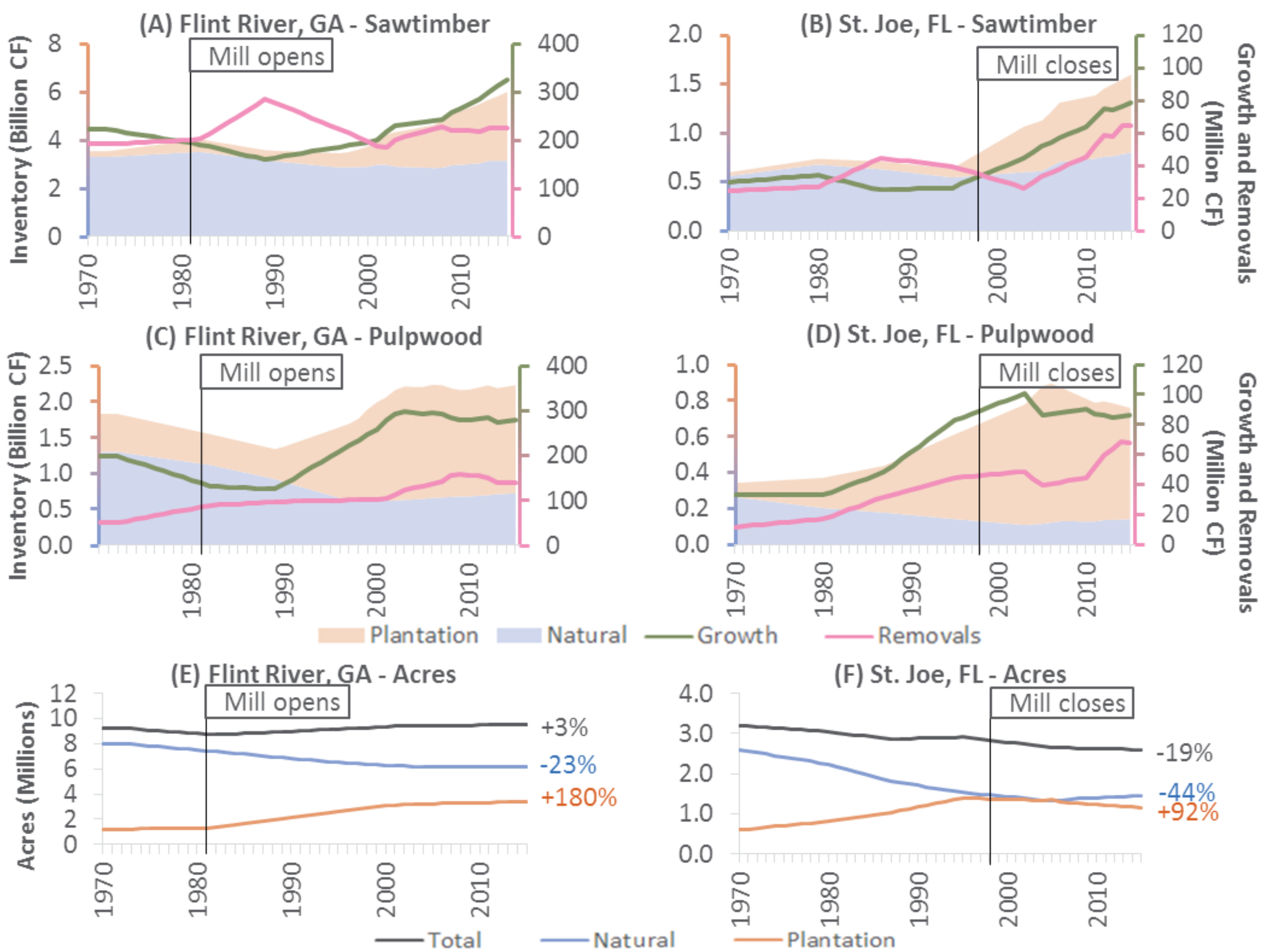

Figure 1-13 Annual Inventory, Growth, Removals and Acres in the Flint River, GA and St. Joe, FL Basins, 1970-2015
(Source: US Forest Service Forest Inventory and Analysis Database.)

- In both basins, inventory, growth and removals were driven not by a single pulpwood-consuming mill; rather, they were shaped by regional trends and the actions of all local market participants, especially sawtimber consumers.
    - First, the case studies failed to demonstrate that the opening or closing of a single-pulpwood consuming mill had the power to interrupt or reverse trends in pulpwood removals in these local markets. In both basins, trends of increasing pulpwood removals, which existed prior to the pulpwood-consuming mill opening (in Flint River, Figure 1-13-C) or closing (in St. Joe, Figure 1-13-D), continued after these mill events because other consumers were active in these basins.
    - Second, because sawtimber-sized trees represented the majority of removals and inventory in both basins (Figure 1-13) and because sawtimber has historically been a higher-value product (Figure 1-14), shifts in sawtimber demand had the power to produce greater impacts on local forests than did changes in pulpwood demand. For example, in both basins, increasing sawtimber demand in the 1980s[15] was followed by an expansion in plantation acres, which led to dramatically increased growth and inventory, first in smaller-diameter pulpwood)and later in larger-diameter sawtimber trees (Figure 1-13). Further, the Flint River case study supports previous Forest2Market findings[16] that reduced sawtimber demand associated with the Great Recession caused landowners to defer final harvests until sawtimber market conditions improve, which limited pulpwood regeneration and inventory.

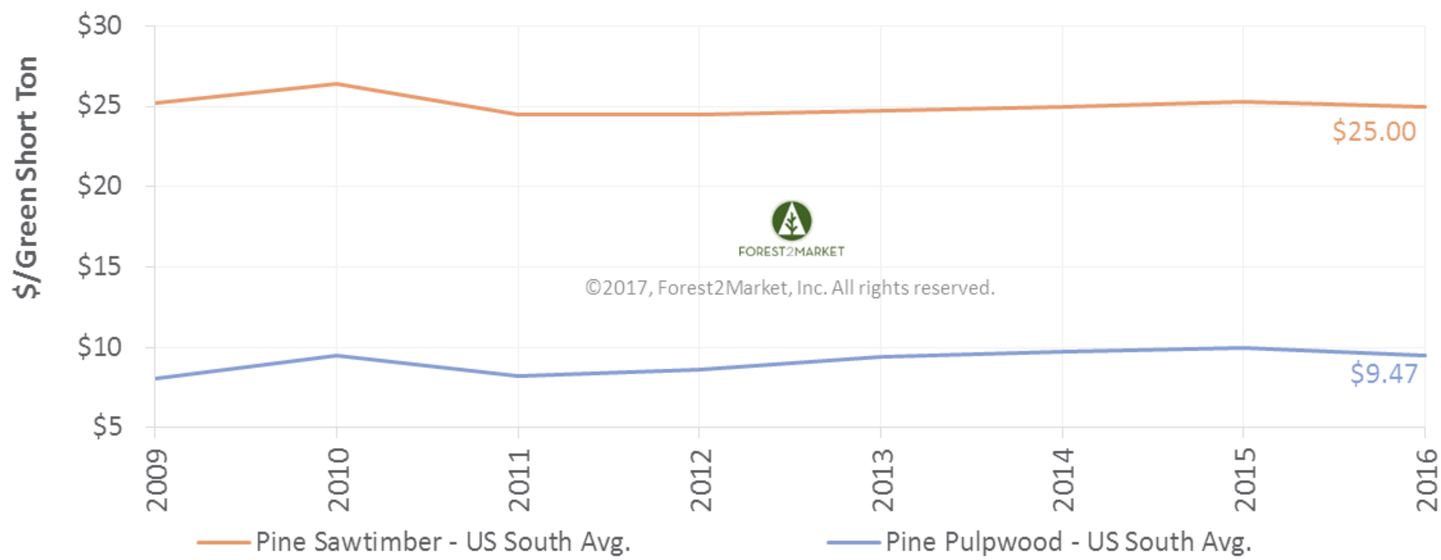

Figure 1-14 Annual Pine Sawtimber and Pulpwood Stumpage Prices in the US South, 2009-2016
(Source: Forest2Market, Inc.[17])

- As in the US South, naturally-regenerated acres declined in both basins while plantation acres increased (Figure 1-13). However, the case studies suggest when basins have an active, centrally-located pulpwood-consuming mill, plantation acres increase more rapidly, which helps to retain total timberland acres: In both basins, plantation acres increased more quickly when the central mill was active, which allowed total timberland acres to increase at a faster rate (in Flint River) and decrease more slowly (in St. Joe) (Table 1-3).

[15] Government incentives from the Conservation Reserve Program also contributed.
[16] See, for example, Stewart 2015 and Stuber 2016.
[17] Prices are annual averages of bimonthly prices reported in Forest2Market's Timber Owner Market Guide (TOMG) and are sourced from our proprietary databases of stumpage transactions.

Table 1-3 Annual Change in Timberland Acres by Stand Origin During Periods When a Central Pulpwood-Consuming Mill was Active and Inactive in the Flint River, GA and St. Joe, FL Basins, 1970-2015
(Source: US Forest Service Forest Inventory and Analysis Database.)

Flint River, Georgia	Time Period	Mill Status	Natural	Plantation	Total
	1972-1981	Inactive	▼ -0.8%	▲ 1.0%	▼ -0.6%
	1981-2015	Active	▼ -0.5%	▲ 2.8%	▲ 0.3%
	1972-2015		▼ -0.6%	▲ 2.4%	▲ 0.1%

St. Joe, Florida	Time Period	Mill Status	Natural	Plantation	Total
	1970-1998	Active	▼ -2.0%	▲ 3.0%	▼ -0.4%
	1998-2015	Inactive	▼ -0.1%	▼ -1.0%	▼ -0.5%
	1970-2015		▼ -1.3%	▲ 1.5%	▼ -0.5%

1.1.7 Key Finding #7

Today, the biggest threat to forests is urbanization, but this threat can be mitigated by healthy markets for forest products, especially for products from highly-productive plantations. Nationwide, between 1982 and 2012, development was responsible for almost half (49.2 percent or 17.7 million acres) of all forest land that converted to other land uses. Conversely, forests reclaimed very little land (1.2 percent or 0.5 million acres) from developed areas. In the US South, the most productive plantation stands are best protected against conversion.

- Nationally, overall forest land acreage increased 0.7 percent while developed land acreage increased 58.7 percent. Across the United States, approximately 39.1 million acres were converted to forests from other uses. At the same time, however, 36.0 million acres of forest land were lost to other uses.
  - Most of the acres that were converted to forest land were previously pastureland (19.8 million acres, 50.8 percent), cropland (10.3 million, 26.4 percent) or other rural land (3.7 million, 9.5 percent). Only 1.2 percent (0.5 million acres) was previously developed land.[18] Rarely does developed land become forest.
  - Of the forest land that was lost, most was converted to developed land (17.7 million acres, 49.2 percent), pastureland (5.8 million, 16.0 percent) or water areas or Federal land (4.7 million, 13.1 percent). These data show that over the past thirty years, the biggest threat to forests has been urbanization.
- Between 1989 and 1999, 5.4 million acres of stocked timberlands in the US South were converted to nonforest uses. Most (94 percent) were previously naturally-regenerated forest management types. Only 6 percent was previously planted pine/oak-pine.

Table 1-4 Timberland Acres Converted to Nonforest in 1999 by 1989 Forest Management Type
(Source: Connor and Hartsell 2002)

1989		1999	
Forest Management Type	Acres (Thousands)	Nonforest Acres (Thousands)	Percent Converted to Nonforest
Planted Pine/Oak-Pine	24,798	300	1%
Natural Pine	40,104	1,394	3%
Natural Oak-Pine	23,850	660	3%
Upland Hardwood	65,906	2,210	3%
Lowland Hardwood	29,817	864	3%
Nonstocked	75	7	9%
Total	184,550	5,435	3%

[18] For definitions of the various land use types, refer to Section 3.5.

1.2 Conclusion

Our historical analysis demonstrates a strong relationship between demand, forest productivity and, ultimately, inventory. The rapid increases in inventory over the past 75 years coincided with consistent increases in forest products demand through the mid-2000s. Productivity and output improvements were a result of the concerted efforts by the forest products industry to improve yield via improved tree genetics, silvicultural treatments and management practices. This is especially true for softwood species, which are often more actively managed. Government programs to promote reforestation and prevent soil erosion also contributed to the establishment and replanting of timber on non-industrial lands.

Our statistical analyses show clear links between removals and growth, removals and inventory and removals and acres. We argue that these attributes operate together to cause changes in forest inventories. Much as it was at the turn of the twentieth century when Southern forests had largely been cut-over,[19] inventory—more specifically, the lack of inventory—can function to limit removals. High demand promotes investment in, and management of, timberland acres, improvements in growth and the building of timber inventories, as it did during the second half of the twentieth century. However, it is not possible to increase removals and maintain or build inventory unless growth and/or forested acres also increase. For the US South, increased growth is the link between increased demand and increased inventory because the forested area has remained stable. Foresight, planning and constructive action by the forest products industry and other private landowners were instrumental in ensuring that the South's forest inventory continued to grow and remain sustainable as demand for forest products increased.

Since the 1950s, the South's forests have demonstrated their ability to adapt to changes in demand without experiencing declines, and forest owners, who are predominantly private individuals, families, corporations and investors, have demonstrated their ability not only to use and maintain, but also to replenish and grow, the forest.

At the same time, forests face competing pressures, not least of which is urbanization. Looking to the future, one US Forest Service report (Wear and Greis 2012, Wear and Gries 2013) forecasted the cumulative change in non-Federal forest land in the South through 2060 under four different scenarios. The scenarios differed in the degree of urbanization and the future value of timber, two important factors that will affect the future of forests. The results of the Forest Service analysis showed that the South was projected to lose between 7 to 13 percent of its forest land by 2060 (Figure 1-15).

However, the amount of forest land lost varied depending on the amount of urbanization and the changing future value of timber. The authors of the report wrote:

> Between 30 million and 43 million [additional] acres of land in the South are forecasted to be developed into urban uses by 2060, from a base of 30 million acres [of urban land that existed] in 1997. The South is forecasted to lose between 11 million and 23 million acres (7 and 13 percent, respectively) of forests from 1997 to 2060. All subregions are expected to lose at least some acreage; nearly all of this area would be converted to urban uses. Strong timber markets can ameliorate forest losses somewhat, by shifting urbanization to agricultural lands. (Wear and Greis 2012, 24)

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[19] According to some estimates, by 1920, over 156 million acres in thirteen southern states had been cut-over (i.e., cleared completely of forest), and only 24 million acres of old-growth pine remained in the yellow pine area from South Carolina to Texas (Boyd 2001). At the time, annual cut exceeded growth by a factor of three (Boyd 2001).

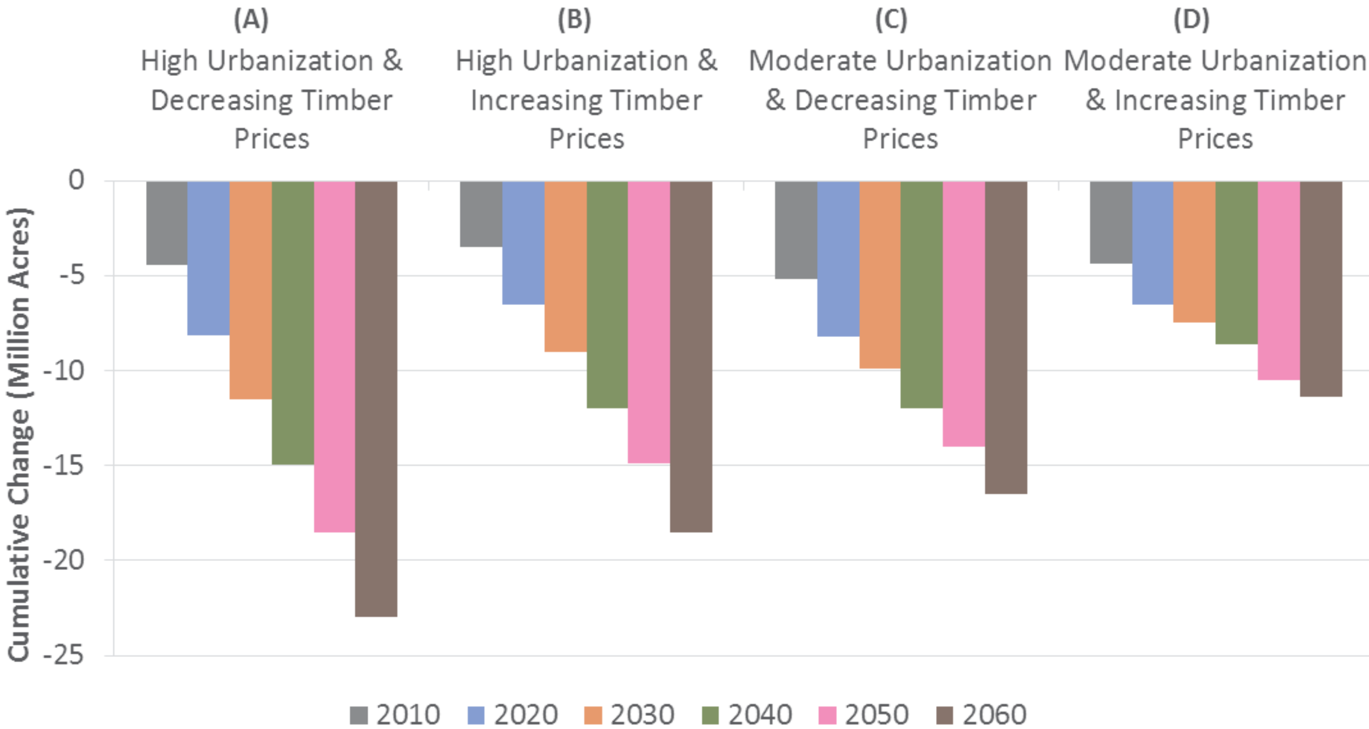

Figure 1-15 Cumulative Change in Forest Land Uses from 1997 to 2060 by Decade under Four Scenarios
(Source: Wear and Greis 2013.[20]**)**

In the Forest Service analysis, higher urbanization and decreasing prices for timber resulted in the most forest land loss (Figure 1-15-A). Moderate urbanization and increasing prices for timber (D) resulted in the least forest land loss. Regardless of the degree of urbanization, increasing timber prices (B, D) functioned to mitigate, but not prevent, the loss of forest. In other words, increasing timber prices—which historically have been due to continued strong, healthy markets for timber—are key to keeping forests forested.

[20] Adapted from Figure 4.9 in Wear and Greis 2013; data in Figure 1-15 are approximated, and bars may not be perfectly to scale.

2 INTRODUCTION

Since the 1950s, total timberland inventory in the United States has increased by around 50 percent (USDA Forest Service 2012). This increase is especially significant given that it occurred alongside dramatic increases in population, housing starts and pulp and paper production. The increase in timberland inventory has often been explained by the presence of—and not in spite of—healthy demand and strong markets for wood products. Today, with ever-increasing attention being focused on the critical role that forests play in sequestering atmospheric carbon, recognition is growing that a windfall of carbon sequestration has occurred alongside the gains in inventory.

The aforementioned statistic about forest inventory is often quoted, but detailed documentation and analysis necessary to establish causation between demand and forest productivity is lacking. While perhaps counterintuitive, if the reality is that using products made from wood results in more, not fewer, trees, then using products made from wood also results in more, not less, carbon storage. Therefore, the intent of this assessment is to document links between demand and forest inventories. This documentation can in turn be used as support in policy discussions about the effect of demand upon forest resources.

The project sponsors contracted Forest2Market, Inc. to provide perspective on the historical relationship between demand and forest productivity in the US South and localized basins within the US South. The US South was selected because, both in terms of standing inventory and annual removals, it is the largest regional market in the United States (Oswalt et al. 2014). Localized basin analyses were layered into the assessment to provide more in-depth looks into what happens when new demand enters a market and when demand exits a market. Therefore, the objectives of this report are to investigate the relationship and interactions between demand and forest productivity in the US South as a region and to provide additional in-depth analysis of selected supply basins. To establish linkage, we seek to align forest resource data against the evolution of the forest products industry and significant events in the greater historical context.

- First, in **Historical Trends in the United States and US South, 1953-2015**, we provide an overview of macro-level historical trends in the United States and US South. This section documents changes in population, GDP, housing starts, land conservation policies and land use change and discusses how these changes have impacted forests and the forest products industry.
- Second, in **Historical Trends in Wood Fiber Markets**, we provide an overview of events that have shaped Southern forests alongside a detailed discussion of sector-specific changes in the US forest products industry. This context is essential to understanding how changes in demand for forest products have affected Southern forests.
- Third, in **Trends in Forest Management Practices and Forest Productivity**, we outline changes in Southern forest ownership, management, growth, removals and inventory. This section begins the analysis of demand and forest productivity by analyzing removals in relation to timberland acres, inventory and growth.
- Fourth, in **Statistical Analyses of Southwide Demand and Forest Productivity Using FIA State Data**, we perform statistical analyses of Forest Inventory and Analysis (FIA) data to correlate removals to various forest productivity measures and analyze the ability of removals to predict changes in selected measures of forest productivity.
- Building off our Southwide analysis, in **Demand and Forest Productivity: Local Market Case Studies**, we analyze changes in two wood basins since the 1970s.
- Finally, the **Conclusion** provides an overview of our findings.

2.1 Data Sources

This report constitutes a comprehensive overview of US South forests and the forest products industry since 1953. It should come as no surprise to the reader that a wide variety of sources of information were necessary to build the analysis over such a long timeframe. For example, data are sourced from various US Forest Service reports, the US Department of Agriculture, the Food and Agriculture Organization of the United Nations and our own proprietary databases of wood fiber transactions, among others.

Because multiple sources of information were used, some discrepancies between seemingly similar measures may become apparent as you progress through the report. These discrepancies are directly attributable to the differences in the ways various sources measure or report a given attribute. For example, our primary sources of data on the amount of timberland area (acres) in the US South over this historical period are US Forest Service Resources Planning Act reports, which provide the most consistent measure of area over this long of a timeframe. However, to assess changes in forest management over time, we used other US Forest Service reports that focus more specifically on various forest management types, and these reports may take a different approach to measuring acres (e.g., by excluding non-stocked stands). Similarly, to assess changes in land use/cover over time, we used data from the US Department of Agriculture's National Resources Inventory, which uses a more restrictive measurement of canopy cover (25 percent required versus 10 percent required) than the US Forest Service and, unlike the Forest Service, excludes forested Federal government lands. Despite these differences, all sources showed stable acres over time.

To assist the reader, we use subcaptions to list the data sources for all charts and tables. As necessary, we use footnotes to provide additional useful information about the data or data sources to aid in interpretation, to provide context and to allow comparison to other data sources, as shown by the example below.

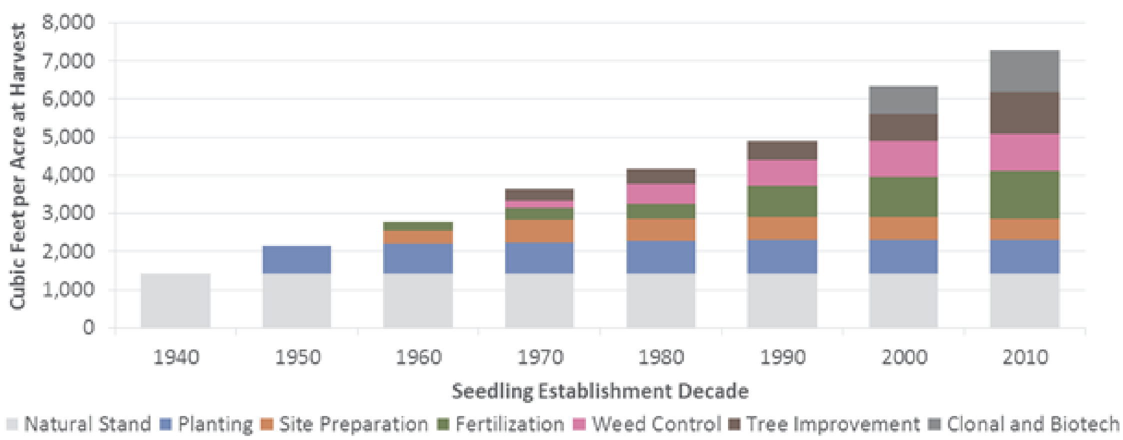

Figure 5-11 Estimated Contributions of Intensive Management Practices to Productivity in Pine Plantations in the US South, 1940-2010

The productivity of pine plantations has increased significantly since 1940 as management became more intensive. (Source: Fox, Jokela and Allen 2004.[48])

[48] Notes: Adapted from Figure 8.3 of original source. Data in the chart are approximated and may not be perfectly to scale. Approximate tons were converted to cubic feet using a conversion factor of 1 ton ≈ 34.48276 cubic feet. Data in the chart correspond to total harvest and are different than the annual yield data reported in text: Dividing totals in the chart by 15 would approximate the average annual productivity of plantations established at different times assuming a 15-year rotation.

3 HISTORICAL TRENDS IN THE UNITED STATES AND US SOUTH, 1953-2015

It is impossible to understand changes in Southern forests without also understanding historical factors that have impacted them. Namely, increasing population, an expanding economy, housing development, government policies and land use all impact forests and the forest products industry. For example, population drives housing construction as well as land conversion to urban uses. This section provides a historical overview of US population, US GDP, US housing starts, land conservation policies and land use change in the United States and the South during the period 1953-2015.

3.1 Population Change

According to US Census Bureau population estimates, the United States population has roughly doubled from 159.0 million in 1953 to 321.4 million people in 2015 (Figure 3-1). Over this same period, population in the US South increased 166 percent from 40.4 to 107.3 million people; population in other areas of the US increased 81 percent from 118.6 to 214.1 million people. Compounded annually, Southern population increased at a rate of 1.6 percent while population in other areas of the US increased at a rate of 1.0 percent. These increases helped drive increased demand for forest products, as discussed later in Section 4.2.

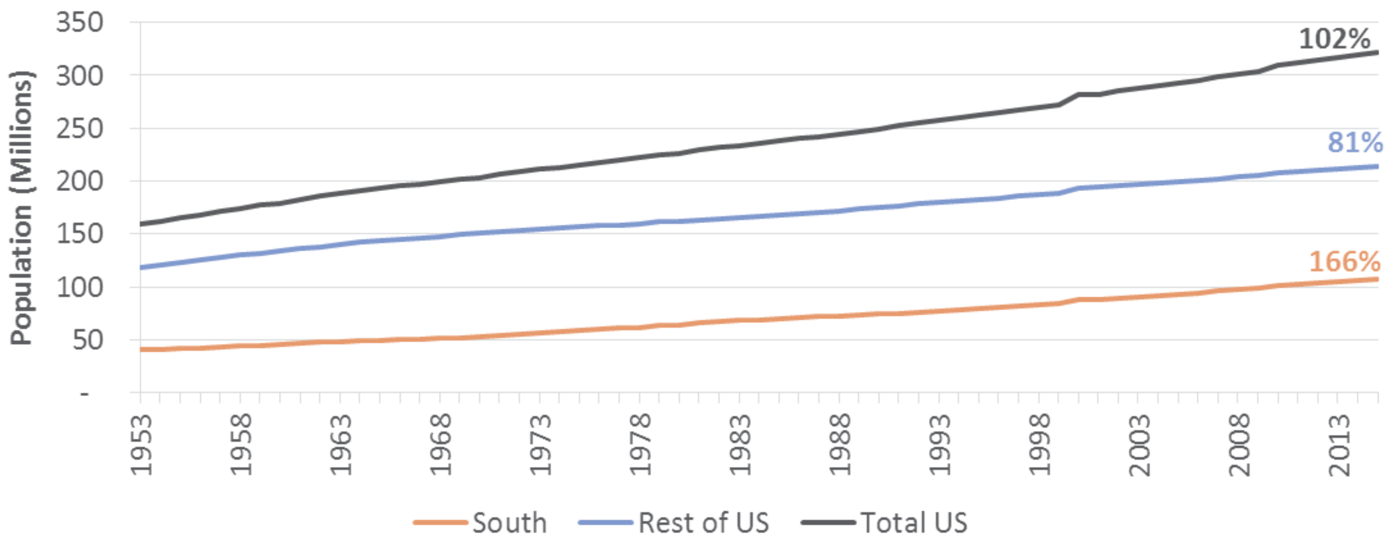

Figure 3-1 Total United States and US South Population, 1953-2015

Between 1953 and 2015, US South population increased 166 percent while population in other areas increased 81 percent. (Source: US Census Bureau.)

3.2 Macroeconomics

Gross Domestic Product (GDP) is "the market value of goods, services, and structures produced by the Nation's economy during a given period less the value of the goods and services used up in production" (US Bureau of Economic Analysis 2016a, 8). GDP is an overall indicator of the pace, growth and health of the economy. It reflects periods of economic expansion and recession[21] and is also related to population. Bureau of Economic Analysis (BEA) data show that real[22]

[21] Recession periods are based on official US Business Cycle Expansions and Contractions from the National Bureau of Economic Research (http://www.nber.org/cycles/). For the purposes of this and subsequent charts that incorporate recession data, any year that included part of a recession is marked as a recession.
[22] Chained 2009 dollars.

GDP has increased from approximately $2.6 trillion in 1953 to $16.4 trillion in 2015 (Figure 3-2). Contractions in GDP were related to periods of economic recession. Like population, GDP similarly contributed to increased demand for forest products (Section 4.2).

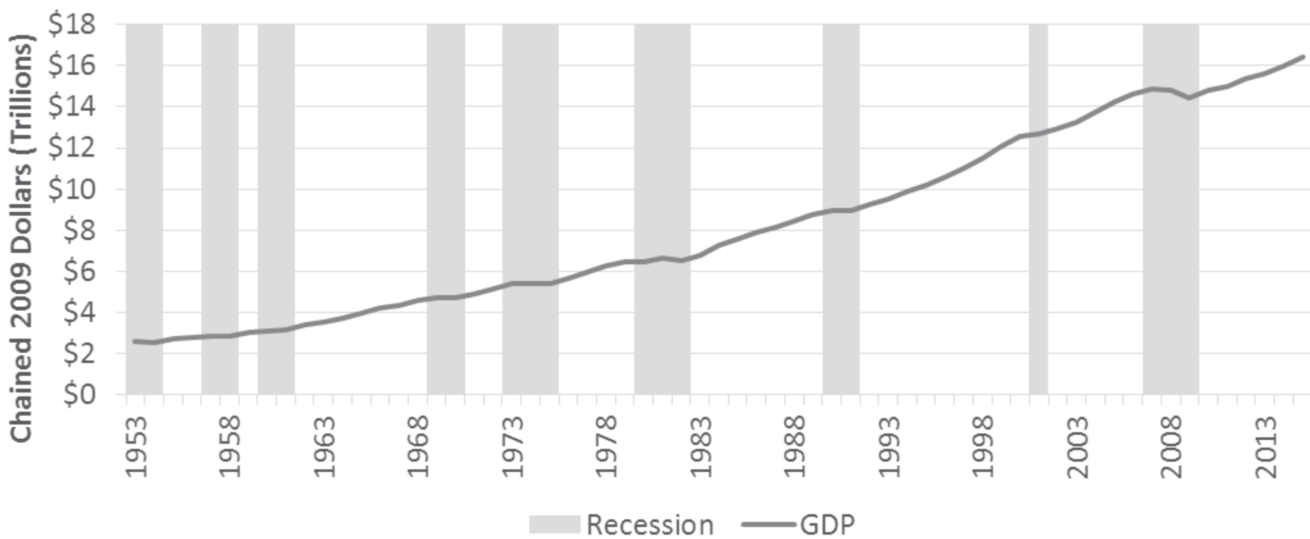

Figure 3-2 US Gross Domestic Product and Economic Recessions, 1953-2015

GDP has increased at a rate of 3.0 percent annually since 1953 despite occasional periodic slowdowns during economic recessions. (Sources: US Bureau of Economic Analysis 2016b, National Bureau of Economic Research.)

GDP and population increased at similar rates through the 1950s. However, since 1953, population has approximately doubled while GDP has increased over six-fold (Figure 3-3).

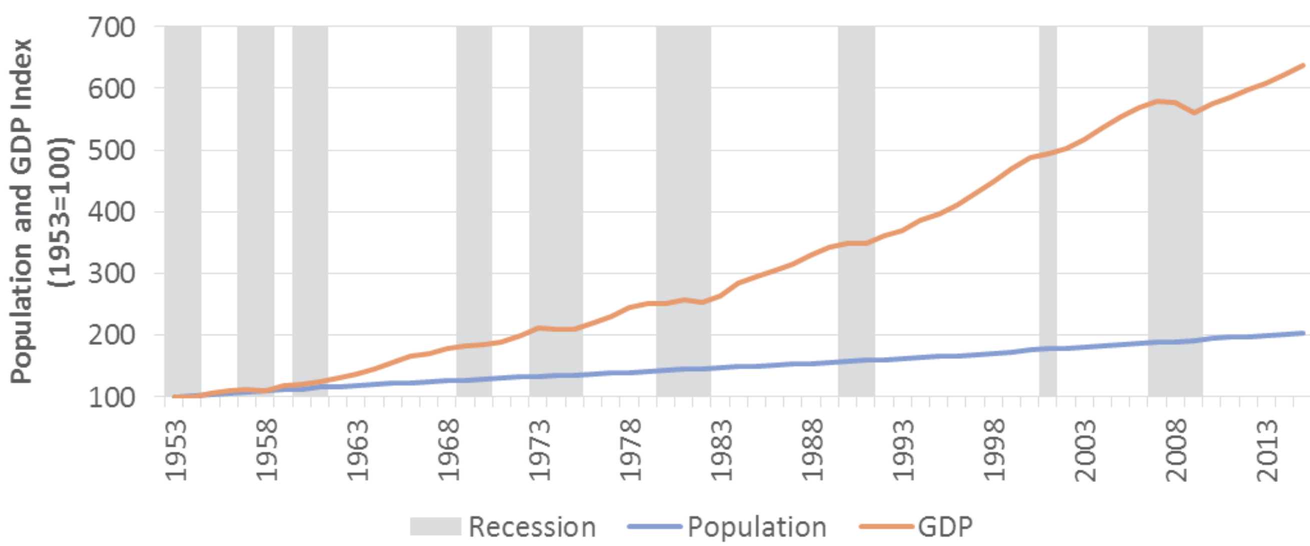

Figure 3-3 US Population and Gross Domestic Product Index (1953=100), 1953-2015

Between 1953 and 2015, US population approximately doubled, and GDP increased over six-fold. (Sources: US Census Bureau, US Bureau of Economic Analysis 2016b, National Bureau of Economic Research.)

3.3 Housing Trends

In addition to population and GDP, housing activity also drives changes in demand for forest products (Section 4.2). During the Great Depression and World War II period of 1930-1945, housing starts averaged a meager 360,000 per year (Fedkiw 1989). Government policies like the Housing Act of 1949 promoted homeownership during the Post-War period. By the end of the 1950's, housing starts were in excess of 1.0 million as pent-up demand was released, families rapidly formed new households, regional shifts in population occurred, homes were replaced and economic livelihoods increased (Figure 3-4).

Housing demand and starts further increased in the 1970s and 1980s as the Baby Boomers established their households, a trend interrupted by high interest rates in the late 1970s and a recession in the early 1980s. Beginning with the economic expansion of the 1990s, housing starts began a steady increase through the "housing bubble" of the mid-2000s.

The crash of the housing market in 2007-2008 and the subsequent Great Recession caused housing starts to plummet to their lowest level of the last 60 years. Housing starts have begun to improve in recent years, but have still not reached pre-Recession levels.

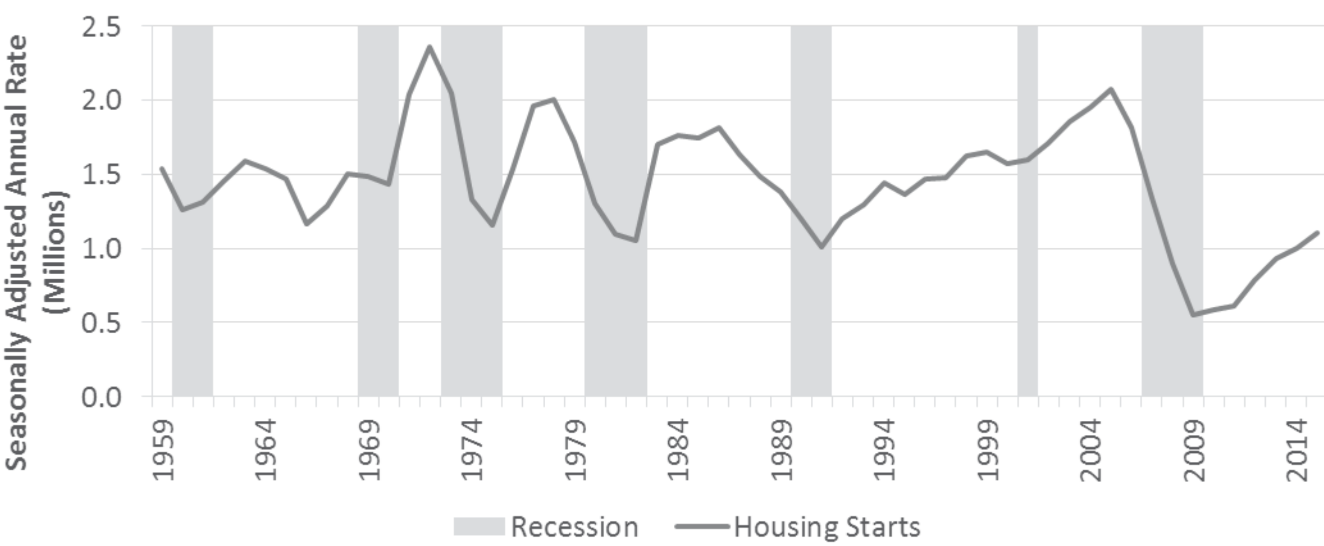

Figure 3-4 US New Privately-Owned Housing Units Started and Economic Recessions, 1959-2015
(Sources: US Census Bureau, National Bureau of Economic Research.)

Single-family homes have been steadily increasing in size since at least 1970 (Figure 3-5). During the expansionary period of the 1990s and early 2000s when housing starts were increasing, the average square footage of both single-family and multifamily homes was also increasing, which created even greater demand for lumber. After peaking at the height of the housing bubble, both single-family and multifamily homes decreased in size. Since 2010, single-family home sizes are again on the rise, but multifamily have yet to recover.

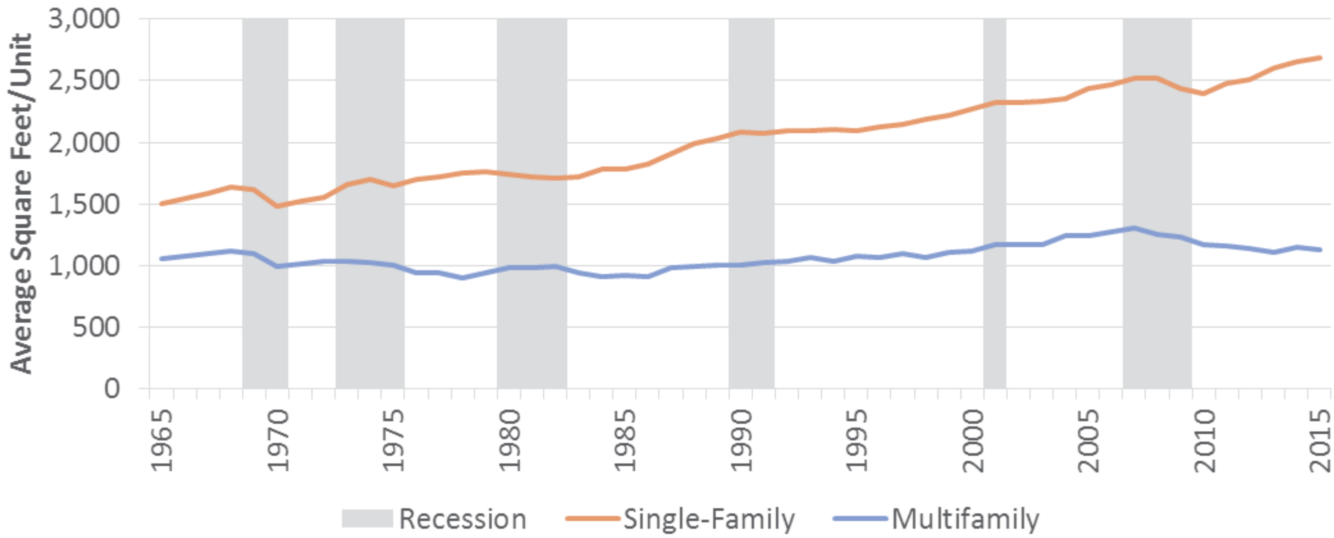

Figure 3-5 Average Square Feet/Unit of New Housing Starts and Economic Recessions, 1965-2015
(Sources: US Census Bureau [including data quoted in Howard and Jones 2016], National Bureau of Economic Research.)

3.4 Land Conservation Policies

In addition to broader social and economic trends that drove demand for forest products, government incentive programs impacted landowners' management choices and therefore impacted forests. Early agricultural practices in the US South contributed to soil erosion while the Great Depression of the 1930s caused many farmers to abandon their lands (Carter et al. 2015). By 1934, 31 percent of the land in the South had lost 25-75 percent of its topsoil. The Agricultural Conservation Program (ACP), a product of the Soil Conservation and Domestic Allotment Act of 1936, was established both to reduce crop surpluses and improve soil quality. While forestry was not the main goal of the program and expenditures directed to forestry annually rarely surpassed 2 percent of the total, the ACP nonetheless impacted forestry practices as its funds could be used to establish timber plantations and engage in timber stand improvement practices. Prior to the mid-1930s, "[a]reas planted or seeded to forest trees… amounted to only a few thousand acres annually" (USDA Forest Service 1988, 48).

Because previous initiatives had been unsuccessful in reducing crop surpluses, the Soil Bank Act of 1956 established the Acreage Reserve Program, which paid farmers not to produce certain crops, and the Conservation Reserve Program (CRP), which attempted to remove cropland from production for lengthier periods (Carter et al. 2015). Between 1956 and 1960, over 1.9 million acres of plantations, primarily loblolly and slash species, were established in the South under the Soil Bank program (Carter et al. 2015), resulting in a rapid increase in the US Forest Service's total tree planting data (Figure 3-6). The CRP was reinstated in the 1985 Farm Bill in part to address environmental concerns over agricultural practices, and 1.1 million CRP acres were planted in the South between 1985 and 1994 (Carter et al. 2015), resulting in another noticeable increase total tree planting.[23]

[23] More detailed information about historical trends in timberland acreage can be found in Section 5.2. More detailed information about planting and other forest management practices can be found in Section 5.3.1.

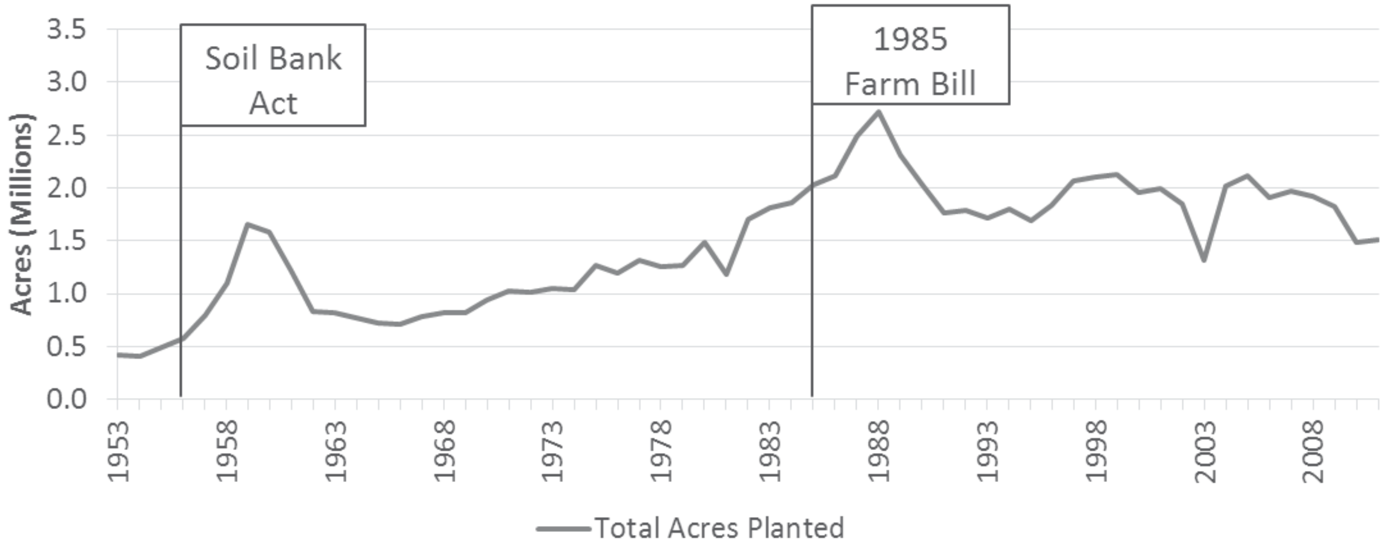

Figure 3-6 Total Acres Planted to Trees in the US South, 1953-2011

Spikes in total planting occurred following the Soil Bank Act of 1956, which introduced the Conservation Reserve Program, and the 1985 Farm Bill, which reinstated it. In total, approximately 1.9 million planted acres received assistance from the Soil Bank Act and 1.1 million acres received assistance under the 1985 Farm Bill. (Sources: Smith et al. 2009, Oswalt et al. 2014, Carter et al. 2015.)

3.5 Land Use Change

Increases in population since the 1950s have contributed significantly to land use change. A US Forest Service report notes that while cropland, pasture/range and forest land each declined by more than 5 percent from 1950 to 2002, during the same period, “urban and other land increased by more than 60 percent.” (Smith et al. 2009, 29).

Table 3-1 shows land cover/use change between 1982 and 2012 as a matrix. Each row sums to the 1982 total for a specific land cover/use type. Each column sums to the 2012 total for a specific land cover/use type. The cell where 1982 and 2012 land cover/uses intersect shows the amount of land that did not change from one period to the next, and is shown in **bold, underlined font** for each land cover/use. Each other cell shows how the land cover/use changed from 1982 to 2012 within each land cover/use type.

Forest land[24] is shown highlighted in gray. Approximately 374.3 million acres[25] were classified as forest land at both measurements; in other words, 91.2 percent of land that was forested in 1982 remained forested in 2012.

---

[24] As used in the NRI, forest land is: “A land cover/use category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cut over forest or abandoned farmland) and not currently developed for nonforest use. Ten percent stocked, when viewed from a vertical direction, equates to an areal canopy cover of leaves and branches of 25 percent or greater. The minimum area for classification as forest land is 1 acre, and the area must be at least 100 feet wide.” This is similar to the definition of forest land used by the US Forest Service FIA program, which defines “forest land” as “Land at least 10-percent stocked by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10-percent stocked with trees and forest areas adjacent to urban and builtup lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre and 120 feet wide measured stem-to-stem from the outer-most edge. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.” Timberland, as used by the FIA, is a subset of forest land, defined as “Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing at least 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)”

[25] Margin of error = ±2.5 million acres.

Forest land cover/use increased from 1982 to 2012 because some other land cover/uses converted to forests. Orange font in Table 3-1 indicates acres that converted to forest land in 2012 from another cover/use type in 1982. For these cells, by looking at the land cover/use associated with the *row*, one can determine what the land cover/use in 1982 was. Most of the converted acres were previously pastureland[26] (19.8 million acres, 50.8 percent), cropland[27] (10.3 million, 26.4 percent) or other rural land (3.7 million, 9.5 percent). Only 1.2 percent (0.5 million) was previously developed[28] land. Rarely does developed land become forest.

Some forest land cover/use converted to other uses. Blue font in Table 3-1 shows the acres that were converted from forest land in 1982 to another use in 2012. Of the forest land that was lost, most was converted to developed land (17.7 million acres, 49.2 percent), pastureland (5.8 million, 16.0 percent) or water areas or Federal land (4.7 million, 13.1 percent). These data suggest that over the past thirty years, the biggest threat to forests has been urbanization.

The United States experienced a net gain of 42.2 million acres[29] (58.7 percent) of developed land that had been converted from other uses during this thirty-year period. In contrast, since 1982, the United States experienced a net gain of approximately 3.0 million acres[30] (0.7 percent) of forest land that had converted from other uses. Much more land has been developed than has become forest.

Table 3-1 Changes in Land Cover/Use between 1982 and 2012 (thousand acres) – United States
(Source: US Department of Agriculture 2015b.)

		Land Cover/Use in 2012								
		Crop	CRP	Pasture	Range	Forest	Other rural	Developed	Water & Federal	1982 total
Land Cover/Use in 1982	Crop	328,410	22,087	35,051	6,254	10,322	4,217	11,783	2,464	**420,588**
	CRP	--	--	--	--	--	--	--	--	**--**
	Pasture	20,856	1,025	74,545	4,585	19,842	2,374	6,928	1,133	**131,289**
	Range	8,177	902	3,849	388,582	3,446	2,733	5,788	5,882	**419,356**
	Forest	2,444	116	5,761	2,566	374,267	2,706	17,705	4,724	**410,289**
	Other rural	1,708	83	1,397	1,141	3,694	33,250	1,177	326	**42,776**
	Developed	333	2	184	184	480	43	70,693	7	**71,925**
	Water & Federal	799	8	352	2,465	1,286	125	39	442,846	**447,920**
	2012 total	**362,726**	**24,222**	**121,138**	**405,777**	**413,337**	**45,449**	**114,113**	**457,381**	**1,944,143**
	Net Change	-57,862	24,222	-10,151	-13,579	3,049	2,673	42,187	9,462	0

3.5.1 Land Use Change in the US South

Building upon the prior section's discussion of how forest and developed land changed in the United States between 1982 and 2012, this section takes a closer look at changes in the US South and compares the region to national trends. Table 3-2 and Figure 3-7 show land use/cover change on non-Federal rural lands in the US South between 1982 and 2012. Forest land increased 1.0 percent from 173.8 to 175.6 million acres. Meanwhile, developed land increased 79.9 percent from 24.2 to 43.5 million acres.

26 As used in the NRI, pastureland is: "A land cover/use category of land managed primarily for the production of introduced forage plants for livestock grazing. … For the NRI, includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock."

27 As used in the NRI, cropland is: "A land cover/use category that includes areas used for the production of adapted crops for harvest."

28 As used in the NRI, developed land is "A combination of land cover/use categories, large urban and built-up areas, small built-up areas, and rural transportation land."

29 Margin of error = +/- .8 million acres.

30 Margin of error = +/- 1.1 million acres.

Table 3-2 Land Use/Cover on Non-Federal Rural Lands (Million Acres), 1982-2012 – US South
(Source: US Department of Agriculture 2015a.)

Land Cover/Use	1982	1987	1992	1997	2002	2007	2012
Forest Land	173.8	174.8	174.7	175.1	175.6	175.4	175.6
Rangeland	113.8	112.2	110.9	111.0	111.0	110.8	110.3
Cropland	100.7	94.3	85.9	81.6	77.7	74.1	73.5
Pastureland	58.7	58.6	59.1	57.6	56.8	56.9	57.5
Developed (Non-Fed.) Land	24.2	26.9	30.1	34.8	39.1	42.0	43.5
Federal land	22.8	23.2	23.9	24.1	24.4	24.5	24.6
Water Areas	22.0	22.4	22.8	23.0	23.2	23.5	23.5
Other Rural Land	12.1	12.2	12.4	12.7	12.8	13.6	13.8
CRP Land	-	3.5	8.5	8.3	7.6	7.3	5.9

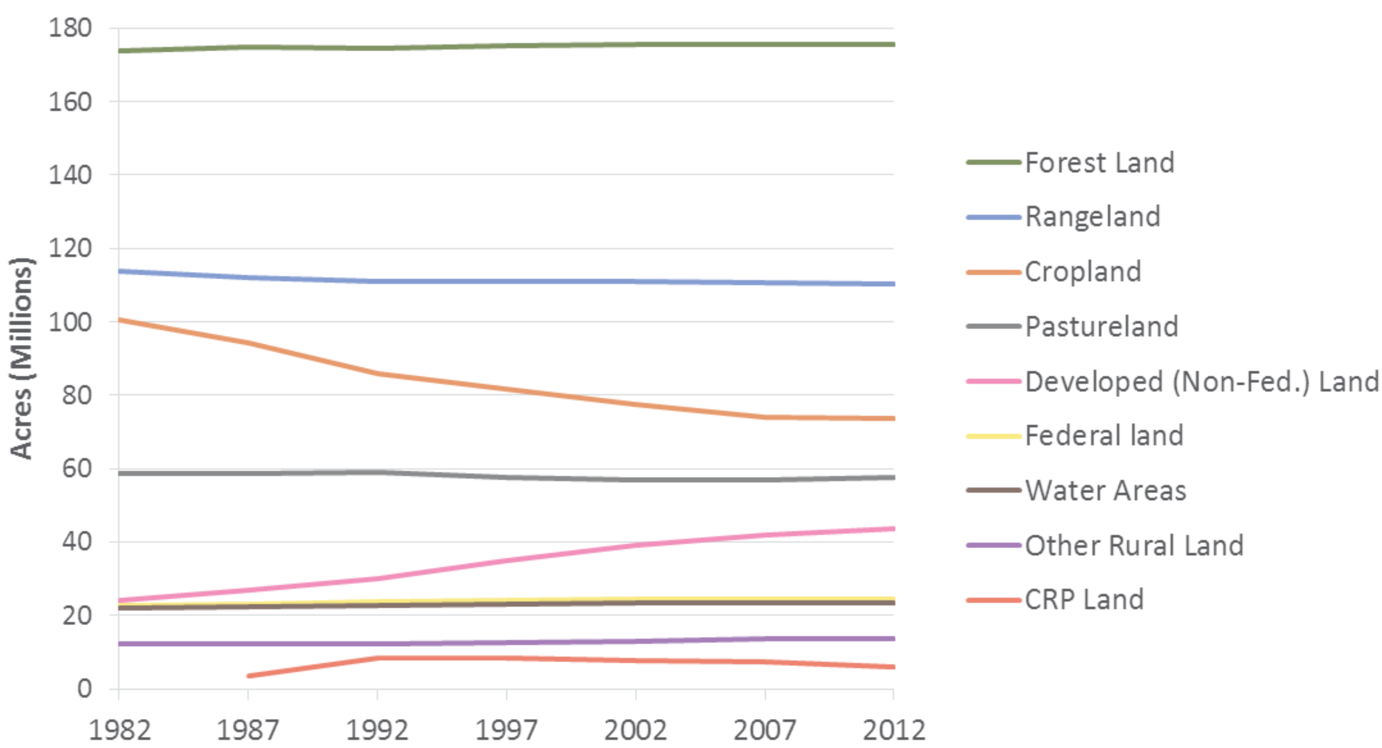

Figure 3-7 Land Use/Cover Change on Non-Federal Rural Lands, 1982-2012 – US South
(Source: US Department of Agriculture 2015a.)

Development pressures had a stronger effect on the US South than in the United States as a whole. Between 1992 and 2011, developed land cover in the lower 48 states increased by about 15 percent to 6 percent of total land area. Regionally, the South experienced "[t]he largest regional percentage increase in developed land cover… at 22 percent" (USDA Forest Service 2016, 2-1).

In addition, the South region had higher than average growth in urban area (defined by population density) between 1990 and 2010. Nationally, urban area increased 45 percent during this period, but urban area growth was 61 percent in the South (USDA Forest Service 2016, 2-1). Figure 3-8 shows the change in urban area between 2000 and 2010 in US South cities. All states in the South have had urban areas increase in size, especially Texas, Florida, Georgia and North Carolina. There was very little decrease in urban area in the South during this period, as can be seen in Figure 3-8 by comparing white areas (which show a decrease or no change in urban area) and green areas (which show increases).

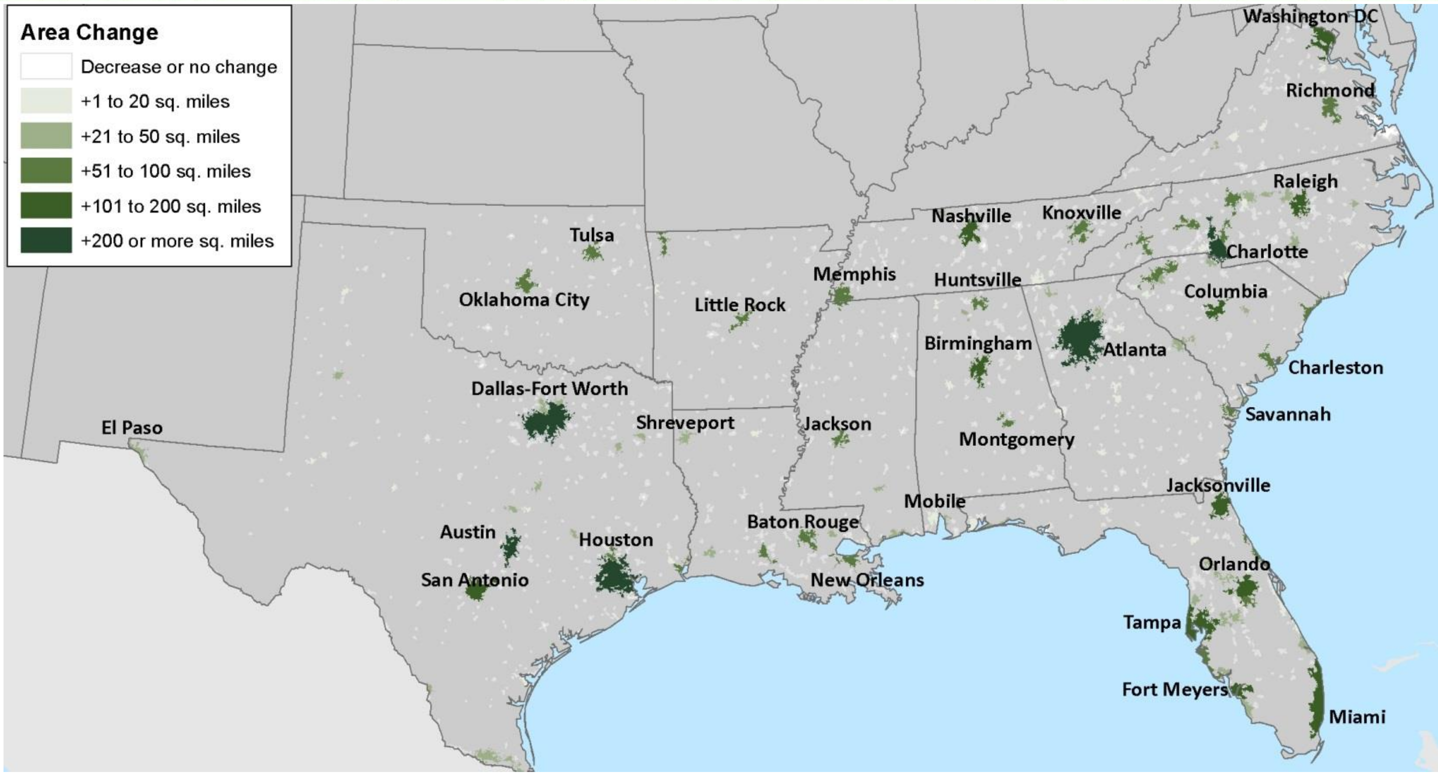

Figure 3-8 Change in Size of Southern Urban Areas between 2000 and 2010

All US South states experienced increases in the size of urban areas, but urban areas in Texas, Georgia, Florida and North Carolina experienced some of the more dramatic increases. (Source: US Census Bureau.)

Land use change and urbanization in particular are potentially powerful influencers on forests. Between 2000 and 2010, the Atlanta, Georgia urban area increased by over 680 square miles (Figure 3-8), the most of any urban area in the United States during this period. Increasing population and urbanization in the Atlanta area has put pressure on nearby forests. On page 40, Figure 3-9 shows an area approximately 33 miles southeast of Atlanta in Henry County as it existed in 1993, and Figure 3-10 shows the same area in 2016. What was once a well-stocked timberland plantation (with some hardwoods) in 1993 was thinned between 1993 and 1999 (not shown). By 1999, the first portions of a housing development were started (not shown). By 2005, the rest of the development had been created on the previously-thinned timberland and the area looked much as it did in 2016 (Figure 3-10).

In contrast, Figure 3-11 and Figure 3-12 (page 41) show a portion of Fairfield County approximately 33 miles northwest of Columbia, South Carolina as it existed in 1994 and 2016. In contrast to Atlanta's urban area expansion of 680 square miles, the Columbia, South Carolina area gained only 111 square miles of urban area between 2000 and 2010. The area was primarily pine plantation in both 1994 and 2016. An area that had been clearcut by 1994 (Figure 3-11) had been replanted and thinned by 2005 (not shown). By 2016, the previously clearcut area was well-stocked with growing sawtimber (Figure 3-12). Another portion of this area (western side) that was mature trees in 1994 (Figure 3-11) had been cut and replanted by 2005 (not shown). In 2016, this area showed evidence of having been thinned (Figure 3-12).

While it is impossible to know the specific motivations of the landowners involved in these two scenarios, they do provide important examples of what can happen to timberland. In the first case, it can be subject to urbanization pressures and converted to development. In the second, it can be continuously managed and regenerated.

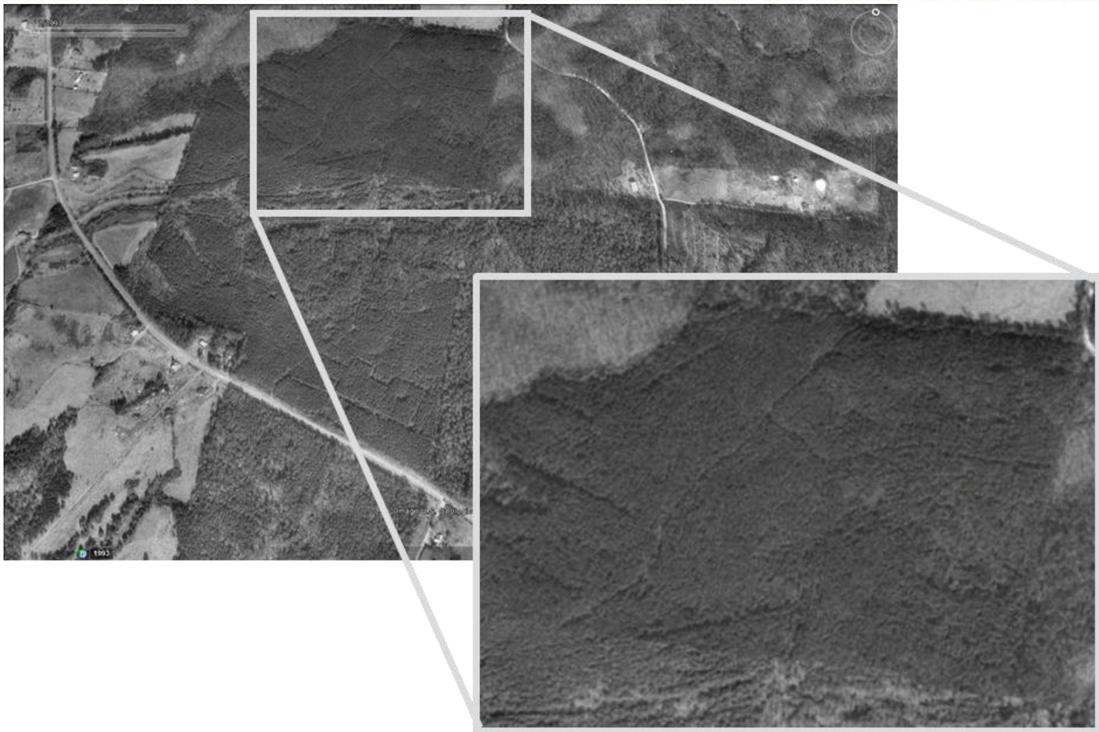

Figure 3-9 Aerial View of Henry County, Georgia, USA, 1993
In 1993, this area was being managed as a timber plantation. The inset shows an area that was thinned between 1993 and 1999. (Image Source: Google Earth.)

Figure 3-10 Aerial View of Henry County, Georgia, USA, 2016
Development began in this area by 1999 and was completed by 2005. It is shown here in 2016. (Image Source: Google Earth.)

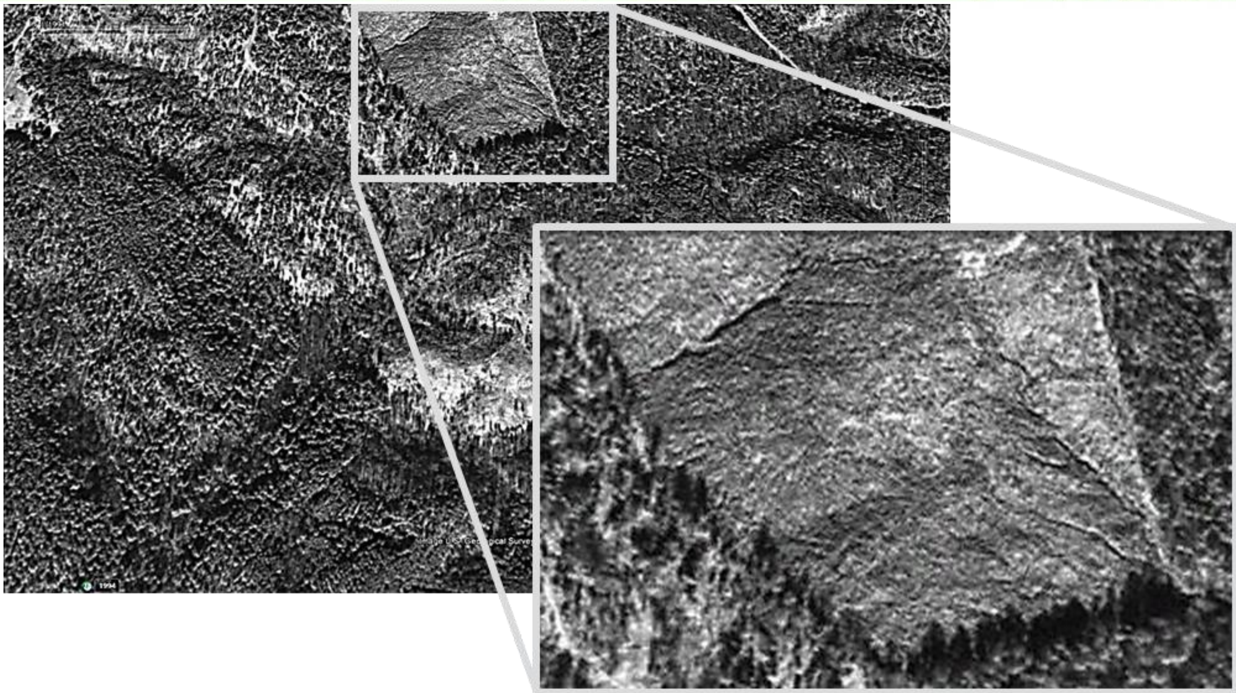

Figure 3-11 Aerial View of Fairfield County, South Carolina, USA, 1994

This area was being actively managed as a timber plantation in 1994. Along the western edge of the full area, mature trees are prepared for harvest. The northern portion (inset) had been clearcut prior to 1994 and was showing signs of early regeneration following replanting. (Image Source: Google Earth.)

Figure 3-12 Aerial View of Fairfield County, South Carolina, USA, 2015

The western edge of the area had been cut and replanted by 2005 and rows of trees that had been thinned were evident in 2016. The previously clearcut area (inset) was thinned by 2005 and, in 2016, was growing mature sawtimber. (Image Source: Google Earth.)

4 HISTORICAL TRENDS IN WOOD FIBER MARKETS, 1953-2015

This section begins with an overview of events that have shaped Southern forests and then focuses in greater detail on the corresponding changes that have occurred in the US forest products industry. Our sector-specific analysis of wood fiber utilization relates trends in the forest products industry to the broader United States and US South market drivers covered in Section 3.

4.1 An Overview of Events that Have Shaped Southern Forests

4.1.1 Southern Forests in the Early Twentieth Century

Prior to colonization, most of the US South was forested (USDA 1988). During settlement, forests were cleared for crops, pastures, cities and roads. In the late 1800s, large sawmills relocated from the cut-over Great Lakes to the South and began harvesting old-growth forests with a “cut and get out” mentality (Boyd 2001, 173), resulting in the loss of most of the South’s old-growth forests by the 1920s. According to some estimates, by 1920, over 156 million acres in thirteen southern states had been cut-over (i.e., cleared completely of forest), and only 24 million acres of old-growth pine remained in the yellow pine area from South Carolina to Texas (Boyd 2001). At the time, annual cut exceeded growth by a factor of three (Boyd 2001).

To better measure and maintain America’s timber resource, the McSweeney-McNary Act was passed in 1928 authorizing a national forest inventory called the Forest Survey (Carter et al. 2015). The results of the survey conducted between 1932 and 1936 confirmed the rapid regrowth of the South’s forests (Carter et al. 2015). In the 1930s and 1940s, land in the South had begun to revert back to trees, especially pine, and timberland experienced an upward trend in the wake of the boll weevil’s impact on cotton, an agricultural recession and the advent of forest protection programs that reduced the amount of forests burned by fire (USDA Forest Service 1988). The South’s “second forest” had taken root (Boyd 2001, 168).

4.1.2 The Migration of Pulp and Paper

In 1930, sixteen southern pulp mills operated in the US South, fifteen of which used a sulfate process (Carter et al. 2015). In 1933, Dr. Charles Holmes Herty, a semiretired professor of applied science, demonstrated that southern pine pulp made from 80 percent ground pulp and 20 percent sulfite pulp could be used successfully to produce newsprint. Together, the results of the Forest Survey and research confirming the viability of Southern pine for pulp and paper production ushered in a new era for pulp and paper mills in the South. By 1954, three newsprint mills had been established in the area. Pulpwood consumption in the South increased from 1.5 million cords (120 billion cubic feet or 3.4 billion cubic meters) in 1930 to nearly 10 million cords (800 billion cubic feet or 22.7 million cubic meters) in 1950. By 1950, 50 percent of US wood pulp and 30 percent of US paper and paperboard were produced in the South, and by 1955, 73 pulp-consuming mills were operating in the region. That number increased to 114 by 1976. By the 1970s, the pulp and paper industry was “by far, the principal industrial forest owner in the South” (Carter et al. 2015, 80). The last “greenfield” pulp mill was built by Willamette Industries in Bennettsville, South Carolina in 1992.

4.1.3 Lumber Adaptation

Southern lumber production was at its lowest levels in 1932 with approximately 3 billion board feet of southern yellow pine and 830 thousand board feet of hardwood lumber produced (Carter et al. 2015). While lumber production returned to pre-Depression levels by 1947, many large, high-volume pine sawmills built to cut virgin timber were disappearing, either by closing or being retrofitted to fit smaller, second-growth logs. Lumber production surged in the post-World

War II era before declining "as the last remnants of the virgin forest were harvested" (Carter et al. 2015, 80). In response to efficiency improvements and higher capital costs, the total number of sawmills in the South decreased from around 24,000 in 1947 to around 5,000 by 1967. Throughout the latter half of the twentieth century, softwood and hardwood lumber production were closely tied to housing starts.

4.1.4 Interregional Relationships

Starting in the 1920s, when the South's first-growth forests were initially commercially harvested, lumber production started to shift to the Pacific Northwest, where widespread commercial harvesting of the region's forests had not yet begun. This remained true until the 1960s and 1970s, when increased environmental protections passed and a revision in the purpose and management of Federal lands via the National Forest Management Act of 1976 reduced harvests in the Pacific Northwest. This deterred expansion of the industry in that region and led some capacity to migrate back to the South (Carter et al. 2015). Western softwood lumber output declined in the 1990s after the Spotted Owl was declared a threatened species (1990) and after the United States "substantially reduced timber harvesting from its Federal lands" in 1992 (Prestemon, Wear and Foster 2015, 14), which disproportionately affected the timber supply in the Pacific Northwest. As a result, demand for Canadian lumber and lumber produced from privately-owned Southern timber increased.

4.2 Wood Fiber Utilization: Forest Product Production

The types of forests prevalent in the US affect wood fiber utilization and production. Figure 4-1, adapted from a US Forest Service map, shows the types of forests that predominate in the contiguous (Lower 48) states. Conifer (softwood) species are commonly used in manufacturing lumber, plywood, panels, paper and paperboard. Hardwood species are commonly used for making furniture, flooring, veneer, millwork, pallets and printing grades of paper.

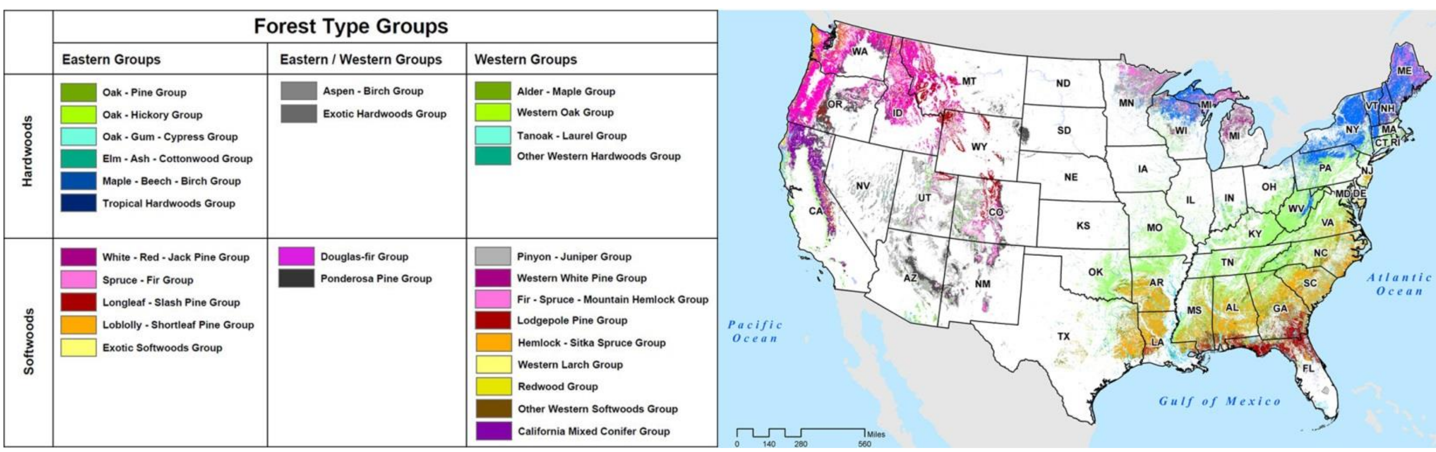

Figure 4-1 Forest Types in the United States

In the South, softwood forest types, such as Loblolly/Shortleaf Pine and Longleaf/Slash Pine, predominate in the coastal plain regions while the Oak/Hickory hardwood forest type is more common in the northern, more mountainous areas. (Source: US Forest Service.)

4.2.1 Solid Wood and Panels

Prestemon and colleagues (2015) note that changes in preferences, technological advancement and macroeconomic shifts have all influenced the US forest products sector. They argue that housing starts are linked to the larger business cycles via consumers' income and savings preferences. In general, annual changes in GDP and housing starts do mirror one another, as shown in Figure 4-2.

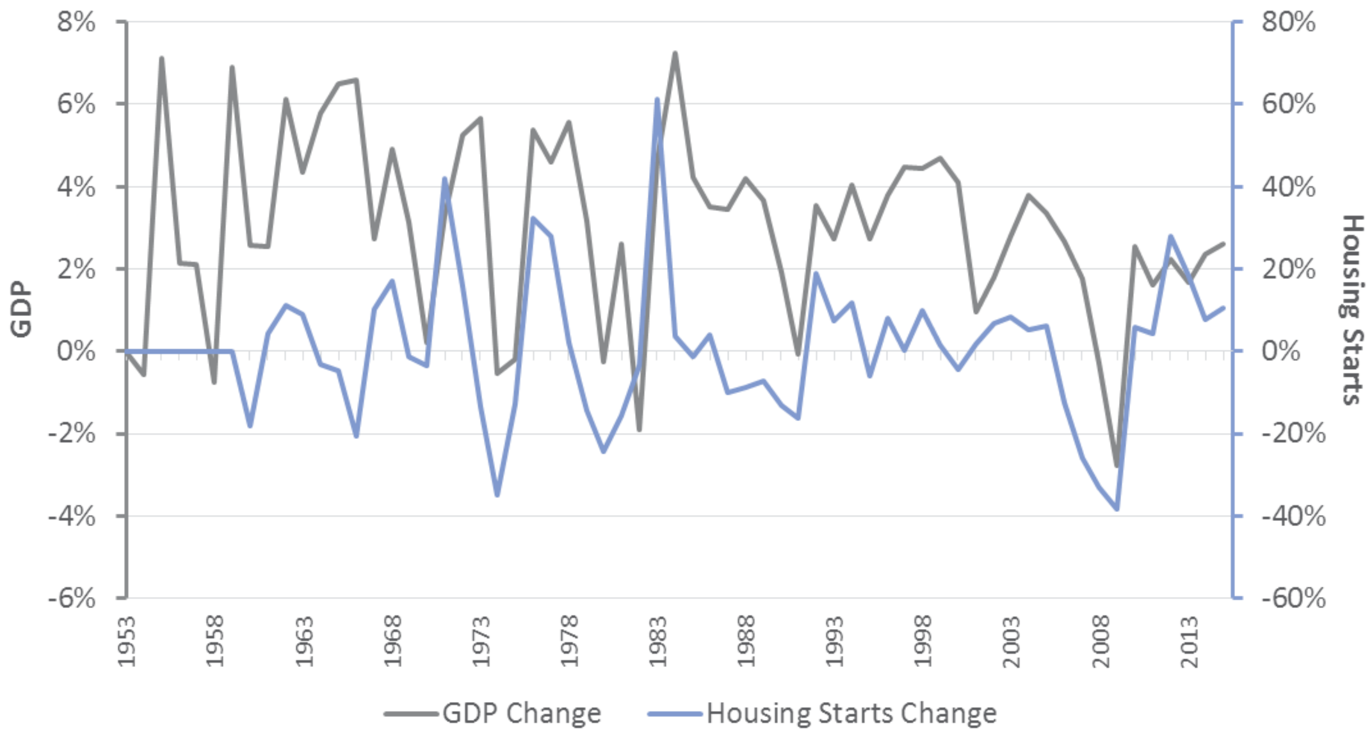

Figure 4-2 US Annual Change in GDP and Housing Starts, 1953-2015
(Sources: US Bureau of Economic Analysis, US Census Bureau.)

Domestic production and imports of solid wood and panel products are used to supply new home construction and therefore typically correlate with housing starts, as shown by Figure 4-3. Both housing starts and production data reflect larger economic cycles of expansion and recession (Figure 4-4). Through the mid-2000s, US solid wood and panel production followed a gently increasing trend that was interrupted by periods of economic recession. The 1982 and 2007 recessions and the 2005 "housing bubble" that preceded the Great Recession of 2007 are each evident in the housing start and production data.

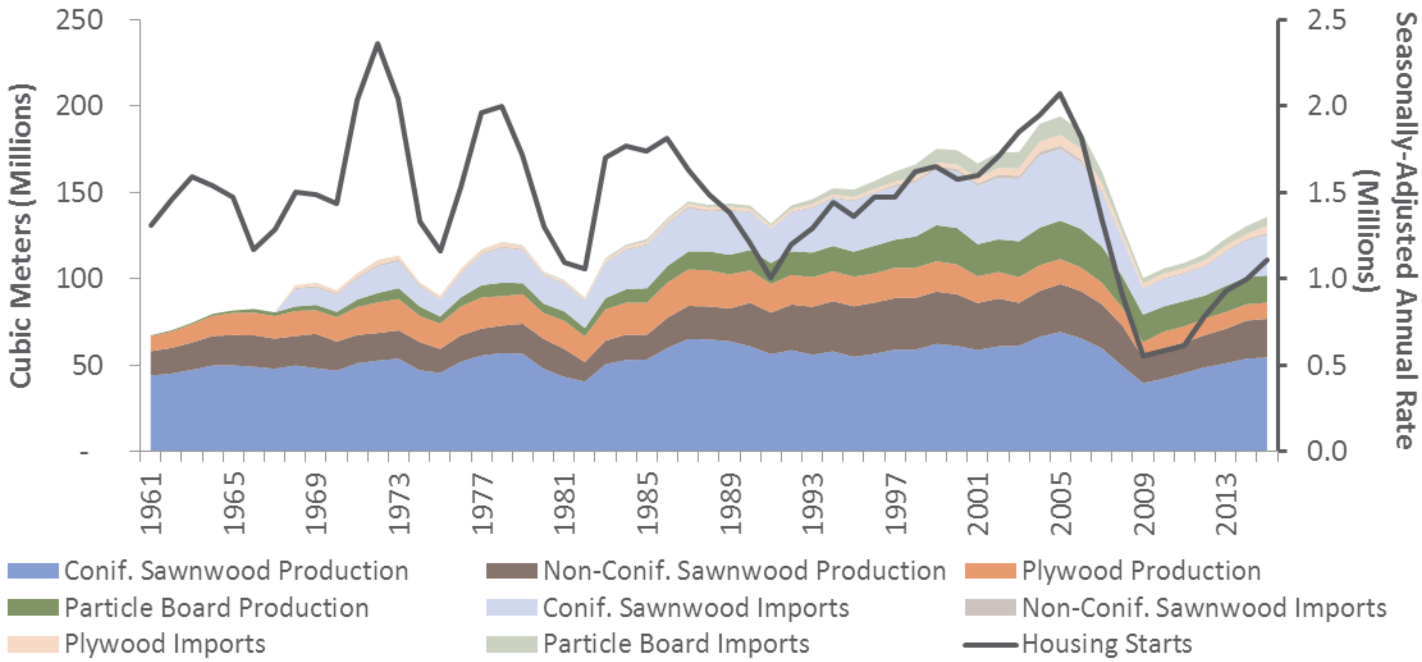

Figure 4-3 US Solid Wood and Panel Production Output and Imports vs. Housing Starts, 1961-2015
(Sources: FAO 2016, US Census Bureau.[31])

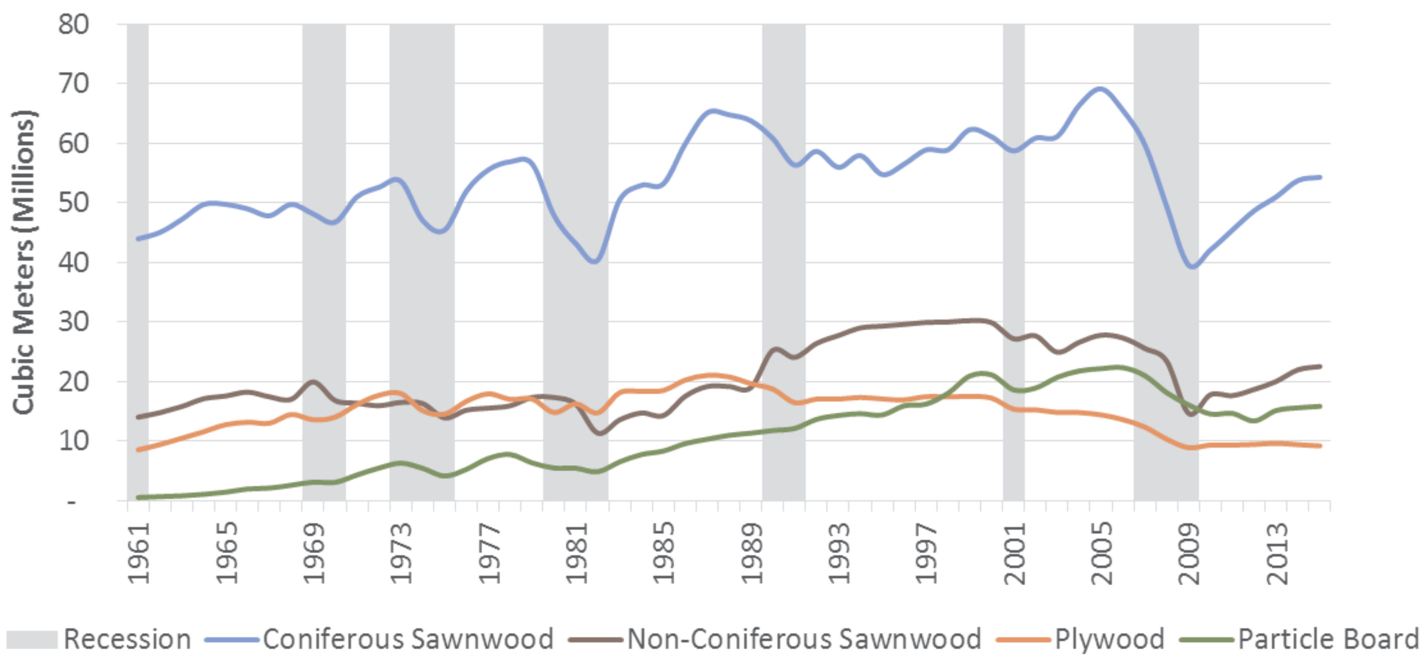

Figure 4-4 US Solid Wood and Panel Production Output and Economic Recessions, 1961-2015
(Sources: FAO 2016, National Bureau of Economic Research.)

[31] FAO import data is unavailable prior to 1968. Note: Particle board includes Oriented Strand Board (OSB).

Most of the increase in housing starts since the Great Recession has been in the construction of multifamily housing (Prestemon, Wear and Foster 2015), which partially explains why housing starts have increased more significantly than production since the Great Recession. Multifamily housing, which typically has less square footage per dwelling unit and therefore uses less wood per person, has made up a larger share of housing starts since 2012 than it did in the 1998-2006 period. This has resulted in fewer square feet per family in the 2009-2013 period than in the 1998-2006 period. Citing Skog and colleagues 2012, Prestemon and colleagues also report that the amount of wood used per installed square foot has decreased by around 10 percent over the past 50 years. The square footage associated with multifamily units has decreased since 2007, but single-family homes have almost exclusively been increasing in size since at least 1965.

Technological advancement in manufacturing processes has allowed for the greater use of more cost-competitive engineered wood products, including Oriented Strand Board (OSB), glulam, I-joists, and laminated veneer lumber (LVL), in lieu of solid wood alternatives, like plywood and timbers, in structural applications (Prestemon, Wear and Foster 2015). Particle board[32] production surpassed plywood production in 1998 (Figure 4-4). Together, these shifts have resulted in decreased demand for large sawlogs (i.e., sawtimber) and greater utilization of smaller logs (i.e., pulpwood and chip-n-saw). Still, by volume, coniferous sawnwood has and continues to consistently far surpass production of non-coniferous sawnwood, plywood and particle board.

4.2.2 Pulp and Paper

Between 1914 and 1955, consumption of paper in the United States was closely related to both population and to gross domestic product (Rettie and Hair 1958, 426). Data from 1961-2015 for both pulp and paper production confirm this general trend, particularly near the beginning of this time period (Figure 4-5 to Figure 4-8). Between 1970 and 1980, market pulp, paper and paperboard capacity increased around 2.4 percent annually (Ince et al. 2001). Capacity growth slowed between 1980 and 1990 to just 1.9 percent. While pulp, paper and paperboard all experienced slower rates, paper, especially communication paper, experienced the greatest deceleration in capacity growth. Since the 1990s, this trend has continued as “Growth in overseas paper manufacturing output; shrinkage in US manufacturing, which demands paper for final products and packaging; and substitution of paper publications by electronic media continue to put downward pressure on US paper and paperboard production” (USDA Forest Service 2016, 2-10).

Pulp is material created through various processes[33] for use in paper, paperboard, fiberboard and other cellulosic products. Total pulp production in the United States peaked in 1991 and has been on a declining trend since (Figure 4-5). As a raw material used in paper manufacturing, the decline in pulp production, especially chemical and mechanical wood pulp, after the 1990s reflects both reduced demand for paper following the dot-com boom and the increased use of recovered paper. Pulp production experienced further declines as GDP contracted during the Great Recession and domestic and global demand for paper decreased.

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[32] Particle board includes oriented strand board, waferboard and flaxboard.

[33] Mechanical wood pulp uses mechanical means, such as grinding, milling or refining, to create pulp. Chemical wood pulp processes wood raw material using a series of chemical treatments. It includes sulphate (kraft), sulphite and soda wood pulp. Semi-chemical wood pulp uses both mechanical and chemical processes to create pulp. Dissolving pulp is chemically-processed pulp made from special woods with typically greater than 90 percent alpha-cellulose content. Dissolving pulp is used in synthetic fibers, cellulose-based plastics, lacquers and explosives.

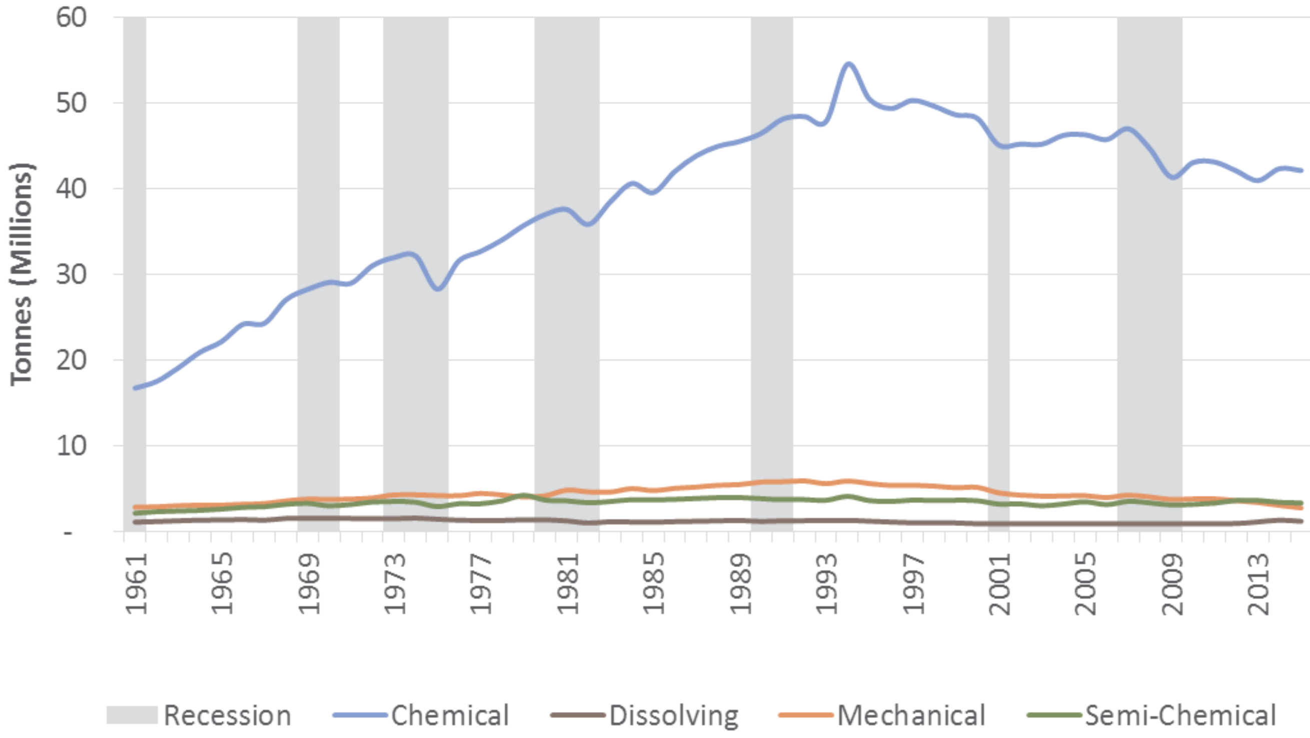

Figure 4-5 US Pulp Production and Economic Recessions, 1961-2015
(Sources: FAO 2016, National Bureau of Economic Research.)

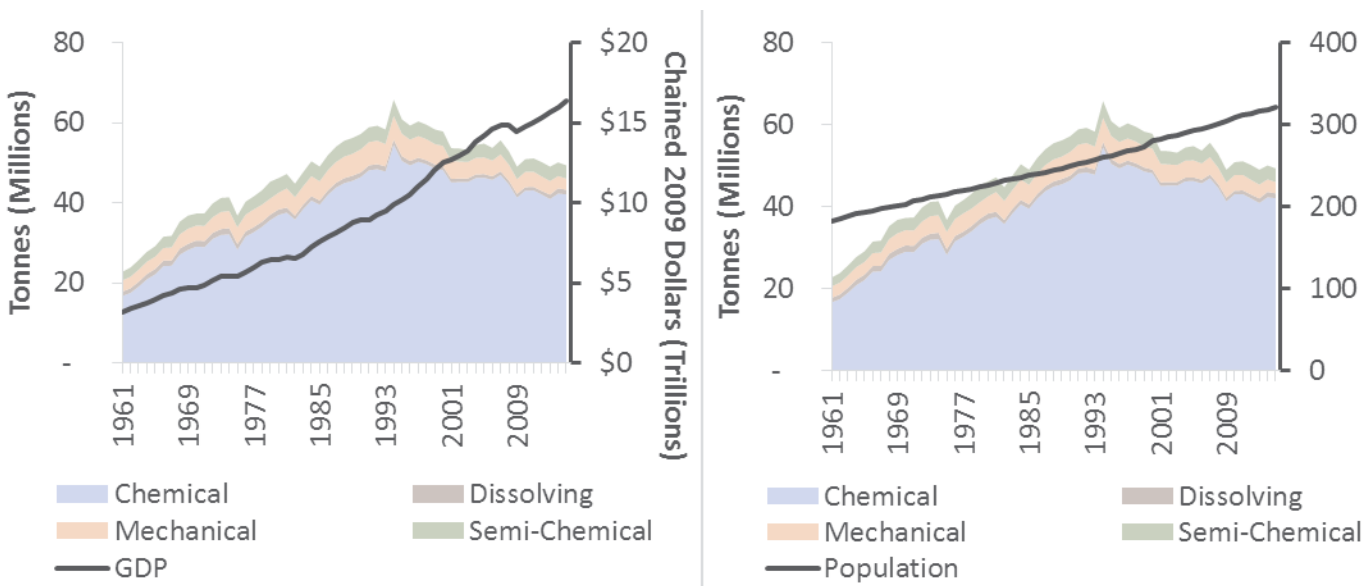

Figure 4-6 US Pulp Production vs. GDP and Population
(Sources: FAO 2016, US Bureau of Economic Analysis 2016b, US Bureau of the Census.)

Domestic printing/writing paper,[34] newsprint,[35] packaging[36] and household/sanitary paper[37] production increased steadily until the mid-1990s, driven by increases in population and rising GDP (Figure 4-7). Since the mid-1990s to early 2000s, printing and writing papers and newsprint production have been in almost continual decline. Packaging production fared somewhat better, remaining almost flat, and actually shows signs of increasing from its modern low during the Great Recession as consumer demand for products has increased. Long-fibered Southern pine is well suited for making packaging materials like high-strength container board. Recovered paper[38] production increased modestly through the 1980s before experiencing significant growth in the 1980s and 1990s; production has been fairly stable for the last ten years. Household and sanitary paper production has increased slowly but steadily since the 1950s driven largely by increases in population; production in this segment was virtually unaffected by the Great Recession.

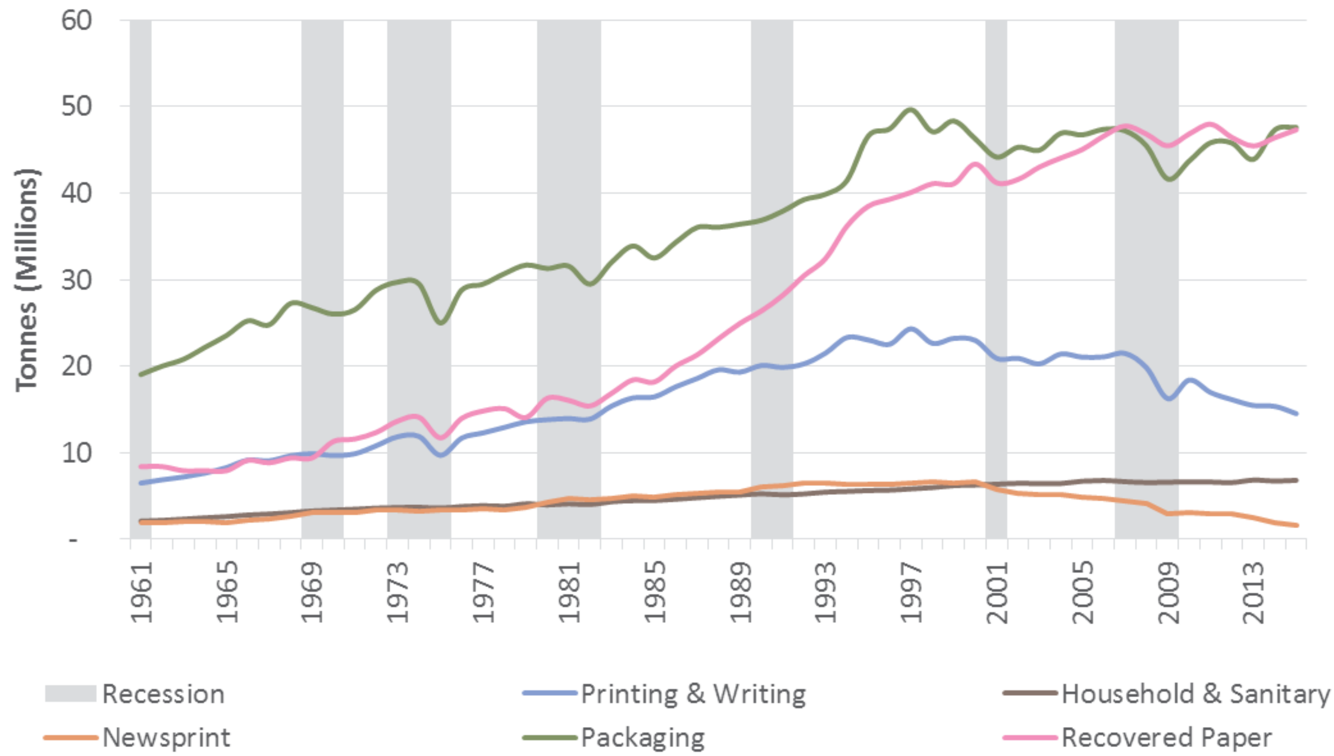

Figure 4-7 US Paper Production and Economic Recessions
(Sources: FAO 2016, National Bureau of Economic Research.)

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[34] The FAO database includes uncoated mechanical, uncoated woodfree and coated papers in its printing and writing paper category. Uncoated mechanical uses less than 90 percent chemical pulp while uncoated woodfree uses greater than 90 percent chemical pulp. Coated papers have at least one side coated with carbon or minerals.
[35] As the name suggests, newsprint is primarily used for printing newspapers.
[36] The packaging category includes paper and paperboard used for wrapping and packaging purposes.
[37] Sanitary and household papers include tissue and other paper hygiene products, such as facial tissues, toilet tissue, hand towels and wipes.
[38] Recovered paper includes residues created during paper and paperboard production as well as waste and scraps of already used paper.

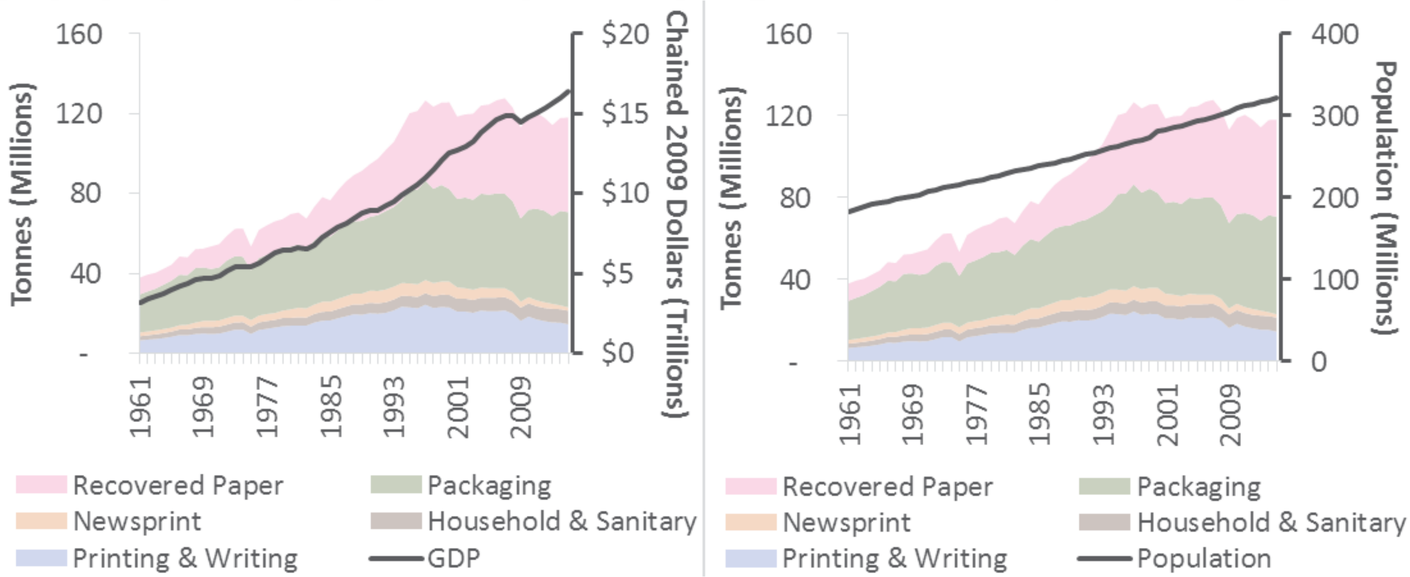

Figure 4-8 US Paper Production vs. GDP and Population
(Sources: FAO 2016, US Bureau of Economic Analysis 2016b, US Bureau of the Census.)

4.2.3 Wood Pellets

While both domestic and export demand promote wood pellet production in the United States, production is increasingly driven by overseas demand for pellets, especially for industrial pellets that are used as a renewable energy substitute for traditional fossil fuels (Goetzl 2015, USDA Forest Service 2016). Global production of pellets increased by 5 percent from the 25.7 million metric tonnes produced in 2014 to reach 27.0 million metric tonnes in 2015 (FAO as quoted in Hawkins Wright Ltd. 2016a). Consumption of wood pellets is most prevalent in Europe where wood pellets are used extensively for home heating as well as industrially for the production of renewable and low-carbon energy. Industrial use of wood pellets is also growing in Asia, which consumed approximately 1.7 million metric tonnes of the global demand in 2015 (Hawkins Wright Ltd. 2016b).

Most US industrial pellet manufacturing capacity is located in the US South, and the South ships over 98 percent of US wood pellet exports (Goetzl 2015), primarily to the EU. According to Eurostat, the EU imported nearly 12.9 million metric tonnes of wood pellets in 2015, with the UK taking in nearly 6.5 million metric tonnes. Wood pellets produced in the US South have increasingly filled the gap between European demand and supply.

Prior to 2012, wood pellet production in the United States was tracked under a broader commodity code that included not only wood pellets, but also sawdust, fire logs and similar products (Goetzl 2015). Figure 4-9 shows US pellet production from 2012 to 2015 and Forest2Market's estimated production from 2000 to 2011.

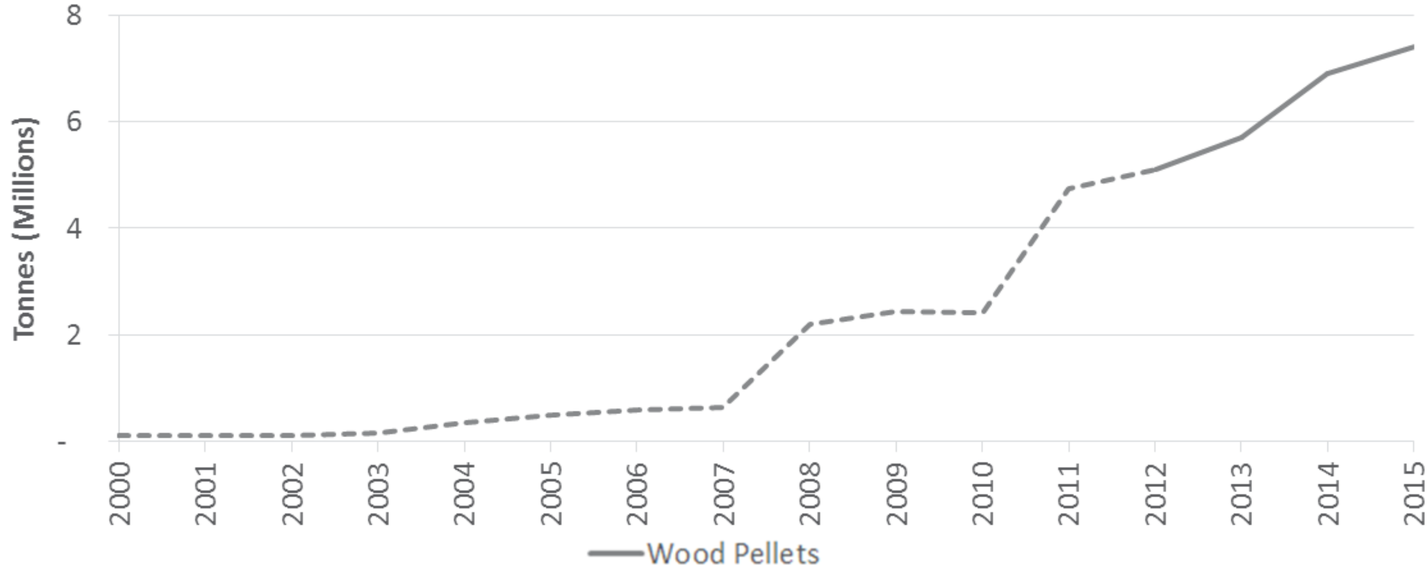

Figure 4-9 US Wood Pellet Production
Pellet production increased significantly in the late 2000s and 2010s. (Sources: FAO 2016, Forest2Market data and estimates.)

While wood pellet production in the United States increased dramatically after 2009, its growth rate has recently moderated as demand for new pellet capacity has stalled. Total pellet production remains dwarfed by pulp and paper production (Figure 4-10), and its wood fiber demand is a small fraction of total demand for wood in the South (Forest2Market 2015). Bioenergy is therefore "unlikely to significantly influence broader markets for timber products nationwide or lead to changes in the overall U.S. position on global markets" (USDA Forest Service 2016, 6-13).

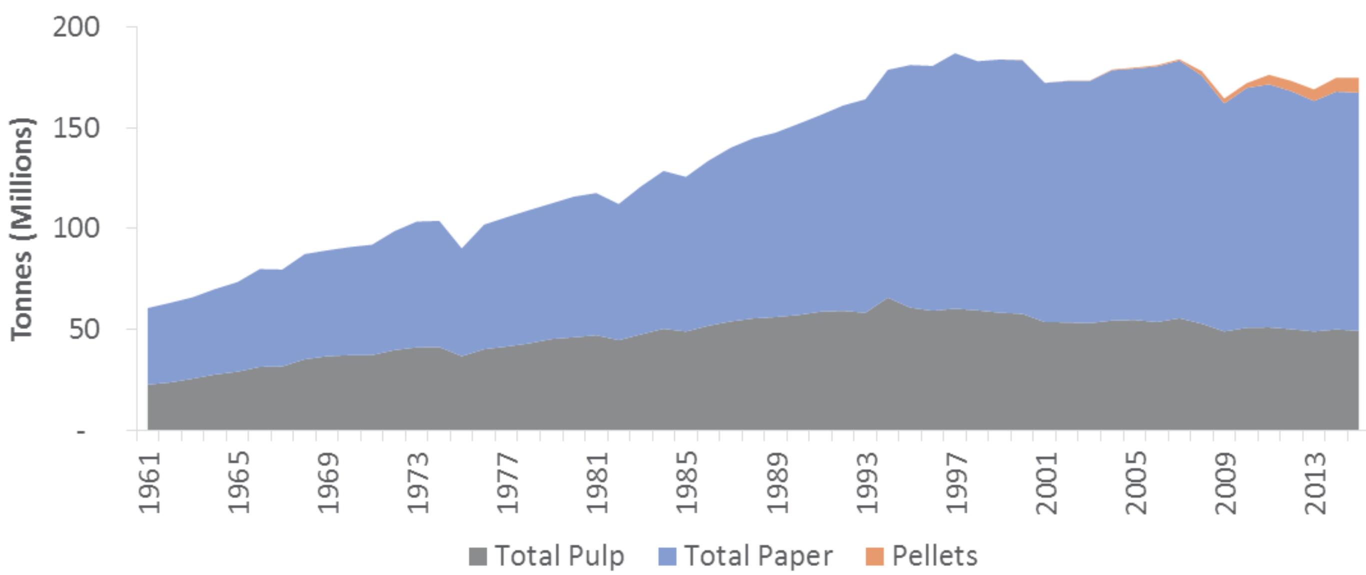

Figure 4-10 Total US Pulp, Paper and Pellet Production, 1961-2015
Despite its rapid growth since the 2000s, pellet production remains small in comparison to pulp and paper production. (Sources: FAO 2016, Forest2Market data and estimates.)

5 TRENDS IN FOREST MANAGEMENT PRACTICES AND FOREST PRODUCTIVITY

Having described the historical and recent macroeconomic and industry trends that have shaped Southern forests, this section provides a deeper look at trends in forest productivity and management. In it, we discuss patterns in timberland ownership, changes in timberland acreage and shifts in management practices. We then report important forest metrics, including annual growth, removals, growth-to-removal ratios and inventory relying heavily on published data from US Forest Service Resources Planning Act (RPA) assessment reports. Finally, we juxtapose removals against various forest metrics to analyze their historical relationships and determine to what extent demand (reflected by removals) impacts forest productivity. All data in this section pertain specifically to the US South unless otherwise specified.

5.1 Timberland Ownership

Timberland ownership in the United States can broadly be grouped into government-owned and privately-owned lands. Throughout most of the last few centuries, private owners have controlled most of the South's forests (USDA 1988). Figure 5-1 shows the geographic distribution of private and public forests and non-forested areas in the US South around 2009.

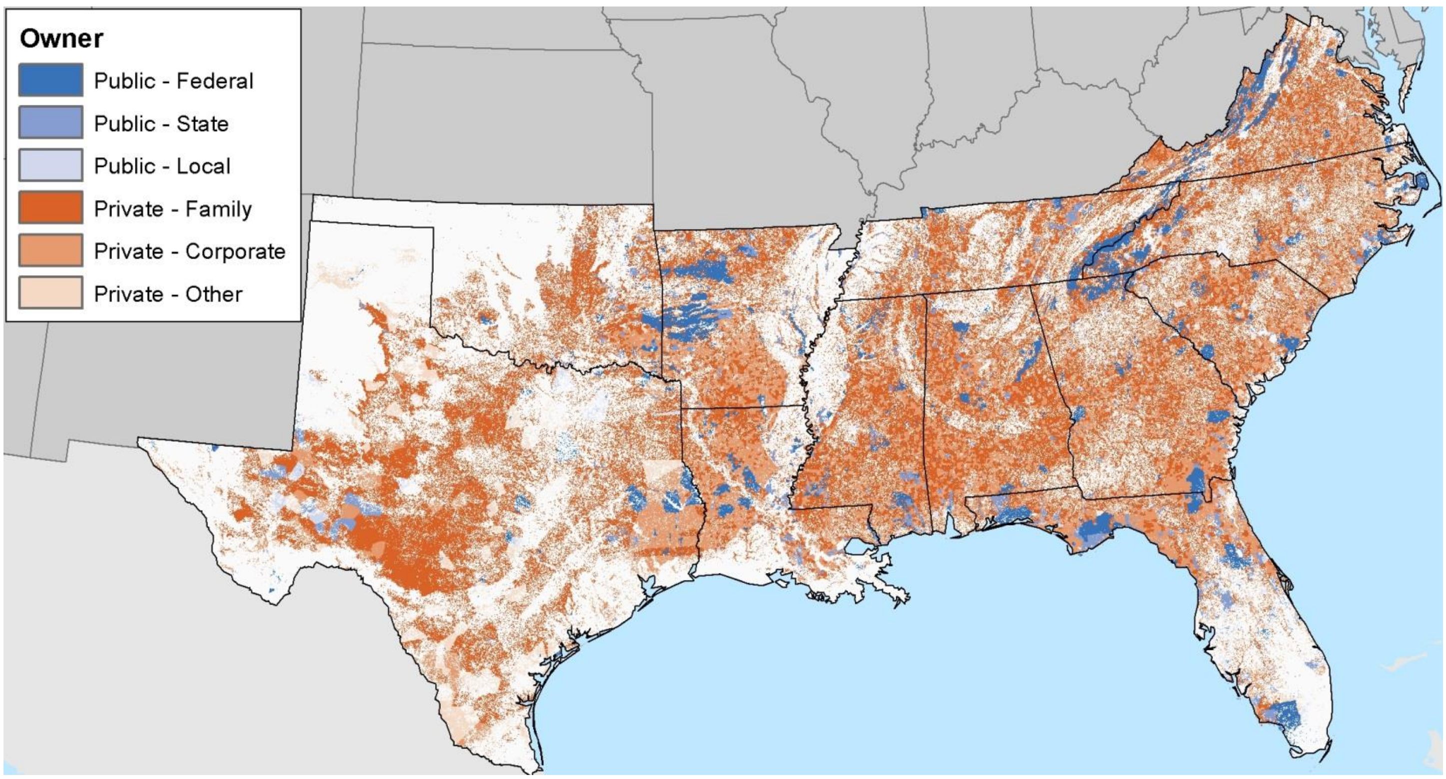

Figure 5-1 Forest Ownership in the US South, circa 2009
(Source: Hewes et al. 2014.)

Most (over 90 percent) of wood fiber used by the forest products industry in the United States originates from private forests (Oswalt et al. 2014), and private forests therefore support more forest products industry jobs than public forests (Forest2Market 2016). Private forests are generally more productive than comparable public forests, are located on higher-quality sites, have higher growth potentials and realize more of their potential growth (Oswalt et al. 2014).

Both large-scale and smaller ownerships are included in the private category. The US Forest Service distinguishes between "corporate" and "non-corporate" owners. "Corporate" ownerships are typically large-scale ownerships held by industrial owners (i.e., vertically-integrated companies that produce forest products using wood harvested from their timberlands), institutional owners (i.e., Timberland Investment Management Organizations [TIMOs] and Real Estate Investment Trusts [REITs]) and other corporate owners, including conservation organizations, partnerships or tribes. Non-corporate ownerships are typically smaller and held by non-industrial private forest land owners (NIPF), which may include individuals and families.

Between 1953 and 2012, corporate acreage increased from 45.9 to 59.4 million acres and the share of timberland controlled by corporate owners increased from 24 to 30 percent (Figure 5-2) as the forest products industry increased their land holdings to support their often integrated[39] manufacturing operations, which produced pulpwood for pulp and paper (and later OSB) production and sawtimber and veneer logs for dimensional lumber and plywood production. Meanwhile, non-corporate owners controlled 18.2 million fewer acres in 2012 than they did in 1953.

Public timberland increased from 16.7 to 26.1 million acres. By far the largest increase in public timberland was in the amount of timberland owned by state governments, which increased by 4.8 million acres. County and municipal government, National Forest and other Federal government timberlands expanded by about 1.5 to 1.7 million acres each.

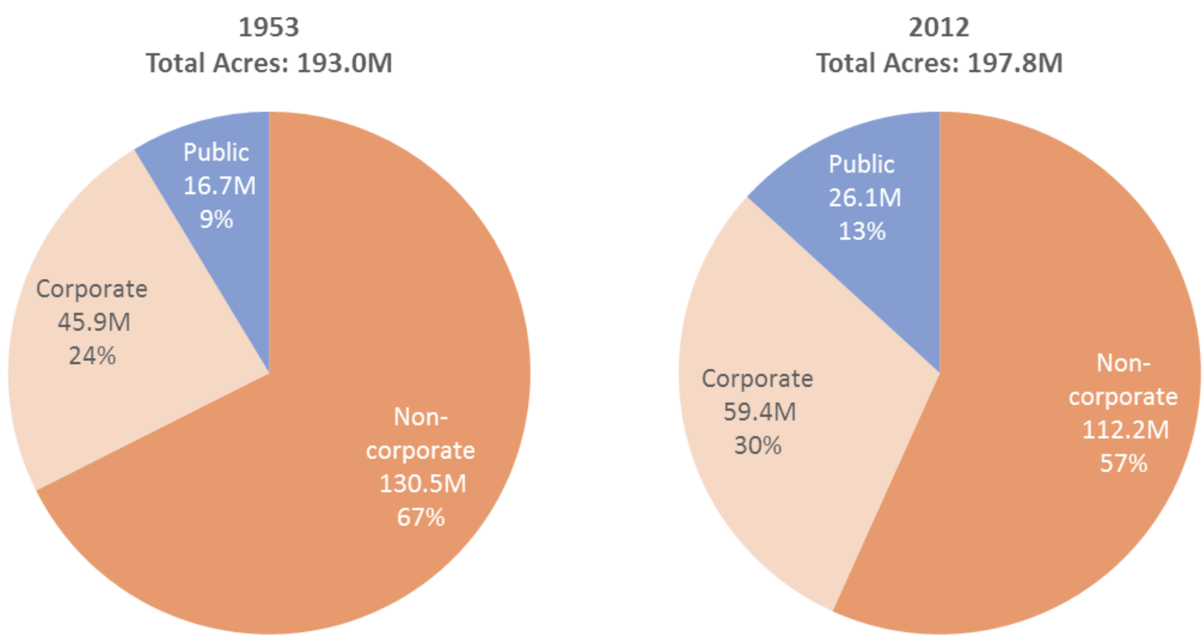

Figure 5-2 Timberland Acres by Ownership, 1953 and 2012

In total, timberland acreage increased by 4.7 million acres between 2012 and 1953. Increases in corporate and publicly-owned timberlands of 13.5 and 9.4 million, respectively, offset a decrease of 18.2 million acres of non-corporate timberlands. (Source: USFS Resources Planning Act reports and Forest2Market estimates.[40])

[39] Initially in the South and elsewhere, some forest products companies used an integrated business model wherein a company owned timberlands to supply raw material to multiple types of manufacturing operations, such as pulp or paper production and dimensional lumber production. Smaller, lower-value wood (i.e., pulpwood and topwood) harvested primarily during thinnings was used in pulp, paper and OSB production. Larger, higher-value wood (i.e., sawtimber and veneer logs) harvested primarily during final harvests was used in production of dimensional lumber and plywood. Residual byproducts from lumber production were sent from sawmills to pulp and paper mills as additional raw material inputs. While few forest products companies remain integrated in the US today, this practice is still common in other places, such as Canada.

[40] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market assumptions. Data exclude

The most significant change in private timberland ownership in recent years has been the shift from forest products industry ownership to ownership by investment organizations, such as TIMOs and REITs (Zhang, Butler and Nagubadi 2012). In the late 1990s, the forest products industry held approximately 20 percent of forest land in the South; by 2013, that number had dropped to less than 5 percent (Wear and Greis 2013).

Between 1998 and 2008, the number of acres owned by industry dropped by 68 percent from 23.2 to 7.5 million acres (Figure 5-3, next page).[41] TIMO ownership increased 507 percent from 2.2 to 13.1 million acres, and REIT ownership increased 21 percent from 5.4 to 6.5 million acres. Other corporate acres increased 16 percent from 1.8 to 2.2 million acres. In total, corporate ownership decreased 10 percent from 32.6 to 29.2 million acres.

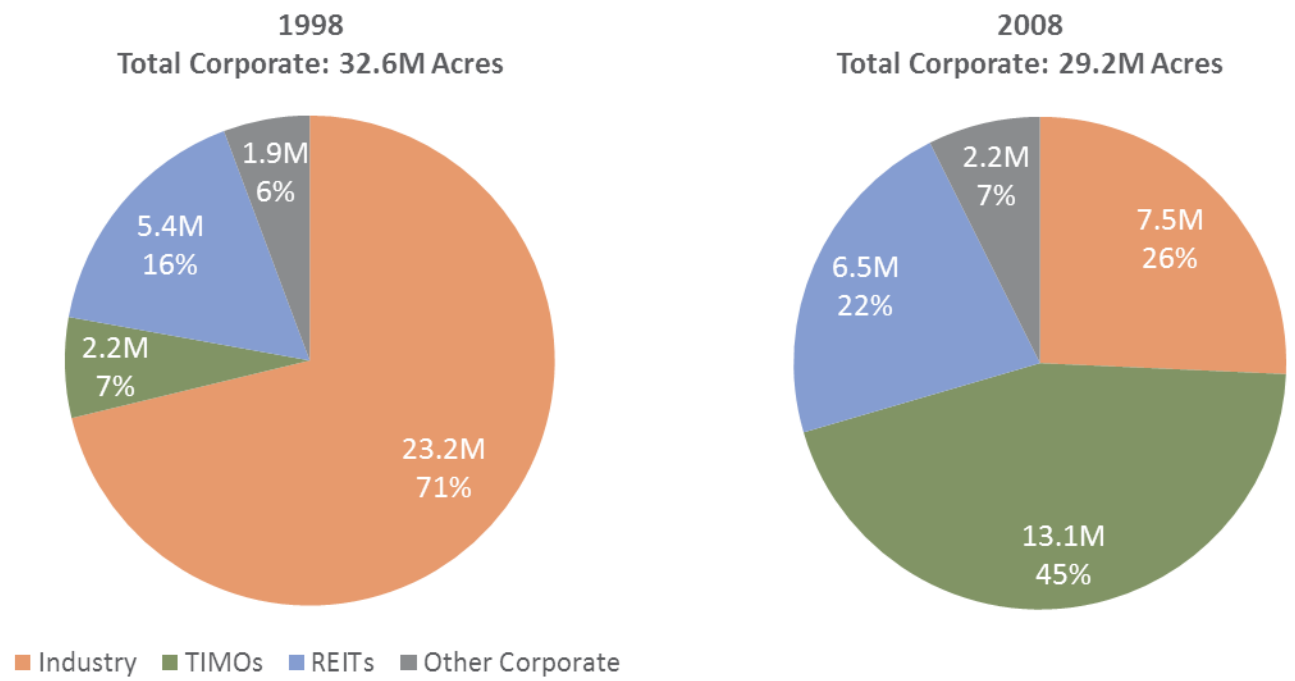

Figure 5-3 Corporate Ownership by Subgroup in the US South, 1998 and 2008
While the forest products industry held the majority (71 percent) of corporate timberlands in 1998, most corporate timberlands (67 percent) were held by investment organizations in 2008 following the divestiture of 15.7 million forest industry acres. (Source: Lanworth, Inc. as quoted in Wear and Greis 2013.)

By 2012, the only major pulp or paper manufacturer who had not sold or divested its timberland assets was Weyerhaeuser Corporation (Carter et al. 2015). It had, however, converted to a REIT by this time. Since completing its merger with Plum Creek in 2016, Weyerhaeuser sold its remaining pulp mill assets. As Wear and Greis (2013) note, the reasons why each particular company divested timberlands during this period vary and are likely a combination of various factors. One factor was likely an Internal Revenue Code change in 1986 that taxed manufacturers at a corporate rate of 40 percent on timber sales, while landowners who did not manufacture timber paid 15 percent in capital gains taxes (Carter et al. 2015).

In addition to the tax rate, Wear and Greis (2013, 114-117) cite the following as factors that contributed to divestiture:

Kentucky. For 1953, the allocation of acres between corporate and non-corporate owners was estimated based on the reported allocation of acres between forest industry and non-industrial private forest ownership and Forest2Market's estimates of TIMO/REIT ownership.

[41] Source: Lanworth, Inc. as quoted in Wear and Greis 2013. Kentucky is excluded.

- Previous consolidation in the forest products industry, which made it advantageous for companies to offset acquisition debt by selling timberland and likely reduced demand for timberlands through mergers
- Diminishing timber scarcity concerns, which made holding timberlands less necessary to ensure a steady supply of raw material
- New technology like Geographic Information Systems (GIS), which made it easier to locate potential supply
- Globalization, which promotes a separation of production tasks across different geographic areas

Similar and other reasons have been cited by Zhang, Butler and Nagubadi (2012, 356); they identify several factors, primarily related to corporate finances that contributed to divestiture, including: “government tax policies that disfavor C-Corp structured ownerships, generally accepted accounting principles that undervalue timberland owned by industrial firms, and the rising interest in timberland as an alternative investment by institutional investors.”

5.2 Timberland Acres

After decreasing through the 1960s to 1980s, the amount of timberland in the South has since been on an increasing trend, and, today, the amount of timberland in the South is comparable to what it was in the 1950s (Figure 5-4). The composition of timberland, however, has changed: Private corporate and public acres have increased over this time period while private non-corporate acres have decreased.

The first statistically accurate survey of timberland area in the South occurred in 1952 and showed that there were approximately 193 million acres of timberland (USDA 1988). Between 1963 and 1987, timberland area declined driven by increasing urbanization (e.g., in Florida) and conversion from timberland to cropland (e.g., in Arkansas and Louisiana). By 1985, “urban and built-up uses in the South ha[d] expanded by 20 million acres since 1952” (USDA 1988, 112). Migration of industry and interregional shifts in population to the South also played a role. The area of timberland increased between 1987 and 2012 buoyed by increases in both private and public acres. If recent trends continued between 2012 and 2015, total timberland area in the South would have been approximately 198.9 million acres in 2015.

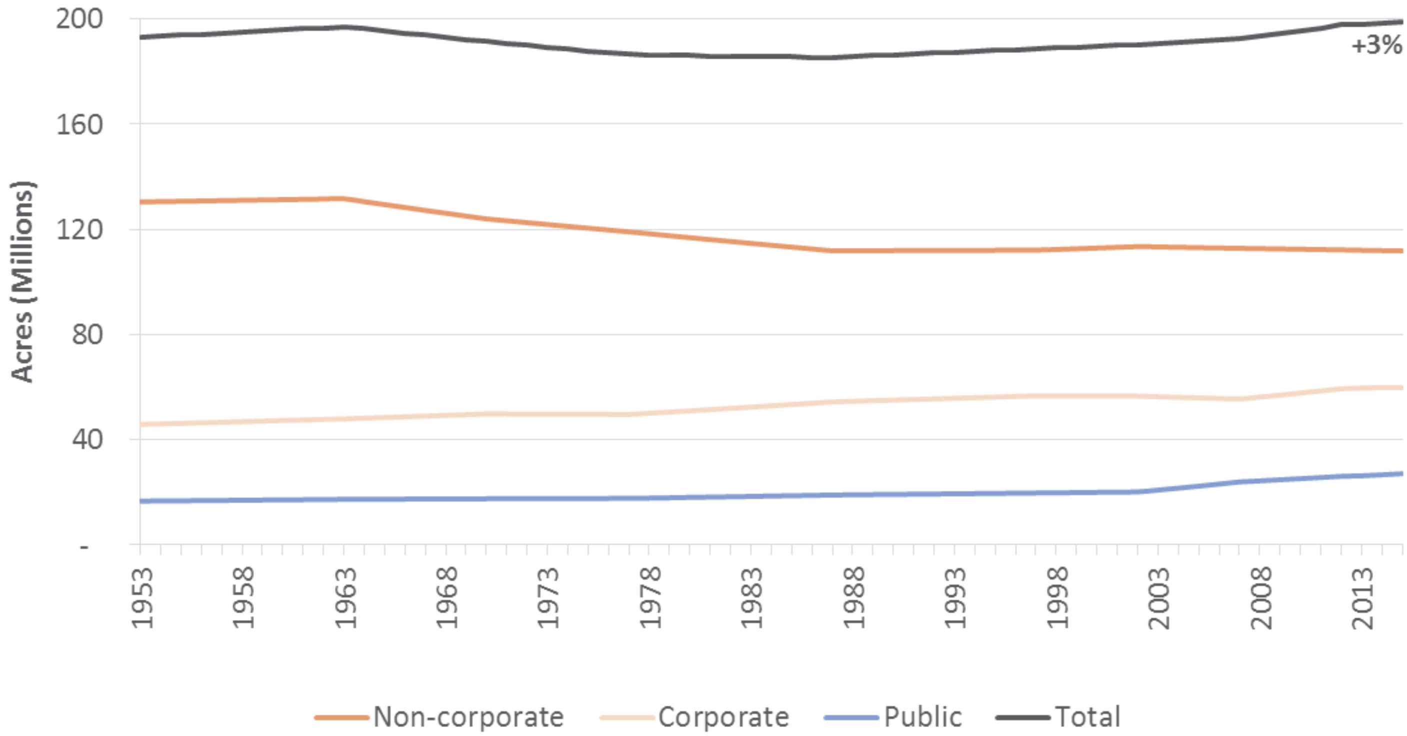

Figure 5-4 Annual Timberland Acres by Ownership, 1953-2015

As increases in public and especially corporate acres have offset decreases in non-corporate acres, total timberland has increased by 3 percent since 1953. (Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.[42])

5.3 Timberland Forest Management Practices

Forest management refers to the manner in which a landowner manages his or her timberland. As noted in Section 4.1, the majority of Southern forests had been cut-over by the 1920s. To combat deforestation and ensure stable future supplies of timber, landowners in the US South adopted a more active approach to management, which incorporates thinning and harvest rotations, silvicultural improvements and other management techniques designed to improve productivity, promote forest regeneration, optimize wildlife habitat, and/or mitigate fire, disease and insect damage. Today, working together with registered foresters or alone, landowners commonly engage in management activities that are designed to meet their objectives related to timber productivity, biodiversity, recreation and/or conservation.

The US Forest Service tracks forest management broadly by looking at the forest type (i.e., predominant species) and the stand origin (i.e., natural regeneration vs. artificial regeneration or planting). Naturally-regenerated forests should not be confused with old-growth or virgin forests. As established in Section 4.1, most of the South's old-growth forests had been cleared by the 1920s, which is why subsequent generations of forest established after this period are referred to as "second growth" and so on. Rather, naturally-regenerated, or "natural", forests are simply forests that are left to regenerate with no human intervention following harvest. The most significant type of artificial regeneration occurs on pine plantations.

[42] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market assumptions. Data exclude Kentucky.

Figure 5-5 shows the trend in forest management types between 1953 and 2010. Over this period, the most significant changes were in planted pine, natural pine and upland hardwood management types. Planted pine acres increased from 1.8 to 36.1 million acres at a rate of 5.4 percent compounded annually. Natural pine acres decreased from 72.0 to 30.8 million acres at a rate of -1.5 percent compounded annually. Upland hardwood acres increased from 55.4 to 67.7 million acres at a compounded annual rate of 0.4 percent.

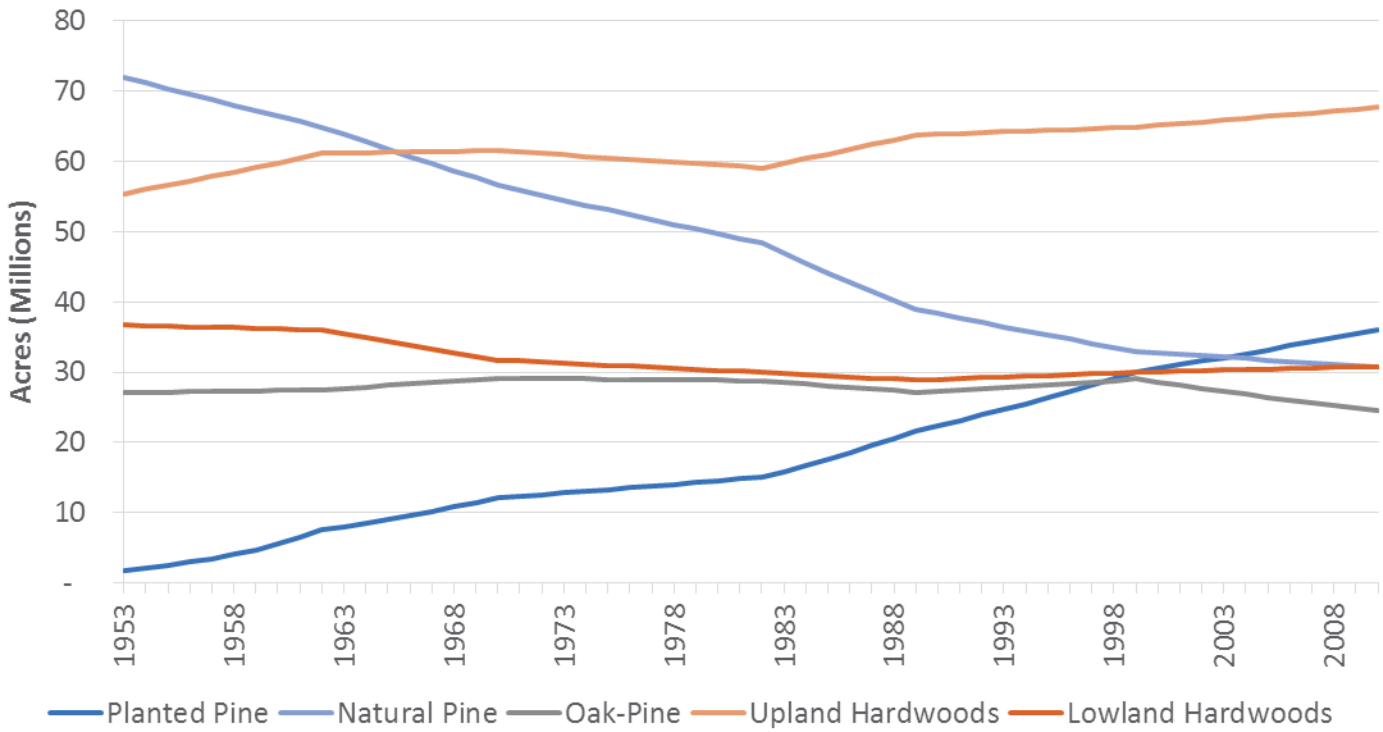

Figure 5-5 Annual Timberland Acres by Forest Management Type, 1953-2010 – All Ownerships

Between 1953 and 2010, plantation pine and upland hardwood increased by 34.2 and 12.3 million acres, respectively. Natural pine, lowland hardwood and oak-pine decreased by 41.2, 5.9 and 2.6 million acres, respectively. (Sources: Conner and Hartsell 2002, Hartsell and Conner 2013, Forest2Market estimates.[43])

5.3.1 Increased Plantation Utilization

Between 1953 and 2010, pine and mixed (i.e., oak-pine) stands experienced a net decrease in acres while hardwood stands experienced a net increase over this period. In total, naturally-regenerated timberlands decreased by 37.5 million acres from 191.2 to 153.7 million acres while artificially-regenerated planted pine increased by 34.3 million acres from 1.8 to 36.1 million acres between 1953 and 2010 (Figure 5-6). Because hardwood timberland acres increased during this period, the loss in natural acres primarily reflects the loss of natural pine and oak-pine stands (Figure 5-5). Planted pine was 1 percent of timberland area in 1953 and 19 percent in 2010.

[43] Data for 1953, 1962, 1970, 1982, 1989, 1999 and 2010 from Conner and Hartsell 2002 and Hartsell and Conner 2013. Data for intervening years are derived by Forest2Market using annual rates of change between available data years. Data are for all ownerships and exclude nonstocked stands and Kentucky acreage. Because data are from a different source, differences exist between these data and the data reported in Section 5.2.

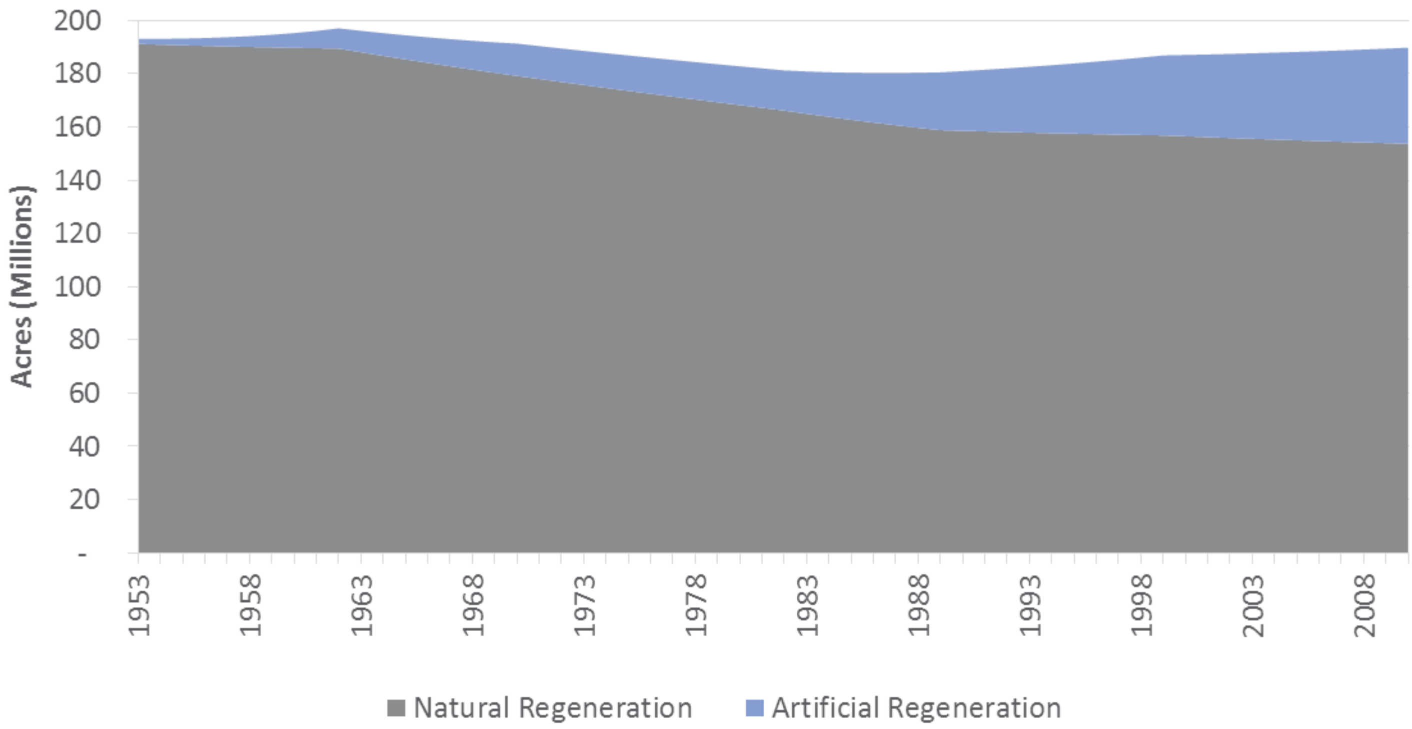

Figure 5-6 Annual Natural and Plantation Timberland Acres, 1953-2010 – All Ownerships
Naturally-regenerated timberland acres have decreased while artificially-regenerated plantation pine acres have increased since 1953. (Sources: Conner and Hartsell 2002, Hartsell and Conner 2013, Forest2Market estimates.[44])

Several factors contributed to the increase in plantations over this time period. First, plantations allow owners to control various traits through genetic improvement, species composition and the amount of stocking on the stand (Sheffield 2009). They are also highly productive: As of 2007 in the South, 57 percent of the net annual growth of softwood species was associated with plantation stands, and 43 percent of softwood removals originated on plantations (Sheffield 2009).

Second, as discussed in Section 3.4, land conservation policies to combat soil degradation and crop surpluses also promoted the establishment of timber plantations. While tree planting on industrial lands also increased through 1980 (as indicated by the industry share line), the abrupt increases in tree planting in the 1950s and 1980s were driven primarily by increases in planting by non-industrial private forest (NIPF) owners, who were the recipients of these financial incentive programs (Wear, Carter and Prestemon 2007) (Figure 5-7).

[44] Ibid.

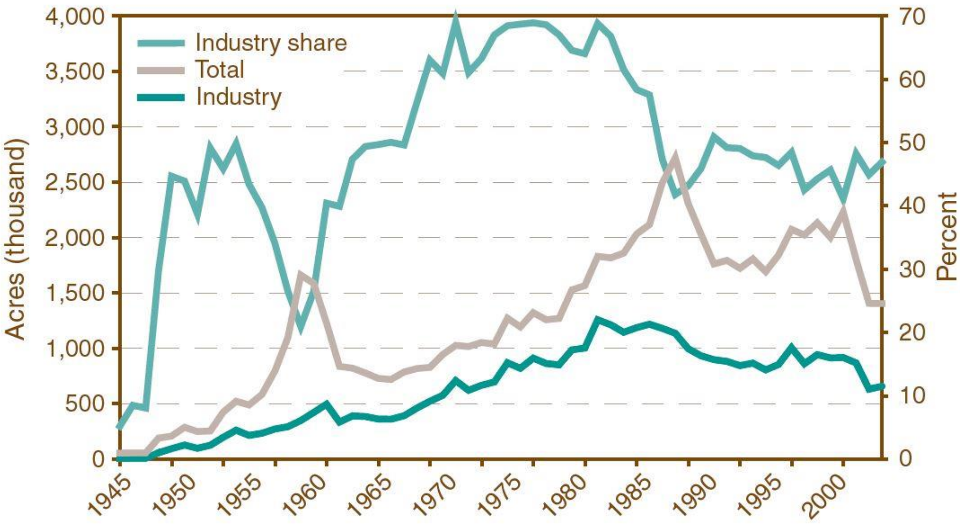

Figure 5-7 Total Planted Acres, Acres Planted by Industry and Industry Share of Total Plantings, 1945-2004
The practice of tree planting increased significantly in the US South in the latter half of the twentieth century. Increases in planting in the 1960s and 1980s were driven by government programs that promoted planting on non-industrial lands. During other times, more tree planting occurred on lands owned by the forest products industry. (Image Source: Wear, Carter and Prestemon 2007.)

The planting data in Figure 5-7 includes both expansion planting (i.e., establishment of new timber stands) and replacement planting (i.e., stands that were replanted after being harvested). Figure 5-8 shows the acres estimated by Wear, Carter and Prestemon (2007) to be either expansion or replacement planting using FIA data about plantation inventory. Initially, most planting was expansionary. In the 1970s and 1980s, this shifted to replacement planting as plantations established previously were harvested and replanted. Expansion planting increased in the 1980s and 1990s before decreasing in the 2000s.

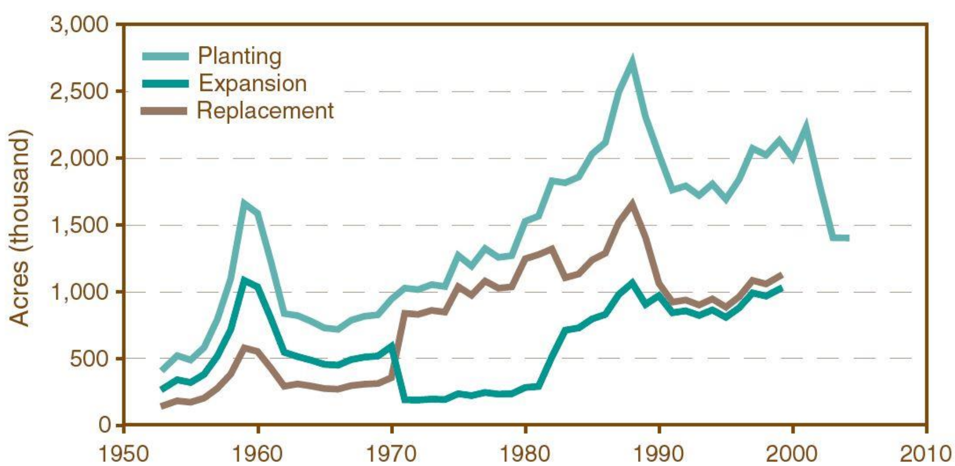

Figure 5-8 Total Planted Acres and Estimated Expansion and Replacement Planting, 1953-2004
Expansion planting occurred between 1950 and 1970 and again between the early 1980s and 2000. Much of the planting between 1970 and 1980 was replacement planting (i.e., replanting of existing timberland). (Image Source: Wear, Carter and Prestemon 2007.)

While it is true that some naturally-regenerated stands are being converted to plantations, it is also true that nonforested stands are being converted to plantations and that natural stands are being converted to nonforested uses.

That is, neither all of the gain in plantation pine stands, nor all of the loss in natural stands can be attributed to conversion from natural to plantation management.

Table 5-1 shows changes[45] in timberland area by management type between 1989 and 1999. Most stocked timberland was the same forest management type in both 1989 and 1999. By percentage, planted pine/oak-pine and lowland hardwood experienced the least conversion at 11 and 13 percent, respectively. By percentage, natural oak-pine experienced the most conversion: Only 53 percent (12.7 million acres) was natural oak-pine at both time periods. In terms of acres, however, natural pine and upland hardwood experienced the most conversion at 14.0 and 13.7 million acres converted, respectively.

Table 5-1 Change in Timberland Area (Thousand Acres) by Management Type, 1989 to 1999

Planted pine/oak-pine stands experienced the least conversion to other land use types. Of land that converted to nonforest, 94 percent (5.1 million acres) was previously a naturally-regenerated timberland type. (Source: Conner and Hartsell 2002.)

	1999 Forest Management Type									
1989 Forest Management Type	Planted Pine/Oak-Pine	Natural Pine	Natural Oak-Pine	Upland Hardwood	Lowland Hardwood	Nonstocked	Nonforest	**1989 Total**	**Total Converted**	**Percent Converted**
Planted Pine/Oak-Pine	**21,951**	970	408	1,001	131	37	300	24,798	2,847	11%
Natural Pine	3,335	**26,140**	5,238	3,437	528	32	1,394	40,104	13,964	35%
Natural Oak-Pine	1,154	3,933	**12,653**	4,710	732	8	660	23,850	23,850	47%
Upland Hardwood	3,881	908	4,997	**52,176**	1,671	63	2,210	65,906	13,730	21%
Lowland Hardwood	634	112	973	1,281	**25,913**	40	864	29,817	3,904	13%
Nonstocked	30	5	—	—	11	**22**	7	75	53	71%
Nonforest	3,046	1,412	895	2,470	1,299	153	—	—	—	—
1999 Total	34,031	33,479	25,163	65,074	30,285	355	—			

The evidence from this time period suggests that planted stands are less likely to be converted to nonforest uses. Only 1 percent (300,000 acres) of planted pine/oak-pine acres converted to nonforest during this time period. By contrast, 3 percent each of the various natural forest types (5.1 million acres in total) became nonforest.

Of the 5.4 million acres converted to nonforest, most was previously natural forest types:

- 41 percent (2.2 million acres) was previously upland hardwood.
- 26 percent (1.4 million acres) was previously natural pine.
- 16 percent (864 thousand acres) was previously lowland hardwood.
- 12 percent (660 thousand acres) was previously natural oak-pine.
- 6 percent (300 thousand acres) was previously planted pine/oak-pine.

[45] **Bold, underlined** font indicates area that did not change from 1989 to 1999. Within each row, data in other columns indicate areas that converted to other forest management types or to nonforested areas. Nonforested lands are not intentionally sampled by the US Forest Service. Data on nonforested land uses are included only if the lands were forested at either the beginning or ending time period.

5.4 Growth

Privately-owned timberlands typically realize more growth than publicly-owned timberlands, and this is reflected in the growth data for 1953-2015 (Figure 5-9). Annual private growth significantly outpaces public growth for both softwood and hardwood species. Since 1953, average annual net growth on public timberland has not exceeded 690 million cubic feet for each species. Net growth on private timberland, on the other hand, has increased by billions of cubic feet annually, especially for softwood species as plantation pine management practices have increased yield. Dramatic increases in private softwood growth after 2007 are indicative of an imbalance in growth and removals wherein growth has significantly outpaced removals as demand for wood products, especially sawtimber used in housing construction and pulpwood used for printing and writing papers, has declined.[46]

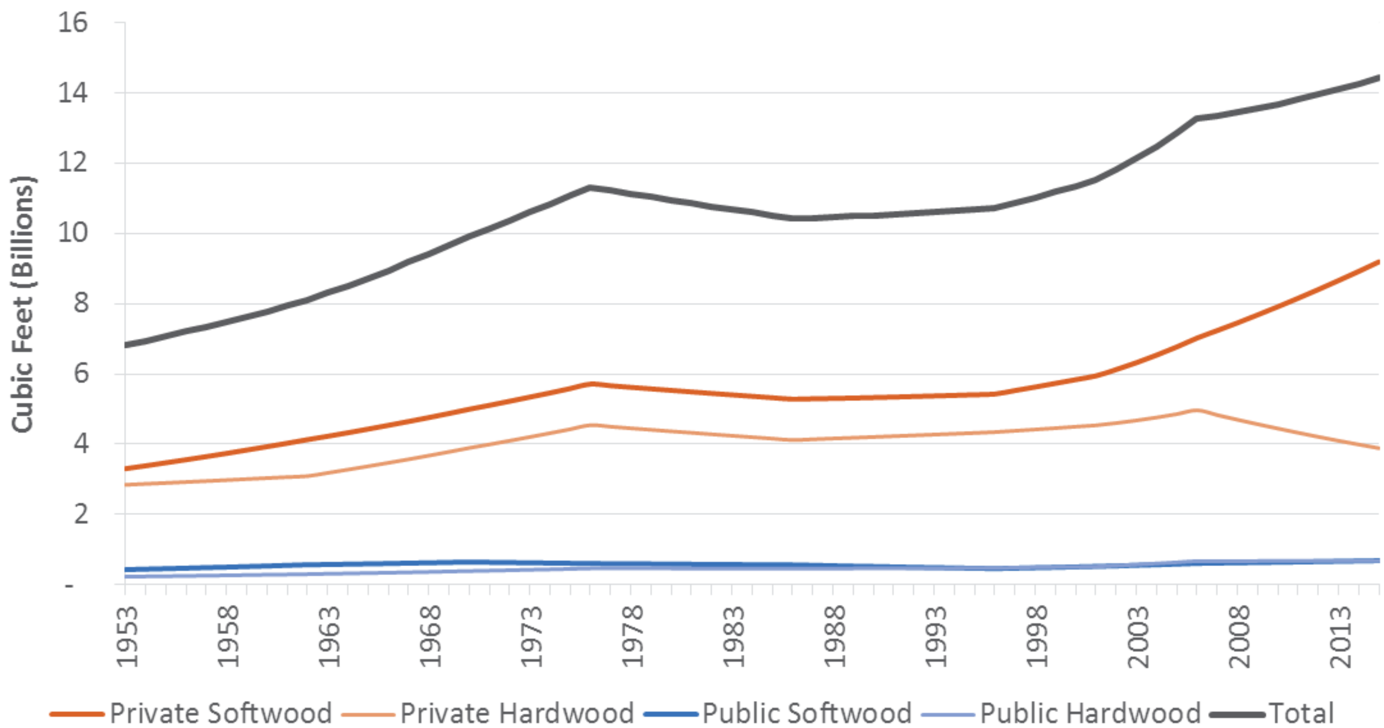

Figure 5-9 Annual Growing Stock Growth on Timberland by Ownership, 1953-2015

Annual private growth consistently and significantly exceeds public growth. This differential has intensified for softwood species and lessened for hardwood species since 1953. While annual growth has increased across all species and ownership groups, the largest increases were in private softwood growth, which increased 178 percent, and public hardwood growth, which increased 195 percent. Increases in annual private hardwood and public softwood growth were much smaller at 37 and 59 percent, respectively. (Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.[47])

[46] Also see Section 5.8.3.

[47] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market assumptions. Data include Kentucky.

On a per acre basis, growth increased significantly between 1953 and 1977 in response to improved silvicultural practices and management (Figure 5-10). Prior to 1977, growth per acre was higher on public timberland than private timberland, but private timberland growth per acre increased at a faster rate. Since 1977, growth per acre has been higher on private timberland than public timberland, which reflects the significant growth improvements realized by private landowners, especially on plantation stands.

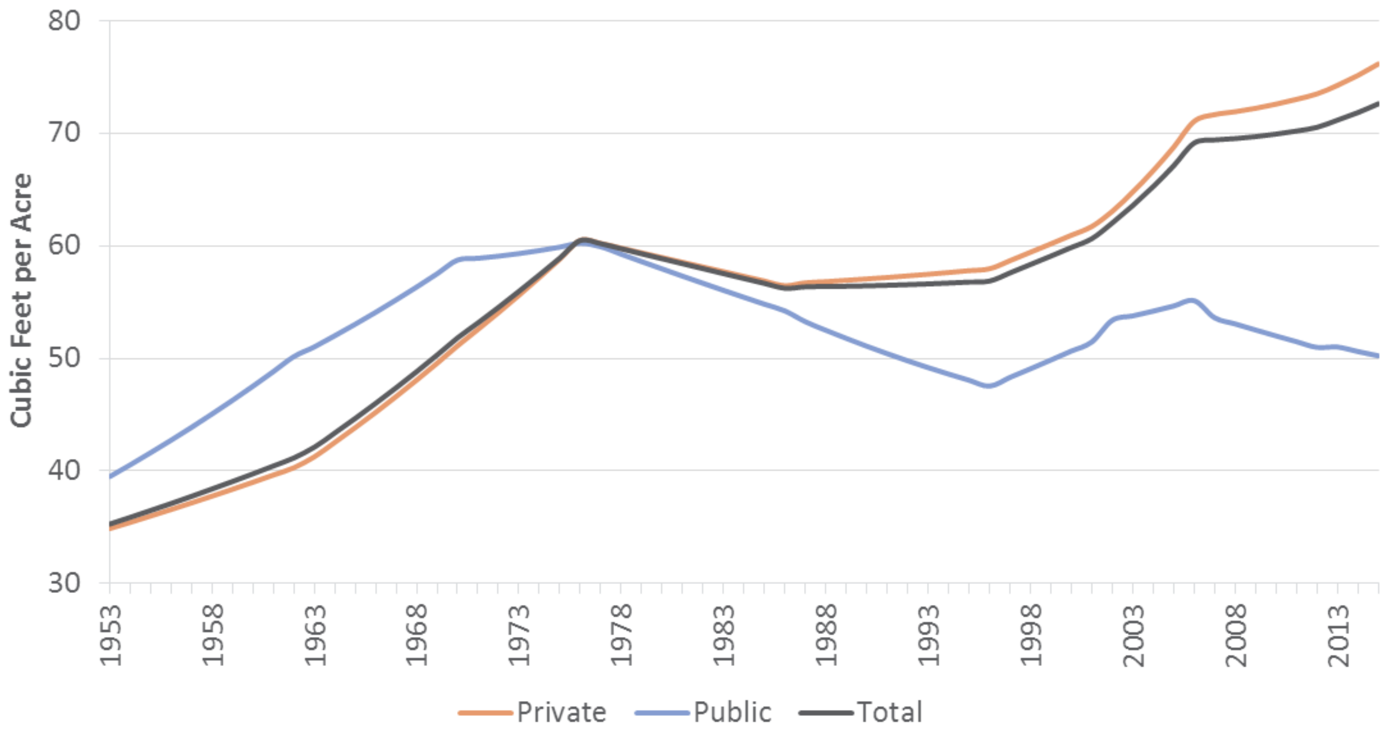

Figure 5-10 Annual Growing Stock Growth per Acre on Timberland by Ownership, 1953-2015
Since 1977, annual growth per acre on private timberlands has increased 0.6 percent annually from 60 to 76 cubic feet per acre; on public timberlands, it has decreased 0.5 percent annually from 60 to 50 cubic feet per acre. (Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.)

5.4.1 Pine Plantation Productivity

Several factors affect growth rates, including species, stand type, stand age, total timberland acres, tree genetics and silvicultural practices. In particular, Southern pine plantations have experienced dramatic increases in productivity over this period. Financed primarily by forest industry, collaborative research conducted by the US Forest Service, forestry schools, state agencies and the forest industry led to improvements in silvicultural practices, including site preparation, weed control, fertilization and tree improvement (Fox, Jokela and Allen 2007):

- Site preparation aims to improve the quality of the site through mechanical or chemical site preparation to reduce competing hardwood growth, using bedding to minimize the negative impacts of poorly drained soils and minimizing logging debris to promote seedling survival and growth.
- Weed control refers to the elimination of herbaceous vegetation that, like hardwoods, would otherwise interfere with the growth of young pine seedlings.
- Fertilization improves soil quality by replacing depleted nutrients, such as nitrogen and phosphorous, to support tree growth.

- Tree improvement refers to the preferential use and genetically-superior seedlings that have better growth, tree form, disease resistance or wood quality. Seed orchards were instrumental in enabling the widespread use of improved seed.

Together, these improvements contributed to increases in growth rates from 90 cubic feet per acre per year for plantations established in the 1950s and 1960s to 350 cubic feet per acre per year or more for plantations replanted in the 2000s (Fox, Jokela and Allen 2007). In the future, clonal forestry, which uses vegetative propagation to produce exact copies of seeds with superior genetic potential and has been used successfully in Brazilian Eucalyptus plantations, “holds the greatest promise to increase the productivity of southern pine plantations in the near term” and could increase the productivity of Southern pine on specific sites to over 500 cubic feet per acre per year (Fox, Jokela and Allen 2007, 340).

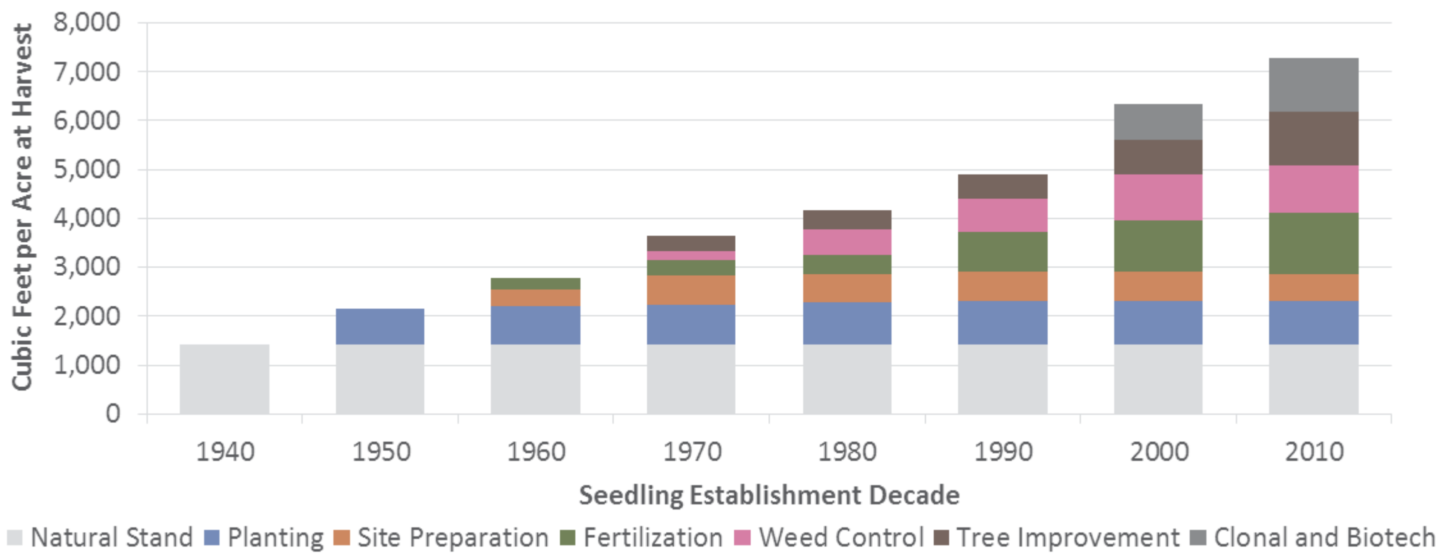

Figure 5-11 Estimated Contributions of Intensive Management Practices to Productivity in Pine Plantations in the US South, 1940-2010

The productivity of pine plantations has increased significantly since 1940 as management became more intensive. (Source: Fox, Jokela and Allen 2004.[48])

[48] Notes: Adapted from Figure 8.3 of original source. Data in the chart are approximated and may not be perfectly to scale. Approximate tons were converted to cubic feet using a conversion factor of 1 ton ≈ 34.48276 cubic feet. Data in the chart correspond to total harvest and are different than the annual yield data reported in text: Dividing totals in the chart by 15 would approximate the average annual productivity of plantations established at different times assuming a 15-year rotation.

5.5 Removals

Removal trends have generally tracked with changes in forest product production (Figure 5-12). Between 1953 and 1996, total removals increased 84 percent before leveling off during the 2000s. Removals dropped noticeably during and immediately following the Great Recession as demand for forest products dropped precipitously. While forest product production and removals have begun to recover in recent years, they have still not reached pre-Recession levels.

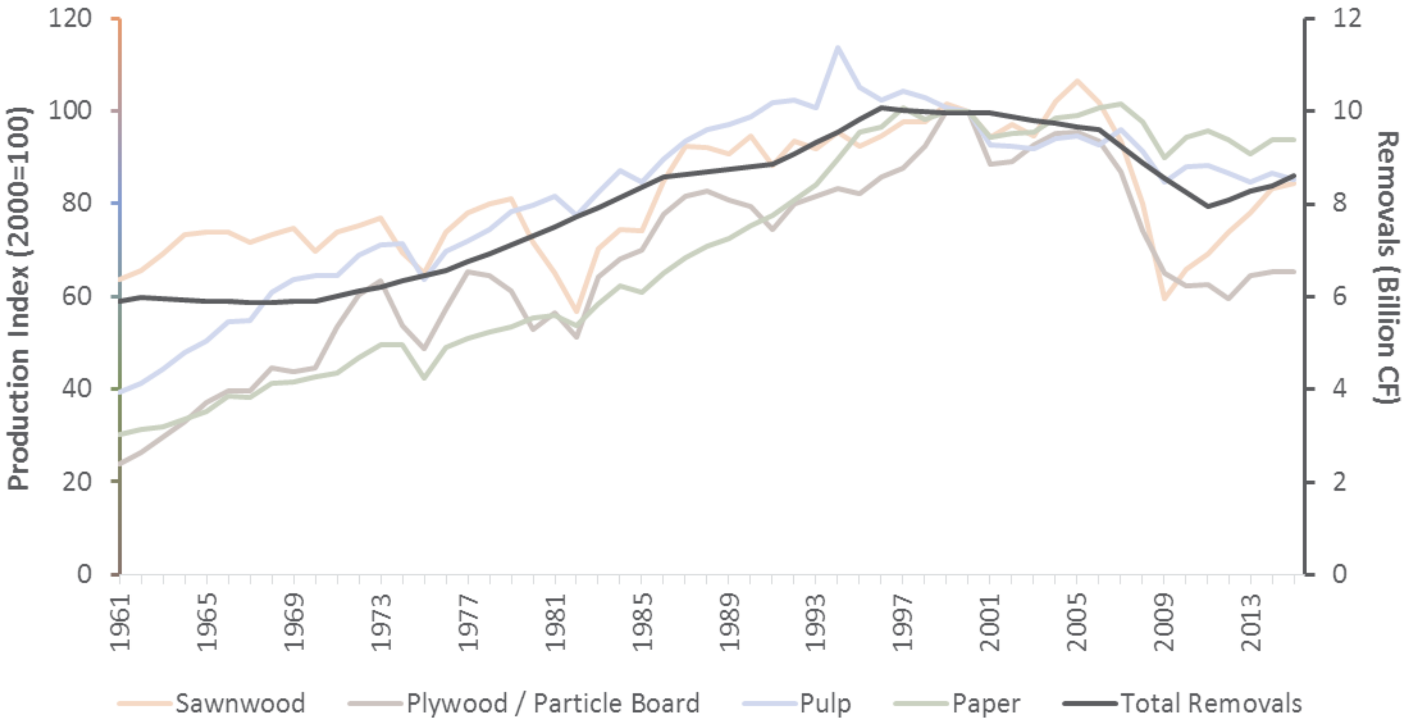

Figure 5-12 US Forest Product Production Indices (2000=100) vs. Total US South Removals, 1961-2015

US South removals have increased and decreased in response to demand for forest products produced domestically. As described in Section 3, forest products production is driven by population, macroeconomics and housing trends. (Sources: FAO 2016, US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

Figure 5-13 shows removals by ownership and species. The dramatic increases in total removals that occurred between 1970 and 1997 were driven largely by increased softwood removals from private timberlands to supply increased lumber, pulp and paper production (Section 4.2). Between 1997 and around 2007, total timberland removals began to decrease slightly as domestic demand for wood fiber decreased in response to increasing imports of finished goods and declining demand for pulp and paper. In the wake of the Great Recession of 2007-2009, timberland removals, especially private softwood removals, decreased as production of lumber and panels used in housing construction plummeted. Private softwood removals shown signs of increasing since the Recession as housing starts have improved, but private hardwood removals have failed to recover.

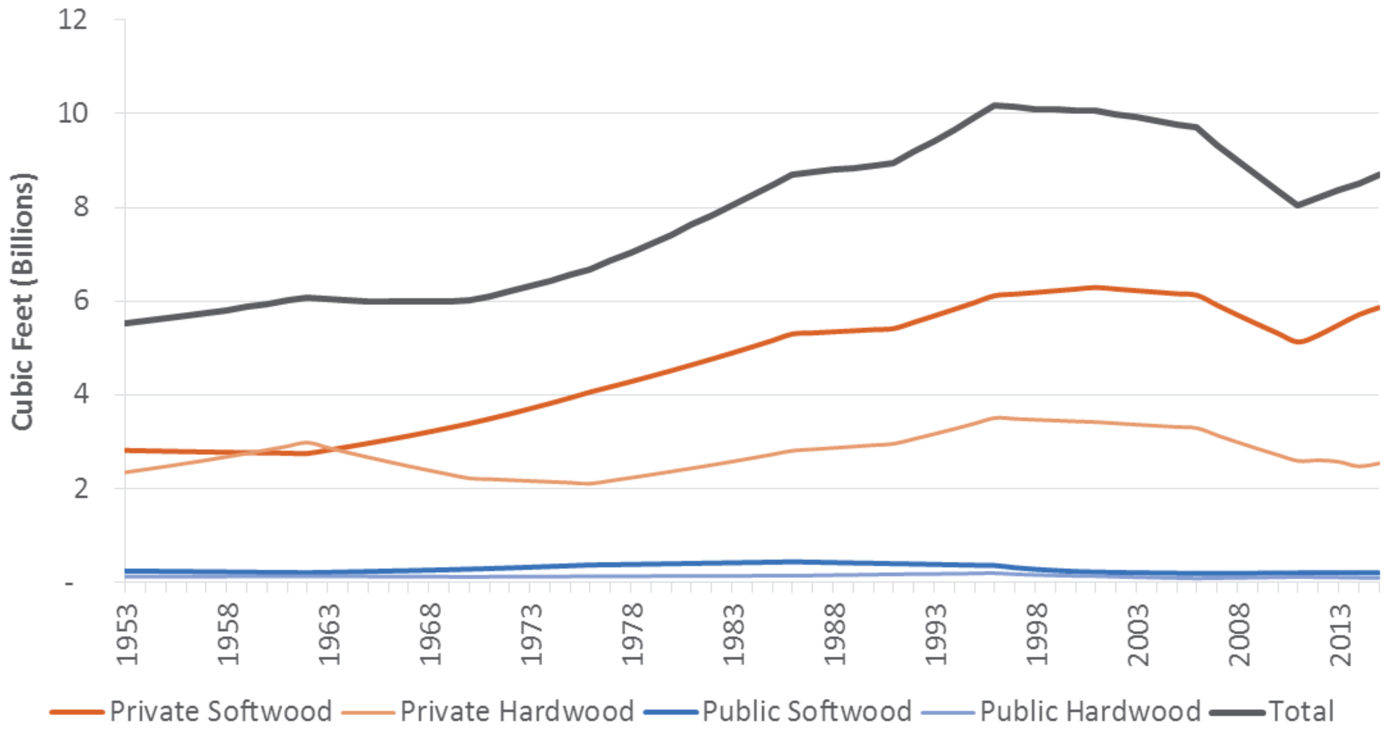

Figure 5-13 Annual Growing Stock Removals on Timberland by Ownership, 1953-2015

Total removals increased from 5.5 billion cubic feet in 1953 to a peak of 10.2 billion cubic feet in 1996. Private softwood removals continued to increase through the early to mid-2000s before falling precipitously during and following the Great Recession of 2007-2009. Public removals have been decreasing since the 1990s in response to increased environmental pressure on government lands. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.[49])

Part, but not all, of the difference in total removals on public and private timberland can be explained by the fact that private owners control much more timberland than public owners (Sections 5.1 and 5.2). Another factor at play is growth: Because private stands have higher growth rates, they can sustain more harvest without depleting the forest.

Figure 5-14 examines removals by ownership group on a per acre basis. It shows that while private removals per acre have outpaced public removals per acre since 1953, the difference in private and public removals per acre (indicated by gray vertical lines) was fairly stable until the 1970s. In the 1970s and 1980s, public removals per acre remained fairly stable while private removals per acre increased. Since the 1990s when governments reduced harvests on public lands in response to environmental regulations, public removals per acre have decreased, further widening the gap between public and private owners.

[49] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market proprietary transaction data. Data include Kentucky.

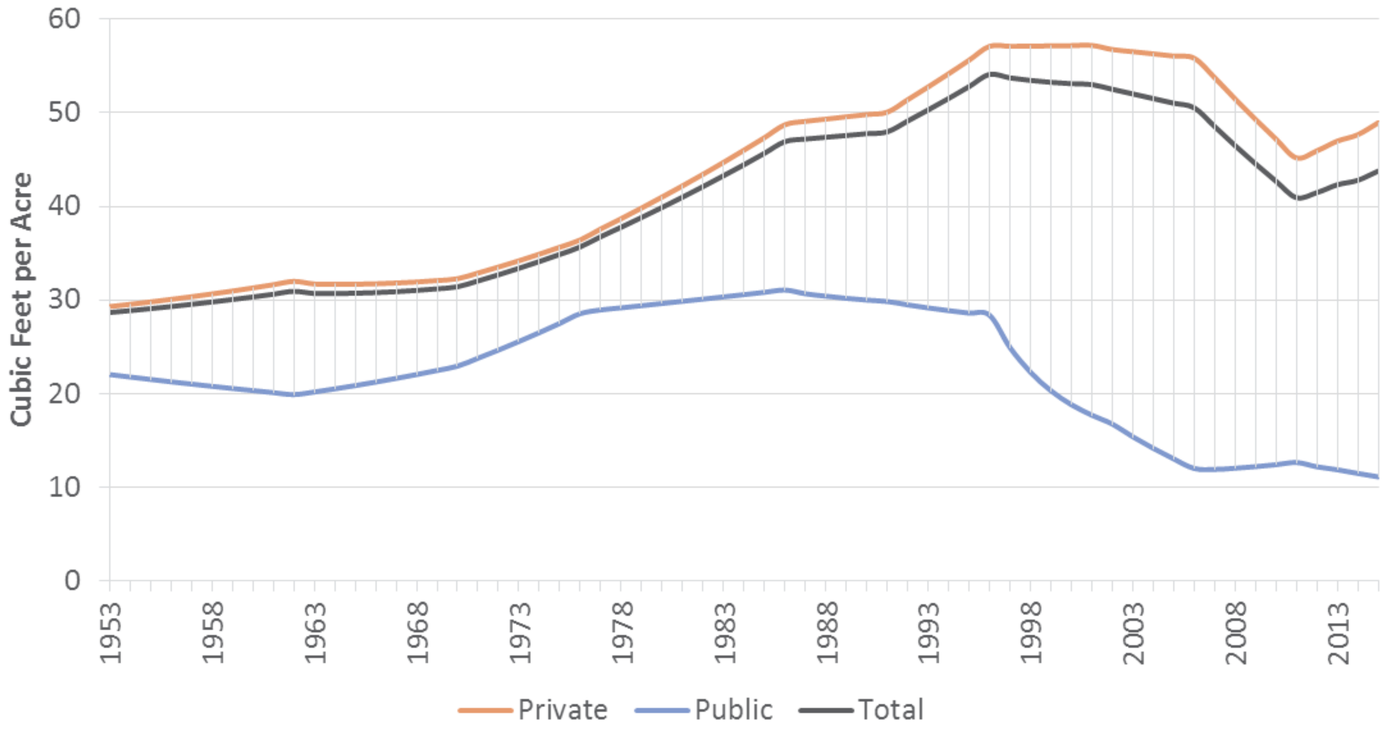

Figure 5-14 Annual Growing Stock Removals per Acre on Timberland by Ownership, 1953-2015

While private removals per acre have always exceeded public removals per acre, this gap widened beginning in the 1970s as productivity improvements and increased demand led to increased removals from private lands. This gap widened further beginning in the 1990s as harvests on public lands became more restricted. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

5.6 Growth-to-Removal Ratios

A growth-to-removal ratio (GRR) indicates the extent to which growth outpaces removals, or vice versa. The GRR is calculated by dividing growth by removals. If the result is over 1.0, more wood was grown than was removed during that time period, and inventory increases. If it is less than 1.0, more wood was removed than was grown, and inventory decreases. For example, a GRR of 1.33 means that growth outpaced removals by 33 percent. Conversely, a GRR of 0.95 means that removals outpaced growth by 5 percent.

Historically, public GRRs have always exceeded private GRRs, as shown by Figure 5-15. GRRs on privately-owned timberlands have been fairly steady on a Southwide basis, typically remaining between 1.02 and 1.66 on a total basis. Put otherwise, growth has consistently[50] exceeded removals by 32 percent on average. Prior to the 1990s, the public GRR was 2.08 on average. Since the 1990s, growth on public lands has significantly surpassed removals and GRRs have averaged 3.80. This increase reflects shifting priorities on public land that have decreased harvests, which has led to an imbalance in the forest resource. When forests are left unmanaged, it increases the dangers associated with drought, wildfire and pest outbreaks. In total (i.e., on public and private timberland), growth has exceeded removals by 38 percent, on average, since 1953.

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[50] Because growth and removal data prior to 1999 are based on periodic rather than annual assessments, this statement is based on trended annual data between reported RPA assessment years, as described in previous footnotes. Therefore, it is possible that GRRs in individual years do not follow this pattern.

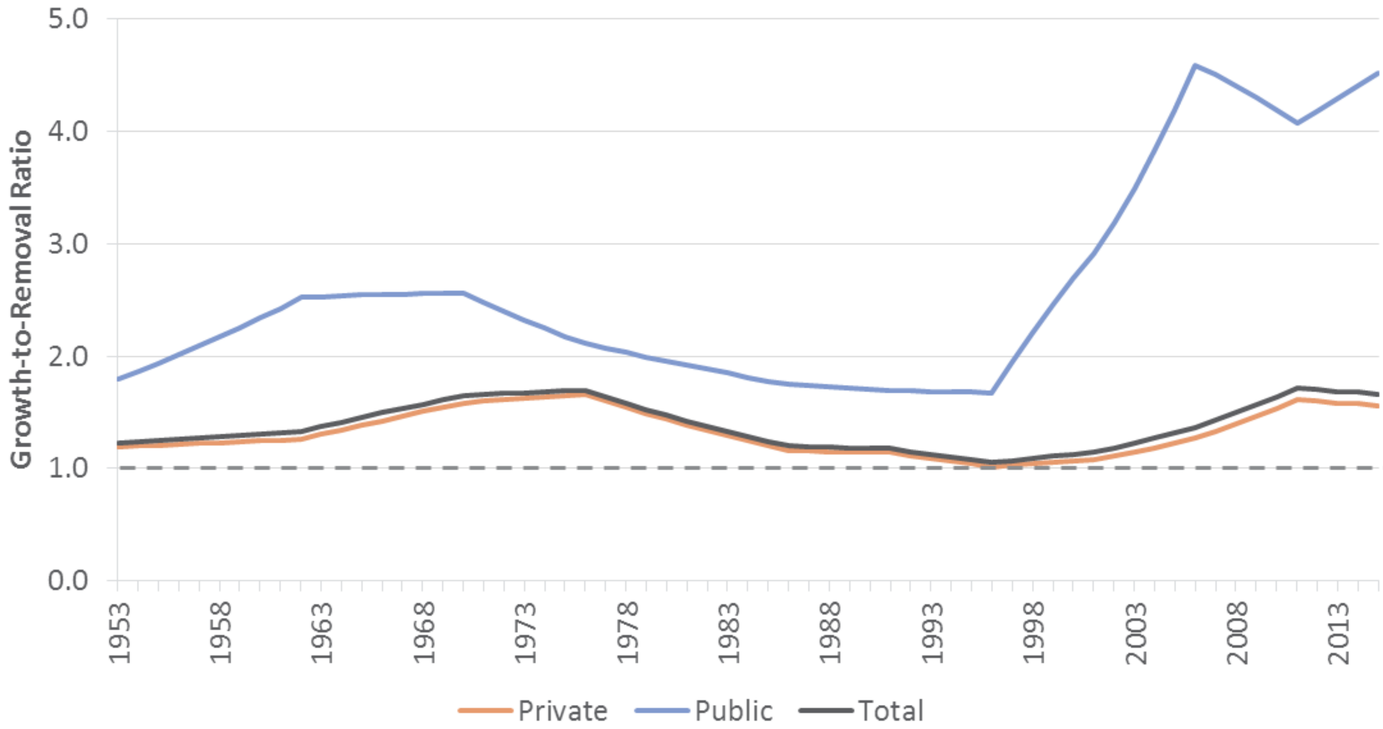


Figure 5-15 Annual Growing Stock Growth-to-Removal Ratios by Ownership, 1953-2015

For both private and public ownerships and in total, GRRs have remained above 1.0, which indicates that annual growth has consistently exceeded annual removals on timberland. Rapidly increasing public GRRs since the 1990s reflect an overbalance of growth due to constrained harvests. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

Typically, hardwood GRRs are higher than softwood GRRs, and public GRRs are higher than private GRRs (Table 5-2). When analyzing all species in the aggregate, Southern timberlands have consistently grown more than they have been harvested. Historically high growth-to-removal ratios, especially for softwood species, following the Great Recession are the result of a significant decline in harvest as demand did not meet landowners' expectations.

Table 5-2 Annual Growth-to-Removal Ratios by Species and Ownership, Selected Years 1953-2015

Hardwood GRRs typically exceed softwood GRRs, and public GRRs are generally higher than private GRRs. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

	All Species			Softwood			Hardwood		
Year	All Owners	Private	Public	All Owners	Private	Public	All Owners	Private	Public
1953	1.23	1.19	1.79	1.22	1.17	1.75	1.24	1.21	1.88
1962	1.33	1.26	2.52	1.59	1.50	2.72	1.09	1.04	2.22
1970	1.65	1.58	2.56	1.54	1.47	2.27	1.83	1.75	3.24
1976	1.70	1.66	2.11	1.42	1.41	1.61	2.23	2.15	3.51
1986	1.20	1.16	1.75	1.02	1.00	1.28	1.55	1.47	3.16
1996	1.05	1.02	1.67	0.91	0.89	1.27	1.30	1.24	2.41
2001	1.14	1.08	2.91	0.99	0.95	2.35	1.42	1.33	3.81
2006	1.37	1.27	4.59	1.21	1.15	3.17	1.67	1.51	7.68
2011	1.72	1.62	4.07	1.65	1.59	3.17	1.84	1.67	5.60

Throughout much of the 1953-2015 period, private growth outpaced removals for all species, and total GRRs remained above 1.0 (Figure 5-16). Private softwood GRRs dipped below 1.0 in the mid-1990s as softwood removals briefly outpaced softwood growth.

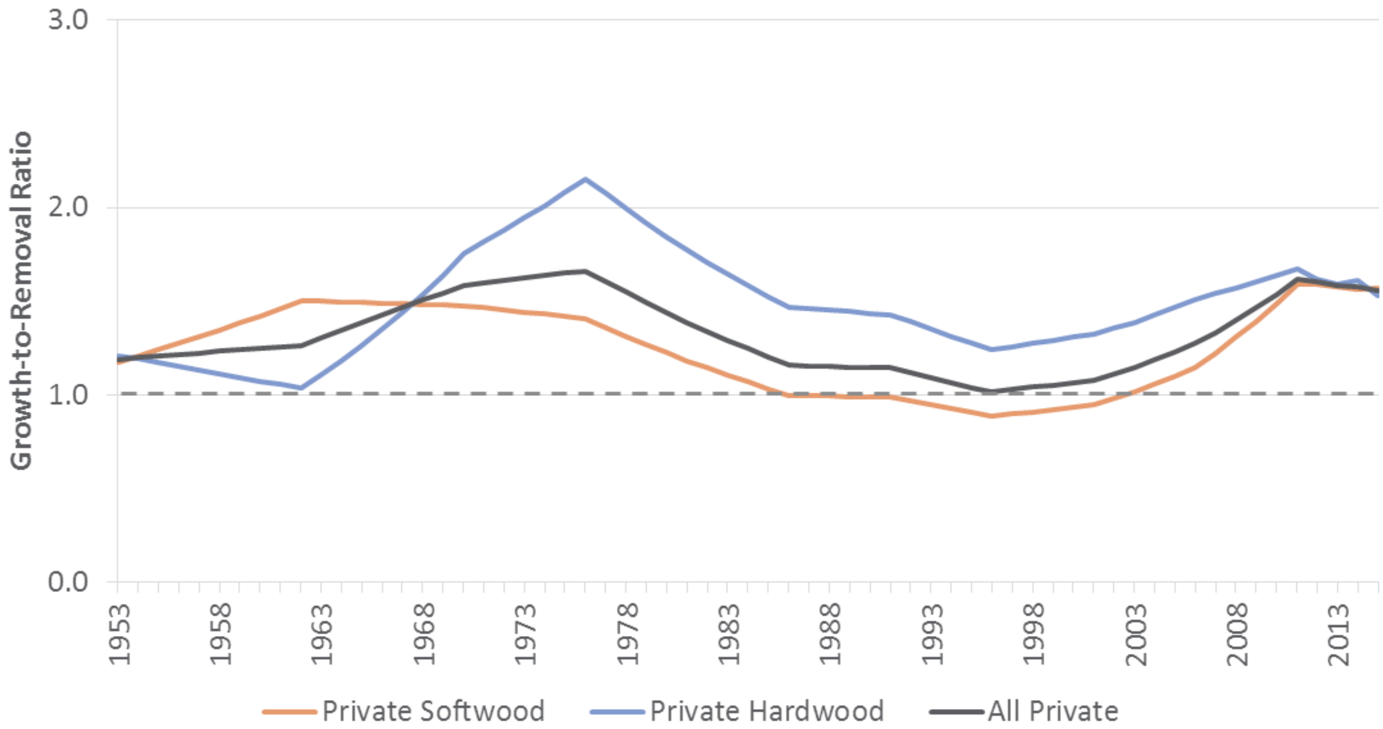


Figure 5-16 Annual Privately-Owned Growing Stock Growth-to-Removal Ratios by Species, 1953-2015
Historical GRRs on private timberlands show a cyclical pattern: GRRs may temporarily fall in response to increased removals, but private owners respond by increasing productivity and supply. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

5.7 Timberland Inventory

Because growth—driven by silvicultural and management improvements funded by the forest products industry to support increased demand—increased at a faster rate than removals, inventory continued to increase throughout this period, as shown by Figure 5-17. The clear majority (87 percent) of Southern timberland inventory has been privately-owned since 1953. Private inventory increased from 128.5 to an estimated 242.7 billion cubic feet (BCF) while public inventory increased from 13.6 to an estimated 53.4 BCF between 1953 and 2015. In total, timberland inventory has doubled in the South due largely to more active management on private lands, which has increased productivity as described in previous sections.

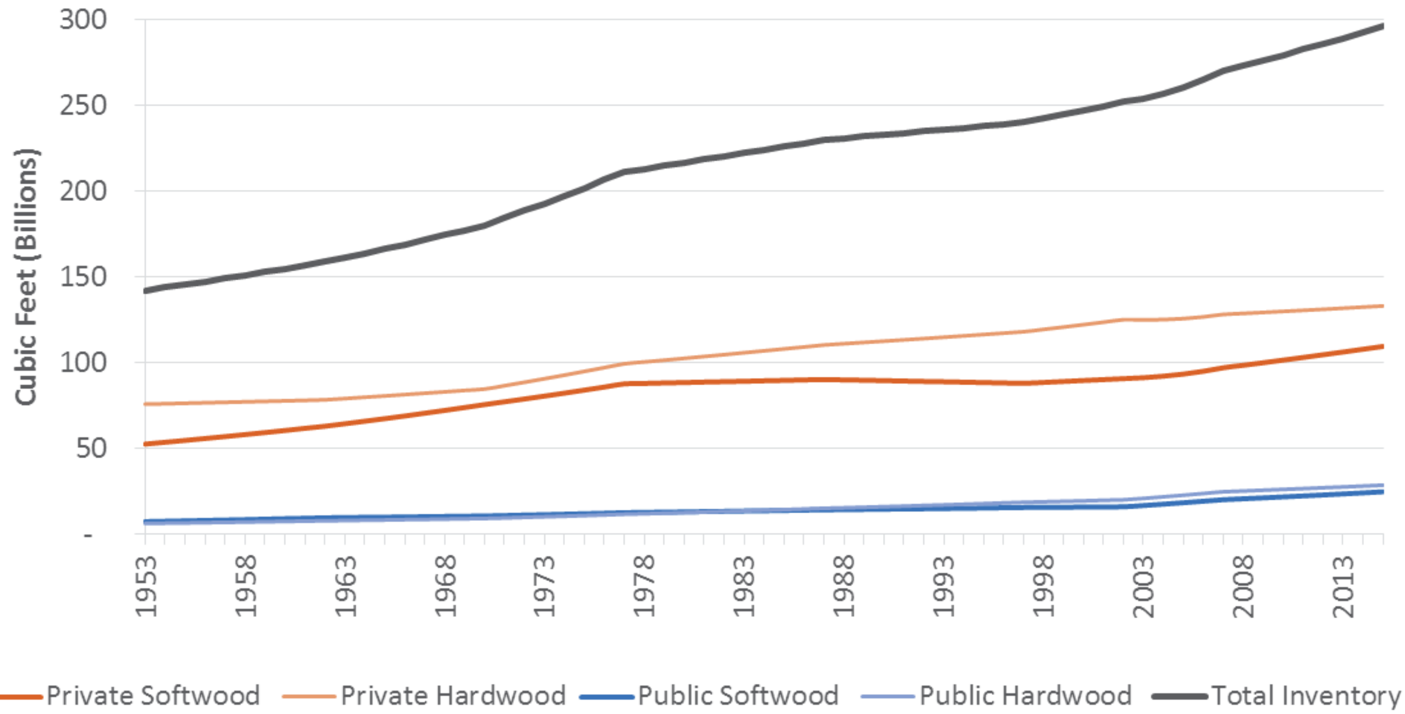


Figure 5-17 Annual Growing Stock Inventory on Timberland by Species and Ownership, 1953-2015
Both private and public inventory increased during the latter half of the twentieth century as private landowners increased forest productivity and public landowners reduced harvests. (Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.[51])

[51] Data for 1953, 1963, 1970, 1977, 1987, 1997, 2002, 2007 and 2012 are from USFS Resources Planning Act reports. Data for intervening years and 2013-2015 are derived by Forest2Market using annual rates of change between available data years and Forest2Market assumptions. Data include Kentucky.

Despite a 6 percent decrease in timberland acres between 1963 and 1987, timberland inventory continued to increase due to improved management and productivity on private lands and less intensive harvest on public lands. While acres increased 7 percent between 1987 and 2015, inventory further increased, which resulted in increased stand density, or the amount of inventory per acre, over time (Figure 5-18). Stand density on public timberland increased by a factor of 2.4 from 816 to an estimated 1968 cubic feet per acre between 1953 and 2015. Stand density on private timberland approximately doubled from 729 to an estimated 1413 cubic feet per acre over the same period.

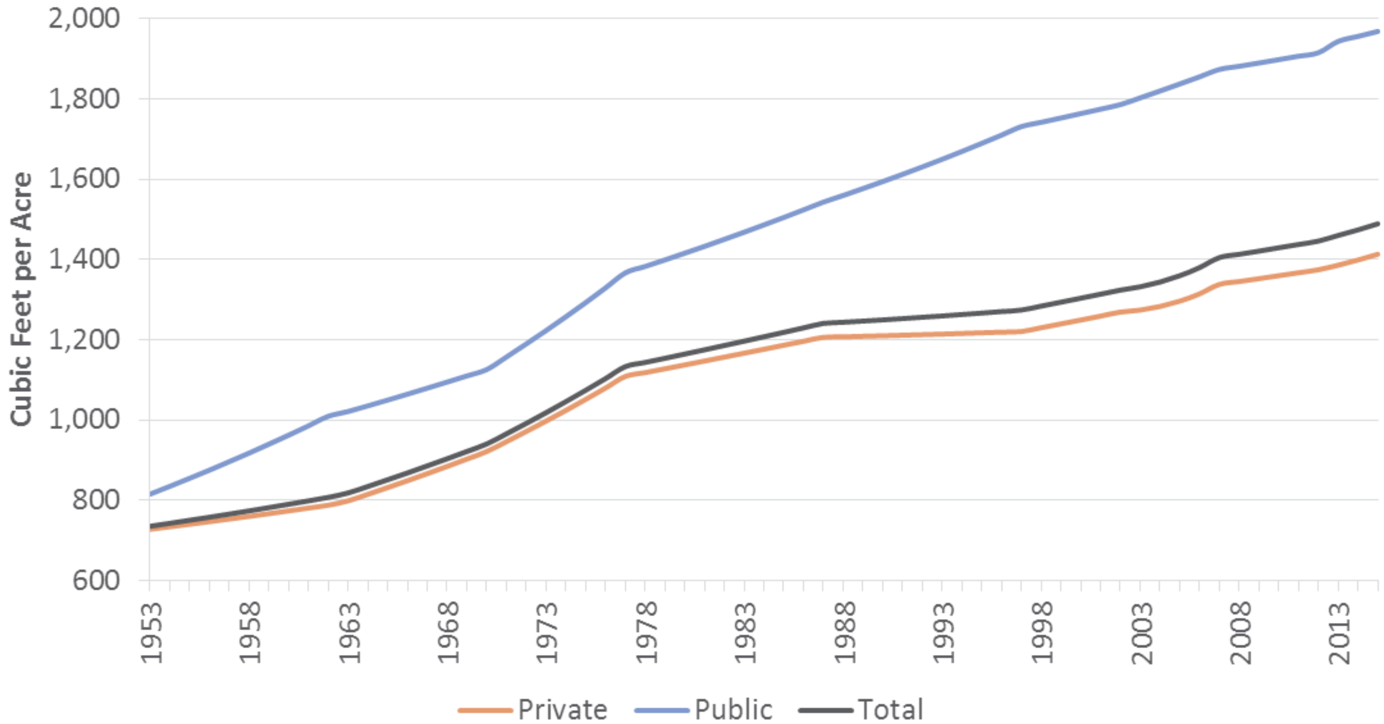


Figure 5-18 Annual Growing Stock Inventory per Acre on Timberland by Ownership, 1953-2015
Productivity increases on private timberlands and reduced harvests on public lands have led to increased stand density. (Sources: US Forest Service Resources Planning Act reports, Forest2Market estimates.)

5.8 Southwide Demand and Forest Productivity

This section compares historical changes in removals to changes in acres, growth and inventory. For conciseness, detailed information regarding changes in removals are omitted from subsequent subsections.

Removals increased 57 percent between 1953 and 2015 (Figure 5-19-A). During this period, removals from privately-owned timberlands were on average 94 percent of total removals. Because most removals are from privately-owned timberlands, trends in private removals drove the overall historical pattern of removals in the South. Most of the increase in total removals is attributable to increased softwood harvest on private timberlands, which, by far, experienced the greatest increase: Private softwood removals increased 108 percent from 2.8 billion cubic feet in 1953 to 5.9 billion cubic feet in 2015 (Figure 5-19-B).

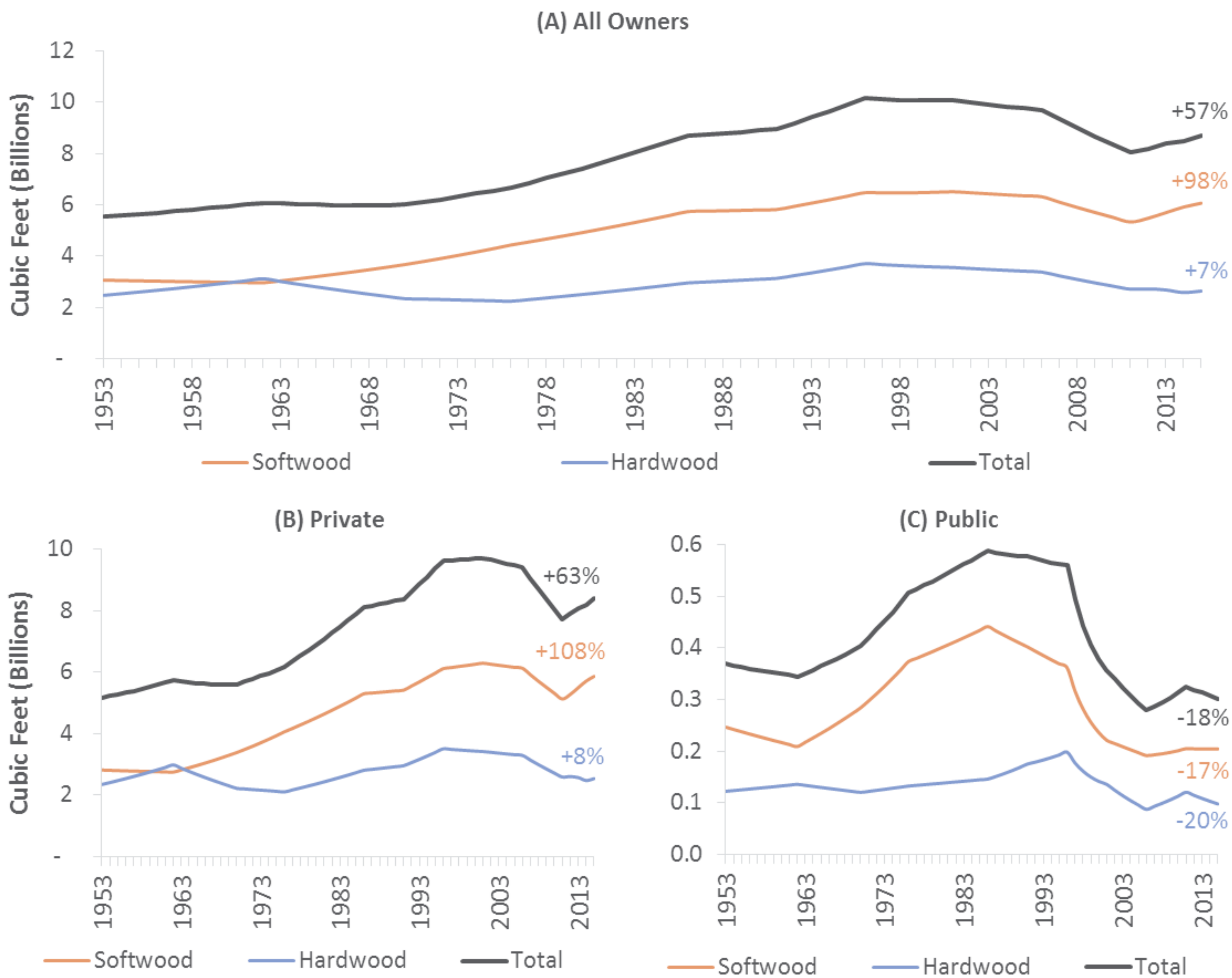


Figure 5-19 Trends in Annual Growing Stock Removals on Timberland by Ownership and Species, 1953-2015

Total removals (A) increased 57 percent between 1953 and 2015 driven largely by increased harvest on privately-owned timberlands, especially private softwood harvest, which increased 108 percent over this time period (B). (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

5.8.1 Removals and Acres

Removals increased at a much faster rate than acres, but both trended upward between 1953 and 2012 (Figure 5-20). Current timberland acreage in the US South is an estimated 198.9 million acres, a net increase of 5.8 million acres (3 percent) since 1953. A decrease of 18.6 million acres (14 percent) in the amount of timberland owned by private, non-corporate owners was offset by a 14.0 million acre (31 percent) increase in corporately-owned timberland and a 10.4 million acre (62 percent) increase in publicly-owned timberland.

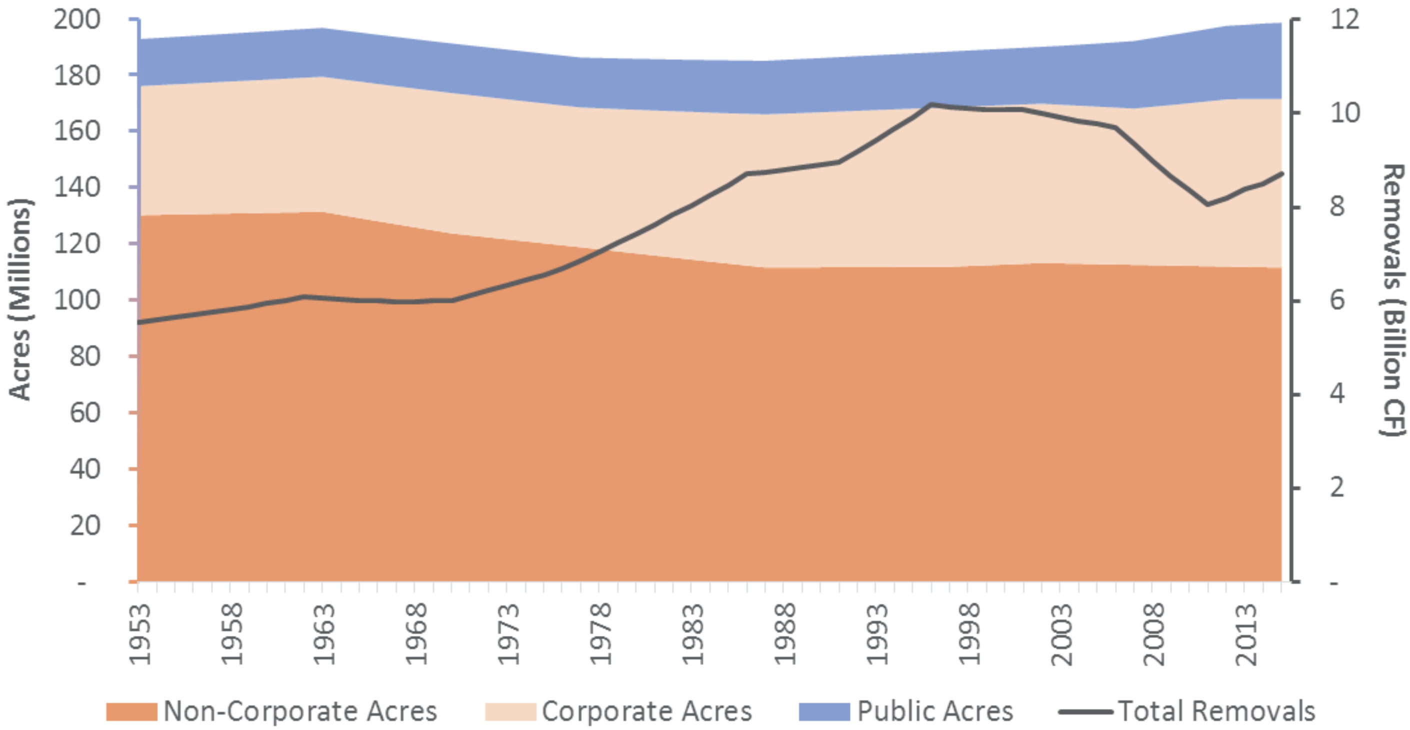


Figure 5-20 Total Annual Growing Stock Removals on Timberland vs. Timberland Acres by Ownership, 1953-2015

Increased removals did not result in forest loss. Rather, historical increases in timberland acres alongside increased removals suggest that landowners, especially corporate owners, maintained or acquired timberlands to support and take advantage of healthy markets for forest products. Current timberland acreage in the US South is an estimated 198.9 million acres, a net increase of 5.8 million acres since 1953. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

5.8.2 Removals and Growth

Both removals and growth have been on an increasing trend since 1953, but growth increases were more dramatic: Total annual growth increased 112 percent from 6.8 billion cubic feet in 1953 to 14.4 billion cubic feet in 2015 (Figure 5-21). Of the 7.6 billion cubic feet increase that occurred in total growth, 5.9 billion cubic feet, or 77 percent, occurred on private softwood stands where annual growth increased 178 percent between 1953 and 2015 (Figure 5-22-B). Most of the increase in annual growth that occurred—and which therefore allowed inventories to continue to increase as removals increased—is directly attributable to efforts by private landowners to increase productivity, especially on softwood plantations.

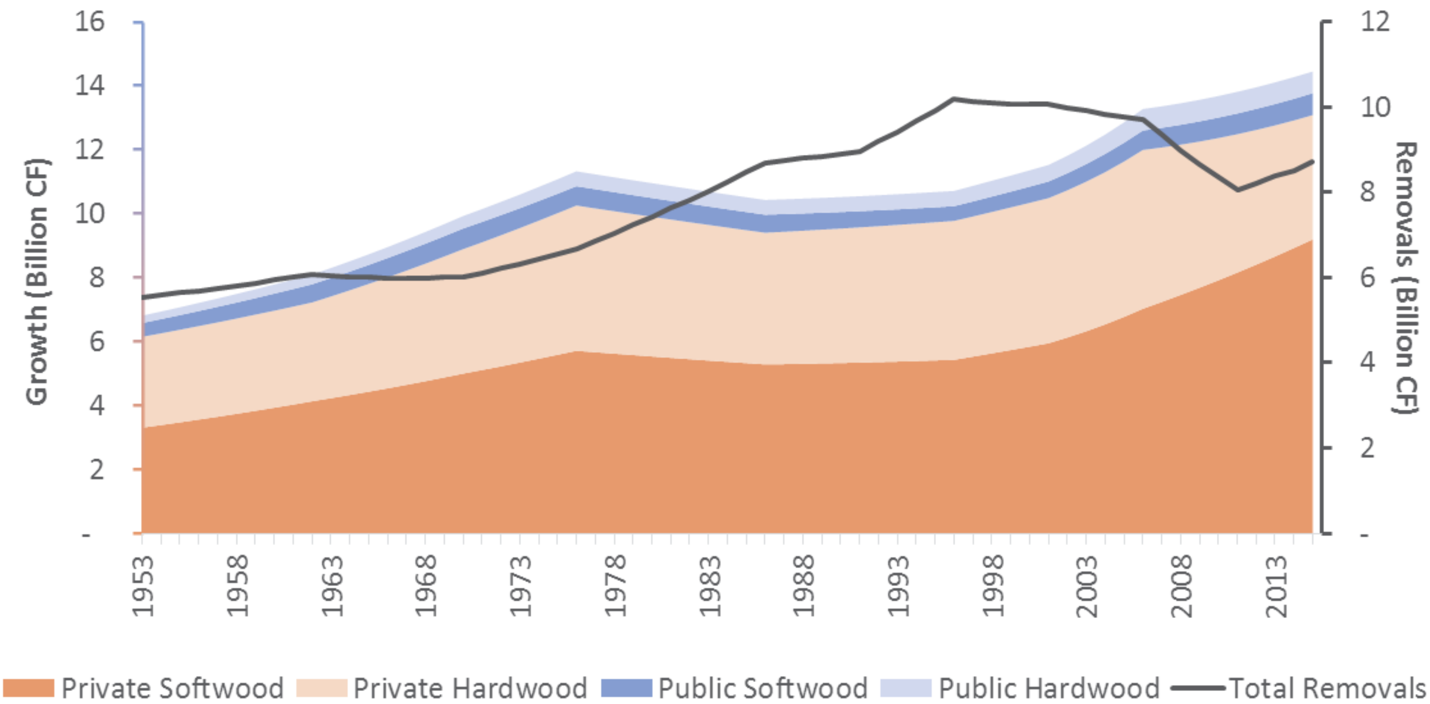


Figure 5-21 Total Annual Growing Stock Removals vs. Annual Growing Stock Growth by Ownership and Species on Timberland, 1953-2015

Growth increased 112 percent between 1953 and 2015 as removals also increased. Most (77 percent) of the increase in growth between 1953 and 2015 occurred on private softwood stands where growth increased from 3.3 to 9.2 billion cubic feet annually. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

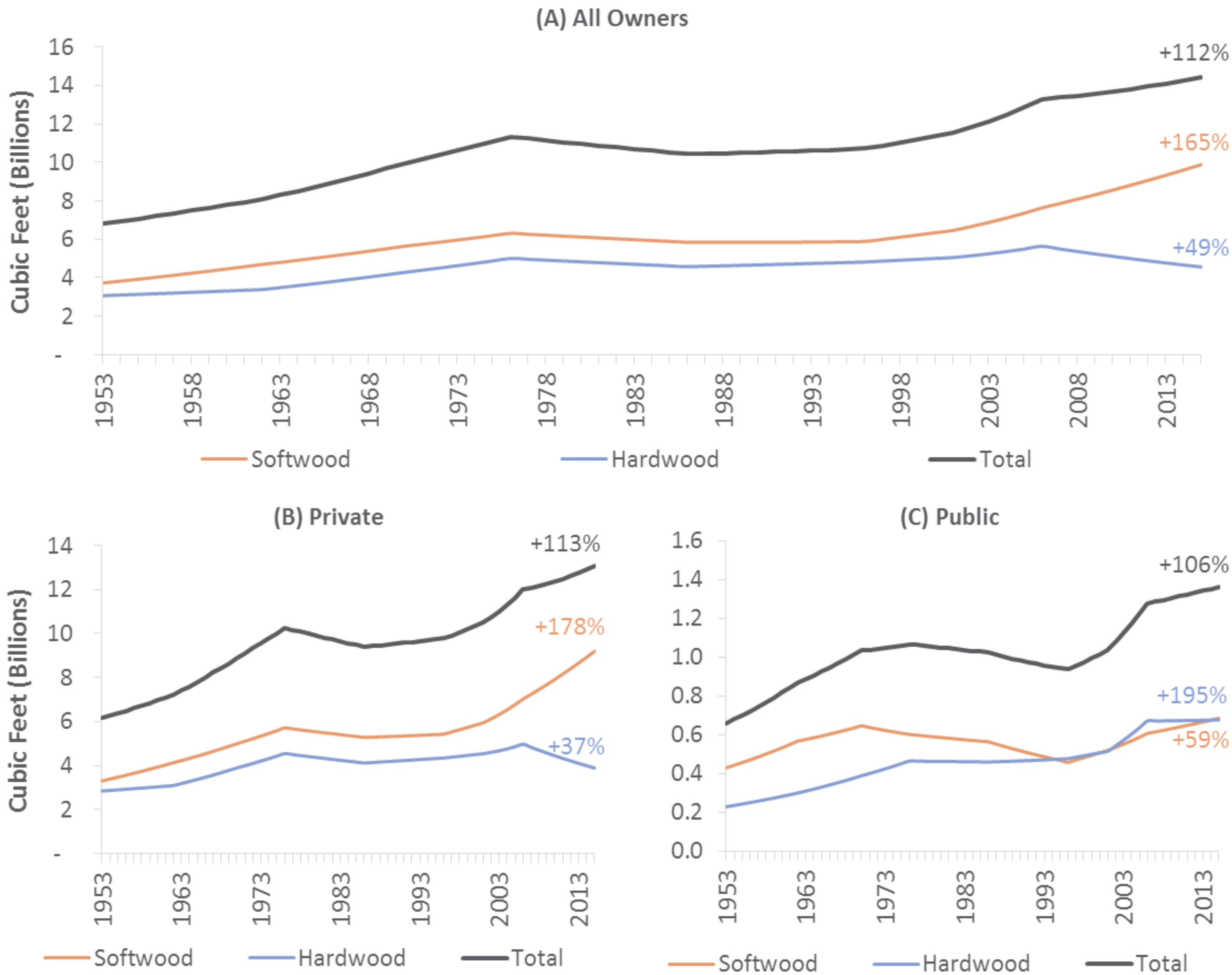


Figure 5-22 Trends in Annual Growing Stock Growth on Timberland by Ownership and Species, 1953-2015

Annual growing stock growth increased 112 percent between 1953 and 2015 driven largely by a 165 percent increase in annual softwood growth (A). Annual growth increased across all species on both private (B) and public (C) timberlands. However, the most significant increases in annual growth were associated with privately-owned softwood, which increased by approximately 5.9 billion cubic feet (178 percent) between 1953 and 2015 (B). Publicly-owned hardwood growth increased 195 percent over this period, but this equated to a difference of only 0.4 billion cubic feet annually, which, despite the large percentage change, is dwarfed by the gains in private softwood growth.

5.8.3 Removals and Inventory

Since 1953, both inventory and removals have been on an increasing trend. Most of the inventory increase occurred on stands owned by private entities, which have held 87 percent of inventory on average since 1953 (Figure 5-23). Over this period, total inventory more than doubled from 142.1 to 296.1 billion cubic feet. In total, softwood inventory increased 124 percent and hardwood inventory increased 97 percent between 1953 and 2015, which resulted in softwood comprising more of the inventory in 2015 (45 percent) than in 1953 (42 percent). The faster increases in softwood inventory are attributable to higher rates of softwood growth on private stands, as described in the previous section.

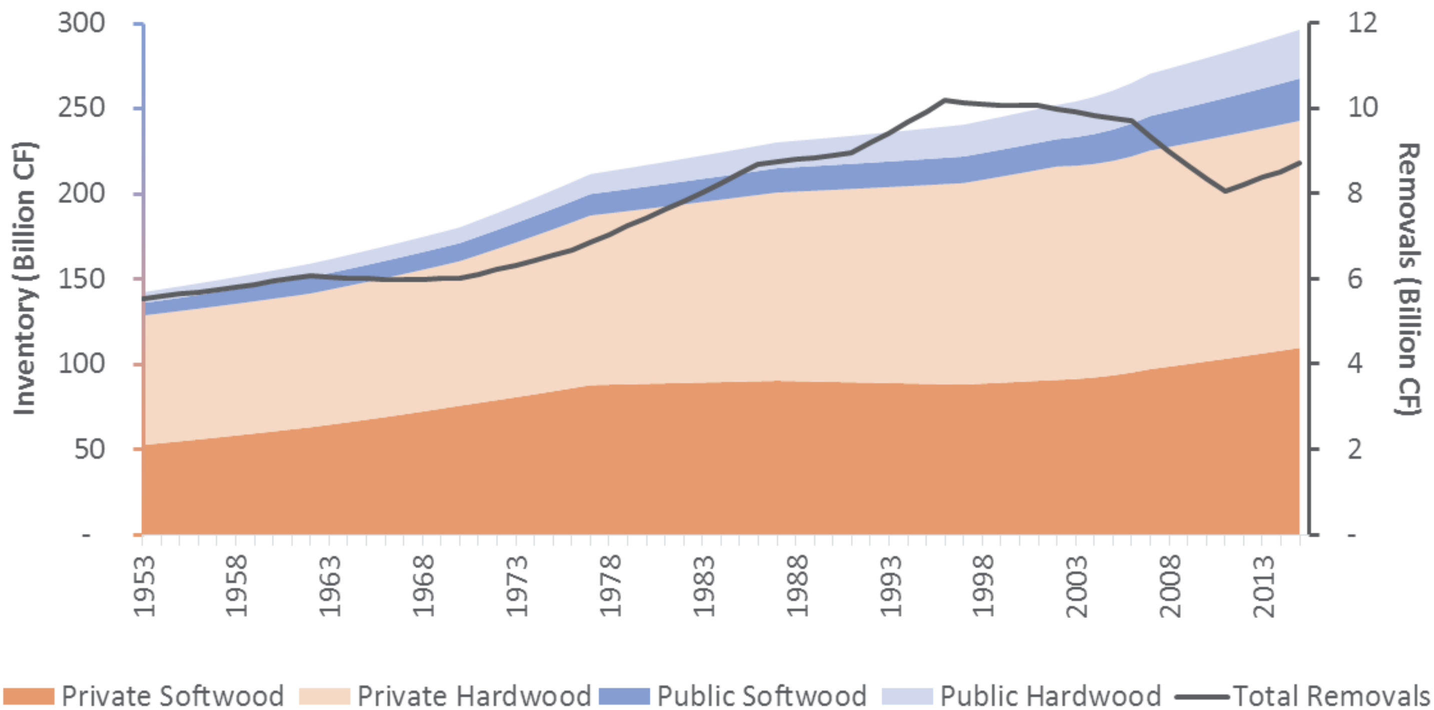


Figure 5-23 Total Annual Growing Stock Removals vs. Annual Growing Stock Inventory by Ownership and Species on Timberland, 1953-2015

Total inventory increased 108 percent since 1953 at the same time that removals also increased. As with timberland acres, private landowners have historically held the overwhelming majority (87 percent on average) of growing-stock inventory in the US South, and much of the increase in inventory occurred on private lands. On private lands, softwood inventory increased more than hardwood inventory (108 percent vs. 76 percent) from 1953 to 2015. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

The build-up in inventory that occurred in the late 2000s and 2010s is attributable to two factors: expansionary investment by landowners during the 1980s-1990s and the Great Recession of 2007-2009, which significantly reduced removals. Of the period analyzed in this report, the height of demand for forest products occurred during the 1980s and 1990s, and landowners, especially private landowners, responded to these demand signals by expanding their investment in increasingly productive plantations (Section 5.3.1, 5.4.1). This expansionary activity led the US Forest Service in January 2007 to predict "an increase in the inventory of standing timber for a long time to come" (Wear, Carter and Prestemon 2007, 24). While inventories would have continued to increase even had the Great Recession not caused a significant decrease in demand for forest products, the abrupt decline in removals associated with the Great Recession most certainly exacerbated the increase and led to a significant imbalance in growth and removals (Section 5.6).

6 STATISTICAL ANALYSES OF SOUTHWIDE DEMAND AND FOREST PRODUCTIVITY USING FIA STATE DATA

The previous section reported historical Southwide trends in order to explore the relationship between demand and forest productivity. This section continues that analysis by using individual state data from the Forest Inventory and Analysis (FIA) database of the US Forest Service to describe the statistical relationships between inventory, growth, removals and acres for privately-owned growing stock on privately-owned timberland. Using state instead of regional data dramatically increased the number of data points and the robustness of the analysis. For the purposes of this section, each available data year was incorporated for each of the states in the South using all available data from the FIA database. The earliest available data year for any state was 1968.

Annual availability of state FIA data varied for two reasons. First, when the US Forest Service previously used the annual inventory approach, each state was only sampled once every few years, and different states were sampled in different years. Second, after the US Forest Service changed to a periodic inventory approach, each state was sampled annually, but only a portion of each state's plots were sampled each year. Different states have different sampling frequencies such that one cycle may be complete in five years in one state but ten years in another.

Rather than try to build an annual trend through time building up gaps and pairing data points based on available data, which distorts statistical relationships, we treated each state inventory as a discrete data point and analyzed these data points in the aggregate. The correlations in Section 6.1 and the regression lines in Section 6.2 reflect this approach. For example, each point on the scatterplots in Section 6.2 represents one state's annual data.

6.1 Correlations between Removals and Selected Forest Measures

Table 6-1 correlates total private removals, private softwood removals and private hardwood removals[52] with various measures of forest productivity on privately-owned timberlands. Pearson correlations (r) are presented with their associated significance levels (p-values) for α=.05. A correlation of 1.0 would indicate a perfect linear relationship between the two variables. Conversely, a correlation of 0.0 would indicate a complete lack of correlation.

Table 6-1 Pearson Correlations between Removals and Acres, Inventory and Growth by Species, 1968-2015

Pearson correlations between removals and various measures of forest productivity are strongest for softwood species, which have shorter rotations and tend to be more consistently actively managed for timber production. (Sources: Forest Inventory and Analysis database, Forest2Market calculations.)

Pearson Correlations (p-values)								
Softwood Removals			Hardwood Removals			Total Removals		
Softwood Acres	0.93056	(p<.0001)	Hardwood Acres	0.81413	(p<.0001)	Total Acres	0.88763	(p<.0001)
Softwood Inventory	0.95007	(p<.0001)	Hardwood Inventory	0.80486	(p<.0001)	Total Inventory	0.79217	(p<.0001)
Softwood Growth	0.91452	(p<.0001)	Hardwood Growth	0.84462	(p<.0001)	Total Growth	0.90229	(p<.0001)

6.1.1 Acres

Removals are strongly and significantly correlated with timberland acres on a same-species basis (r=.93056 for softwood and r=.81413 for hardwood), confirming the trends visible in the Southwide data in Section 5.8.1. Higher removals are

[52] Additional correlations between removals and various forest measures and growth and various forest measures are provided in Appendix B.

associated with more acres. Softwood removals had a stronger correlation with total acres (r=.82496) than did hardwood removals (r=.61636).

6.1.2 Inventory

Removals are strongly and significantly positively correlated with inventory on a same-species basis, which confirms the trends visible in the Southwide data in Section 5.8. Softwood removals have an almost perfect positive correlation (r=.95007) with softwood inventory and a moderate positive correlation with total inventory. While somewhat smaller, hardwood removals still have a strong positive correlation (r=.80486) with hardwood inventory. Higher removals are associated with more inventory.

6.1.3 Growth

Softwood removals are strongly correlated with softwood growth (r=.91452) and with total growth (r=.86498). Hardwood removals are strongly correlated with hardwood growth (r=.84462) and moderately correlated with total growth (r=.5511). Higher removals, especially softwood removals, are associated with more growth.

6.2 Regression Lines

This section presents regression lines to describe the ability of various forest measures (x) to predict other forest measures (y). R^2 statistics for each regression equation are included with the scatterplot and best fit line for each analysis. The R^2 statistic describes the amount of variation in y explained by x. It is the square of Pearson's r (refer to Table 6-1). F-statistics and their p-values are discussed. A significant F statistic demonstrates that a model based on a specific x variable is useful for predicting[53] y.

6.2.1 Removals vs. Acres

Private softwood removals describe approximately 87 percent of the variation in private softwood acres (Figure 6-1-A). The model is significant (F= 949.54, p<.0001); softwood removals, therefore, are useful for predicting softwood acres. It stands to reason that softwood demand drives the retention of productive softwood acres. The model predicting hardwood acres from hardwood inventory is also significant (F= 288.95, p<.0001); however, hardwood removals explain less of the variance (66 percent) in hardwood acres (Figure 6-1-B), which is likely a reflection of the fact that hardwood stands may be owned for reasons other than timber production, and hardwood stands also have longer rotations, which may reduce the predictive capability of hardwood removals to explain hardwood inventory. Total removals explain approximately 79 percent of the variance in total acres, and the model is significant (F=546.00, p<.0001) (Figure 6-1-C).

6.2.2 Removals vs. Inventory

Private softwood removals describe approximately 90 percent of the variation in private softwood inventory (F= 1362.65, p<.0001) (Figure 6-2-A). Hardwood removals explain approximately 65 percent of the variance in hardwood inventory, much less than the variance in softwood inventory explained by softwood removals (F=270.37, p<.0001) (Figure 6-2-B). It is likely that softwood removals bear a stronger relationship to inventory because more active plantation management, which largely occurs on softwood stands and includes harvesting at regular intervals, provides

[53] The regression lines reflect the historical relationships between removals, acres, inventory and growth observed between 1968 and 2015 in states in the US South. Each model considers only a single independent (x) and single dependent (y) variable and does not attempt to account for other influences, such as landowner motivations or timber value. As such, changes in these or other characteristics not accounted for in these models may affect the ability of these models to accurately predict forest productivity in the future.

for a stronger relationship between removals and inventory. Combined, total removals explain approximately 63 percent of the variance in total inventory (F=247.67, p<.0001) (Figure 6-2-C).

6.2.3 Removals vs. Growth

Private softwood removals explain approximately 84 percent of the variance in softwood growth (F=751.20, p<.0001) (Figure 6-3-A). On softwood stands, removals and growth are related as active management results in both high growth and high removals, especially on plantation stands (Section 5.3.1, 5.4.1). Hardwood removals explain a lower percentage (71 percent) of the variance in hardwood growth (F=365.87, p<.0001) (Figure 6-3-B). Total removals explain 81 percent of the variance in total growth (F=643.86, p<.0001) (Figure 6-3-C).

6.2.4 Growth vs. Inventory

Private softwood growth explains 89 percent of the variance in softwood inventory (F=1220.81, p<.0001) (Figure 6-4-A). This is about 1 percent less than the variance in softwood inventory explained by softwood removals. For softwood species, both growth and removals are predictive of inventory, but removals are a slightly better indication of inventory levels. Hardwood growth explains 86 percent of the variance in hardwood inventory (F=902.37, p<.0001), which is 21 percent more than the variance explained by hardwood removals (Figure 6-4-B). Total growth explains approximately 76 percent of the variance in inventory (F= 457.91, p<.0001), which is 13 percent more than the variance explained by total removals (Figure 6-4-C).

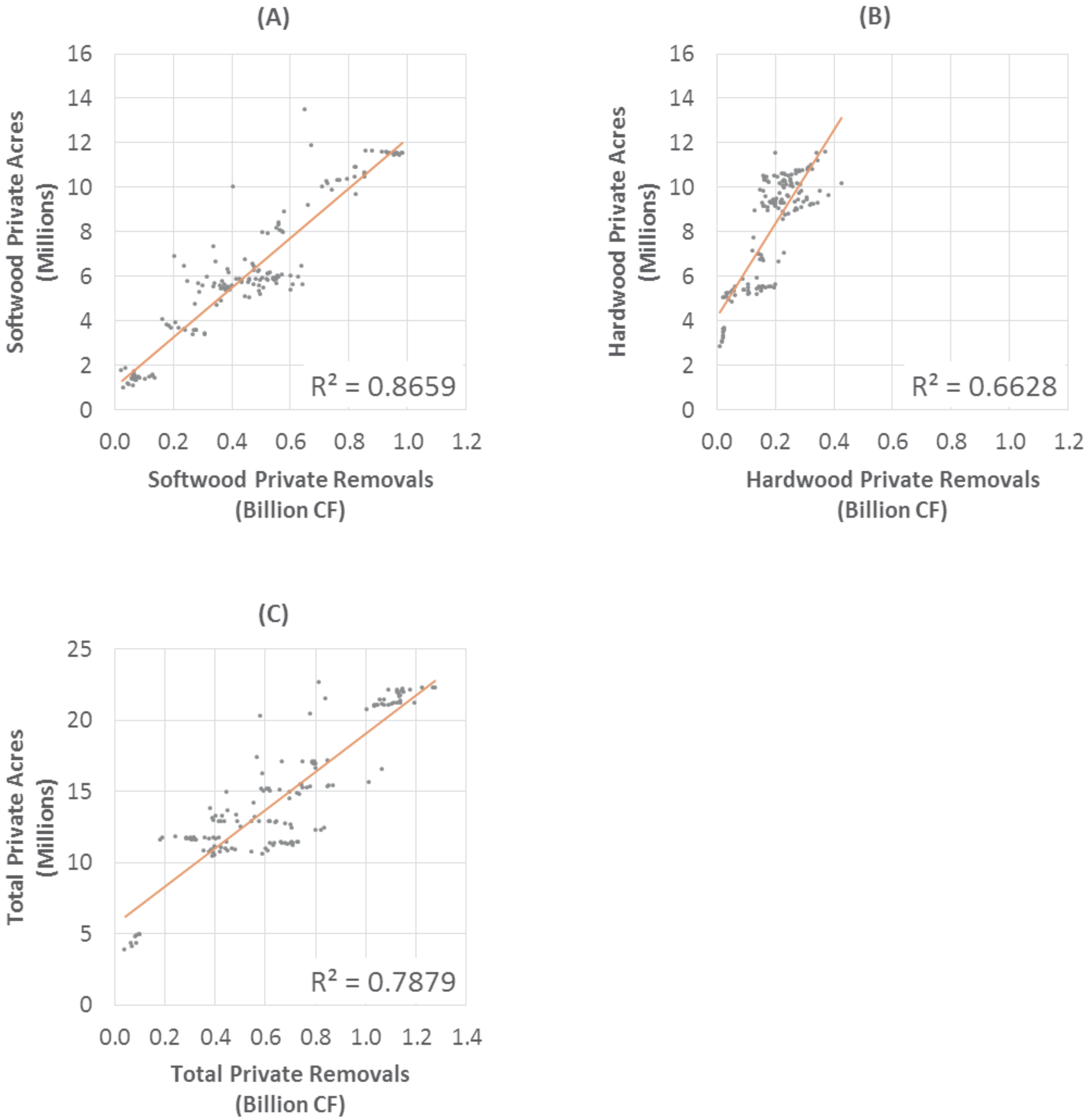


Figure 6-1 Private Removals vs. Acres by Species, 1968-2015

By species, private softwood removals explain approximately 87 percent of the variance in private softwood acres (A) while private hardwood removals explain approximately 66 percent of the variance in private hardwood acres (B). In total, private removals explain around 79 percent of the variance in private acres (C). (Sources: US Forest Service Forest Inventory and Analysis database, Forest2Market calculations.)

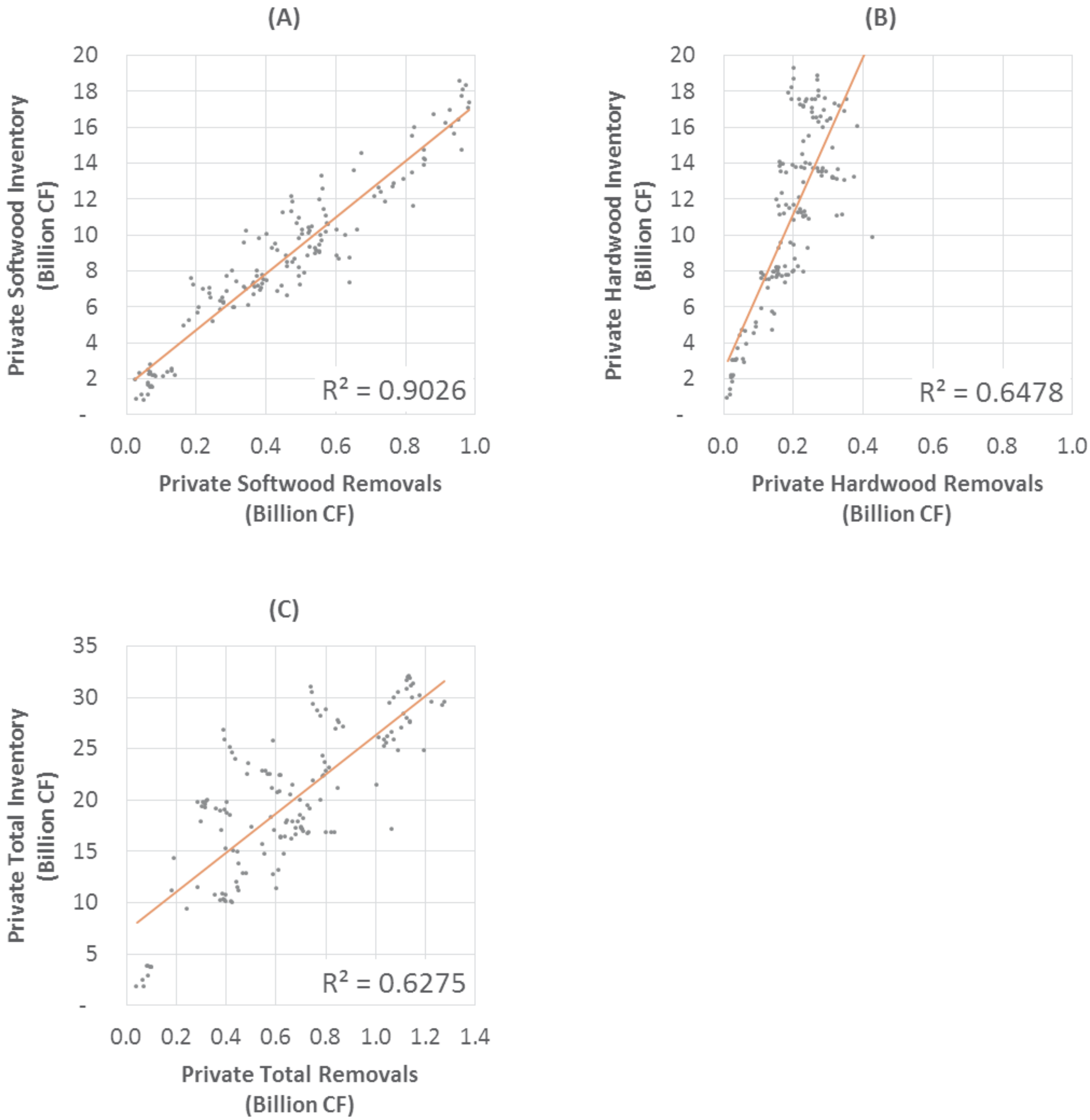


Figure 6-2 Private Removals vs. Inventory by Species, 1968-2015

By species, private softwood removals explain approximately 90 percent of the variance in private softwood inventory (A) while private hardwood removals explain approximately 65 percent of the variance in private hardwood inventory (B). In total, private removals explain around 63 percent of the variance in private inventory (C). (Sources: US Forest Service Forest Inventory and Analysis database, Forest2Market calculations.)

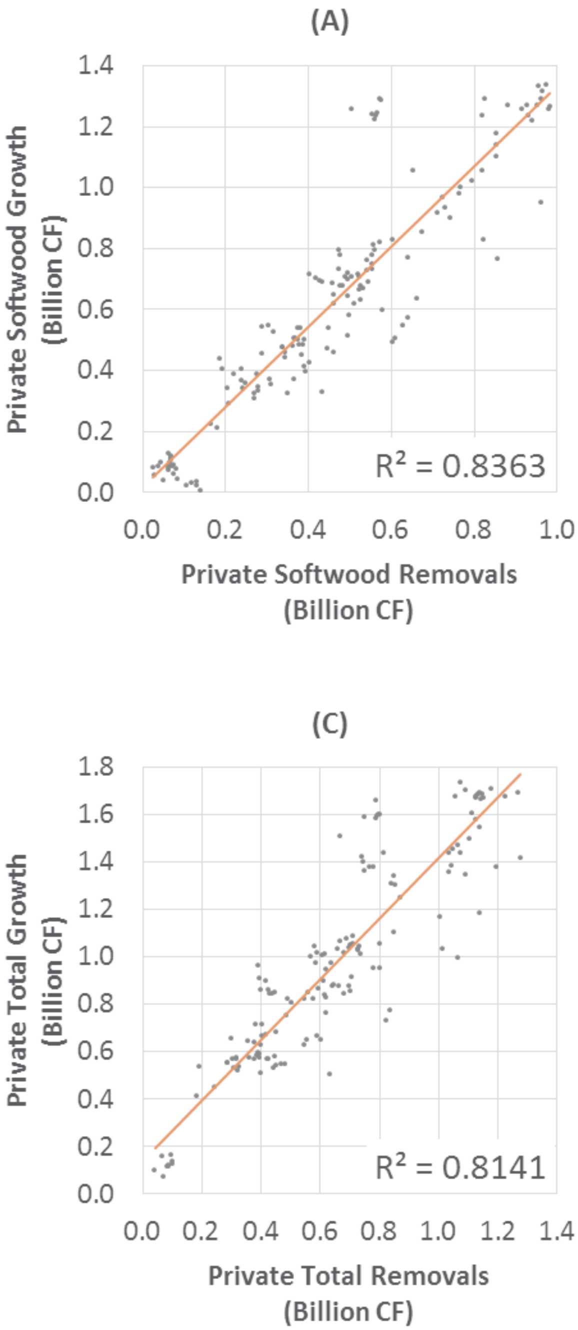
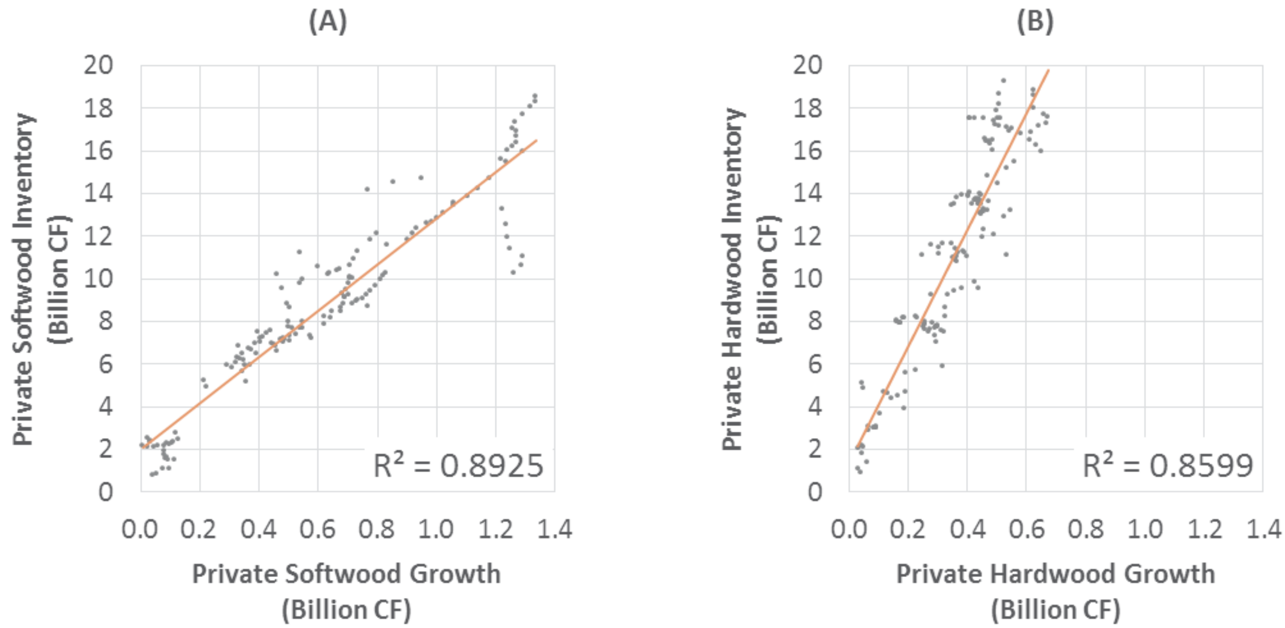


Figure 6-3 Private Removals vs. Growth by Species, 1968-2015

By species, private softwood removals explain approximately 84 percent of the variance in private softwood growth (A) while private hardwood removals explain approximately 71 percent of the variance in private hardwood growth (B). In total, private removals explain around 81 percent of the variance in private growth (C). (Sources: US Forest Service Forest Inventory and Analysis database, Forest2Market calculations.)



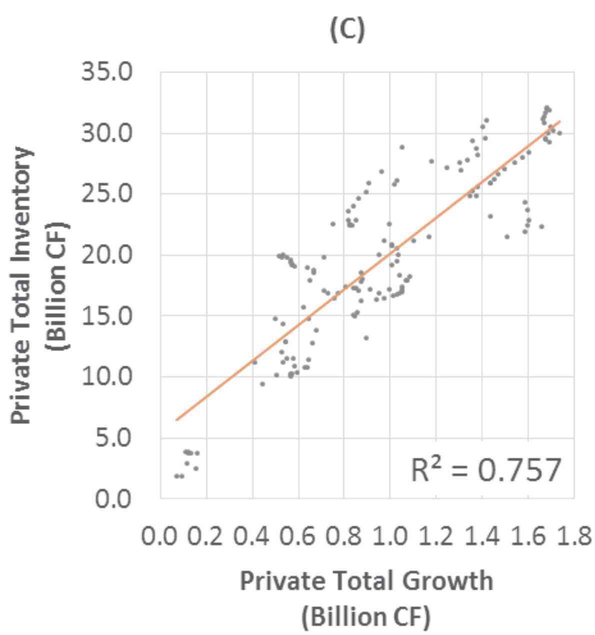


Figure 6-4 Private Growth vs. Inventory by Species, 1968-2015

By species, private softwood growth explains approximately 89 percent of the variance in private softwood inventory (A) while private hardwood growth explains approximately 86 percent of the variance in private hardwood inventory (B). In total, private growth explains around 76 percent of the variance in private inventory (C). (Sources: US Forest Service Forest Inventory and Analysis database, Forest2Market calculations.)

6.3 Southwide Summary Observations

Removals are positively correlated with acres, inventory and growth on private timberland. Higher removals due to increased demand are associated with more acres, greater inventory and higher growth rates. Using regression analysis shows that removals have historically been a useful predictor of acres, inventory and growth. This is especially true for softwood species where active management typically results in expansive inventories, healthy removals and productive growth.

While there is a strong relationship between removals and inventory, there is also a strong relationship between growth and inventory, especially for hardwood species which are harvested less often and may be managed for other reasons than simply maximizing timber production. There is also a strong relationship between removals and growth, especially for softwood species where plantation management encourages shorter, regular cycles of growth and harvest. It is clear that growth and removals act together to influence inventory, and, in cases of timber scarcity, inventory limitations would inhibit removals.

Figure 6-5 shows the indexed change in growth, inventory and removals since 1953. Each measure has been indexed separately to its starting value in 1953. This chart demonstrates that, together, changes in growth and removals drive changes in inventory. As removals wane or increase at a slower rate, more growth accumulates, and inventory temporarily rises. As removals increase at faster rates, increases in growth—and therefore inventory—typically decelerate; however, as the market responds to the new demand, landowners take steps to increase supply, as shown by the rapid growth increase in the 2000s that occurred following the sustained increase in removals that occurred through the 1980s and 1990s. Notably, despite periodic decelerations, Southern inventory has consistently increased as total (all species together) GRRs have remained above 1.0 (Section 5.6).

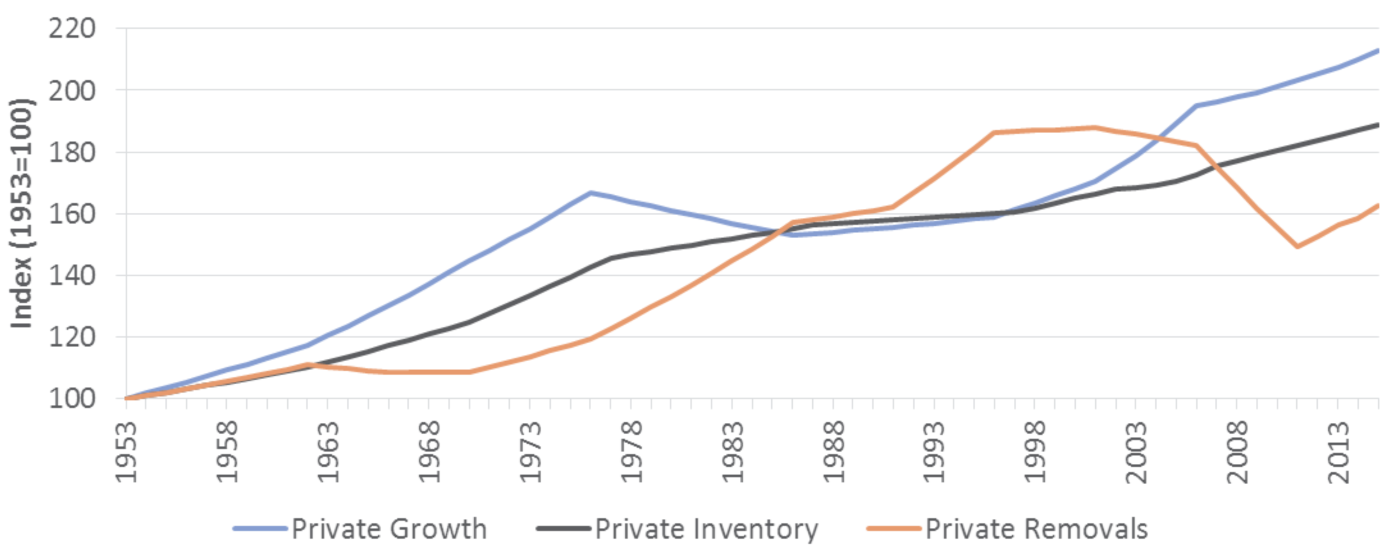


Figure 6-5 Privately-Owned Growing Stock Inventory, Growth and Removals Index (1953=100), 1953-2015

Removals, growth and inventory in the South have each increased since 1953. Southern forests are managed to promote a balance between growth and removals to ensure a healthy inventory; therefore, temporary periods where removals increase more quickly than growth are usually followed by periods where growth increases more quickly than removals. (Sources: US Forest Service Resources Planning Act reports, Forest2Market data and estimates.)

While regression and correlation alone do not prove causality, together they unequivocally show that these forest measures are related, and historical data confirm that demand for forest products led the forest products industry to invest in timberlands and productivity improvements in order to support increased removals. Strong demand supports the economics of growing timber. Our historical analyses in previous sections suggest other factors, including population increases, economic growth, changes in the housing market, government policies and programs that affect timberland owner management practices, land use change and the decades-long nature of timber rotations, also affect forests. The next section builds on our Southwide analyses by taking a look at two local markets.

7 DEMAND AND FOREST PRODUCTIVITY: LOCAL MARKET CASE STUDIES

In order to supplement the Southwide analyses performed earlier in this report, two additional case studies of local areas were performed to compare the trends observed at a regional level to those that occurred in local mill basins and to provide a more in-depth analysis of the relationship between demand and forest productivity. Specifically, in addition to the analysis of total removals, inventory and growth, the case studies also looked at trends in sawtimber and pulpwood. Sawtimber, a higher-value product, is typically used to manufacture solid wood products, such as dimensional lumber, veneer and plywood. Pulpwood, a lower-value product, is used to manufacture pulp, paper, Oriented Strand Board (OSB, a type of composite engineered wood panel) and bioenergy products.

The analysis is limited to privately-owned softwood pulpwood and sawtimber on naturally and artificially regenerated (i.e., plantation) stands. Total natural and plantation acres as well as natural and plantation softwood inventory, growth and removals for sawtimber and pulpwood are reported. Both basins are located in the Coastal Plain to minimize the potential impacts of geographic factors like forest type, temperature and precipitation. These analyses are performed on the basin level: All demand for wood sourced from the basin is considered, so the basin response to demand is representative of a market system rather than specific market participants. However, to control for the possible impacts of significant mill changes, both a basin where a mill opened (Flint River, Georgia) and a basin where a mill closed (St. Joe, Florida) were chosen (Figure 7-1). Both mills consumed primarily pulpwood.

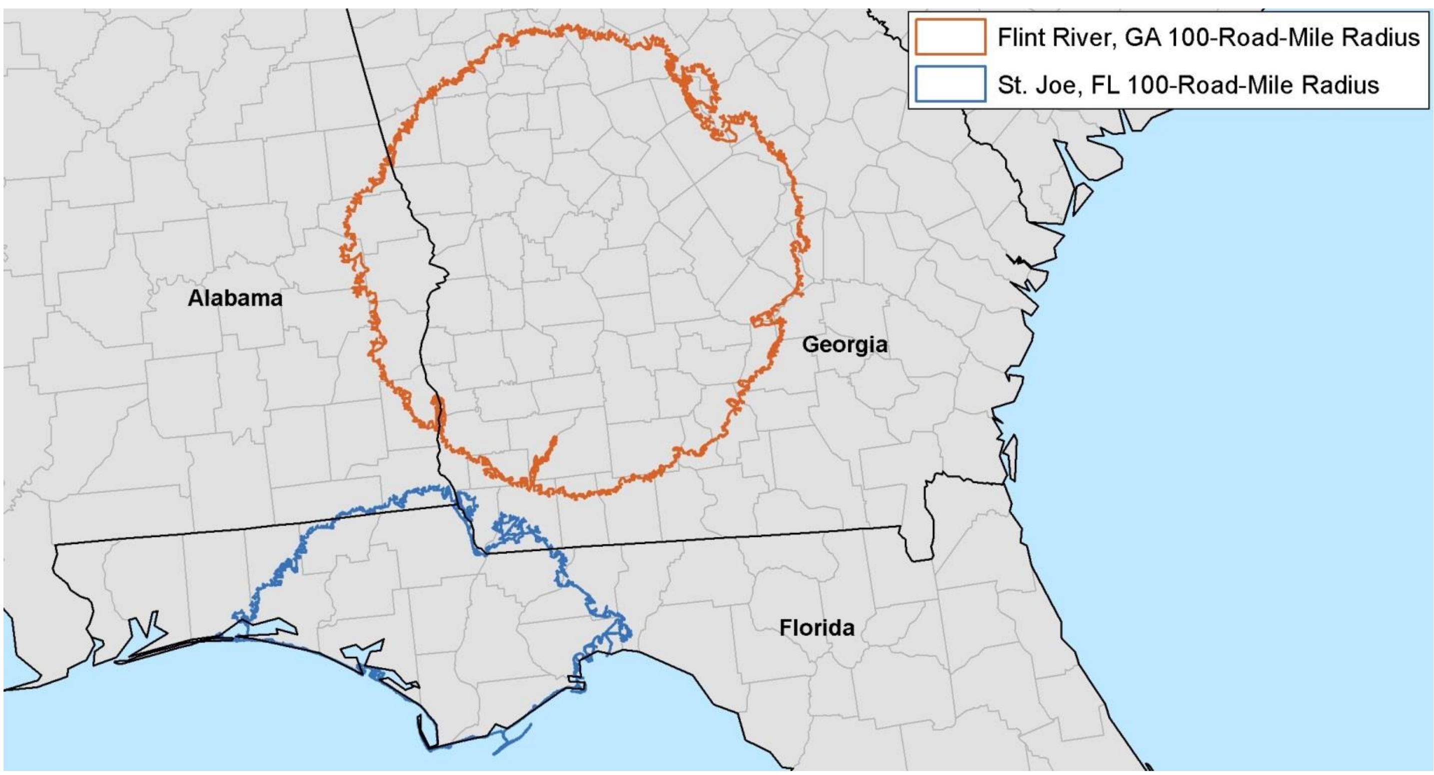


Figure 7-1 Case Study Analysis Areas – Flint River, GA and St. Joe, FL

Proctor and Gamble opened a pulp mill in Flint River, Georgia in 1981. The mill and associated timberlands were sold to Weyerhaeuser Corporation in 1992. Weyerhaeuser divested itself of the timberland assets around the mill in 2004 and sold the mill to International Paper in 2016. The St. Joe Company was founded in 1936. In 1938, the Company constructed the paper mill in St. Joe, Florida. In the 1950s and 1960s, the St. Joe Company aggressively purchased timberland in the Florida Panhandle to support the mill and to invest in the growing real estate market. By the 1990s, the mill was struggling, and St. Joe sold the mill to Florida Coast Paper in 1996 in order to focus more heavily on its real estate and timberland segments. Florida Coast Paper closed the mill in 1998. In 2013, St. Joe Company sold its non-strategic and rural timberlands to AgReserves.

7.1 Methodological Considerations

In this section, inventory, growth and removal data are primarily drawn from the US Forest Service's Forest Inventory and Analysis (FIA) database supplemented with more current removal data from Forest2Market's proprietary transaction databases. As noted in the introduction to Section 6, FIA data shifted from periodic to annual inventories during this period, and states have different annual sampling frequencies. These changes necessitate certain caveats when attempting to build or interpret an annual trend over several decades.

First, annual data between the various periodic inventories that occurred prior to roughly 2000 is trended between available data years and may therefore fail to capture annual volatility.[54] Second, because the annual inventory approach means that only a portion of a given state's plots is sampled each year, annual data has a certain time lag associated with it. For example, the most current FIA data in the St. Joe basin includes plots sampled between 2011 and 2015, which means that the data are closest to representing the forest as it existed during the midpoint of this interval, or 2013. In addition, the most current data from different states may reflect different midpoint periods. For example, the most current data in the Flint River basin includes plots sampled between 2011 and 2015 (midpoint=2013) in Georgia and between 2006 and 2015 (midpoint=2010.5) in Alabama.

This analysis classified removals, growth and inventory into pulpwood and sawtimber based on the size (diameter-at-breast-height [DBH]) of the tree. Consistent with US Forest Service definitions for pine, this analysis classified sawtimber trees as at least 9.0 inches in DBH. Smaller trees (5.0 to 8.9 inches in DBH) were considered pulpwood.

Product classifications based on tree size are useful for analyzing historical forest inventory data, which tracks removals, growth and inventory by tree size. However, these definitions deviate from actual operational product classifications, which are much more fluid. First, in weak sawtimber markets, larger trees may be sold as pulpwood, particularly if they have defects that make them less desirable or unusable for solid wood production; in these cases, landowners would cull these trees and sell them at pulpwood prices in order to recoup as much value for the tree as possible. Second, the portion of sawtimber trees above the main sawlog portion (i.e., topwood) would be sold as pulpwood when the sawtimber tree is harvested. Third, sawmills that focus on producing commodity grades of lumber (i.e., 2x4 and 2x6 inch studs) may purchase smaller logs.

Because sawtimber is derived from a larger tree, it takes longer to grow but can also be used for a greater variety of end uses. This makes sawtimber more valuable. Forest2Market's proprietary stumpage data show that, since 2009, pine sawtimber stumpage has been on average 2.8 times more valuable than pine pulpwood stumpage in the US South and 2.5 times more valuable in the greater Flint River and St. Joe areas (Figure 7-2). In 2016, pine sawtimber averaged $25.82 per green short ton, 2.2 times more valuable than pine pulpwood, which averaged $11.89 per green short ton in the area containing these two basins. Because sawtimber stumpage has historically been the higher-valued product and the primary size of log consumed in these areas, it follows that sawtimber was a very important part of landowners' management decisions in these basins.

[54] Similarly, the last periodic inventory data year (~1990) and the first annual inventory data year (~2000) may not be directly comparable to one another.

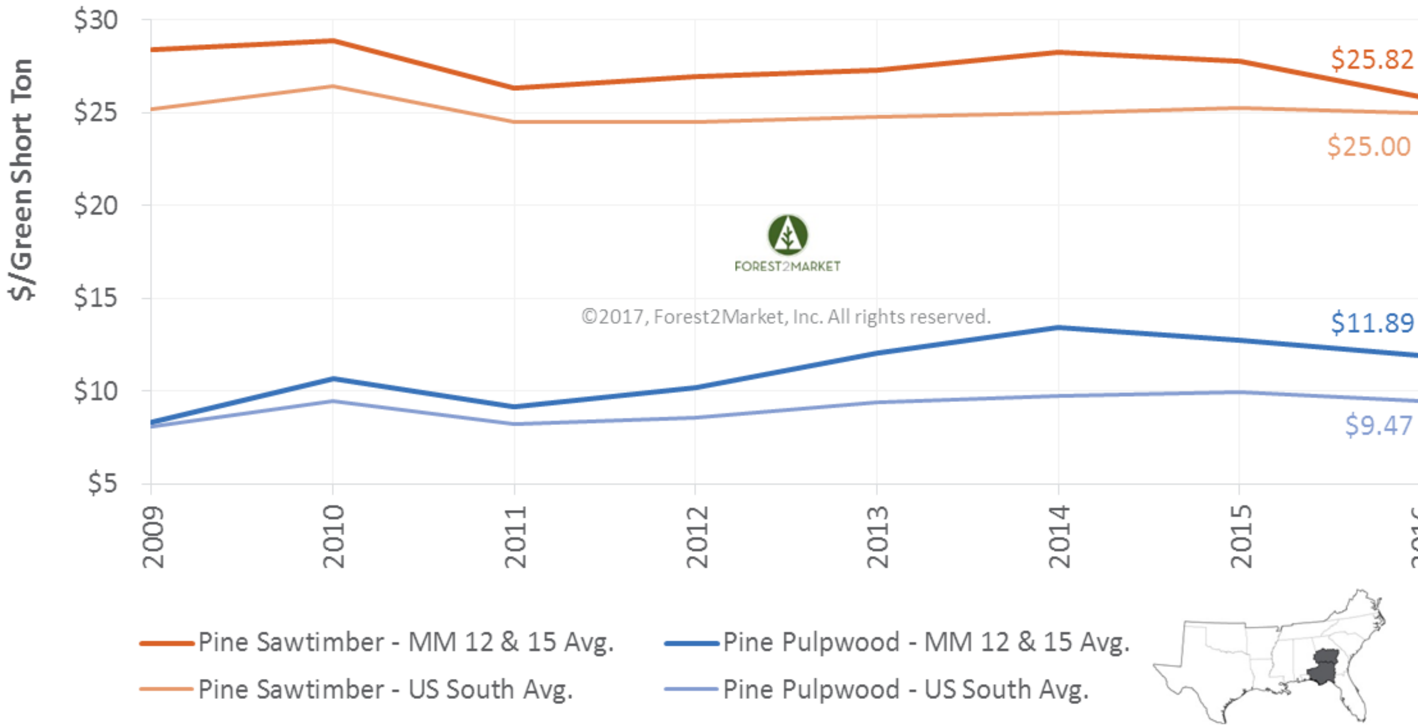


Figure 7-2 Annual Pine Sawtimber and Pulpwood Stumpage Prices in the US South and Micromarkets 12 and 15, 2009-2016 **(Source: Forest2Market, Inc.[55])**

7.2 Case Study Results

The Flint River, Georgia and St. Joe, Florida basins revealed several trends. First, the case studies support our Southwide findings that increased demand and government incentives caused timberland acres—albeit temporarily in St. Joe—and inventory to increase because landowners increased their utilization of highly-productive plantations. The case studies further specify that rapid increases in sawtimber demand were particularly important in stimulating this activity. Second, the Flint River case study supports previous Forest2Market findings[56] that reduced sawtimber demand (and therefore price) caused landowners to defer final harvests until sawtimber market conditions improve, which limits pulpwood regeneration and inventory. Third, the St. Joe case study provides support for our Southwide finding that increased development pressures place timberland at risk of conversion to other uses, especially when combined with an important mill closure.

In Flint River, Georgia, between 1972 and 2015, total removals increased 51 percent while growth increased by 44 percent and inventory increased 53 percent (Table 7-1). In St. Joe, Florida, removals increased 266 percent between 1970 and 2015; growth increased 162 percent, and inventory increased 150 percent.[57]

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[55] Prices are annual averages of bimonthly prices reported in Forest2Market's Timber Owner Market Guide (TOMG) products and are sourced from our proprietary databases of stumpage transactions. Data for Forest2Market Micromarket 12 (West Central Georgia/East Central Alabama) and 15 (Western Florida/Southwest Georgia/Southeast Alabama) include the Flint River, Georgia and St. Joe, Florida basins.
[56] See, for example, Stewart 2015 and Stuber 2016.
[57] The smaller area associated with the coastal St. Joe basin increased the potential for volatility in the basin, which may partially explain the greater rates of change that occurred there. Additional analyses that incorporate age class distributions may shed further light on the steeper increases in this basin.

Table 7-1 Annual Removal, Growth and Inventory Trends in Flint River, GA and St. Joe, FL Basins, Early 1970s to 2015

Since the 1970s, annual removals, growth and inventory increased in both basins for both products and in total. Increases in removals, growth and inventory were more dramatic in the smaller St. Joe basin. Landowners demonstrated a preference for sawtimber in both basins: On average from the early 1970s to 2015, sawtimber was 68 percent of removals and 69 percent of inventory in Flint River and 52 percent of removals and 61 percent of inventory in St. Joe. (Sources: US Forest Service Forest Inventory and Analysis Database, Forest2Market data and estimates.)

Flint River, GA									
	Removals (Billion CF)			Growth (Billion CF)			Inventory (Billion CF)		
Year	**Total**	Sawtimber	Pulpwood	**Total**	Sawtimber	Pulpwood	**Total**	Sawtimber	Pulpwood
1972	**0.24**	0.19	0.05	**0.42**	0.22	0.20	**5.37**	3.54	1.83
2015	**0.36**	0.22	0.14	**0.60**	0.32	0.28	**8.23**	6.00	2.23
Avg. Percent of Total		68%	32%		51%	49%		69%	31%
Change, 1972 - 2015	**51%**	17%	178%	**44%**	46%	41%	**53%**	70%	22%

St. Joe, FL									
	Removals (Billion CF)			Growth (Billion CF)			Inventory (Billion CF)		
Year	**Total**	Sawtimber	Pulpwood	**Total**	Sawtimber	Pulpwood	**Total**	Sawtimber	Pulpwood
1970	**0.04**	0.02	0.01	**0.06**	0.03	0.03	**0.94**	0.60	0.34
2015	**0.13**	0.06	0.07	**0.17**	0.08	0.09	**2.35**	1.59	0.76
Avg. Percent of Total		52%	48%		38%	62%		61%	39%
Change, 1970 - 2015	**266%**	164%	478%	**162%**	164%	159%	**150%**	167%	122%

In both basins, notable increases in sawtimber removals in the 1980s and government incentives associated with the Conservation Reserve Program encouraged landowners to expand plantation acres between 1980 and 2000 (Figure 7-3). The expansion in acres led to dramatic increases in pulpwood growth beginning around 1990 in Flint River and 1980 in St. Joe and sawtimber growth in both basins beginning in the late 1990s (Figure 7-5). Increased growth, particularly on plantations, caused steep increases, first, in pulpwood and, later, in sawtimber inventory (Figure 7-4, Figure 7-5). Thereafter, the two basins began to diverge (Figure 7-3).

In the Flint River area as in the US South more broadly (Section 5.8.3), the increase in sawtimber inventory—driven by increased plantation inventory (Figure 7-5-A, Figure 7-5-C)—was well underway prior to the Great Recession but was nonetheless accelerated by it. By the early 2000s but especially after the Great Recession, sawtimber removals leveled off (Figure 7-4-A, Figure 7-5-A), and sawtimber inventory began to accumulate (Figure 7-4-C, Figure 7-5-A) as landowners delayed final harvest while waiting for sawtimber demand (and therefore price) to return to previous levels. This delay in final harvests negatively impacted pulpwood regeneration on plantation stands, and the 1990s' dramatic increase in pulpwood inventory was abruptly interrupted as stands that were not harvested also were not replanted (Figure 7-4-C, Figure 7-5-C).

In Flint River, this inventory shift occurred on a timberland base that was fairly stable and that experienced an overall 3 percent increase in timberland acreage (Figure 7-3-A). Data from before and after the mill opened suggest that the opening of the mill may have helped preserve timberland in the area. From 1972 to 1981, natural acres were decreasing at an annual rate of -0.8 percent annually and plantation acres were increasing at a rate of 1.0 percent annually; in total, timberland acres were decreasing at a rate of -0.6 percent annually. From the opening of the mill in 1981 to 2015, the decline in natural acres slowed to -0.5 percent annually, and plantation acres increased at an even faster rate (2.8 percent annually). This was enough to cause total timberland acres to reverse trend, and total timberland increased 0.3 percent annually from 1981 to 2015.

The St. Joe basin presents a different interaction between removals and inventory: Except for interruptions between the mid-1980s and early 2000s for sawtimber (Figure 7-4-B, Figure 7-5-B) and a brief period in the early 2000s and 2014-2015 for pulpwood (Figure 7-4-B, Figure 7-5-D), removals increased consistently[58] and at a faster rate in the St. Joe basin than in the Flint River basin. Nonetheless, sawtimber inventory continued to increase through 2015 (Figure 7-4-B, Figure 7-5-B), but pulpwood inventory—specifically plantation inventory (Figure 7-5-D)—began to decrease after the mid-2000s as continued strong demand for pulpwood-sized logs outpaced regeneration on a declining plantation timberland base (Figure 7-3-B). After the St. Joe mill closed, most of the decline in timberland acres occurred on plantation timberland, and, while total timberland acres had already been on a declining trend, they decreased at a faster rate after the mill closed. This provides some evidence that the loss of a central mill in a geographically-limited basin may have detrimental impacts on timberland, especially when that basin is also located in an area already facing development pressures.

Overall, the case studies show that local wood basins are dynamic and the result of the interaction of multiple market participants. Changing demand for sawtimber, the more highly valued timber product, has the power to affect pulpwood demand and inventory. While pulpwood removals increased briefly after the opening of the Flint River mill in response to new demand from the facility, the effect was not pronounced (Figure 7-4-A, Figure 7-5-C), which indicates that demand that was previously fulfilled from within the basin may have migrated outside the basin. Similarly, despite the closure of the St. Joe mill, pulpwood removals continued to increase as new demand filled the void (Figure 7-4-B, Figure 7-5-D). However, acreage data from both basins underscore the importance of a centrally-located pulpwood-consuming mill to preserving timberland in the area, particularly in the St. Joe basin, which faced competing pressures from urbanization.

[58] There are a few possible explanations for this. First, several of the area's sawmills are optimized to consume the smaller slash pine sawlogs that are common in the area (see Section 4.2, Figure 4-1), and additional analyses (not shown) indicate that most of the increase in pulpwood removals that occurred during this time period was in the larger "pulpwood" diameter class (i.e., 7.0-8.9" DBH). Therefore, it is possible that a fair amount of the "pulpwood"-*sized* removals may have actually been going to sawmills. Second, between the mid-1980s and the early 2000s, sawtimber (9.0"+ DBH) removals were declining. In addition to chips made from smaller logs (i.e., pulpwood), pulp and paper mills typically consume residual chips produced during solid wood manufacturing because they are typically cheaper than chips made from pulpwood logs. Declines in solid wood production reduced residual chip supply and likely therefore also increased demand for pulpwood.

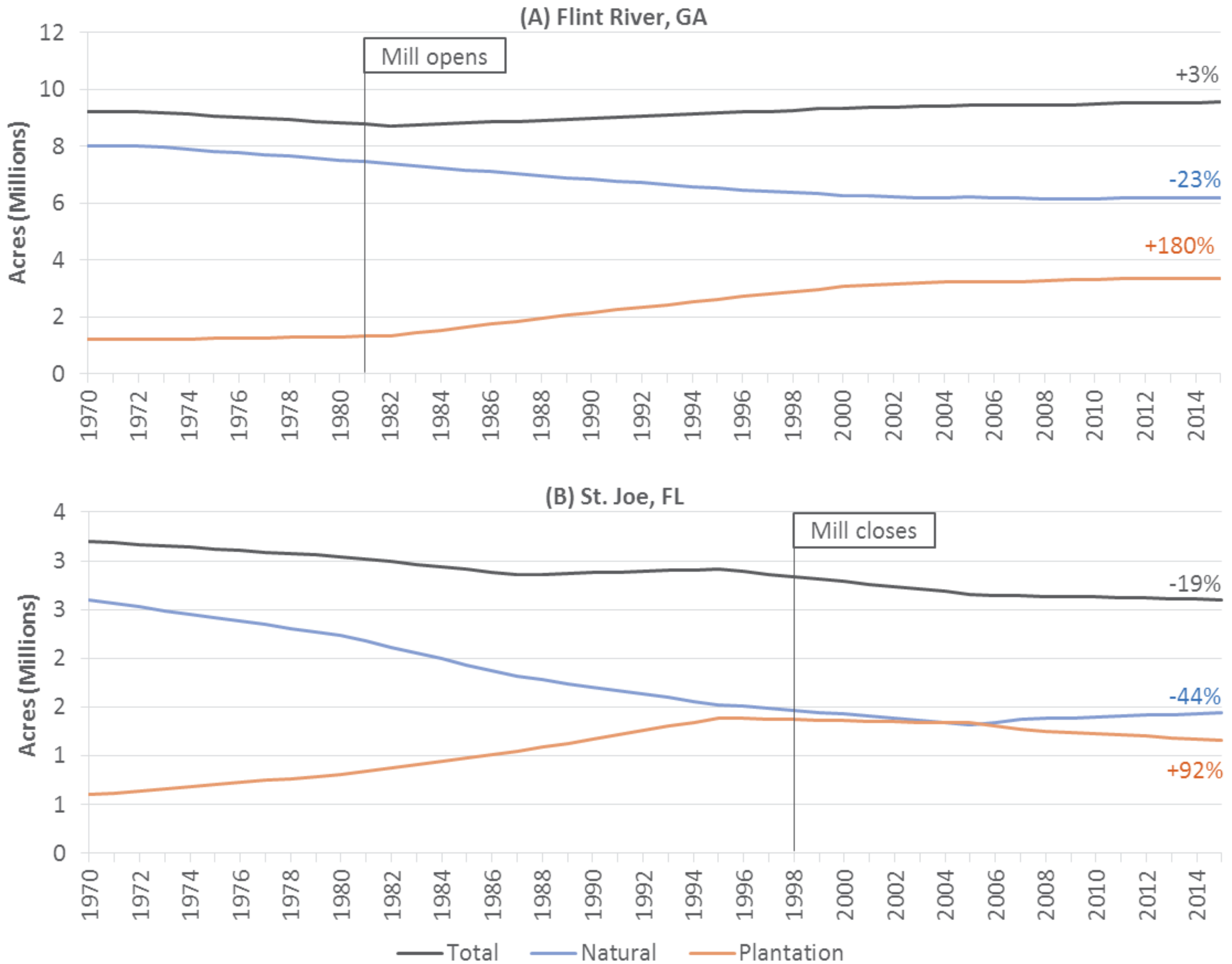

Figure 7-3 Privately-Owned Acres by Stand Origin in Flint River, GA and St. Joe, FL Basins, 1970-2015

As in the US South more generally, both the Flint River, Georgia (A) and St. Joe, Florida (B) basins have experienced declines in naturally-regenerated timberland and increases in artificially-regenerated (plantation) timberland. However, the Flint River basin (A) was much more stable overall and experienced a 3 percent gain in timberland acres by 2015, a shift largely attributable to the dramatic increase (180 percent) in plantation timberland that occurred there. These increases occurred following the reinstatement of the Conservation Reserve Program in 1985 and during the period of dramatic growth in US forest products production that occurred from the 1980s to the 2000s (Section 4.2). Similar increases in plantation timberland in St. Joe (B) suggest that an increase in plantation acres in Flint River would likely have occurred around this time whether or not the Flint River mill opened. However, the *size* of the increase (180 percent in Flint River vs. 92 percent in St. Joe) reflects the concerted efforts of the Flint River mill's owners, who also acquired and managed nearby timberlands, to ensure a steady supply of timber by promoting forest productivity. By contrast, the St. Joe basin (B) lost 44 percent of its naturally-regenerated timberland—and 19 percent of its total timberland—between 1970 and 2015. Also, unlike the Flint River basin, which increased or maintained its plantation acreage through the 2000s and 2010s, plantation timberland acres leveled off in the St. Joe area in the mid-1990s shortly before the mill closed and began decreasing in the mid-2000s. Real estate development put pressure on the St. Joe basin, and the loss of the St. Joe paper mill may have hastened the decline in acres that were lost to urbanization. In both basins, the presence of an active, centrally-located mill was associated with faster increases in plantation acres and increases (in Flint River, A) or less rapid decreases (in St. Joe, B) in total timberland acres (Sources: US Forest Service Forest Inventory and Analysis Database, Forest2Market estimates.)

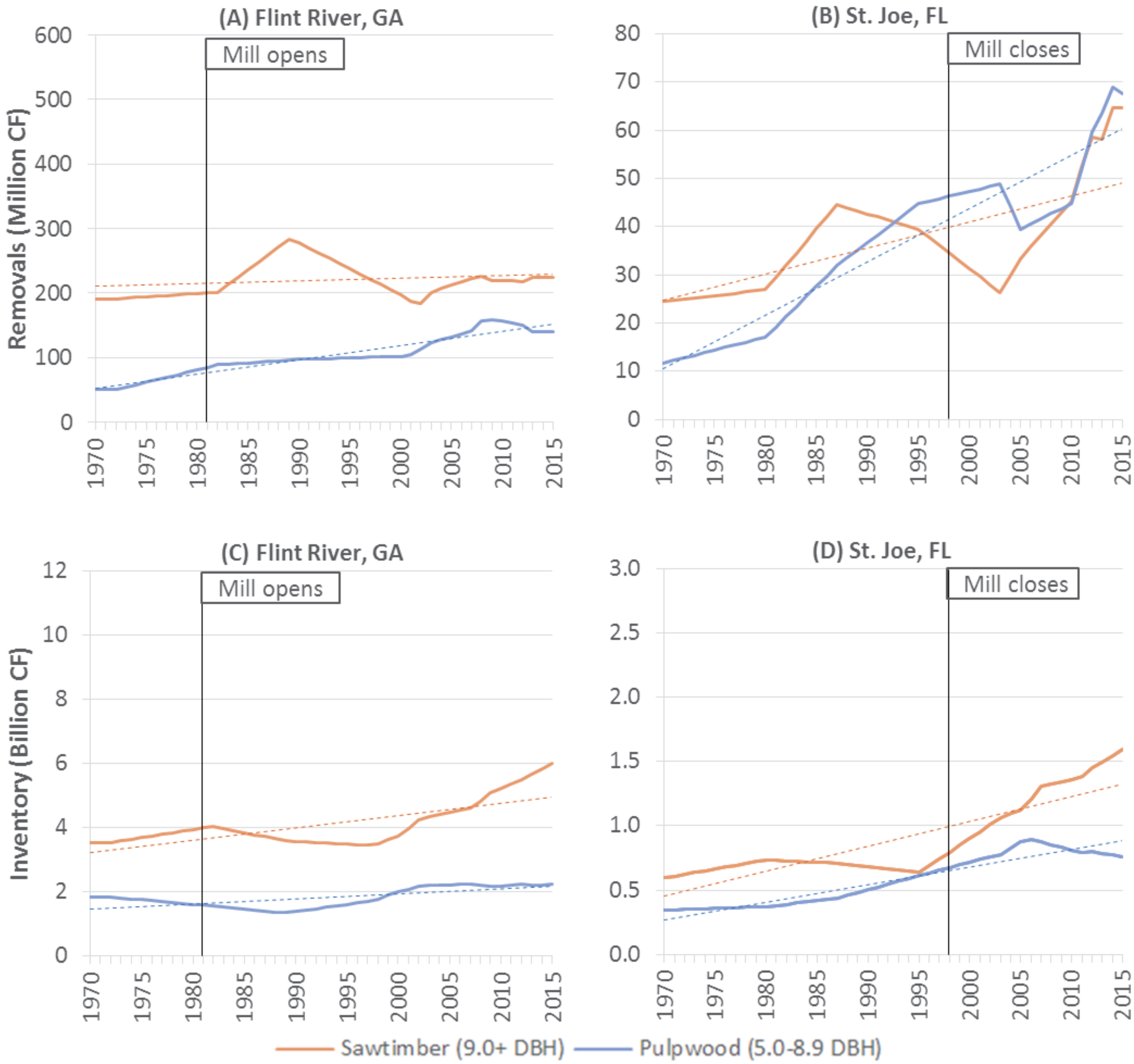

Figure 7-4 Removals and Inventory by Product in Flint River, GA and St. Joe, FL Basins, 1970-2015

While the Flint River, Georgia basin had much higher removals and inventory than the St. Joe, Florida basin—due mostly to its larger size—the basins nonetheless experienced some similar patterns in removals and inventory. In both Flint River (A) and St. Joe (B), sawtimber removals increased during the 1980s before decreasing through the 1990s. Sawtimber removals began increasing again in both basins during the early 2000s. Between 1980 and 2000, pulpwood removals remained fairly flat in Flint River (A) but increased in St. Joe (B). Removal patterns diverged after the turn of the century: In Flint River (A), sawtimber and pulpwood removals increased through the mid-2000s before leveling off or decreasing slightly, but removals of both product size-classes increased significantly in St. Joe, likely due in part to the ability of area sawmills to consume smaller logs (B). Similarly, in both basins, sawtimber inventory increased prior to 1980 before decreasing or remaining stable through the mid-1990s (C, D). After 2000, sawtimber inventory increased in both basins. (Sources: US Forest Service Forest Inventory and Analysis Database, Forest2Market data and estimates.)

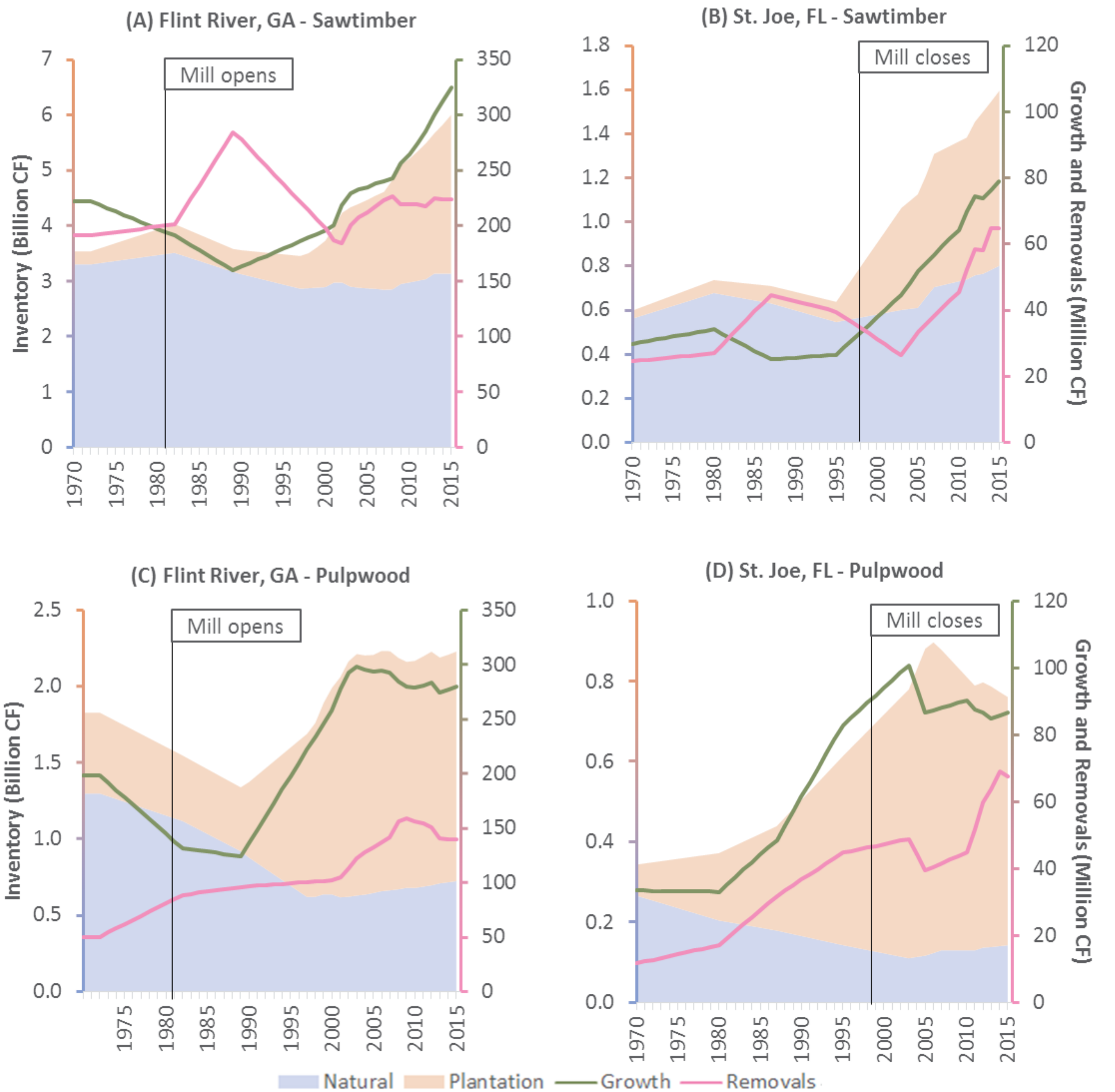

Figure 7-5 Natural and Plantation Inventory and Total Growth and Removals by Product in Flint River, GA and St. Joe, FL Basins, 1970-2015

As in the US South, inventory, growth and removals in the Flint River and St. Joe basins increased between 1970 and 2015. The St. Joe basin (B, D) experienced steeper increases than Flint River (A, C). Driven by CRP incentives and high sawtimber harvests in the 1980s, pulpwood growth and inventory increased significantly during the 1990s in both basins (C, D). By the 2000s, a similar increase occurred in sawtimber growth and inventory (A, B) as pulpwood-sized trees grew into sawtimber. After the Great Recession, Flint River area landowners deferred final harvests as demand for sawtimber decreased (A), and pulpwood growth and inventory leveled off due to reduced regeneration (C). In the St. Joe area, both sawtimber (B) and pulpwood (D) removals increased from the mid-2000s, and a simultaneous decline in plantation timberland (Figure 7-3-B) reduced pulpwood inventory. (Sources: US Forest Service Forest Inventory and Analysis Database, Forest2Market data and estimates.)

8 CONCLUSION

Southern forests have changed dramatically since the 1950s. While most of the South's old-growth, virgin forests were cut prior to the 1950s, Southern forests rapidly regrew and have undergone multiple harvest and regeneration cycles. Today, growth exceeds removals by 72 percent on timberland in the US South, and timberland covers more area today than it did in 1953. History shows that the South's forests can be and have been managed sustainably.

Some of the changes in Southern forests were driven by changes in the forest products industry. Land conservation policies and acquisition of timberlands by the forest products industry promoted the establishment of fast-growing, productive pine plantations. The forest industry increased its holdings through the 1980s to ensure a stable wood supply before divesting most of its holdings in the 1990s and 2000s as timber supply concerns lessened and divestiture allowed companies to improve their financial positions. US production of solid wood and panels increased through the mid-2000s in response to housing demand, which was a product of economic expansion and increasing population, before dropping during the Great Recession and slowly increasing since 2009. Pulp and paper production increased through the mid-1990s as paper consumption tracked increases in population and GDP; the digital age and later the Great Recession led to declines in pulp and paper production. Since the mid-2000s, pellet production has been growing rapidly and is helping to replace some demand that was vacated by declines in pulp and paper capacity but is still miniscule in comparison to these historic pulpwood-consuming giants. Forests continue to face competing pressures due to population growth and urban expansion.

Our historical analysis demonstrates the resiliency of Southern forests. Southern forests, when well-managed, are capable of supporting robust demand from the forest products industry. Despite periods when timberland acres declined slightly, demand remained steady or increased throughout most of the last sixty years, and while the composition of timberlands have changed in that time, there are more acres today than there were in 1953. Inventory has increased significantly in response to improved growth, especially on pine plantations. Total growth and growth per acre have increased since the 1950s as silvicultural practices improved output, especially on privately-owned softwood plantations. These improvements were largely in response to the concerted efforts of the forest products industry, which wanted to ensure a stable supply of raw material despite increased demand and therefore funded research carried out by public-private partnerships to improve productivity. Improved growth made it possible for the forest to sustain increased removals without upsetting the growth-to-removal balance of the forest.

Our statistical analyses of the US South show a strong relationship between removals and inventory, removals and growth, and removals and acres. Higher removals are associated with more inventory, more growth and more timberland acres. This is especially true for softwood species where the correlation between removals and inventory is almost perfect (r=.95007). Our regression analyses show that removals are useful for predicting acres, inventory and growth. Growth is also useful for predicting inventory and is in fact a better predictor than removals for hardwood species and in total (i.e., all species combined).

While our statistical analyses in the South show that removals are related to these different measures, they do not prove causality. Indeed, history has shown that there are many interrelated factors that affect forests, including population growth, economic trends, globalization and technological change, government policies and programs, timberland owner management objectives and urbanization and other land use change. Our local case studies also point to additional factors, especially the importance of the sawtimber market, in driving both sawtimber and pulpwood inventory changes. Analyses that seek to definitively relate removals to changes in the forest must account not only for removals, growth, inventory and acres, but also these other factors. A complex multivariate model that accounts for these variables is necessary to truly understand the relative impact of each of these factors on changing forests.

That said, the evidence clearly demonstrates the positive impact that demand for forest products had on growing the South's forests during the second half of the twentieth and beginning of the twenty-first centuries. The reforestation of the South was supported by government, which was combatting soil erosion and deforestation, but it was carried out and maintained largely by private owners, especially the forest products industry, which needed a stable and productive supply of wood. Industry owners promoted sound forestry practices not only on their own lands, but on non-industrial, privately-owned lands as well.

Looking ahead, one US Forest Service report (Wear and Greis 2012, Wear and Greis 2013) forecasted the cumulative change in non-Federal forest land in the South through 2060 under four different scenarios. The scenarios differed in the degree of urbanization and the future value of timber, which are two important factors that will affect the future of forests. The results of the Forest Service analysis showed that the South was projected to lose forest land in all scenarios (Figure 8-1).

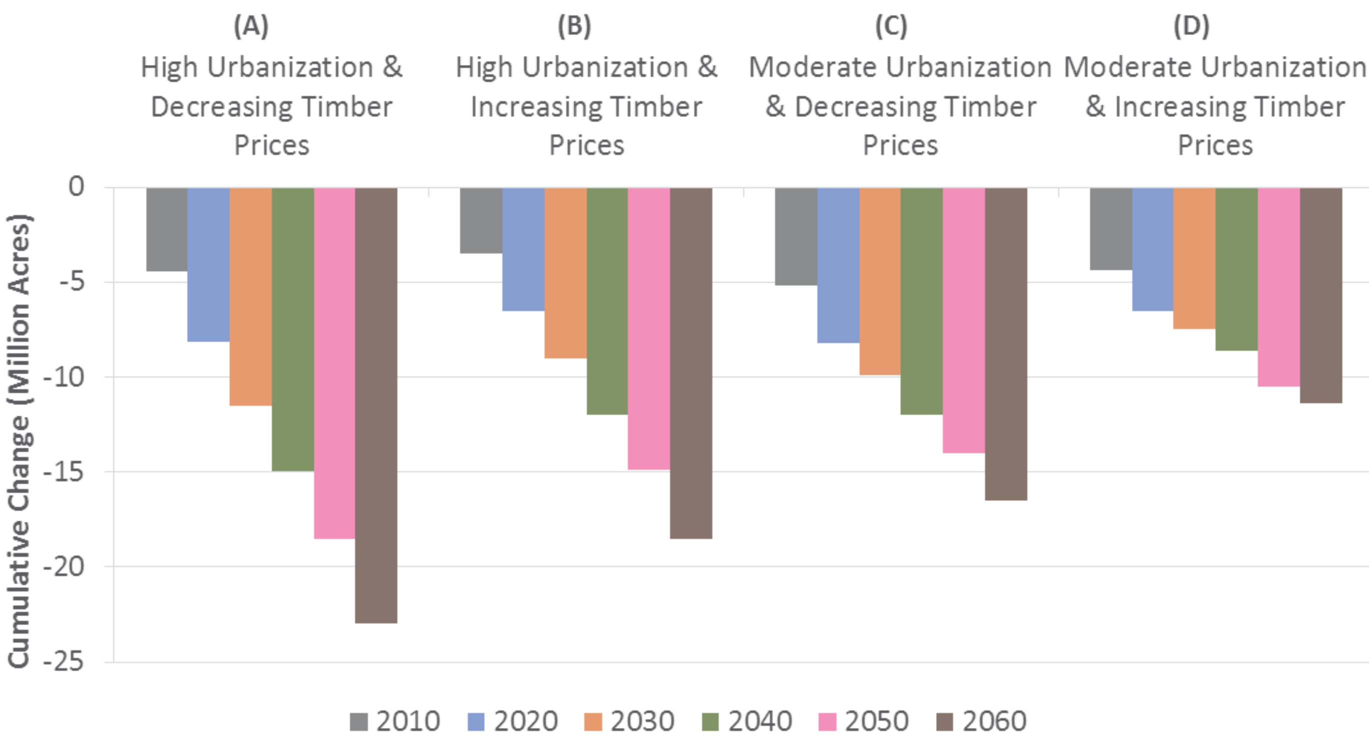

Figure 8-1 Cumulative Change in Forest Land Uses from 1997 to 2060 by Decade under Four Scenarios
(Source: Wear and Greis 2013.[59])

However, the amount of forest land lost varied depending on the amount of urbanization and the changing future value of timber. The authors of the report wrote:

> Between 30 million and 43 million [additional] acres of land in the South are forecasted to be developed into urban uses by 2060, from a base of 30 million acres [of urban land that existed] in 1997. The South is forecasted to lose between 11 million and 23 million acres (7 and 13 percent, respectively) of forests from 1997 to 2060. All subregions are expected to lose at least some acreage; nearly all of this area would be converted to

[59] Adapted from Figure 4.9 in Wear and Greis 2013; data in Figure 8-1 are approximated, and bars may not be perfectly to scale.

> urban uses. Strong timber markets can ameliorate forest losses somewhat, by shifting urbanization to agricultural lands. (Wear and Greis 2012, 24)

In the Forest Service analysis, higher urbanization and decreasing prices for timber (Scenario A) resulted in the most forest land loss. Moderate urbanization and increasing prices for timber resulted in the least forest land loss (Scenario D). Regardless of the degree of urbanization, increasing timber prices (Scenarios B and D) functioned to mitigate, but not prevent, the loss of forest. In other words, increasing timber prices—presumably due to continued strong, healthy markets for timber—are key to keeping forests forested.

9 RECOMMENDED CITATION

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11 APPENDIX A: GLOSSARY

Conifer species are coniferous needle-leaved species of trees, such as pine, fir and spruce. They may also be referred to as softwood trees or evergreens.

Containerboard includes corrugated medium and linerboard, which are used in corrugated packaging.

Diameter-at-breast height (DBH) is a measurement of the diameter of a standing tree taken at 4.5 feet off of the ground (the breast height of a forester taking a forest inventory). DBH is an indication of the size of the logs that could result from the tree (e.g., pulpwood or sawtimber).

Fluff pulp is an absorbent chemical pulp commonly used in diapers and feminine hygiene products.

Forest land is defined differently somewhat depending on the data source, as follows:

- As used in the USDA Natural Resources Conservation Service's National Resources Inventory, forest land is: "A land cover/use category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cut over forest or abandoned farmland) and not currently developed for nonforest use. Ten percent stocked, when viewed from a vertical direction, equates to an areal canopy cover of leaves and branches of 25 percent or greater. The minimum area for classification as forest land is 1 acre, and the area must be at least 100 feet wide."
- The US Forest Service FIA program's definition is: "Land at least 10-percent stocked by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10-percent stocked with trees and forest areas adjacent to urban and builtup lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre and 120 feet wide measured stem-to-stem from the outer-most edge. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide."

Forest management type encompasses both the **forest type** and the **stand origin** of particular stands of trees. Common forest management types in the US South include:

- Planted pine – Includes all stands with a pine, oak-pine or nonstocked forest type that show evidence of artificial regeneration.
- Natural pine – Includes all stands with a pine forest type that do not show evidence of artificial regeneration.
- Oak-pine – Includes all stands with an oak-pine forest type that do not show evidence of artificial regeneration.
- Upland hardwood – Includes all stands in the oak-hickory, maple-beech-birch, and aspen-birch forest type groups.
- Lowland hardwood – Includes all stands in the oak-gum-cypress and elm-ash-cottonwood forest type groups.
- Nonstocked – Accessible land where one of the following conditions is true: The land is less than 10 percent stocked by trees, seedlings and saplings and not classified as cover trees, or, for woodland species where stocking standards are not available, there is less than 10 percent canopy cover of trees, seedlings and saplings.
- Nonforest – Includes land that has "less than 10 percent canopy cover of tally tree species of any size and, in the case of afforested land, fewer than 150 established trees per acre; or land that has sufficient canopy cover or stems, but is classified as nonforest land use. Nonforest includes areas that have sufficient cover or live stems to

meet the forest land definition, but do not meet the dimensional requirements." Nonforest land uses include developed, agricultural, pasture, range, wetland and various other land uses.

Forest type describes the tree species or species groups that form a plurality of all live stocking on a stand.

Growing-stock trees, according to the US Forest Service's definition, include: "All live trees of commercial species that meet minimum merchantability standards. In general, these trees have at least one solid 8-foot section, are reasonably free of form defect on the merchantable bole, and at least 34 percent or more of the volume is merchantable. For the California, Oregon, and Washington inventories, a 26 percent or more merchantable volume standard is applied, rather than 34 percent or more. Excludes rough or rotten cull trees."

Growth, according to the US Forest Service's definition, is the "[a]verage annual net growing-stock cubic-foot growth of growing-stock trees on timberland" or "[t]he net change in cubic-foot volume per year for growing-stock trees that were on timberland."

Growth-to-Removal Ratio (GRR) is the ratio of growth over removals. GRRs over 1.0 indicate that more wood was grown than was removed during that time period. If it is less than 1.0, more wood was removed than was grown.

Hardwood species are deciduous broad-leaved species of trees, such as oak, maple, aspen, beech and birch.

Inventory, as calculated by the US Forest Service, refers to the net volume (in cubic feet) of growing-stock trees at least 5 inches in diameter-at-breast-height on timberland. Inventory may also refer to the annual or periodic assessments conducted by the US Forest Service to measure and assess the nation's forests.

Natural stand. – See **Stand origin**.

Net cubic foot volume, according to the US Forest Service's definition, varies by timber species, as follows: "For timber species (trees where the diameter is measured at breast height [DBH]), this is the net volume of wood in the central stem of a sample tree >=5.0 inches in diameter, from a 1-foot stump to a minimum 4-inch top diameter, or to where the central stem breaks into limbs all of which are <4.0 inches in diameter. For woodland species (trees where the diameter is measured at root collar [DRC]), this is the net volume of wood and bark from the DRC measurement point(s) to a 1-1/2 inch top diameter; includes branches that are at least 1-1/2 inches in diameter along the length of the branch."

Nonstocked. – See **Forest management type**.

Oriented Strand Board, or **OSB**, is an engineered wood product used in construction and building applications.

Pellet mills use wood fiber to manufacture condensed wood pellets that are burned as a fuel in domestic heating stoves or in industrial electricity-generating facilities.

Performance or specialty fiber mills produce cellulose that is used in a range of specialized products, such as pharmaceutical additives, biochemicals, rayon and various other consumer product applications.

Planted stand/plantation. – See **Stand origin**.

Plywood, manufactured by **plymills**, is a solid wood product used in construction and building applications.

Pulpwood includes logs from conifer trees that are generally 5 to 9 inches in DBH and hardwood trees that are generally 5 to 11 inches in DBH. **Topwood** from sawtimber trees and low-quality trees and that are not suitable for veneer or lumber may also be merchandized as pulpwood. Pulpwood is used by chip mills, Oriented Strand Board (OSB) mills, pellet mills and pulp and paper mills.

Removals, as described by the US Forest Service, refer to "[t]rees that were growing-stock trees on timberland at the time of the previous inventory and were removed from timberland by the time of the current inventory." Removals include "cut and utilized trees, trees killed as a result of harvest operations but not utilized, and live trees associated with land-use reclassifications."

Sawlogs, as defined by the US Forest Service, are logs "meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods [i.e., conifers] and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards."

Sawtimber includes stemwood from conifer trees that are over 9 inches in DBH and hardwood trees that are over 11 inches in DBH.

Stand origin refers to the method of regeneration used to regrow trees on a stand. Planted stands demonstrate clear evidence of artificial regeneration, such as through the use of planting or artificial seeding. All other stands are classified as natural stands.

Stemwood refers to wood from the main part of a tree and excludes the branches, stump and roots.

Timberland, according to the US Forest Service's definition, is: "Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. …Areas qualifying as timberland are capable of producing at least 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included."

Topwood is the portion of the sawtimber tree above the **sawlog** portion. Topwood of sufficient quality is sold on the open-market as pulpwood.

Uncoated freesheet is a grade of paper commonly used to produce copy and office paper.

12 APPENDIX B: FOREST MEASURE CORRELATIONS

Table 12-1 Pearson Correlations between Privately-Owned Total, Softwood and Hardwood Removals and Selected Forest Measures

Forest Measure	Total Removals	Softwood Removals	Hardwood Removals
Total Acres	0.88763 (p<.0001)	0.82496 (p<.0001)	0.61636 (p<.0001)
Softwood Acres	0.88341 (p<.0001)	0.93056 (p<.0001)	0.30034 (p<.001)
Hardwood Acres	0.57344 (p<.0001)	0.38746 (p<.0001)	0.81413 (p<.0001)
Total Inventory	0.79217 (p<.0001)	0.66961 (p<.0001)	0.7406 (p<.0001)
Softwood Inventory	0.91155 (p<.0001)	0.95007 (p<.0001)	0.33891 (p<.0001)
Hardwood Inventory	0.38267 (p<.0001)	0.16707 (p<.05)	0.80486 (p<.0001)
Total Inventory/Acre	0.24271 (p<.01)	0.0817	0.57985 (p<.0001)
Softwood Inventory/Acre	0.16691 (p<.05)	0.07329	0.34987 (p<.0001)
Hardwood Inventory/Acre	0.25194 (p<.01)	0.06659	0.65399 (p<.0001)
Total Removals/Acre	0.78603 (p<.0001)	0.77201 (p<.0001)	0.42727 (p<.0001)
Softwood Removals/Acre	0.60077 (p<.0001)	0.58728 (p<.0001)	0.33449 (p<.0001)
Hardwood Removals/Acre	0.52297 (p<.0001)	0.31015 (p<.001)	0.86602 (p<.0001)
Total Growth	0.90229 (p<.0001)	0.86498 (p<.0001)	0.5511 (p<.0001)
Softwood Growth	0.8577 (p<.0001)	0.91452 (p<.0001)	0.26006 (p<.01)
Hardwood Growth	0.40802 (p<.0001)	0.18288 (p<.05)	0.84462 (p<.0001)

Forest Measure	Total Removals	Softwood Removals	Hardwood Removals
Total Growth/Acre	0.6322 (p<.0001)	0.61122 (p<.0001)	0.37139 (p<.0001)
Softwood Growth/Acre	0.49307 (p<.0001)	0.55336 (p<.0001)	0.07052
Hardwood Growth/Acre	0.28876 (p<.001)	0.10012	0.68152 (p<.0001)
Total GRR	-0.35828 (p<.0001)	-0.37768 (p<.0001)	-0.12102
Softwood GRR	-0.08885	-0.03271	-0.20424 (p<.05)
Hardwood GRR	-0.30914 (p<.001)	-0.25588 (p<.01)	-0.30452 (p<.001)
Total Removals/Inventory	0.59011 (p<.0001)	0.68009 (p<.0001)	0.03344
Softwood Removals/Inventory	0.57023 (p<.0001)	0.60657 (p<.0001)	0.17697 (p<.05)
Hardwood Removals/Inventory	0.43354 (p<.0001)	0.33108 (p<.0001)	0.50646 (p<.0001)
Total Growth/Inventory	0.47408 (p<.0001)	0.59589 (p<.0001)	-0.11472
Softwood Growth/Inventory	0.45229 (p<.0001)	0.56134 (p<.0001)	-0.08897
Hardwood Growth/Inventory	0.13772	0.07311	0.25254 (p<.01)

Table 12-2 Pearson Correlations between Privately-Owned Total, Softwood and Hardwood Growth and Selected Forest Measures

Forest Measure	Total Growth	Softwood Growth	Hardwood Growth
Total Acres	0.89211 (p<.0001)	0.79022 (p<.0001)	0.53387 (p<.0001)
Softwood Acres	0.85476 (p<.0001)	0.90736 (p<.0001)	0.17246 (p<.05)
Hardwood Acres	0.62032 (p<.0001)	0.3499 (p<.0001)	0.82165 (p<.0001)
Total Inventory	0.87005 (p<.0001)	0.65862 (p<.0001)	0.7736 (p<.0001)
Softwood Inventory	0.91885 (p<.0001)	0.94474 (p<.0001)	0.25461 (p<.01)
Hardwood Inventory	0.49199 (p<.0001)	0.15538	0.92732 (p<.0001)
Total Inventory/Acre	0.36815 (p<.0001)	0.09887	0.73316 (p<.0001)
Softwood Inventory/Acre	0.28046 (p<.001)	0.10742	0.48609 (p<.0001)
Hardwood Inventory/Acre	0.37385 (p<.0001)	0.07443	0.80314 (p<.0001)
Total Removals/Acre	0.62966 (p<.0001)	0.64254 (p<.0001)	0.18543 (p<.05)
Softwood Removals/Acre	0.42817 (p<.0001)	0.4253 (p<.0001)	0.15234
Hardwood Removals/Acre	0.43265 (p<.0001)	0.20543 (p<.05)	0.66021 (p<.0001)
Total Removals	0.90229 (p<.0001)	0.8577 (p<.0001)	0.40802 (p<.0001)
Softwood Removals	0.86498 (p<.0001)	0.91452 (p<.0001)	0.18288 (p<.05)
Hardwood Removals	0.5511 (p<.0001)	0.26006 (p<.01)	0.84462 (p<.0001)

Forest Measure	Total Growth	Softwood Growth	Hardwood Growth
Total Growth/Acre	0.78726 (p<.0001)	0.73078 (p<.0001)	0.39568 (p<.0001)
Softwood Growth/Acre	0.6229 (p<.0001)	0.73362 (p<.0001)	-0.03768
Hardwood Growth/Acre	0.4105 (p<.0001)	0.0815	0.8824 (p<.0001)
Total GRR	0.01719	-0.08312	0.23226 (p<.01)
Softwood GRR	0.18257 (p<.05)	0.27514 (p<.001)	-0.14672
Hardwood GRR	-0.09302	-0.17343 (p<.05)	0.14981
Total Removals/Inventory	0.33563 (p<.0001)	0.52803 (p<.0001)	-0.31992 (p<.0001)
Softwood Removals/Inventory	0.30012 (p<.001)	0.40003 (p<.0001)	-0.12326
Hardwood Removals/Inventory	0.19853 (p<.05)	0.18547 (p<.05)	0.09712
Total Growth/Inventory	0.54246 (p<.0001)	0.72559 (p<.0001)	-0.22852 (p<.01)
Softwood Growth/Inventory	0.53746 (p<.0001)	0.74369 (p<.0001)	-0.28236 (p<.001)
Hardwood Growth/Inventory	0.17034 (p<.05)	0.02996	0.37486 (p<.0001)