FOREST BIOMASS SUPPLY FOR BIOENERGY IN THE SOUTHEAST: EVALUATING ASSESSMENT SCALE

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ABSTRACT

This study evaluates the potential impacts of expanded forest biomass use in the Southeast from present year through 2036, focusing on the forest supply, industrial, and GHG emissions implications of maximizing biomass co-firing with coal. We model demand scenarios at the state, subregional, and regional levels, and assess the influence of study scale on the observed results. We find that pricing effects are greatest under a state-level assessment scenario, followed by subregional and regional assessments. This has important impacts on observed shifts in forest land use and forest stand carbon, with the state-level assessment resulting in the greatest amounts of forested acreage and carbon relative to the other assessment scales. State-level assessments also experience the lowest relative displacement of pulpwood capacity of the three scales considered, with spatial and temporal dynamics of resource allocation playing a strong role in our findings. If forested acres, forest carbon, and aggregate displacement are the only issues of concern, then these results would suggest that a program encouraging the use of forest biomass for renewable energy production may be best implemented at the state level, rather than at some larger scale. Given the wide variety of other environmental, economic, and social objectives that must be satisfied, however, continued careful evaluation of the multiple impacts of increased forest biomass use is necessary.

INTRODUCTION

Interest in renewable sources of energy is increasing for a variety of reasons, including the mitigation of climate change and furtherance of energy independence. This interest is reflected in an increasing number of proposed and enacted regulations, programs, and initiatives at both state and federal levels. In the Southeastern United States, attention is often focused on the role that forest biomass can play in meeting these and other policy objectives (English and others, 2004). Although abundant, the supply of forest resources in the region is subject to a number of ecological, institutional, and economic constraints.

Despite these multiple factors and potential limitations, the impact of renewable energy policy has not always been carefully evaluated prior to program inception (Sedjo and Sohngen, 2009). Even though multiple studies have estimated potential biomass supply (e.g., Pennock and Doron, 2009; Perlack and others, 2005; see also Gronowska and others, 2009), estimates of aggregate supply are complicated by the potential interplay between increasing resource demand for biofuel and bioenergy and the competition with current users of the resource (e.g., Lundmark, 2006; Galik and others, 2009; Abt and others, 2010a; Abt and others, 2010b).Also complicating matters are the various scales at which policy to encourage the use of biomass are being discussed (e.g., State, federal) and the differing market responses that could occur as a result. For example, an increase in demand for forest biomass could induce greater harvest activity, as well as displacement of existing pulpwood capacity. A land use response would likewise be expected (Abt and others, 2010b). Should the scale at which biomass demand is evaluated itself influence the magnitude of the resulting price response, we would likewise expect harvest, forest land use, and displacement responses to vary by assessment scale.

In the analysis that follows, we consider the role that assessment scale factors into the potential near-term impacts of expanded forest biomass use in the Southeast. In particular, we focus on the forest supply, industrial, and greenhouse gas (GHG) emissions implications of maximizing biomass co-firing with coal. To better understand the spatial issues at play, we model demand scenarios at the state, subregional, and regional levels from present year through 2036, and evaluate the influence of assessment scale on the observed results. For each assessment level, we examine the effect of increased biomass demand on weighted pine pulpwood prices, potential displacement of existing pine pulpwood capacity, forested acreage, and forest carbon. We identify the important trends and tradeoffs that emerge, and conclude with areas of future research needed to improve and expand this and related work.

METHODS

This analysis builds off of the methodology and findings of Abt and others (2010b), which assumes that the increased

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demand for bioenergy is driven by a maximization of co-firing potential (on a direct injection basis) at existing coal-fired boilers in a ten-State Southeastern region. Below we discuss the establishment of three separate policy assessment scales, estimation of baseline forest product demand, and the calculation of biomass co-fire demand. We then discuss the modeling of forest biomass supply response and the estimation of forest stand carbon.

ASSESSMENT SCALE

The analysis is conducted at three assessment scales: individual State, subregional, and regional levels. The region evaluated includes Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. In the State-level analyses, we assume that co-firing demand is met purely with in-state biomass resources. For regional assessments, we assume that demand for any plant may be met with biomass sourced from anywhere within the entire ten-State region. At the subregional level, we identify seven semi-distinct clusters within which woody biomass may be sourced to meet co-firing demand (Figure 1).

The implementation of the regional definitions has important market implications. Both demand (which is determined by co-firing boiler capacity) and supply (which is determined by harvest level and associated logging residuals in the short run and by forest type and age class structure in the long run) are defined by a particular regional specification. For example, State level analysis reflects the probability that State-level renewable energy policies will differ. Co-firing demand in the seven subregions is met by the overlapping supply basins within each cluster that are by definition distinct from other clusters. The State and subregional analyses treat the markets as independent; supply and demand pressures in one State or subregion do not affect neighboring ones. These are useful for gauging regional comparative advantage where demand will be affected by State policy and clustering of boiler capacity and resource prices and industry displacement will be affected by the distribution of resources and associated industry capacity. Alternatively, results from the regional analysis are useful for gauging the region-wide market effects assuming that price differences between markets will be minimized by market pressures. This may represent a longer term view of market behavior that may be dominated by regional differences in the short-run.In this analysis, we have chosen to look at the aggregate impact of market and resource metrics. This approach allows us to simply identify the impact of regional scale, but it does so at the expense of exploring regional variation.

BIOMASS DEMAND

We assume here that the forest products industry experienced a 30 percent decline in demand for four separate product classes (pine pulpwood, pine sawtimber, hardwood pulpwood, hardwood sawtimber) from 2006 to 2010. We also assume a recovery to near pre-recession demand levels by 2013, beyond which demand remains constant at pre-recession levels through the end of our projection. We then add to this base level of biomass demand the estimated amount of biomass used under a maximization of coal co-fire capacity in the region. Year-2007 coal co-firing capacity for individual facilities is determined at the boiler level using boiler configurations contained in the eGRID database (U.S. Environmental Protection Agency, 2008) and maximum coal co-firing capacity on a direct injection basis for each boiler type as indicated in various technical sources (e.g., Grabowski, 2004; Federal Energy Management Program, 2004). Gross energy demand is converted to woody biomass demand using a wood-to-energy conversion rate of 9,000 BTU per pound of dry biomass is the estimated energy content of wood. The value used here falls in the upper-middle portion of estimates of biomass energy content (For example, see http://bioenergy.ornl.gov/papers/misc/energy_conv.html [Retrieved March 26, 2010]); we acknowledge that different types of biomass have different energy content and that additional energy will be necessary to dry green biomass to achieve this energy content on a per-pound basis.

It is also important to note that we make no assumptions about the type of policy that drives this emerging market, only that the incentive to use biomass exists and that co-firing represents among the quickest and easiest paths to do so. Indeed, co-firing is often thought to represent a cost-effective path to biomass utilization in the near term (Robinson and others, 2003; De and Assadi, 2009; Lintunen and Kangas, 2010). While we do not specifically consider the added effects of biomass use in dedicated, low-GHG generation facilities or for the production of pellets or other wood fuels, the near-term demand for co-firing provides a point estimate from which we may begin to assess the various sectoral and temporal tradeoffs likely to accompany an expanding forest biomass energy market.

BIOMASS SUPPLY

Supply effects of maximization of co-firing in the Southeast are assessed using the Sub-Regional Timber Supply (SRTS) model. SRTS models product demand as a function of product stumpage price and demand shifts through time; greater description of the SRTS model and its application may be found in Abt and others (2009) and Prestemon and Abt (2002). To simulate the impact of added biomass demand, we conduct a baseline run of traditional wood-using industries to derive estimates of logging residuals. For all runs, we consider two separate scenarios of residual utilization, one in which utilization of residuals increases over time and peaks at a 50 percent utilization rate in 2020, and one in which utilization peaks at 25 percent. Utilized residuals are assumed to reduce biomass demand for roundwood, with the net remaining roundwood demand shifting demand for both pine and hardwood pulpwood proportionately.

GHG IMPLICATIONS

Finally, we consider the GHG implications of our modeled scenarios. As in previous analyses, we convert SRTS inventory output into estimates of forest carbon using forest-type-specific relationships and equations defined by the U.S. Forest Service (see Foley, 2009; Abt and others, 2010b). Although Abt and others (2010b) include an estimate of emissions displaced from a reduction in coal usage as compared to observed shifts in on-the-ground forest biomass carbon sequestration, we limit our discussion here to the GHG implications of shifts in planting and harvest behavior.

RESULTS AND DISCUSSION

The results of the analysis are described below, beginning with an overview of total biomass co-fire demand. We then describe the effects of increased biomass demand on pulpwood prices, displacement, forested acreage, and forest carbon for each of the three assessment scales evaluated here. We conclude with a brief discussion of the implications of these findings for bioenergy policy.

When maximizing co-firing capacity at existing coal-fired boilers, we estimate an aggregate average co-firing rate of approximately 10.1 percent. This translates to an annual biomass consumption of approximately 532 million MMBTU or just over 59 million green tons of wood. Disaggregating the larger region into seven distinct supply subregions and into the ten individual States, we find that biomass co-fire demand varies significantly across the Southeast (Table 1).

We next examine the relative shift in the price of pine pulpwood, the biomass component most likely to be affected by increases in near-term demand. Because our price output for each State or subregion is reported as a price shift relative to 2006 prices (and not as an absolute value), we use the weighted average of these price shifts over time to make comparisons across the different assessment scales. The weighted average is based on the relative price shift reported for each State or subregion, multiplied by the volume of removals in that State or subregion. When summed across all States or subregions and divided by total removals, this yields a single metric for each assessment scale, allowing direct comparison. There is of course some detail lost in this aggregation process; this is further discussed below in the context of pulpwood capacity displacement.

Figure 2 compares the relative pine pulpwood price shifts over time. The regional assessment (South-wide) has the smallest shift, followed by the subregional assessment. The greatest relative shift is generally found in the State-level assessment. The pattern holds for both residue utilization scenarios, though is slightly shifted lower in the 50 percent scenario. This is expected, as the greater amount of available residues both satisfies a greater portion of the biomass demand and tempers price increases in the process. There is also a temporal component, as prices tend to diverge somewhat as magnitude of biomass co-fire demand increases over time and is sustained through the later years of the assessment.

The shift in resource pricing is expected to have several affects. One area of concern is feedstock allocation, or the source of biomass from which increasing levels of demand are met. Although previous work indicates that significant differences in feedstock source exist when comparing different portions of the study to each other (Abt and others, 2010b), we are more concerned here with aggregate feedstock contributions across three assessment scales. Specifically considered in the analysis were shifts in hardwood and pine pulpwood harvests, displacement of existing hardwood pulpwood capacity, displacement of existing pine pulpwood capacity, harvest residues from hardwood or pine pulpwood, and residuals stemming from harvest of roundwood specifically for biomass.

Focusing on the displacement component, we find that relative displacement likewise varies by assessment scale. Further exploration of the findings, however, expose the potential hazards of weighting or aggregating findings at different assessment scales for comparison at the regional level. This is because harvest patterns in the SRTS model shift over time based on relative price pressure, which is itself driven on the supply side by changes in inventory. Inventory change across regions is driven by harvest and growth distributions and age class structure of the inventory. On the demand side, regional variation is driven by the regional co-firing capacity tempered by the availability of residuals. Co-firing capacity tends to be associated with population while residual availability is associated with the distribution of forest product industry capacity. The interrelationship between harvest and co-firing demand drive the displacement impacts.

The overall displacement pattern increases as co-firing demand increases from 2015 to 2030 (Figure 3). After 2030 wood supplies increase as the trees planted in response to initial price increases enter the product supply inventory. For both State and subregional assessment scales, the available supply is constrained relative to the regional one. Figure 3 also shows that both the State and subregion assessment scales follow a similar pattern. The higher displacement for the subregion assessment stems a very high correlation (r= +.98) between initial harvest levels (industry location) and co-firing demand. Across States, the correlation is much smaller (r= +.46).

For the regional assessment, the same overall pattern of displacement over time occurs, but another dynamic exists since supply can react to differences in price pressure across regions. Because the regions with the highest initial pine inventory increases also have the highest concentration of current industry as reflected by harvest (r= +.61), biomass harvest in the regional assessment shifts to areas with existing industry (e.g., Alabama, Florida, Georgia). This results in a higher displacement trend during the 2015 to 2030 period. Over time the increased harvest from co-firing reduces the comparative advantage of these regions and correlation of additional harvest with initial harvest declines (Figure 4). Since this harvest is also located in areas with the largest planting response to prices, displacement drops faster as new plantations come online.

We would also expect to see a land use response consistent with the ranking of resource pricing shifts. Stated another way, if relative price increases are greater the smaller the assessment area, we would expected forest land use response to be greater with a State-level policy requirement than in the presence of a subregional and regional one. This is reflected in the findings, with the State-level assessment possessing the greatest relative shift in forested acres relative to the baseline, non-co-fire scenario, followed by the subregional assessment, and finally the regional assessment (Figure 5). As before, the influence of residue harvest efficiency is evident, with a lower amount of forest acres being added relative to the baseline in scenarios in which greater residue availability is assumed.

Finally, we examine the effects of assessment scale on aggregate forest stand carbon. As with forested acreage, the greatest amount of forest carbon storage is found under a State-level assessment (Figure 6), followed by subregional and regional levels. We note, however, that some reductions in forest carbon relative to the baseline scenario are found for all three policy scenarios, but that the storage under a State-level policy scenario is greatest. Even though forested acreage increases relative to a non-co-fire scenario, total forest carbon falls due to management intensification and a shift towards younger (and smaller), faster growing trees. Net carbon sequestered under a given assessment scale and for a given year is a function of both this shift in intensity, as well as the total number of forested acres across the landscape.

While forest stand carbon provides one measure of the GHG performance of a policy scenario, also important to consider are corresponding reductions in GHG emissions from fossil fuels. We do not specifically evaluate this component here, but hypothesize that a State-level policy scenario would result in greater net emission reductions relative to both the regional and subregional assessment scales. The amount of fossil GHG emissions foregone through the use of forest biomass in place of coal is the same across all policy assessment scales, as is the volume of biomass being removed from the forest. This means that the carbon dynamics of the standing forest would likely determine the net GHG performance of the scenario. Using a similar level of biomass demand and a similar method to calculate the effects of this demand, Abt and others (2010b) find that GHG emissions relative to a non-co-firing scenario are possible at both region-wide and subregional assessment scales. In the current study, estimated State-level forest carbon exceeds the carbon stored for either of these, implying that GHG reductions would likely exceed those reported in Abt and others (2010b) for regional and subregional levels.

CONCLUSION

The results presented here indicate that the scale at which bioenergy policy is enacted can influence the resource management trends, even if the amount of energy produced as a result is unchanged. This suggests that if acreage, displacement, and carbon are the only metrics of concern, then a program encouraging the use of forest biomass for renewable energy production may be most efficiently implemented at the State level, rather than at some larger scale. Given the wide variety of other environmental, economic, and social objectives that must be satisfied, however, continued careful evaluation of the multiple impacts of increased forest biomass use is necessary. There are also site-specific opportunities and tradeoffs to consider, such as the local and community impacts of increased harvest activity, construction and operation of new energy facilities, or shifts in activity in existing mills, none of which are directly addressed here.

Furthermore, we make no assumption about the type of policy that is put in place to achieve this increase in biomass demand; we assume only that the demand exists. Because different types of policies can affect markets in various ways, we do not suggest that this finding is universal. In situations where compliance with bioenergy targets are mandated and energy producers are less sensitive to pricing increases than existing industrial users of biomass resources, however, the price effects induced by the increase in demand for woody biomass are greater the smaller the assessment scale.

An important concluding point is the impacts of increased bioenergy demand for woody biomass demand vary over time and space, and that the scale of the policy applied also influences modeled effects. As assessment scale decreases from the region to the subregion to the state level, price increases lead to increased forest acreage retention and moderated carbon loss. Our displacement estimates at different scales are complicated by spatial and temporal dynamics of biomass allocation, and break from this trend somewhat, with subregional and regional assessments experiencing greater relative displacement than at the state level.

The empirical findings with regard to shifts in pricing, acreage, and carbon confirm the otherwise intuitive relationship between assessment scale and increases in biomass demand. Further investigation of the spatial and temporal dynamics necessitated by our initially counterintuitive findings with regard to displacement likewise provide interesting perspective on resource allocation over time. As such, we believe that the analysis adds much-needed information and perspective to the debate over the role that biomass utilization is to play in state, regional, and national climate and energy policy. More research is needed to fully grasp the economic, social, and environmental implications of increased forest biomass utilization. In particular, the potential market for harvest residues remains uncertain, with multiple questions remaining with regard to the cost-effectiveness of their harvest, transportation, and use. The potential for dedicated energy crops, including switchgrass and short rotation woody biomass, to displace forest biomass as a fuel of first resort is likewise uncertain at the present time. Further work to evaluate the economics of these key questions is necessary to improve our understanding of biomass market response to policy drivers.

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Table 1—Total co-fire demand (green U.S. tons) in each State and supply subregion.

Subregion	Co-fire Demand (gr. U.S. tons)	State	Co-fire Demand (gr. U.S. tons)
Florida	5,989,003	Alabama	9,203,234
Gulf Coast	20,277,996	Arkansas	2,826,722
Highland Rim	4,534,124	Florida	6,943,748
Mid-Atlantic	21,323,771	Georgia	9,708,566
Middle Valley	639,694	Louisiana	2,977,997
North Valley	3,050,383	Mississippi	2,298,985
South-Central Valley	3,373,239	North Carolina	8,622,239
		South Carolina	4,582,469
		Tennessee	7,110,574
		Virginia	4,913,675
Southeast Regional Total	59,188,213	Southeast Regional Total	59,188,213

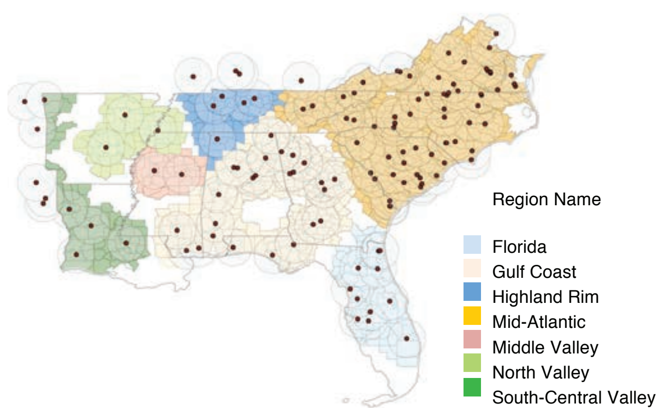

Figure 1—Supply regions used for the assessment of spatially explicit resource impacts. Coal-burning facilities potentially affecting counties in the Southeast region are indicated; circles represent 50-mile supply radii used to highlight those counties potentially providing biomass to a given facility.

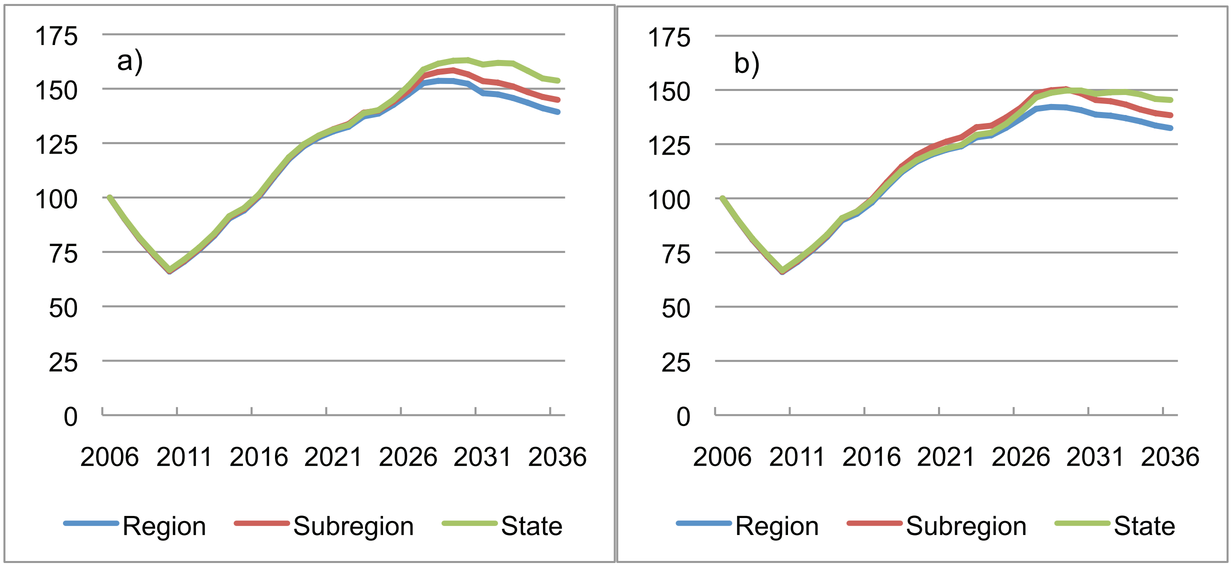

Figure 2—Weighted shift in pine pulpwood prices for a) 25 percent and b) 50 percent residue utilization scenarios. Values indicate magnitude of shift relative to 2006 pine pulpwood prices (100 = 2006 pine pulpwood prices).

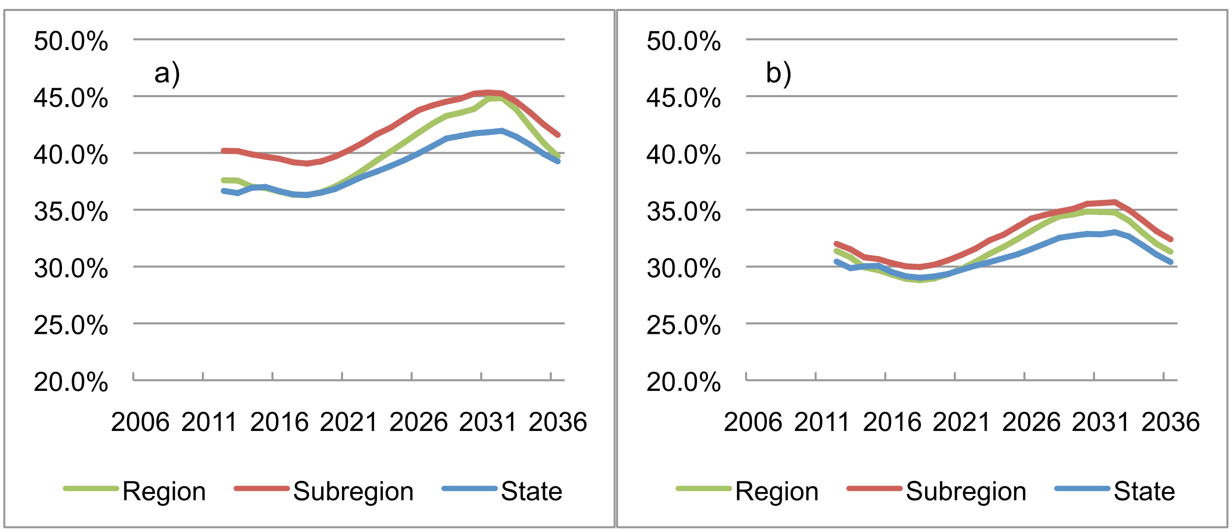

Figure 3—Percent of demand met from displacement of existing soft and hardwood pulpwood capacity, for a) 25 percent and b) 50 percent residue utilization.

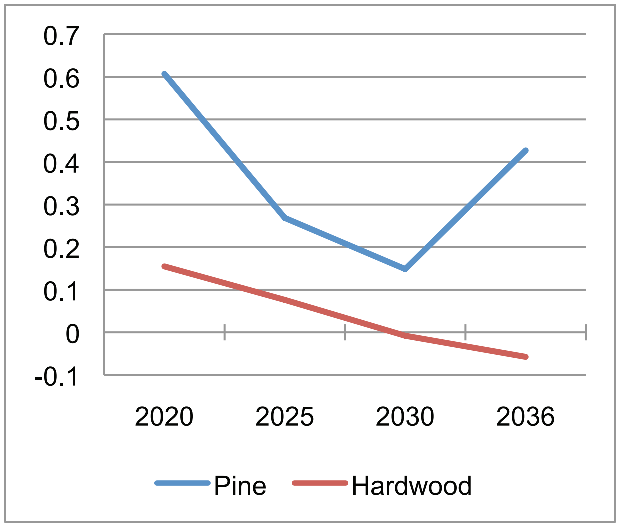

Figure 4—Spatial correlation between starting pulpwood harvest and increased pulpwood harvest due to biomass demand. The example presented here is for a 50 percent residue utilization scenario.

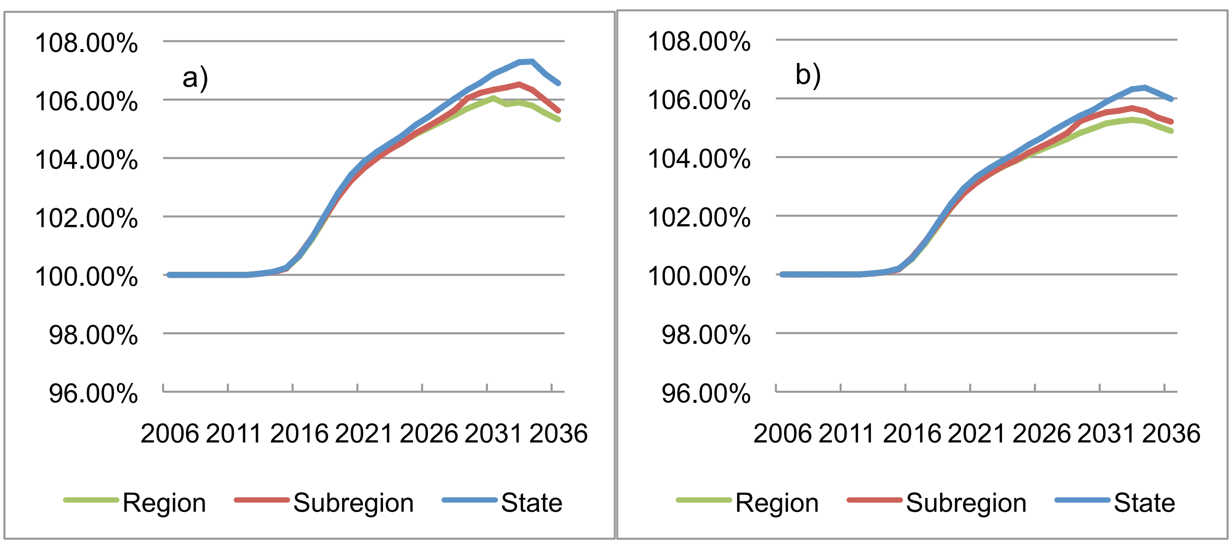

Figure 5—Percent acerage differential, co-fire scenario versus baseline, for a) 25 percent and b) 50 percent residue utilization scenarios. Values above 100 percent indicate an increase in forested acerage relative to baseline conditions.

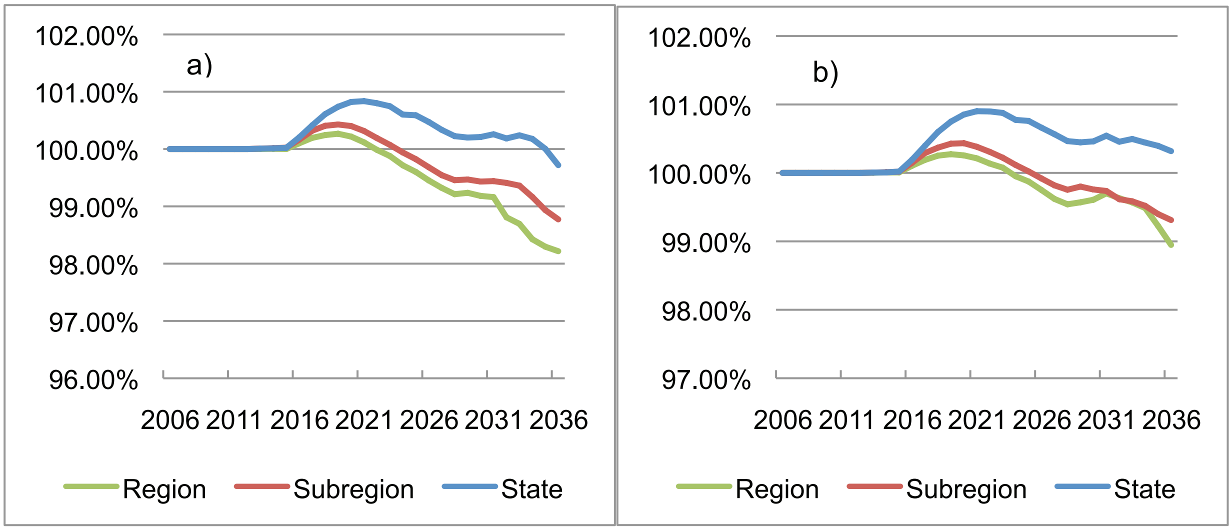

Figure 6—Percent carbon differential, co-fire scenario versus baseline, for a) 25 percent and b) 50 percent residue utilization scenarios. Values above 100 percent indicate an increase in forest carbon storage relative to baseline conditions.