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IMPACT OF BIOENERGY MARKETS ON THE FUTURE OF SOUTHERN UNITED STATES FORESTS

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ABSTRACT: *The demand for forest biomass for energy production is on the rise. Bioenergy may offset fossil fuel use, diversify energy sources, reduce emissions, provide additional income for forestland owners, and create new jobs. The southern US, which is known as the 'wood basket of the world' has a huge potential for woody bioenergy. One of the most contentious issues surrounding woody bioenergy markets is biomass availability and market supply. We explored the likely effects of the emergence of a mature bioenergy market in the southern US and assessed how the supply of woody biomass for energy varies with time. We also predicted how these variations can impact traditional forest product industries, landowners, and future of forests in the region. We used a goal programming based regional timber supply model to assess these supply variations. The woody biomass required for energy use scenarios are developed based on Intergovernmental Panel on Climate Change storylines. Our results suggest that the emergence of a new woody bioenergy market will potentially lead to price increases for merchantable timber, resulting in increased returns to forest landowners. The price volatility is expected to be higher in case of softwoods relative to hardwoods. The impacts of wood based energy markets tend to be higher on non sawtimber than sawtimber industries. While woody biomass harvest and forest acreage are expected to increase with higher prices, the forest inventory trend is hard to predict as increased plantation numbers and afforestation of agricultural or pasturelands tend to counter the increased removals due to woody bioenergy markets.*

Keywords: *bioenergy, forest biomass, regional timber supply model, forest inventory, Southern United States*

INTRODUCTION

The United States is the largest consumer of petroleum products in the world (Energy Information Administration [EIA] 2015). Significant shares of these petroleum products are imported from politically unstable regions of the world. This reliance on fossil fuels has led to economic, social and environmental concerns that have gained public attention. Bioenergy appears to offer hope to us by reducing the gap between domestic energy supply and demand, diversifying energy sources, reducing greenhouse emissions, and by providing socio-economic benefits in the form of additional income and new jobs.

Woody bioenergy is considered as an option to reduce dependency on fossil fuels, increase the current share of the nation‘s renewable energy, and improve the sustainability of the forests. Historically, woody biomass used for energy comprised of residues from the production of lumber, pulp, paper, and other wood products. However, if woody bioenergy markets become competitive, biomass from several sources including logging residues, stands damaged by natural disturbances, small diameter trees from thinning, plantations and other forests, and energy crops such as eucalyptus and poplar can be used for energy production. At high enough prices, even millable timber can be diverted for bioenergy production. Woody bioenergy markets can improve current forest conditions as well. The effect of high-density plantations in the Southern US, coupled with limited markets for small diameter wood, have led to extensive areas being overstocked and susceptible to wildfires and pest attacks (Polagye et al., 2007). Woody bioenergy markets could also increase thinning and removals, thereby reducing these risks (Gan and Mayfield, 2007). Schmidt et al. (2002) estimated that 2.7 billion dry tons of forest biomass needs to be removed through forest fuel reduction treatments in the region, at the annual rate of about 20 million dry tons. Such type of woody bioenergy markets could improve the profitability of forest management for landowners in the region (Lal and Alavalapati, 2014; Susaeta et al., 2013, 2012). Furthermore, southerners appear willing to pay more for cleaner sources of energy such as wood based biofuels (Susaeta et al., 2011, 2010).

Federal policies such as the 2002 Farm Bill, 2005 Energy Policy Act, 2007 Energy Independence Security Act (EISA), and 2008 Farm Bill have specifically encouraged the production of cellulosic biofuels such as those produced from wood. Current and future estimates of woody biomass production for energy must be in accordance with the EISA of 2007, which established a Renewable Fuel Standard of 15.5 billion gallons in 2012 and 36 billion gallons by 2022, of which 21 billion gallons must be cellulosic biofuel. Hughes (2000) suggests that the combination of forest bioenergy plantations with the continued use of wood residues from forest product industries might supply 7–20% of the US electricity generation.

There have been studies to delineate impacts of advanced biofuel expansion at the national level using the input-output model and the Policy System Analysis model (e.g., Ugarte et al., 2007). However, woody bioenergy expansion pathways have not been duly emphasized in these studies. Even the United States Department of Energy [USDOE] (2011) update to earlier Perlack et al. (2005) research failed to incorporate site level price analysis, supply side response, or stakeholder willingness to participate while determining supply curves. Another set of studies have been undertaken at the much finer level such as the one by Hodges et al. (2010), exploring economic impacts of renewable fuel standards in the state of Florida and setting up two woody biomass power plants with a combined capacity of 60 megawatts in North Carolina (Hodges and Rahmani, 2008). Existing estimates fail to gauge the supply of woody biomass for bioenergy, which is affected by an array of economic, environmental, and policy considerations. The woody biomass supply information is essential to national and state policymakers who establish renewable energy goals and formulate subsidies, credits, trade tariffs, and other biomass initiatives. This study is significant as it undertakes an integrated approach, weaving together future woody biomass requirements, energy supply from harvest residues and urban wood waste, land use change, merchantable timber diversion for energy use, and the impact on traditional forest industries. In particular, the specific research objectives of this study are to: (1) estimate forest biomass supply variations in the Southern US in face of woody bioenergy markets; and (2) simulate effects of changes in woody biomass supply due to sustainability constraints imposed by policies and programs.

STUDY AREA

Forestlands present in the 13 southern states in the US (Figure 1) occupy about 28% (215 million acres) of total forestlands (751 million acres) in the nation (Smith et al., 2009), with most being timberlands. The forests in the 13 southern states (hereafter "Southern forests"), spanning from Texas to Virginia with around 40% of total land under forest cover, 5 million private landowners, and 62% of the country's total growing stock removals in 2006 (Smith et al., 2009) are expected to play a dominant role in woody biofuels market development.

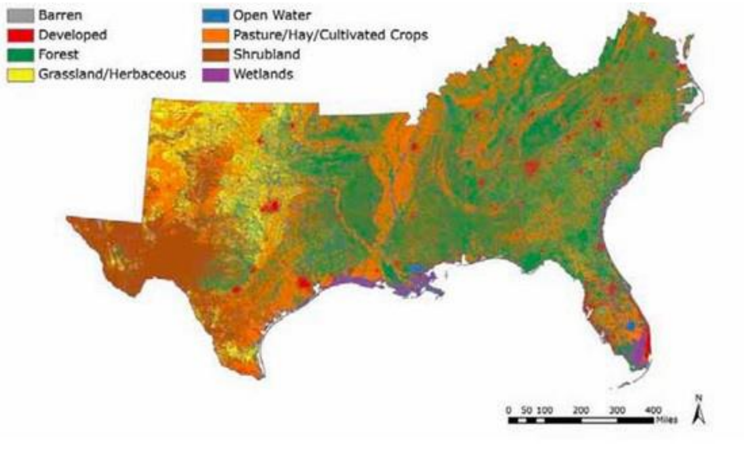


Figure 1. Land cover map of the study region (Southern United States)
Source: World Resource Institute Southern Forest for Future Report.

This region could produce 10.5 billion gallons of advanced biofuels per year, or about 50% of advanced biofuels by volume USDA (2010) including those produced from woody biomass. Another factor that supports the importance of the study region in woody biofuel future is the fact that forest inventory volume in the region has responded to increased management and harvesting since 1990s, when more of the harvest shifted to private lands in the region largely from national forests in the Pacific Northwest (Smith et al., 2009).

DATA SOURCES

Woody biomass can be used for three principal energies: (1) as biopower for electricity generation through combustion or gasification processes, cofiring with coal, or for combined heat and power systems in industrial facilities; (2) as liquid fuel that can be blended with conventional transportation fuels and co-products and (3) as bioproducts such as highly compact wood pellets used for heating purposes. The total wood demand for energy has been estimated in terms of these three types of energies. Demand for the first two bioenergy types has been calculated based on Energy Information Administration (2010) forecasts, while wood pellet demand has been estimated based on Spelter and Toth (2009) data on pellet plant capacity and efficiency. Although harvesting unutilized residues (discarded tree tops and limbs generated during the harvesting process) might provide a portion of woody bioenergy consumption, analysis by researchers such as Galik et al. (2009) and Rossi et al. (2010) indicate that merchantable timber is also likely to be required. In addition, woody bioenergy demand figures need to account for urban wood wastes that could be used for energy production (Rossi et al. 2010). Kumarappan et al. (2009) suggest that existing wood can be diverted to bioenergy if the price is high enough. We also follow similar approach whereby bioenergy industry can compete with traditional forest industries. This approach seems plausible under current policy conditions where wood biomass suppliers are not obligated to supply woody biomass for energy only after meeting the demand for conventional forest products industry. Because our model deals only in harvested wood, the urban waste and other sources of non harvested woody biomass were netted out of the consumption estimates, and defined the remainder as harvested-wood consumption (including harvesting residues) for woody bioenergy. Utilization percentages consistent with timber product output data for the region (Johnson et al., 2009) were used to determine availability of harvest residuals.

The elasticity of supply and demand prices can vary by product, as can the inventory supply elasticity. The consensus regarding these elasticities is that they are inelastic (Pattanayak et al. 2002; Liao and Zhang 2008). In this study, a demand elasticity of 0.5 was used for all four timber products (softwood non-sawtimber, softwood sawtimber, hardwood non-sawtimber, hardwood sawtimber) following Abt and Abt (2012). The inventory elasticity has been assumed to be 1 for all products and owners. For supply elasticity, we used the values estimated for the three IPCC storylines through timber supply equations (Pers. Comm. David Wear, Project Leader, Forest Economics and Policy Research March 8, 2010). These supply elasticities are not uniform; rather we allow them to vary. These elasticity values vary across products and years within a range between 0.1 and 0.5. Applying broad regional elasticities, we undoubtedly underestimate regional and product variation. However, lack of specific products and sub-regions allows us to go for average elasticities and assume the law of one price rather than going for a more realistic assessment that encapsulates sub-regional economic responses. Furthermore, we needed to specify cull factor and diameter range which determines the volume (in each product category) contributing to non-saw timber. The cull factor outlined in Abt and Abt (2012) and Forest Inventory Analysis diameter demarcation for softwoods and hardwoods (sawtimber is timber having more than 8 inch diameter for softwood and more than 13 inch for hardwoods) was used. Less than 5 inch diameter trees are assumed to be saplings, and are not considered as harvestable timber.

MODELS AND ASSUMPTIONS

We modified the Sub Regional Timber Supply (SRTS) Model originally developed by Abt et al. (2000) to assess the impacts of mature woody bioenergy markets. Using the extended model, biomass supply variations and changes in Southern US forests was assessed in response to low, medium and high woody bioenergy consumption scenarios. However, we explain the results only through high woody bioenergy consumption scenario. We netted out harvest residues while estimating merchantable timber required by bioenergy industry and assumed that percentage share of species (hardwoods and softwoods) and products (sawtimber and pulpwood) diverted for energy use are exogenous. Following Rossi et al. (2010), the tradeoffs between the traditional forest product industry and the woody bioenergy industry, woody biomass supply variation through time and associated price, inventory, and removal responses were assessed. In order to ensure that some slash is left on the ground to maintain harvest sustainability (Lal et al., 2013,2011), the model was constrained so that no more than 67% of harvesting residues could be diverted for energy production. The constant consumption scenario (with no expanded demand for bioenergy) defined a base harvest projection for the traditional wood products industry. For estimating biomass supply variations, the woody biomass requirement of forest industry and woody biomass requirement net of urban wood waste and harvest residues were fed into the model as input demand. The model equations—defined through supply, demand, and inventory elasticity values—were used to forecast the market-clearing price and quantity levels, and to project the next period's inventory values. A Goal Program categorized the total wood requirement by forest type and age class and made allocations to sub regions, owners, and products (please see Alavalapati et al., 2013 for further details). We modified the age-class from a five-year period to annual levels so that the supply response could be consistent with our woody biomass expansion scenarios.

We assumed woody bioenergy scenarios based on three Intergovernmental Panel for Climate Change (IPCC) emission pathways namely A2, A1B, and B2. The A2 pathway can be treated as a low wood-for-energy demand scenario. Here, technological innovations or policy efforts to accelerate the use of renewables is not emphasized, resulting in higher emissions when compared to A1B and B2. For example, the percentage share of renewables in total electricity demanded in year 2050 is projected to be just 7.74 % as per reference case scenario. The other two IPCC pathways emphasize reduction in fossil fuel demand. To account for reduction in fossil fuel use in A1B and B2 storylines, the study assumed that 20 % of total electricity demand will be met through renewable sources (including woody bioenergy) by 2050. The share of wood-based biomass energy in renewables and the ratio of wood-based liquid fuels to total renewable fuels differ for the A1B and B2 pathways. The balanced technologies case (A1B) emphasizes increased use of renewables, including woody biomass-based energy. However, it is presumed that the policymakers allow for natural growth of all particular renewable technologies rather than emphasizing woody biomass energy over other renewable technologies. This storyline can thus be treated as medium woody biomass consumption scenario. The unbalanced technology case (B2) assumes introduction of clean and resource-efficient technologies such as woody biomass-based energy. In this case the study assumes that woody biomass-based energy grows at a faster pace than other renewable sources due to policy and technology support provided by policymakers. This storyline can thus be treated as high woody biomass consumption scenario. The consumption forecast is essentially a vertical demand curve added to the downward sloping demand curves for traditional forest products for each period using modified Energy Information Administration (2010) projections. As a counterfactual, the study also introduced a constant consumption scenario with no forest biomass-based energy market and ran the SRTS model to define the amount of woody biomass that would be required by traditional forest industry without a bioenergy market. Subsequent years are held constant at the original 2007 level on the assumption that the traditional forest product industry will not increase wood consumption beyond what would be expected at the constant price level estimated by SRTS. This helps in discerning impact of woody bioenergy markets on existing forest industries.

Although the study describes consumption scenarios, it is important to understand that they are not demand projections, as the study does not specify price-responsive demand relationships for woody biomass and traditional forest products. To account for uncertainty in bioenergy technologies, demands, and policies, the study considered three consumption scenarios: high, medium, and low. The low-consumption scenario assumes that 7.74 % of total electricity will be derived from renewable sources based on Energy Information Administration (2010) reference case forecasts. The medium-and high-consumption scenarios assume that 20% of total electricity consumption derives from renewable sources; in the high-consumption scenario, woody biomass is assigned a higher percentage of the total electricity generation from renewable sources.

RESULTS

How woody bioenergy markets are likely to affect the future of forests in the region in terms of inventory, forest type, land use change, prices, and harvests are discussed. The results of high bioenergy consumption simulations are summarized here as the price, inventory, removals, and land use trends are accentuated as compared to low and medium bioenergy consumption scenarios. By 2050, woody biomass consumption is forecasted to range from 170 million green tons (MGT) for the low-consumption scenario, 256 MGT for the medium scenario, to 336 MGT for the high scenario (Figure 2).

The amount of urban wood waste and harvest residue amounts to about 48.56 MGT in 2010 and increase throughout the projection period to reach 71.39 million by 2050. In all the woody biomass consumption scenarios, it can be observed that merchantable timber is required for energy production, even though harvest residues and urban wood waste take care of the initial years of woody bioenergy demand. In contrast, the forecast of biomass requirement for the forest products industry (held constant through the projection period) is about 278.46 MGT. By 2050, the biomass requirement for energy reaches about 61% of the forest products requirement for the low-consumption scenario and 92% for the medium scenario. For the high-consumption scenario, the bioenergy requirement exceeds the forest products requirement by 2045 and is 21% greater than the forest product requirement in 2050. Backing out urban wood waste and the harvest residues from the forest biomass for energy requirement in 2050 would bring merchantable timber demand to 99 MGT for the low consumption scenario, 185 million for the medium scenario, and 249 MGT for the high scenario.

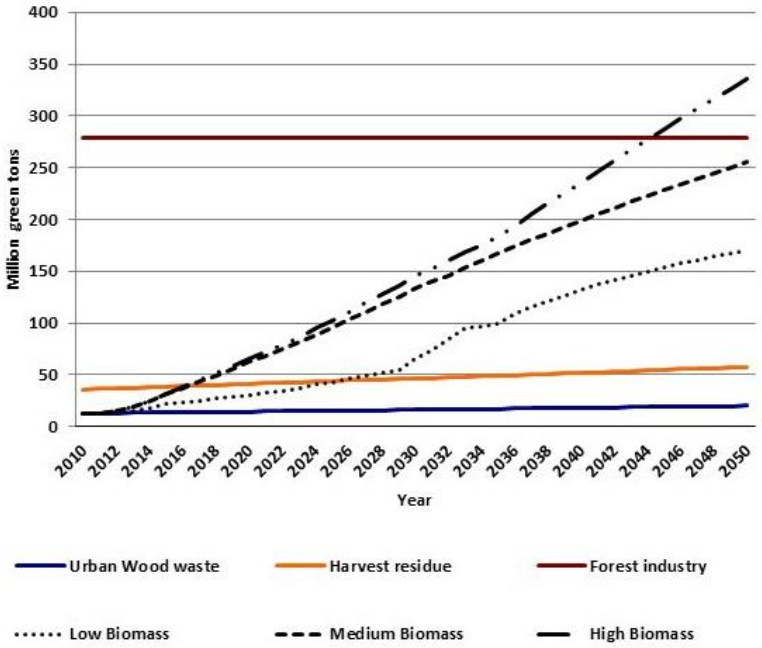


Figure 2. Woody biomass demand for energy in the South under low-, medium-, and high- consumption scenarios; with demand from traditional forest industry, harvest residues, and availability from urban wood waste, 2010 to 2050.

While interpreting price, inventory, and removal indices for different woody biomass consumption scenarios, few things need to be borne in mind. Firstly, the land use projections in modified SRTS are determined by timber revenues, financial returns to agricultural land uses, and other factors such as population growth, aggregate US economic growth, residential land uses. As agricultural revenues are specified as constant over the entire projection period, increase in forest product prices results in land diversion from forest towards agriculture and vice versa. Secondly, removal is a function of both price and standing inventory. As inventory elasticity values are posited higher than price elasticity values, removal follows the dominant inventory trend. Thirdly, the year after which the urban wood waste and harvest residues fail to meet the woody biomass demand for energy production for different climate cases is significant. After this year the increased demand of merchantable timber results in price increases and landowner response in term of increased plantations. Fourthly, there is a gestation gap of 10 years when the new plantations can be realized. Fifthly, the actual output of the model differs than the aggregate demand fed into the model, largely because of the economic equations that define how the resource will be harvested across different time periods. Lastly, one needs to factor in the 'unmet demand' as well. As not all woody biomass demand can be translated into removals, magnitude and timing of unmet demand is important as well.

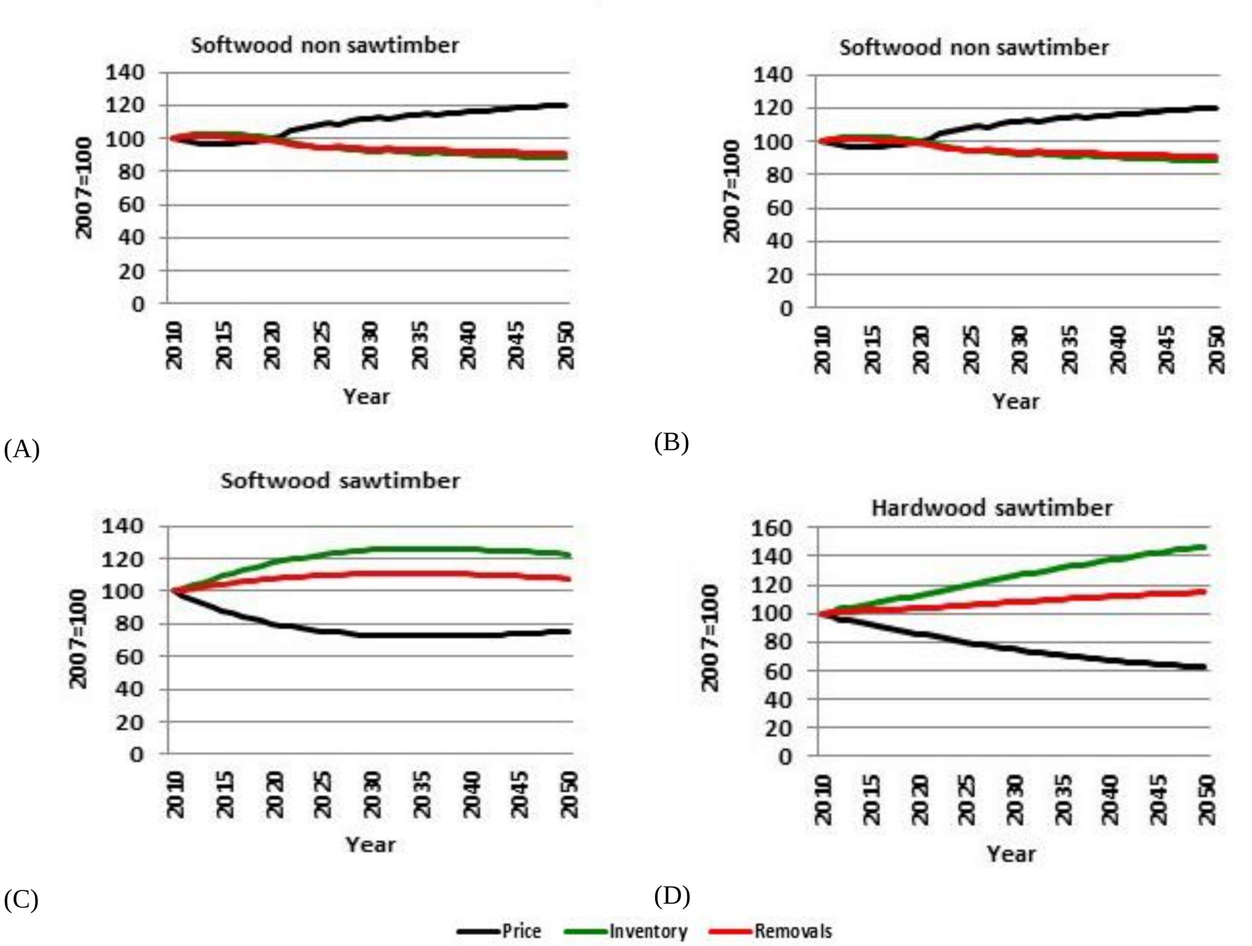
No Woody Biomass for Energy Scenario

In order to discern the impacts of woody biomass-based energy markets on the traditional forest product industries, a reference case in terms of constant consumption for forest products has been assumed. The results of the SRTS model run for four products in this reference case are depicted in Figure 3.

The results are shown in terms of index values for prices, inventory, and removals with respect to 2007 figures. There is little increase in price of softwood non sawtimber (20% of 2007 price), while the prices for the other three products decline. Harvest removals and inventory of softwood non sawtimber decline, while other removals and inventory of other products increase. This is consistent with the SRTS-based analysis of Abt and Abt

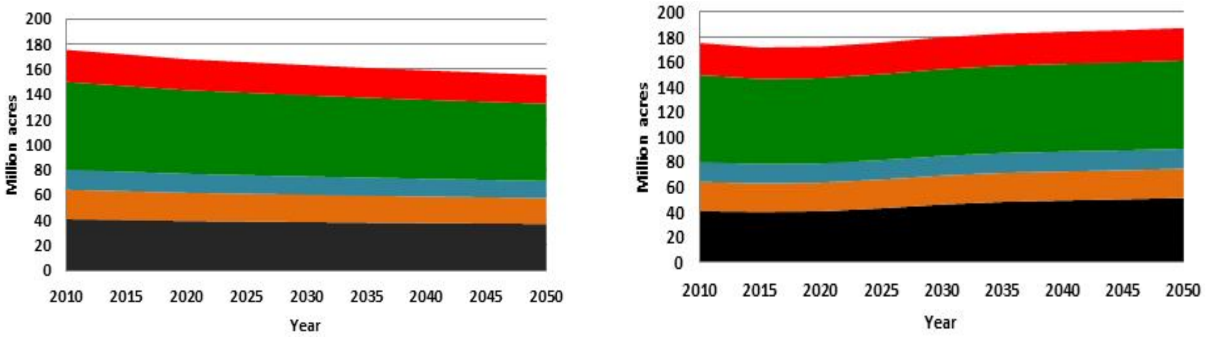
(2012) that plays out the implications of a protracted recession. Under this no bioenergy scenario, Southern private forestland acreage declines by 11.4% from 175.39 million acres in 2010 to 155.40 million acres in 2050 (Figure 4). This is consistent with maximum forecasted forest losses described in Wear (2011).

This scenario is also consistent with the forest product demand analysis contained in Wear et al. (2013) using supplies generated by the US Forest Assessment System and constant product demands—i.e., harvest levels stay constant or expand somewhat and timber prices decline over time. This analysis is intuitive as declines in timberland would lead to increased scarcity and, ceteris paribus, lead to upward pressure on product prices.



(A) (B) (C) (D)

Figure 3. Market responses in price, inventory, and removals for Southern US for no woody biomass for energy scenario.



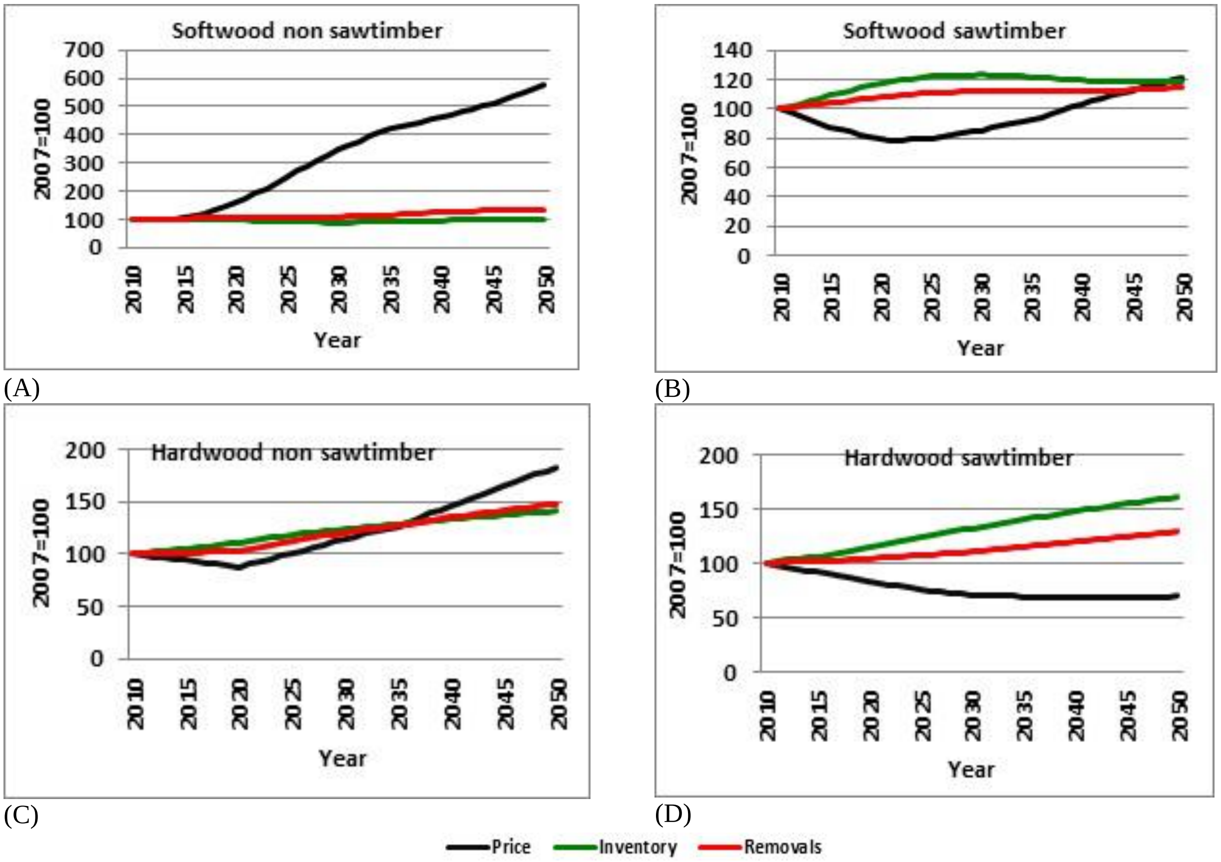
(A) (B)

🟥 Lowland hardwood 🟩 Upland hardwood 🟦 Oak pine
🟧 Natural pine ⬛ Planted pine

Figure 4. Private forest acreage change in the Southern US (A) No woody biomass for scenario, and (B) High woody biomass for energy scenario.

High Woody Biomass Consumption Scenario

Under this scenario, it is assumed that larger share of energy portfolio of the country is sourced from wood biomass than medium or low woody biomass demand scenarios. The simulation results point that the prices of softwood non sawtimber spike ups to six times the 2007 level (Figure 5) and the inventory and harvest levels are higher as compared to medium, low or no woody biomass consumption scenarios.



(A) (B)

(C) (D)

Figure 5. Market responses in price, inventory, and removals for Southern US for high woody biomass consumption for energy scenario.

The peaking of softwood non sawtimber prices is fueled by an inability to meet woody biomass for energy requirement via harvest residues and increased. The hardwood non sawtimber prices' fall is arrested in later half largely due to inability of harvest residues taking care of woody bioenergy requirements. Inventory and removals follow an increasing trend, with the trend being more prominent for hardwoods than for softwoods. These responses are similar to the one observed in the case without bioenergy, though the price reductions for softwood sawtimber and hardwood non sawtimber seem to be lower. This result supports the general conclusion that forest landowners might benefit from higher product prices in the future. Comparing the index values for prices, inventory, and removals also illustrate the typical inelastic market response as price changes more than removals or inventory. The price and inventory levels for hardwood non sawtimber are much higher than no woody biomass consumption scenarios. In fact, the price hike is 80% higher than 2007 level. The price of softwood sawtimber is shown to decline first, increase later, and then decline again. This trend might be attributed to the fact that in the initial years harvest residues and urban wood waste are able to fulfill the wood demand for energy requirements so no extra softwood sawtimber harvest is required. However, in later years higher requirement for wood for energy stimulates the use of softwood sawtimber for energy, so prices start increasing. As new plantations emerge, the supply of softwood sawtimber increases resulting in declining prices. The inventory and removal index tend to support this trend. The prices, inventory, and removal levels of softwood sawtimber are higher than no woody biomass consumption scenarios. The price fall for hardwood sawtimber is much lower and removal level for hardwood sawtimber is higher than the one observed in the no bioenergy scenario. The Southern private forestland acreage increases by 6.85% from 175.39 million acres in 2010 to 187.41 million acres in 2050 (Figure 4). This acreage is 20.59% higher than the one observed in case where no woody bioenergy exist. Apart from natural pine forest types, all the forest types observe increased acreage. The planted pine acreage increases from the current levels by 26% by 2050. Planted pine acreage increase is consistent with expansion in pine planting by landowners in response to increased product prices. The acreage decrease trend of other three forest types is reversed post 2025 resulting in acreage in 2050 being higher than the current level.

The pulp industry is adversely impacted as significant non-saw timber supply is diverted away from traditional forest industry for energy production. The forest industry’s softwood non sawtimber demand is completely wiped out by 2028 and hardwood non sawtimber by 2047. According to simulations, there is significant unmet softwood non sawtimber demand, whereby the existing forests in the region fail to meet even half of the woody biomass required for energy production by 2050. This ‘unmet softwood non sawtimber demand’ is met by softwood sawtimber which means that the sawtimber industry faces significant impacts. As much as 110 MGT of sawtimber from both hardwoods and softwoods is diverted for energy production. On the other hand hardwood saw the timber industry face significantly lower impact as most of the ‘additional’ bioenergy demand is met by new removals.

DISCUSSION

Our bioenergy estimates ranging from 170 MGT to 336 MGT of woody biomass consumption for low and high consumption scenarios are comparable to other estimates in the literature if one assumes that supply of wood from the study region mirrors the national harvest share as per Hanson et al. (2010). Walsh (2008) estimated that approximately 121 MGT of forest and mill residues could be supplied at a price of $100 per dry short ton, compared to estimates of 154 MGT by Kumarappan et al. (2009). Perlack et al. (2005) estimated that 420 MGT of wood resources could be annually made available for energy production from Southern forests. The demand projections that based on policy goals tend to be much higher. For example, the Energy Information Administration (2007) estimated that as much as 414 MGT of wood from the region might be required to meet Federal goal of 25% of renewable fuel and electricity standards. Sample (2009) suggested that this demand figure could be much higher, estimating the yearly requirement at 992 MGT. Without accounting for milling residues, such variation in demand and supply estimates in the literature can be attributed to number of factors. Biophysical estimates such as Perlack et al. (2005) ignore the fact that the actual supply of forest biomass will be determined by forest inventory growth along with an array of economic factors such as price of feedstocks and demand and supply elasticities of forest products. Another reason that can account for variations is whether merchantable timber (roundwood) is diverted for energy production or not. Studies such as Energy Information Administration (2007) and Walsh (2008) do not consider roundwood while estimating woody biomass supply estimates. It is expected that the demand and supply estimates will be significantly different if roundwood based energy is also accounted for. Using urban wood waste for energy is another factor that has been ignored in most of these estimates. According to our analysis urban wood waste can potentially offset 11% of low, 8% of medium, and 6% of total woody bioenergy demand in 2050.

The bioenergy use in future will increase simultaneously with other renewable sources of energy such as solar, wind, additional hydro, and geothermal. Policy mandates such as EISA do not require that increased renewable energy demand is met by woody biomass alone. Clearly, there is no expectation that wood will be able to meet all the biomass needs, or that one harvests vast amounts of growth from Southern woody biomass energy markets. This might explain unusually high estimates by researchers who base the woody biomass requirement estimates on the assumption that renewable mandates will largely be met by woody bioenergy sources. Consumption increases of this magnitude (at a minimum 33% increase in timber harvesting) could imply a structural change in forest products markets. Analysis of traditional wood products markets indicates that the supply of biomass could grow by about 43% under current levels of productivity without increased scarcity, largely because of declining demands for wood products (Wear et al., 2011). The emergence of a new woody biomass based energy market will potentially lead to price increases for merchantable timber, resulting in increased returns for forest landowners. While woody biomass harvest is expected to increase with higher prices, the inventory trend is hard to predict as increased plantations of fast growing species, afforestation of agricultural or pasturelands and intensive forest management tend to counter the increased removals due to woody bioenergy markets. The price changes are expected to be higher in case of softwoods relative to hardwoods. Utilizing merchantable timber for energy production may not necessarily decrease the forest inventory. Existing forest products industries will be impacted and the impacts of wood based energy markets tend to be higher on non sawtimber than sawtimber industries. At higher level of wood demand for energy, however, saw-timber industry will be impacted. Consistent with Wear et al. (2013), our simulation results suggest that the woody bioenergy markets result in higher forestland acreage.

Also, public policy and dollar support might be necessary to promote this nascent market. Both demand and supply side policy instruments ranging from incentives and regulations to infrastructure and extension support might help establish this market in future. Some of the policy issues, such as technological and financial incentives to the woody biomass-for-energy industry, put the wood-energy market in direct competition with established wood-using industries. Some of these issues would result in winners and losers. Therefore, not surprisingly, stakeholders are increasingly participating and debating these issues. It is imperative that each side should respect the positions and arguments of the other and strive to collectively make progress. However, this consensus building effort is stymied by the fact that bioenergy in general and wood-based energy in particular are still in a nascent stage.

CONCLUSIONS

This study estimated aggregate woody biomass requirements for Southern US for low medium and high bioenergy scenarios. The total woody bioenergy requirement was estimated net of urban waste wood and harvest residues. To explore market implications of the three biomass consumption scenarios, the study modified the SRTS model and ran simulations. The study estimated that by the year 2050, woody biomass consumption ranges from 170 MGT for the low consumption scenario to 256 MGT for the medium consumption scenario and 336 MGT for the high consumption scenario. These estimates are comparable to other estimates in the literature. Consumption increases of this magnitude could imply a structural change in forest products markets. The results show that softwood non sawtimber prices increase in the future, with larger price increases observed in medium and high woody biomass demand scenarios. The price increment for softwood non sawtimber is significant, resulting in it being almost six times that of the level observed in 2007 for high demand scenario. Our analysis shows that the wood biomass demand for energy will not be met through harvest residues and urban wood waste alone. When the market matures, woody biomass could become preferred feedstock for energy production. The pulpwood inventory level is also higher compared to the no-wood-for-bioenergy scenario. The price fall for the softwood and hardwood sawtimber is lower in woody bioenergy scenarios compared to the one where no woody bioenergy markets exist. Planted pine forest type is most responsive to these price trends. The simulation results demonstrate that with timber prices increase, the supply of harvested merchantable timber to the existing forest industry decreases. Without factoring in management and technological advancements to account for increased productivity, the woody biomass sourced from Southern forests could not be able to meet forest products sector demands as well as high wood for energy demand. The results show that the impacts would be more pronounced for pulp based industries than for sawtimber industries. However, at high levels of bioenergy demands, the softwood sawtimber industry would be adversely impacted. The results also suggest that emergence of woody bioenergy markets would increase the forestland acreage in the region.

The woody biomass supply variations will depend on a multitude of factors such as future demand for wood biomass from bioenergy markets; advancements in conversion technologies; product prices and elasticities; and productivity increases. The forest inventories will also depend on factors like forest growth, afforestation of agricultural or pasture lands, intensive management of forest land, and increased plantations of fast growing species. The models used for the analysis attempts to account for these factors, but future conditions are clouded by large uncertainties about demand and supply factors. Results will likely vary when some of these factors are accounted in the model. We need new sources of energy, and forest biomass could provide important revenues to landowners, ensure higher inventory levels, and maintain or enhance forest land. However, similar to any nascent industry, wood based energy industry has lot of uncertainties associated with its growth and future. The cost of productions and technological breakthroughs, nature of federal, states and policies in support of renewable technologies, are few key factors that might determine the future of this industry. If carbon markets emerge and carbon credits for displacing fossil fuels with woody bioenergy are considered, more changes in forest conditions and forest product markets are expected in the region. The uncertainty associated with this industry will most likely snowball to impact forest landowners, forest industry, contractors and other stakeholders as well. Further research is needed to fill these research gaps.

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