*Journal of Sustainable Forestry*, 32:175–194, 2013
ISSN: 1054-9811 print/1540-756X online
DOI: 10.1080/10549811.2011.652044





# Potential Impact of Bioenergy Demand on the Sustainability of the Southern Forest Resource

ROBERT C. ABT[1] and KAREN L. ABT[2]
[1]*Professor of Forest Economics, North Carolina State University, Raleigh, North Carolina, USA*
[2]*Research Economist, United States Forest Service, Southern Research Station, Asheville, North Carolina, USA*

*The use of woody biomass for the production of domestic bioenergy to meet policy-driven demands could lead to significant changes in the forest resource. These impacts may be limited if woody biomass from forests is defined as only the residues from logging. Yet, if only residue is used, the contribution of woody biomass to a renewable energy portfolio will also be limited. As the definition of woody biomass is expanded, the impacts on the forest resource increase, as does the contribution of woody biomass to the renewable portfolio. A combination of markets and policies will determine the extent to which woody biomass can be used to meet renewable electricity requirements. This article develops two hypothetical demand scenarios based on the use of woody biomass in renewable electricity generation and uses these scenarios in a model of timber supply in the U.S. South to evaluate the effects on both timber markets and forest resource sustainability. The demands for woody biomass are met by a combination of residues from logging on private forests and increased harvest of pine pulpwood. We identify the dynamics of key characteristics of the southern forest resource, including forest type and age class distributions that vary under these demand scenarios.*

*KEYWORDS* *woody biomass, renewable energy, timber supply, Southeastern United States*


Address correspondence to Robert C. Abt, Professor, North Carolina State University, Department of Forestry and Environmental Resources, 3126 Jordan Hall, Campus Box 8008, Raleigh, NC, 27695, USA. E-mail: bob_abt@ncsu.edu

## INTRODUCTION

Recent recognition of carbon's role in climate change and a national security interest in reducing dependence on offshore oil has intensified interest in renewable energy and increased the focus on woody biomass as a potential source. Current state-level renewable energy portfolio standards (RPS) and federal renewable fuel standards (RFS) include woody biomass as a feedstock, but have varying definitions of qualifying woody biomass. Most studies into the sustainability of using wood for energy have focused on, or have at least limited their discussion to, the use of residues from logging and manufacturing (Perlack et al., 2005; Gan & Smith, 2006, 2007; Energy Information Administration (EIA) 2007, 2009a, 2009b; Biomass Research and Development Board 2008; Perez-Verdin *et al.* 2009; Southeast Agriculture and Forestry Energy Resources Alliance 2009; Creech, Metzger, Putt Del Pino, & Wilson, 2009). If woody biomass for energy is limited to residues, the amount of energy that can be produced will be limited by the production level of the current industry (Galik, Abt, & Wu, 2009), and the impact on the sustainability of the resource may be small. If woody biomass for energy can come from standing timber inventory, the energy potential from wood increases. Energy demand would affect timber markets by competing for wood with existing industry and increasing income for forest landowners. Higher harvests reduce short run inventories while higher prices induce increased planting which increases long run supplies. A discussion of the various bills under consideration and the differences in woody biomass definitions can be found in Campbell (2009) and Bracmort and Gorte (2009).

Most previous analyses of woody biomass supply do not address the impacts of including standing timber harvests as woody biomass. These studies assume constant harvest levels with a high and constant level of residue utilization. We use the Subregional Timber Supply Model (Abt, Cubbage, & Abt, 2009) and two hypothetical timber and woody biomass demand scenarios to model the impact of wood-for-energy under differing assumptions regarding timber markets, timber inventories, bioenergy demands, alternative compliance price, residue utilization, and the recession.

This article investigates the consequences of accelerated biomass energy demands from two hypothetical RPS policies. These policies are converted into hypothetical woody biomass demand scenarios: (a) a high initial contribution of woody biomass to renewable energy derived from Creech et al. (2009) which implies that wood could contribute 21% of total new renewable energy by 2015 and 15% by 2025; and (b) a lower initial contribution derived from EIA (2009a, 2009b) analyses which imply that wood could contribute 20% of total renewable energy in 2012, rising to 27% of total renewable energy by 2025. The demand scenarios are referred to as "WRI" or "high initial demand" and "EIA" or "low initial demand" scenarios, respectively. Our base scenario also includes a demand reduction from the current recession of 30% from 2005 to 2009 and a rebound of the same magnitude between 2010 and 2013. The energy demands are added to the base demands, but no increases are assumed for the traditional industry, and potential demand increases from federal renewable fuel standards and other sources are not included. Key characteristics of the timber resource, such as management type and age class distribution, are explored throughout the projection period.

## METHODS

This analysis used the Subregional Timber Supply (SRTS) model to characterize the existing and projected timber inventories, supply, and harvest (Abt et al., 2009). We developed two hypothetical demand scenarios for use with SRTS that incorporated (a) the current recession and a possible recovery in traditional wood using industries, and (b) use of woody biomass in renewable energy generation. Below we discuss the SRTS model and data as well as the assumptions made in this analysis, followed by a detailed discussion of the two alternative demand scenarios.



### SRTS Model, Data, and Assumptions

SRTS combines economic resource allocation with biological growth to link timber markets (price and harvest by product) with forest resource dynamics. The model simulates the impact of market-level demand assumptions on the subregional, ownership, and forest type components of the supply side of the market. In this analysis, we vary the demand for woody biomass and the utilization of residue for electricity production to ascertain the likely impacts over time on pine pulpwood and sawtimber markets and the underlying forest resource.

A demand scenario in SRTS consists of an elasticity assumption and a time path of demand changes. For this application, a demand-price elasticity of −0.5 was assumed with demand shifts derived from the scenarios discussed below. Product supply is a function of product stumpage price and inventory, with supply-price elasticity by product and owner set at 0.5 and supply inventory responsiveness for all owners set at 1.0 for this analysis. The product price and harvest levels by product, subregion, and owner are simultaneously determined in the market equilibrium calculations. Although region-owner-product specific elasticities are not available, econometric studies indicate that supply and demand price responses are inelastic (Murray, 1995, Pattanayak, Murray, & Abt, 2002).

After using the market clearing price to allocate harvest to regions and owners based on product inventory changes, a goal program allocates product harvest across management types and age classes. The objective function for the goal program is to harvest across management types and age classes for each owner/region to get the projected target removals mix, while harvesting consistent with historical harvest patterns for a particular region/owner. Inventory is adjusted from the starting inventory by subregion, owner, species, forest type, and 5-yr age class by adding net growth and subtracting the harvest estimated from the market model. Timberland acreage is determined using an updated response surface from the Hardie, Parks Gottlieb, and Wear (2000) land use model. This model includes county level demographic forecasts which drive the urban-rural transition. Rural land is then allocated between agricultural and timberland based on relative returns. For these runs, agricultural returns were held fixed and timberland responded to pine pulpwood prices. Forest type allocations within timberland reflect the price responsiveness of plantations relative to other forest types.

The basic SRTS inventory data consists of estimates of growing stock inventory, growth per acre, removals, and acreage by subregion, species group, ownership, forest type, and 5-yr age class. These data sets are provided by the USDA Southern Research Station Forest Service Forest Inventory and Analysis group (FIA), see U.S. Forest Service (2009). The survey dates in this analysis are Alabama 2008, Arkansas 2005, Florida 2007, Georgia 2008, Louisiana 2005, Mississippi 2006, North Carolina 2006, South Carolina 2007, Texas 2008, and Virginia 2007.

## Demand Scenarios

Demand for woody biomass for renewable energy will depend on (a) policies such as federal or state RPS and renewable fuel standards; (b) economic and physical availability of alternative sources of renewable energy such as wind and solar; (c) economic and physical availability of alternative sources of biomass—such as energy crops, crop residues, and municipal waste; and (d) the alternative value of woody biomass for carbon storage or use in traditional industries. In the scenarios below, we do not address the impacts of fuel standards, we take as given existing assumptions by EIA and Creech et al. (2009) on the physical and economic availability of all other sources of renewable energy, and we do not address the value of timber for carbon storage. Below we discuss the two scenarios which include (a) recession and rebound in wood product demands, (b) woody biomass demand deriving from two hypothetical demand scenarios, (c) a residue utilization timeline, and (d) a hypothetical alternative compliance price for renewable energy credits.

### Recession and rebound

Both scenarios include a representation of the current recession. We assume a drop in demand for all wood products of 30% from 2005 to 2009, with a rebound of equal magnitude occurring from 2010 to 2013. The recession does not directly affect the renewable energy demands, but it does affect current forest management, and thus influences timber supply for many years. For example, the reduced demands delays harvest and reduces plantings, which influences the age class distribution of the plantations and will affect the prices and harvest quantities for 10–20 yr after the recession.

### Low initial woody biomass demand (EIA)

Renewable woody biomass demands for the low initial scenario are derived from an EIA report assessing the impacts of a proposed national RPS which sets a renewable energy requirement for large electricity providers of 6% in 2012, increasing in steps to 25% in 2025, and staying at that level until 2040 (EIA, 2009a). In the U.S. South, there are four electricity regions addressed by the EIA. We used the forecast biomass demands from SERC (Southeast), FLCC (Florida), and TRE (Texas) to represent biomass demands for the Southeast (EIA, 2009b). We used the alternative that includes full efficiency credits and assumes that some of the renewable energy target will be met by purchasing renewable energy credits from outside the South. The biomass demands from EIA, however, include biomass from forests, agriculture, and municipal sources. In order to determine the contribution of wood to renewable energy, we used the assumption that 30% of biomass will come from forests in the Southern Bioenergy Roadmap (Southeast Agriculture and Forestry Energy Resources Alliance, 2009). This is an important assumption, and one we examine by doubling the woody biomass demand in the sensitivity analysis reported below.

These demands, given in billions of kilowatt hours, were converted to demands for green tons of woody biomass by assuming 9 million BTU/green ton, 3412 BTU/kWh, and a 26.25% wood efficiency in energy production. This results in assumed demands of 1.44 million green tons per billion kilowatt hours. For this scenario, wood is assumed to supply 16 bb kWh in 2012, 38 bb kWh in 2025, and 45 bb kWh in 2028. The resulting green tons of demand increase are shown in Table 1.

### High initial woody biomass demand (WRI)

An alternative demand scenario is based on a different renewable portfolio, which assumes that woody biomass can supply 21% of all renewable energy needs in the South in the near-term and 15% of renewable energy needs in the medium-term (Creech et al., 2009), but with different total energy and renewable demands than are used by EIA. This analysis specifically labels the woody biomass contribution as “Forestry Residue.” We set the near-term at 2015, and the medium-term at 2028. This results in woody biomass contributing to 7 b kWh in 2010, 21 b kWh in 2012, and 45 b kWh in 2028.

**TABLE 1** Base Pine Pulpwood Demands, Biomass Consumption, and Residue Availability Scenarios

| Year | Base pine pulpwood demand (million green tons) | Biomass consumption | | | | Residue availability | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | High initial consumption | | Low initial consumption | | Moderate utilization | | High utilization | |
| | | Moderate | High | Moderate | High | Pine | Hardwood | Pine | Hardwood |
| 2006 | 78.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.76 | 0.74 | 1.52 | 1.48 |
| 2007 | 74.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.89 | 1.82 | 1.78 |
| 2008 | 71.38 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 1.02 | 2.10 | 2.04 |
| 2009 | 68.09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.17 | 1.14 | 2.34 | 2.27 |
| 2010 | 65.00 | 10.11 | 20.22 | 0.00 | 0.00 | 1.28 | 1.24 | 2.57 | 2.48 |
| 2011 | 67.67 | 20.22 | 40.44 | 0.00 | 0.00 | 1.51 | 1.46 | 3.02 | 2.91 |
| 2012 | 70.50 | 30.33 | 60.66 | 23.40 | 46.80 | 1.76 | 1.69 | 3.52 | 3.38 |
| 2013 | 73.34 | 40.44 | 80.88 | 24.44 | 48.87 | 3.67 | 3.54 | 7.35 | 7.07 |
| 2014 | 76.15 | 50.55 | 101.10 | 25.69 | 51.39 | 5.55 | 5.36 | 11.11 | 10.72 |
| 2015 | 76.09 | 60.66 | 121.32 | 26.95 | 53.90 | 7.11 | 6.88 | 14.22 | 13.76 |
| 2016 | 76.04 | 61.45 | 122.90 | 27.99 | 55.98 | 8.48 | 8.24 | 16.97 | 16.47 |
| 2017 | 75.96 | 62.24 | 124.47 | 29.03 | 58.06 | 9.67 | 9.42 | 19.33 | 18.85 |
| 2018 | 75.65 | 63.02 | 126.05 | 29.46 | 58.93 | 10.63 | 10.42 | 21.26 | 20.83 |
| 2019 | 75.16 | 63.81 | 127.62 | 31.20 | 62.39 | 11.37 | 11.21 | 22.75 | 22.41 |
| 2020 | 74.66 | 64.60 | 129.20 | 31.63 | 63.26 | 11.92 | 11.81 | 23.83 | 23.62 |
| 2021 | 74.15 | 65.39 | 130.77 | 30.76 | 61.53 | 12.26 | 12.23 | 24.52 | 24.46 |
| 2022 | 73.72 | 66.17 | 132.35 | 43.33 | 86.66 | 12.41 | 12.46 | 24.82 | 24.92 |
| 2023 | 72.50 | 66.96 | 133.93 | 43.33 | 86.66 | 12.40 | 12.59 | 24.80 | 25.18 |
| 2024 | 72.42 | 67.75 | 135.50 | 48.96 | 97.92 | 12.42 | 12.67 | 24.84 | 25.34 |
| 2025 | 71.94 | 69.33 | 138.65 | 54.59 | 109.19 | 12.41 | 12.74 | 24.82 | 25.49 |
| 2026 | 71.19 | 69.33 | 138.65 | 60.23 | 120.45 | 12.32 | 12.77 | 24.65 | 25.54 |
| 2027 | 70.28 | 69.33 | 138.65 | 65.86 | 131.72 | 12.22 | 12.79 | 24.44 | 25.58 |
| 2028 | 70.44 | 69.33 | 138.65 | 64.99 | 129.99 | 12.18 | 12.83 | 24.37 | 25.65 |
| 2029 | 70.66 | 69.33 | 138.65 | 64.99 | 129.99 | 12.18 | 12.86 | 24.37 | 25.71 |
| 2030 | 71.27 | 69.33 | 138.65 | 64.99 | 129.99 | 12.20 | 12.88 | 24.40 | 25.77 |
| 2031 | 71.67 | 69.33 | 138.65 | 64.99 | 129.99 | 12.20 | 12.90 | 24.40 | 25.81 |

We used this information to develop the demands shown in Table 1. Again, we also modeled a wood demand level that was twice the Creech et al. (2009) level of demand.



### Residue utilization and availability

A key component of the demand scenarios includes the assumptions made about residue utilization and availability. The estimated distribution of pine and hardwood residue in 2006 assuming 100% utilization across the South is shown in Figure 1. In our high utilization scenario, we assume that current residue utilization is low (4%) in 2006 and rises to a 66% average across all harvests by 2025. We then examine a moderate residue utilization scenario that begins at 2% and assumes that 33% utilization is possible by 2025.

Previous studies have assumed that residue can be utilized at rates up to 65% in the short term. Utilization is the proportion of residue left on the ground using current harvesting technology that are expected to be delivered to an energy producer. High levels of utilization in the literature are often based on stand level tests of chipping and gathering technology in pine plantations. In our analysis, assuming that 65% is available south-wide means that on average, every harvest must yield residue at this level of efficiency. To reach a level of 33% would require meeting this standard on one-half of all private harvests in the South.

One reason why all harvests are not likely to be used to produce residue is that not all stands will be within a feasible haul distance from an energy plant. Given that residues only provide about 20% of the volume that round-wood harvest provides, it would take residue harvest from five times as many

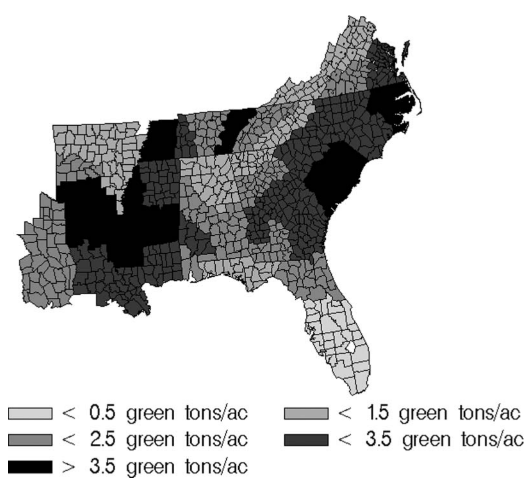


**FIGURE 1** Estimated logging residue per acre of timberland by the Forest Inventory and Analysis (FIA) survey unit in 2006.

harvested acres if only residues were used. Thus, the haul radius required to include sufficient residues could be significant. At an estimated hauling cost of $0.13/ton mile, a 40-mile haul distance would eliminate a $5/green ton on-site price differential between residue and roundwood.

Dependence on residues also causes strategic location problems since locating near concentrations of residues requires locating near concentrations of traditional wood users. For pine, these are likely to also be areas with high roundwood prices (Galik et al., 2009). Higher roundwood prices, restrictions on the use of roundwood, and policy incentives could lead to higher residue utilization; the key question for the next decade is the timetable and ultimate utilization that will be observed. We tested the impact of these assumptions in the sensitivity analysis described below.



### Alternative compliance payments

Most renewable energy portfolio standards include some mechanism to ensure that renewable energy prices stay below some prescribed level. One mechanism, the alternative compliance price (ACP), sets a cost per MWh that a utility can pay rather than meet renewable portfolio standards. A utility will use wood to produce electricity only when the cost of providing non-renewable electricity plus the ACP is greater than the cost of producing electricity from wood. Otherwise they would choose to pay the ACP and provide non-renewable electricity. For example, with an ACP set at $25/MWh and using published costs and a current stumpage price of $9.50/green ton (Timber Mart South, 2012) utilities would choose to pay the ACP rather than produce wood-based electricity. If the ACP were $50/MWh, however, the stumpage price could more than triple and wood-based electricity will still have a cost advantage.

### Implementing supply and demand scenarios in SRTS

The impact of bioenergy demand on the stumpage market is illustrated in Figure 2. Suppose that biomass demand net of residue utilization shifts the demand curve for pine pulpwood from $D_1$ to $D_2$. Since biomass demand is assumed to be non-price sensitive in the short run, this is a parallel shift in the demand curve. The size of the demand shift at current prices is $H_4 - H_1$. Given the inelastic (more price response than harvest response) nature of timber markets, this shift raises price from $P_1$ to $P_2$ and only increases harvest from $H_1$ to $H_2$. Demand for traditional products has not increased, so at price $P_2$ the traditional industry only demands quantity $H_3$. The biomass harvest quantity is $H_2 - H_3$, which represents an $H_2 - H_1$ increase in harvest and an $H_1 - H_3$ displacement of the traditional industry.

If supply, which is assumed to shift with inventory, is increasing (decreasing), then the amount of displacement decreases (increases). For

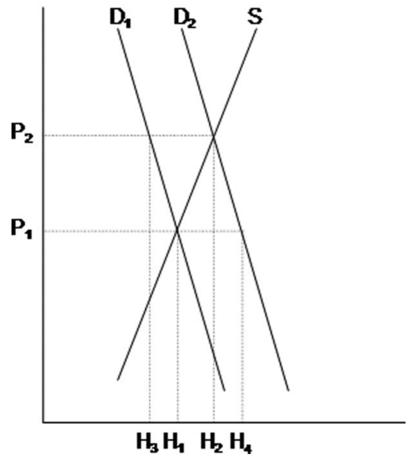


**FIGURE 2** Subregional Timber Supply (SRTS) stumpage market with biomass demand.



the first 15 yr of the projection, the current age class distribution is the key factor affecting product supply. After 15 yr, the planting induced by higher prices begins to affect supply and reduce displacement. In SRTS, log-linear constant elasticity curves are used and supply is represented by 98 individual region-owner supply curves. Harvest shifts among regions and owners depend on aggregate demand and region-owner-product inventory changes over time (Abt et al., 2009).

## RESULTS

The results show that relatively small changes in the assumptions regarding residue utilization and the rate at which woody biomass is assumed to supply electricity can have dramatic differences in the impact on the forest resource. As expected, the higher initial demand scenario (WRI) leads to larger impacts on the resource. Due to the limited ability of forest supply to change in the short run, market impacts are very sensitive to the timing of the demand increase relative to the utilization of residues. Below we discuss the detailed impacts of our demand scenarios on (a) prices, inventory, and harvest of pine; (b) land use and management type; and (c) pine plantation age class distributions. We also provide a sensitivity analysis of the effect of changes in consumption and residue utilization on the provision of wood for energy.

### Prices, Inventory, and Removals

The results for price, inventory, and removals from the base run, as well as the low initial (EIA) and high initial (WRI) woody biomass demand runs are

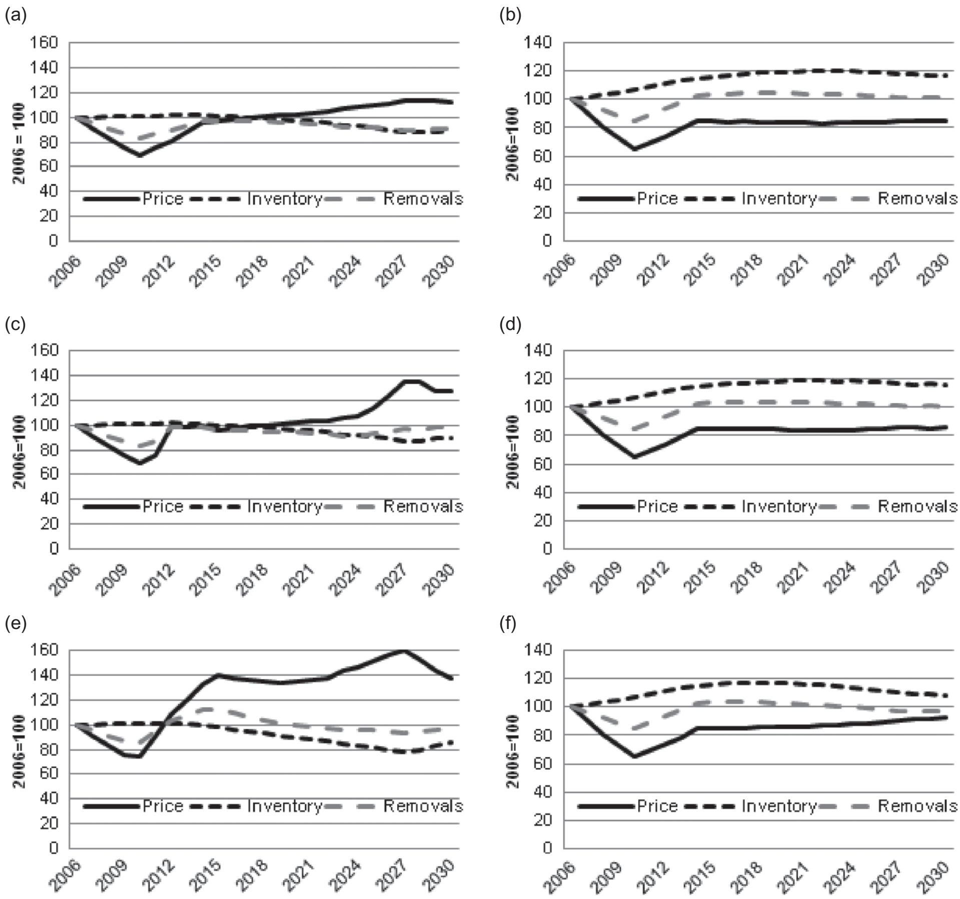


**FIGURE 3** Southwide price, removal, and inventory changes from 2006 to 2031 for pine pulpwood and pine sawtimber for the base, low initial demand (EIA), and high initial demand (WRI) scenarios: (a) base scenario—pine pulpwood; (b) base scenario—pine sawtimber; (c) low initial demand (EIA) scenario—pine pulpwood; (d) low initial demand (EIA) scenario—pine sawtimber; (e) high initial demand (WRI) scenario—pine pulpwood; (f) high initial demand (WRI) scenario—pine sawtimber.

shown in Figure 3 for pine pulpwood and pine sawtimber. Also included in these runs, but not displayed here, were hardwood pulpwood and hardwood sawtimber. By assumption, none of the alternatives changed the demands for these products—woody biomass demand was assumed to come from residues (from all product harvests) or from pine pulpwood, if necessary. Pine sawtimber response is illustrated because changes in consumption of pine pulpwood change the inventory available for pine sawtimber in subsequent years. Thus, increased harvest of pulpwood will reduce inventory in pine sawtimber, leading to increases in price and decreases in harvest of that product, ceteris paribus.

Figure 3 shows the impact of the recession on all three demand scenarios. The initial price and harvest effects in the biomass scenarios are ameliorated by the decrease in wood demand during the recession. Under the base scenario, little change is projected for pine pulpwood prices after the recession, while pine sawtimber price stays low even after removals return to near pre-recession levels. The reduced demand during the recession allowed inventories to accumulate, thus reducing future prices in a constant demand scenario.

The low initial demand (EIA) scenario results in recovery of the pulpwood market by 2012, the 1st yr of the hypothetical policy, where prices, inventory and removals are all at or near pre-recession levels (Figure 3c). After that, pulpwood prices continue to rise with the demand increases due to the policy. Under the assumptions of moderate demand and moderate residue use, pulpwood prices will not reach the alternative compliance price during the projection. There is little impact of this scenario over the base scenario on pine sawtimber markets (Figure 3d).

The high initial demand (WRI) scenario has larger impacts on the markets, both because the impacts occur sooner and because the demands reach slightly higher levels at the end of the projection (138 million green tons compared to 130 million green tons). Because the consumption of woody biomass exceeds the supply of residues available in the early years, pulpwood demand increases, resulting in large price increases accompanied by smaller harvest increases. The harvest increases lead to inventory declines (Figure 3e) and inward supply shifts which increase the proportion of biomass coming from displacement of traditional wood-users. This scenario affects the pine sawtimber market by reducing the inventory, and thus raising prices and harvest over the base scenario, although price remains below the pre-recession level (Figure 3f). The higher pulpwood prices also lead to increased planting which increases supply and reduces prices toward the end of the projection.

If the ACP is $25/MWh and all costs except stumpage are held constant, these projected prices would favor paying the ACP for both the WRI and EIA scenarios. If the ACP is $50/MWh, however, and all non-stumpage costs are held constant, these projected prices would favor the use of wood for energy for both WRI and EIA scenarios.

## Land Use and Management Type

The base scenario (Figure 4a) shows that the recession decreases timberland acres as timberland prices decrease. Agricultural prices were assumed constant, so the decline in timber prices provides an incentive to convert timberland. The rebound after the recession favors the more price responsive plantation component of the forest. Urbanization, however, continues to reduce timberland acres by the end of the projection, where total timberland

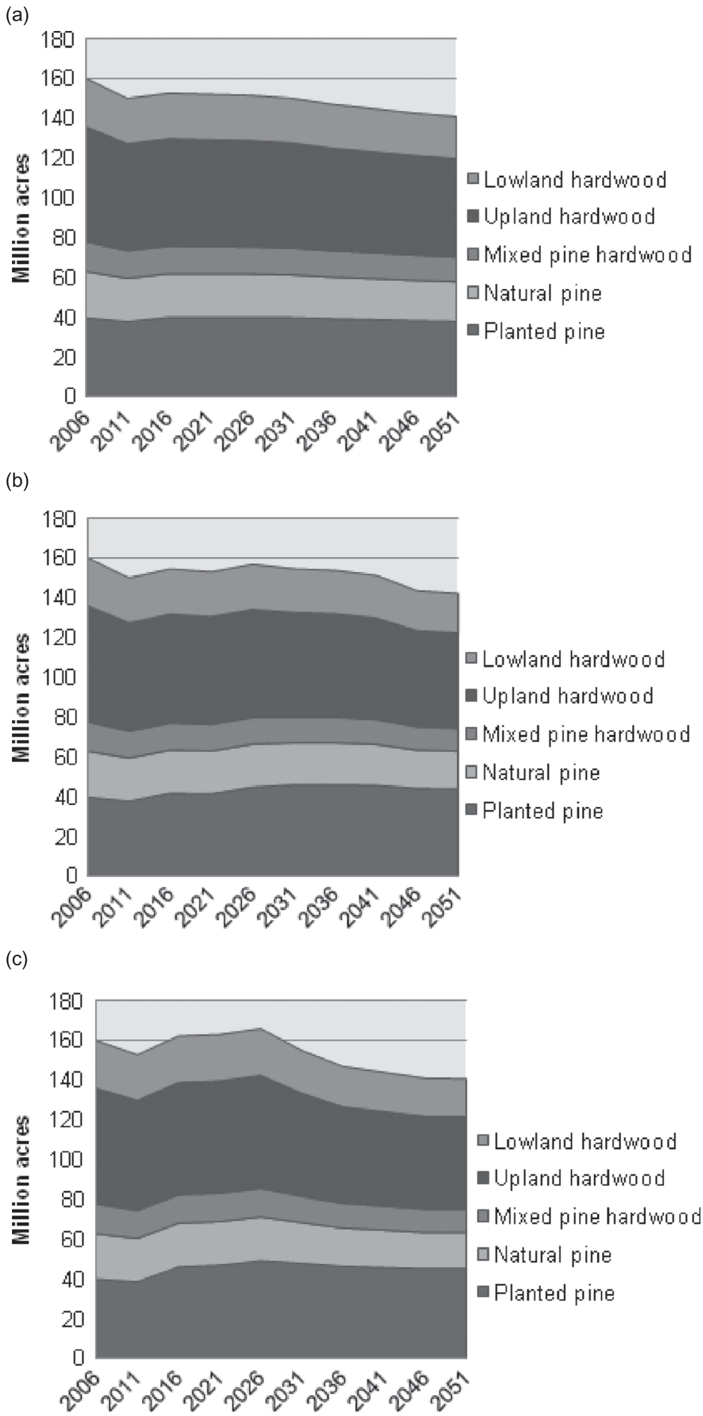


**FIGURE 4** Southwide timberland area by forest type from 2006 to 2051 for the base, low initial demand (EIA), and high initial demand (WRI) scenarios: (a) base scenario; (b) low initial demand (EIA) scenario; (c) high initial demand (WRI) scenario.

declines from 160 to 141 million acres. Pine plantation acres decline from about 40 million in 2006 to 38.5 million in 2051. We extended the projection to 2051 to show the long-run land use market adjustments.

Land use in the low initial demand scenario (EIA; Figure 4b) follows the pattern shown in pine pulpwood prices above (Figure 3c) during the early years of the projection. Timberland increases after the recession as pine pulpwood prices increase. Total timberland declines to 142 million acres in 2051, with pine plantations increasing from 40 to 44 million acres.

Land use is most volatile in the high initial demand scenario (WRI; Figure 4c), corresponding to the volatile timber prices (Figure 3e). The high initial demands, combined with the moderate residue utilization, lead to higher pulpwood harvests and prices in the early years of the RPS, thus increasing pine planting. These pine plantation acres do not affect inventory for pulpwood harvest until 15 years after planting, at which time the increase in inventory leads to price and acreage reductions. Total timberland declines to the same level as in the base scenario (141 million acres), although with considerably more acres in pine plantations (45.6 million acres in the high initial demand scenario compared to 38.5 in the base scenario).



## Pine Plantation Age Class Distribution

Figure 5 shows the age class breakdown of the pine plantation management type of the three scenarios. The base run (Figure 5a) shows a recession-induced reduction in the youngest age class (0–5 yr) in 2011, followed by a rebound-induced increase in the youngest age class in 2016. As prices level off, the acres in the youngest class stabilize, but the "bubble" of planting from 2016 can be traced through subsequent years, ending with an addition to the 16- to 20-yr age class in 2031. Similar bubbles can be seen in both the low (Figure 5b) and high (Figure 5c) initial demand scenarios, corresponding to the size of the increase in planting in the years following the recession. In the base scenario, the average age of the plantation resource increases during the recession and remains higher until the end of the projection. The more intensive harvesting and planting from biomass demand for pulpwood lowers the average age of the plantation resource.

## Sensitivity Analysis of Consumption and Residues: Effect on Wood Provision

For each (EIA and WRI) woody biomass demand scenario, we evaluated the sensitivity of our assumptions regarding residue utilization and biomass demands. In addition to the initial alternative discussed above, we ran the model for scenarios with demands doubled and with residue utilization halved. Figures 6 and 7 show the effects of these eight alternatives—two

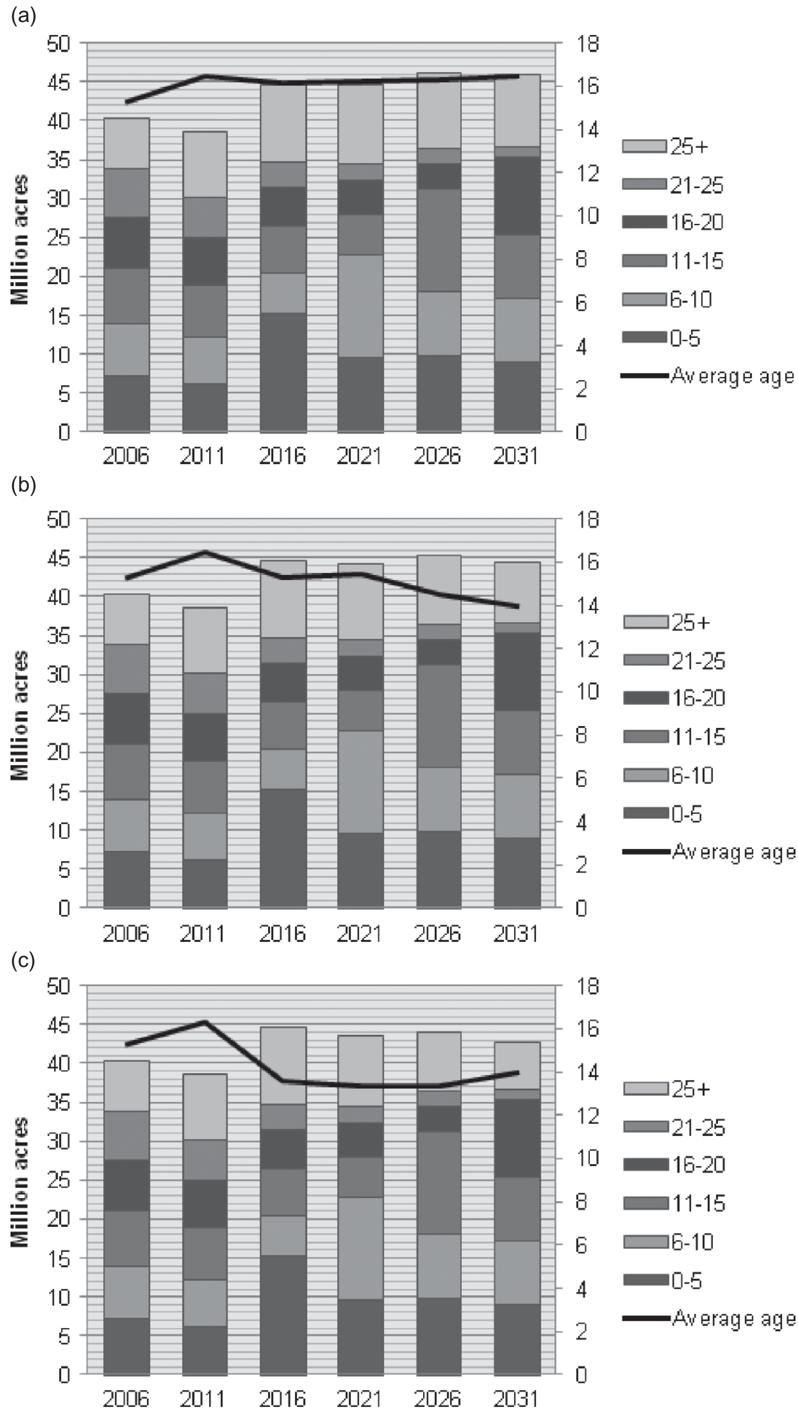


**FIGURE 5** Southwide pine plantation age class distribution and average age from 2006 to 2031 for the base, low initial demand (EIA), and high initial demand (WRI) scenarios: (a) base scenario; (b) low initial demand (EIA) scenario; (c) high initial demand (WRI) scenario.

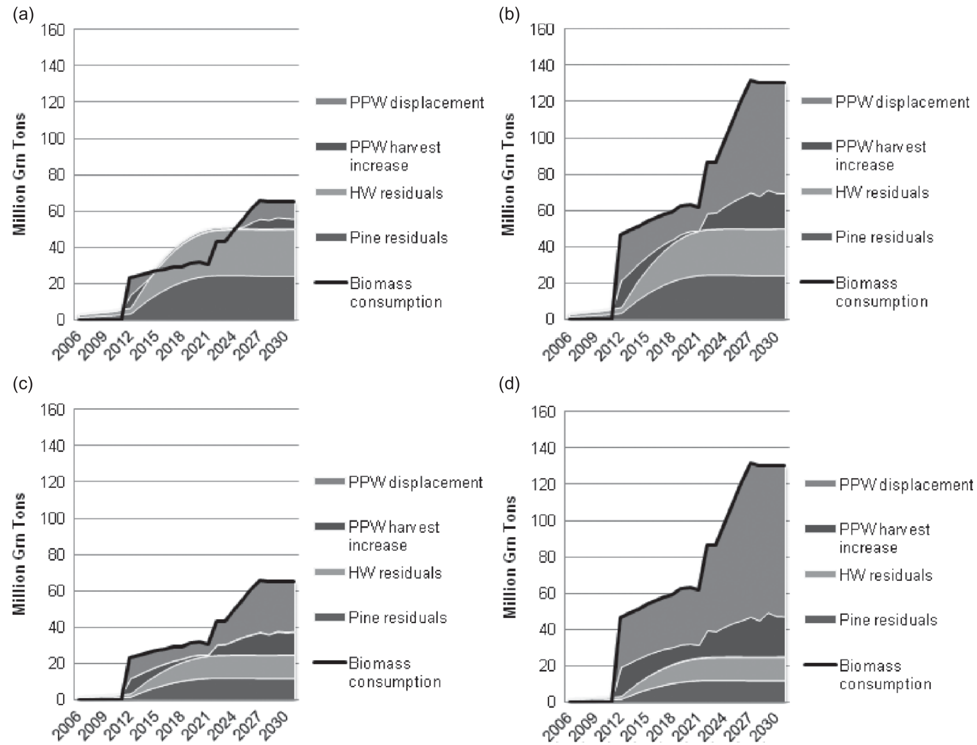


**FIGURE 6** Southwide sources of wood to fulfill low initial demand (EIA) scenario from 2006 to 2031: (a) original consumption and original residue utilization; (b) original consumption and halved residue utilization; (c) doubled consumption and original residue utilization: (d) doubled consumption and halved residue utilization.

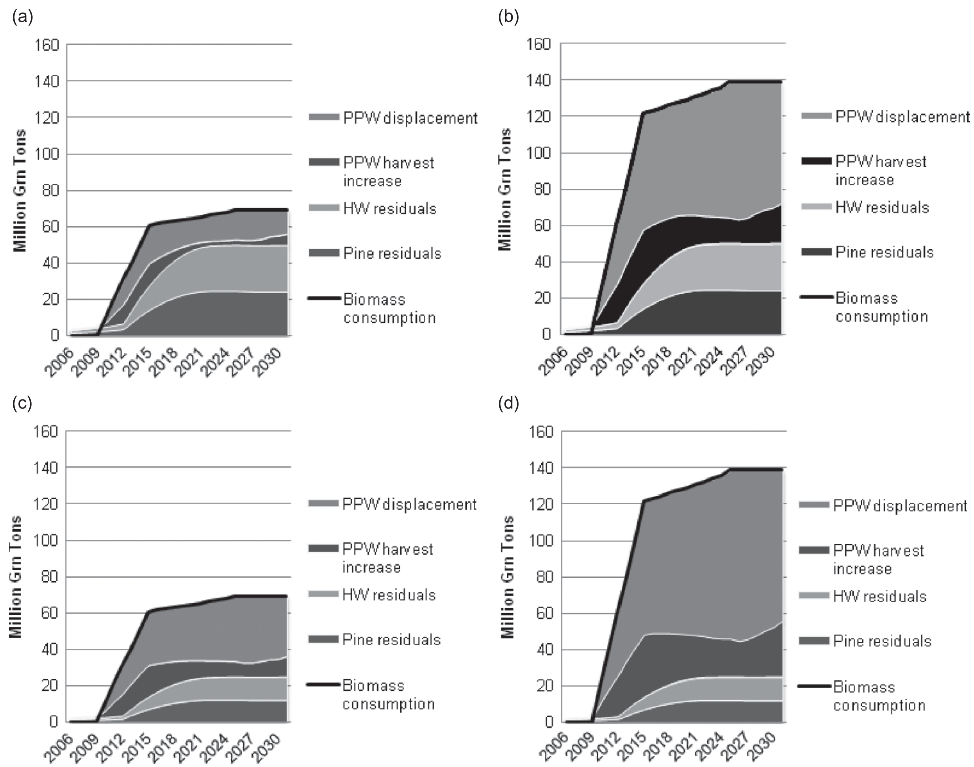


**FIGURE 7** Southwide sources of wood to fulfill high initial demand (WRI) scenario from 2006 to 2031: (a)original consumption and original residue utilization; (b) original consumption and halved residue utilization; (c) doubled consumption and original residue utilization; (d) doubled consumption and halved residue utilization.

demand scenarios (EIA and WRI), two residue utilization levels (original and halved), and two demand levels (original and doubled)—on the change in sources of woody biomass feedstocks.

The low initial woody biomass (EIA) demand scenario discussed above is shown in Figure 6a, where original demand and original residue utilization results in biomass consumption that cannot be fully met using residues alone, although between 2014 and 2024, residues can fulfill biomass consumption. At the end of the projection (2031), residue meets more than 75% of total woody biomass for energy. Figures 6b–d show how doubling biomass demands (whether from changing the percentage of biomass that comes from wood, or changing the percentage of renewable that comes from biomass) and/or halving residue utilization affect both the total harvest quantity (pine pulpwood displacement + pine pulpwood harvest increase) and the amount of new harvest (pine pulpwood harvest increase). Only the original consumption-original residue alternative has residues exceeding consumption for part of the projection with correspondingly small increases in harvest and levels of displacement.

The high initial demand scenario (WRI; Figure 7) shows similar results, with the original consumption-original residue alternative meeting 72% of demand through residues at the end of the projection. In the other alternatives, residue provides from 18–36% of woody biomass used for energy in 2031. The double consumption-half residue run leads to a net 40 million ton increase in roundwood demand. In all of these runs, the mix between biomass supply from harvest increase and from displacement of the traditional industry is driven by the inelastic nature of timber supply and the state of the inventory. Early in these runs the additional demand for roundwood leads to the expected doubling of price response relative to harvest response, (supply price elasticity = 0.5) because Southwide inventories are stable. The increased harvest leads to lower inventories, thus reducing the harvest increases and increasing the industry displacement component. This situation holds until the increase planting allows inventories to recover near the end of the projection, which again allows the harvest response to play a more significant role.

## SUMMARY AND CONCLUSIONS

Assessments of the viability of wood for renewable energy in the U.S. South have often been focused on the technical feasibility of full utilization of residues and pre-commercial thinning (Perlak et al., 2005). This analysis starts with the current timber market situation and a detailed accounting of timber inventories by forest type, region, and ownership class (corporate and non-corporate) on 49 FIA survey unit regions. We based our assumptions regarding the role of wood in the renewable energy portfolio on work by the Creech et al. (2009) and the EIA (2009a, 2009b). These studies include assumptions about the contributions from bioenergy crops, agricultural residues, wind, and solar. In the Creech et al. report (2009), these alternative energy sources are assumed to reach their potential within the decade. In the EIA reports (2009a, 2009b), these sources take longer to develop. We built in the impact of the current recession on markets and inventory and looked at the consequences of residue availability on markets, land use, and age class distribution of the forest resource. These impacts will depend significantly on the precise terms of the RPS—including beginning year, renewable target, alternative compliance price, and the definitions of, and incentives for, both agricultural and forestry biomass.

The rate and timing of residue utilization are key issues. If higher pulpwood prices are needed to provide the incentive to increase utilization, then roundwood market impacts will occur sooner. While higher prices and policy incentives could expedite broad-scale utilization, our original utilization assumption of a Southwide regional 66% utilization rate on all harvests in 10 yr seems improbable. In the sensitivity analyses that reduced the starting point and the ending level of utilization, we found that residues can only meet 18–36% of woody biomass consumption at the end of the projection. The results show that changes in the level of residue utilization and the timing of demand increases can change the extent of timberland, the mix of forest types, and the age class distribution of the forest resource.

All of the demand and residue utilization scenarios considered affect pulpwood markets. The inelastic nature of timber supply means that in the short run the price consequences of increased demand are greater than the harvest response. Higher prices lead to displacement of traditional wood-using industry in the short run, while providing the incentive for more intensive management, increase in forest acreage, and increasing residue utilization in the longer run.

Our base run assuming constant demand after the recession is an artificial construct that allows us to isolate market impacts from biomass demand. If, instead, we assumed that the traditional industry were in long-term decline without biomass demand, some of what is characterized as displacement in this study would be characterized as demand substitution. This demand substitution would ameliorate falling prices for timber and subsequent reductions in forestland. Less logging residue would be available from traditional harvests and lower pulpwood prices would lead to less incentive to utilize residues. Alternatively, post-recession increases in demand for paper, housing, cellulosic biofuels, or woody feedstock for European energy markets would lead to increases in wood product demand. This may increase residue availability but the resulting price effects could push wood to alternative compliance prices even without significant bioenergy wood consumption.

## REFERENCES

Abt, R. C., Cubbage, F. W., & Abt, K. L. (2009). Projecting southern timber supply for multiple products by subregion. *Forest Products Journal*, *59*(7–8), 7–16.

Biomass Research and Development Board. (2008). *Increasing feedstock production for biofuels: Economic drivers, environmental implications, and the role of research* Retrieved from http://www.usbiomassboard.gov/pdfs/increasing_feedstock_revised.pdf

Bracmort, K. S., & Gorte, R. W. (2009, April 17). *Biomass: Comparison of definitions in legislation* (Rep. R40529). Washington DC: Congressional Research Service.

Campbell, R. J. (2009, May 4). *Biomass resources: The Southeastern United States and the renewable electricity standard debate* (Rep. R40565). Washington DC: Congressional Research Service.

Creech, D., Metzger, E., Putt Del Pino, S., & Wilson, D. D. (2009, April). Local clean power: Renewable electricity opportunities in the Southeast United States. Retrieved from http://pdf.wri.org/southeast_local_clean_power.pdf

Energy Information Administration. (2007). *Energy and economic impacts of implementing both a 25-percent renewable portfolio standard and a 25-percent renewable fuel standard by 2025* (SR/OIAF/2007-05). Washington, DC: U.S. Department of Energy.

Energy Information Administration. (2009a). *Impacts of a 25-percent renewable electricity standard as proposed in the ACESA discussion draft* (SR/OIAF/2009-04). Washington, DC: Energy Information Administration, Office of Integrated Analysis and Forecasting, U.S. Department of Energy. Retrieved from http://www.eia.doe.gov/oiaf/servicerpt/acesa/pdf/sroiaf(2009)04.pdf

Energy Information Administration. (2009b). *Impacts of a 25-percent renewable electricity standard as proposed in the ACESA discussion draft. Regional compliance mix, RESFEC case (Full efficiency credits)*, (SR/OIAF/2009-04). Washington, DC: Energy Information Administration Office of Integrated Analysis and Forecasting, U.S Department of Energy. Retrieved from http://www.eia.doe.gov/oiaf/servicerpt/acesa/pdf/resfec_fec.pdf

Galik, C. S., Abt R. C., & Wu, Y. (2009). Forest biomass supply in the Southeastern United States—Implications for industrial roundwood and bioenergy production. *Journal of Forestry*, *107*(2), 69–77.

Gan, J., & Smith, C. T. (2006). Availability of logging residues and potential for electricity production and carbon displacement in the USA. *Biomass and Bioenergy*, *30*, 1011– 1020.

Gan, J., & Smith, C. T. (2007). Co-benefits of utilizing logging residues for bioenergy production: The case for East Texas, USA. *Biomass and Bioenergy*, *31*, 623–630.

Hardie, I. W., Parks, P. J., Gottlieb P., & Wear, D. N. (2000). Responsiveness of rural and urban land uses to land rent determinants in the U.S. South. *Land Economics*, *78*(4), 659–673.

Murray, B. C. (1995). Oligopsony, vertical integration, and output substitution: Welfare effects in U.S. pulpwood market. *Land Economics*, *71*(2), 193–206.

Pattanayak, S., Murray, B., & Abt, R. (2002). How joint is joint forest production? An econometric analysis of timber supply conditional on endogenouse amenity values. *Forest Science*, *48*(3), 479–491.

Perez-Verdin, G., Grebner, D. L., Sun, C., Munn, I. A., Schultz, E. B., & Matney, T. G. (2009). Woody biomass availability for bioethanol conversion in Mississippi. *Biomass and Bioenergy*, *33*, 492–503.
Perlack, R. D., Wright, L. L., Turhollow, A. F., Graham, R. L., Stokes, B. J., & Erbach, D. C. (2005). *Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply*. Oak Ridge, TN: U.S. Department of Energy, Oak Ridge National Laboratory.
Southeast Agriculture and Forestry Energy Resources Alliance. (2009). *Southern bioenergy roadmap*. Retrieved from http://saferalliance1.files.wordpress.com/2010/12/roadmap_exec_sum.pdf
Timber Mart South. (2012). *Timber Mart South, Southwide Average Prices*. Retrieved from http://www.tmart-south.com/prices.html
U.S. Forest Service. (2009). *Forest inventory and analysis national program, FIA database*. Retrieved from http://fia.fs.fed.us/tools-data/default.asp