

Regional Impacts of a Program for Private Forest Carbon Offset Sales

Darius M. Adams, Ralph Alig, Greg Latta, and Eric M. White

ABSTRACT

Policymakers are examining a wide range of alternatives for climate change mitigation, including carbon offset sales programs, to enhance sequestration in the forest sector. Under an offset sales program, on-the-ground forestry could change as a result of both afforestation and modifications in the management of existing forests. These effects could vary markedly by region in the United States because of differences in areas of agricultural land suitable for afforestation, forest carbon and volume growth characteristics, the structure of landownership, and forest industry concentration. Using a dynamic model of North American markets, our analysis of alternative carbon price levels suggests that the largest carbon increment response would come from changes in forest management: extending rotations, shifting silvicultural regimes, and reforestation to hardwood forest types (in some regions). Carbon payments could also stimulate a substantial afforestation response in eastern regions (North and South). Afforestation is particularly important in the North where timberland area could expand markedly. Much of the area would be planted to hardwoods, stemming the projected decline in hardwood forest types and growing stock volume.

Keywords: forest carbon payments, afforestation, policy simulations

In this article we present estimates of the effects of one specific form of carbon offset sales program—a national system applied uniformly across all regions in the United States. In our projections we account for regional forest sector differences and land-use interactions with the agricultural sector. Specifically, we quantify policy-induced changes in the regional patterns of forest carbon accumulation, shifts in regional forest area (including areas afforested and changes in composition by forest type), timber harvests, and inventories. We also examine impacts on the traditional forest industries and forest products markets.

Characteristics and Complexities of a Carbon Offset Sales Program

Recent Congressional hearings on climate policy included extensive input on carbon offset sales programs (COSP) and revealed the marked diversity in details of emerging programs (e.g., Climate Action Reserve, Verified Carbon Standard, and more). There appear to be six major program characteristics that can impact the efficacy of a COSP.

What counts? This is the additionality question. Afforestation has been the benchmark for forestry project standards because the additional carbon capture is readily verifiable. However, altering the management of existing forests,

Forests of the United States can make significant contributions to climate change mitigation through expanded sequestration of atmospheric carbon (Stavins and Richards 2005, Society of American Foresters 2008). Although many policy measures have been suggested to foster increased sequestration, perhaps the most widely discussed has been the development of a market for carbon offset sales—a system that would price forest carbon (e.g., Stavins 2008, US Senate Committee on Energy and Natural Resources 2010). Despite a growing body of literature, much uncertainty remains about the potential impacts of such a market on the US forest sector, particularly at the regional level. Regional

differences are important to understand, in part because policymakers need to know the potential for leakage as a result of interregional shifts in response to policy actions and because political support often turns heavily on distributional issues—who might gain and who might lose. Developing an understanding of the regional sequestration potential and impacts of an offset sales system is complicated by the diversity of US forested regions, including differences in the suitability of agricultural lands for afforestation, the dynamics of forest growth and carbon sequestration, forest ownership structure, concentration of forest products processing, and interactions with other sectors of the economy that compete for use of the land base.

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through changes in rotation age or silvicultural regime, also has a substantial sequestration potential, if additionality can be reliably and consistently established.

Cut or not cut? Some COSP approaches, both existing and proposed, require that additional carbon sequestered under the program remain uncut for substantial periods. Others would allow harvesting at the owner's discretion as long as the changes in the overall additional carbon stock are verified. If timber is harvested, the program may or may not recognize increments in the carbon pool of products made from harvested timber. Clearly, the investment attributes of a program would change markedly depending on these restrictions.

How are uncertain outcomes recognized? Several of the desired outcomes of forest carbon sales programs cannot be predicted with certainty. Increments in carbon stock on a particular ownership may not represent net atmospheric carbon reductions if there are offsetting increases in emissions from other ownerships. This is commonly called leakage and arises because ownership behaviors are linked through markets for forest products. For large changes in harvest, we expect leakage to occur, but its extent and regional concentration can only be approximated. Even with the best of intentions, carbon stock increments may not survive to the desired contract termination date because of fires and other unforeseeable losses or some private owners may change their minds and withdraw from a COSP. These reversals are commonly recognized through the application of various discount factors to the computation of the net carbon increment arising from a project. These factors recognize the potential for reversals but are, at best, only very rough approximations.

For how long? To be useful for purchasers in computing the duration of their offset activities, a COSP must specify something about the permanence of the increase in sequestration—the length of time the offset will be in place. There are multiple ways to specify or guarantee permanence, including conservation easements recorded against the property deed and implementation contracts that bind the seller to provide certain levels of offsets for the duration

of a project subject to various penalties for failure to meet the agreed extent or timing.

Who gets paid? The concern here is whether the program is mandatory for all private owners (a so-called carbon tax/subsidy approach of the sort examined in Adams et al. 1999) or voluntary (as examined by Parks and Hardie 1995). Incentives to opt out of a voluntary program would rise as enrollment in the program rose, if owners anticipate the effects of aggregate harvest reduction on future forest products prices. Presumably, mandatory programs would have larger carbon impacts.

How do owners pay or get paid? Owners can be paid either for gross or net carbon sequestration. Under a gross or asymmetric system, owners are paid for any increments in carbon stock but do not have to pay anything back when stocks are reduced. A symmetric system, also called a carbon subsidy-tax system, pays owners for increments and “taxes” them for any decrements in carbon stock.

In the absence of a clearly defined protocol in the current federal policy debate, combined with the multitude of registries often with inconsistent methodologies, it is important to be specific about the details of the COSP we examine. In our analysis, incremental carbon from both afforestation and changes in management of existing forest stands can be counted. Our model can readily measure the increments relative to the “business as usual” case (BAU), so we can perfectly track additionality in both cases. We allow cutting at the owner's discretion, with no minimum period for retention of plantations or forest management changes. We assume a mandatory program that enrolls all owners, and its payments are symmetric, being based on net carbon increments. We do not make payment adjustments for leakage at the ownership level, because our model recognizes North American (and key offshore) product market interactions and allows us to measure net carbon losses at that geographic level. Finally, we do not apply a discount for unforeseen losses. The projections assume that outcomes are certain.

Modeling Forest Carbon Sequestration Opportunities

Because forestry and agriculture are connected through land conversion and

product substitutability (e.g., bioenergy feedstocks), we use a linked model of the two sectors to examine the hypothetical forest carbon offset program. Termed FASOM-GHG (forest and agriculture sector optimization model—greenhouse gases), the model uses a dynamic optimization approach to simulate the markets for all forest and agricultural products in the United States at the regional level (and for key trade partners and products). FASOM-GHG is, in effect, a very large demand–supply model. As it finds the demand–supply balance in each market over time, it projects production, consumption, and prices for each major category of product (Adams et al. 1996, Alig et al. 2010a). International trade of all classes of forest and agricultural products is recognized in the model. In the forest sector, all forms of trade with Canada are endogenous, as are other significant trade flows to offshore regions (e.g., softwood lumber trade with non-Canadian regions). Smaller flows are treated as exogenous and follow projections in the 2005 Resource Planning Act (RPA) Timber Assessment (Haynes et al. 2007).

Details of the forest resource, including inventory, growth, forest management investment, and harvest, are explicitly modeled together with agricultural cropping mixes, harvests, and the processing of agricultural commodities. Land suitable for both forest and agricultural uses can move between the two sectors over time. Exogenous projections are used to account for land shifts out of production entirely through conversion to developed uses.

The model has a full accounting for carbon in both sectors. The forest ecosystem carbon pools recognized in FASOM-GHG include those in live trees (both above- and belowground), standing dead trees, coarse woody debris, understory vegetation, litter on the forest floor, and soil organic carbon. To estimate the carbon in standing live and dead trees, we convert the FASOM-GHG timber yield (growing stock) volumes to standing live and dead tree biomass using the approach described by Smith et al. (2003) with updated coefficients derived from Smith et al. (2006). Because the standing tree biomass in younger stands is poorly predicted from yield tables, we incorporate an adjustment for stand age, consistent with Smith et al. (2006). The carbon fraction of total biomass is assumed to be 0.5 in all regions.

Biomass in coarse woody debris and the

forest understory is calculated as a percentage of standing live biomass based on ratios reported by US Environmental Protection Agency (EPA) (2010), converted to carbon using the standard conversion. The carbon in forest floor litter is estimated using equations and coefficients reported by Smith and Heath (2002) that relate the carbon in forest floor litter to forest types within US regions, adjusting for stand age and litter decay over time. These relations are also described by Smith et al. (2006). Average forest soil carbon figures for region, forest type, and forest management intensity are based on the soil carbon values reported by Birdsey (1996). In addition to the aforementioned pools, FASOM-GHG tracks carbon stored in harvested wood products, based on the approach in a study by Skog et al. (2000), but this carbon stock is not considered in the present analysis.

FASOM-GHG recognizes deforestation, reforestation, and afforestation treatments and allows multiple silvicultural regimes and forest management options in each region (including partial cutting, natural versus planted regeneration for even-aged regimes, stocking control, rotation length, and forest type conversion). Descriptions of the array of silvicultural regimes are available at our documentation website. [1]

Selection of forest management regimes, regeneration forest type, and rotation age are endogenous in the model (they are not preassigned or fixed) depending on associated costs and prospective returns. The principal source of the FASOM-GHG timber yields is the US Forest Service's national 2005 RPA Timber Assessment Update (Haynes et al. 2007). The model also accounts for the production of an array of bioenergy feedstocks (McCarl et al. 2000) from the forest and agricultural sectors and includes policy-based fuel limitations such as the existing Renewable Fuels Standard.

To identify the maximum area to be potentially afforested by region, we drew on USDA Natural Resource Conservation Service estimates of agricultural land that is environmentally sensitive or of lower productivity. Lands deemed suitable for afforestation included cropland that was either eroding at rapid rates, in lower agricultural productivity Land Capability Classes (LCC; V–VII), or cropland classified as wet soil. For pastureland, we used similar criteria except for restricting the LCC to VII and VIII. Forest yields on afforested lands are generally higher for former cropland than

pastureland and the yields for both included in FASOM-GHG are consistent with those reported for afforested agricultural lands by Birdsey (1996).

Recently, FASOM-GHG has been used in national scale studies to assess how continued rates of conversion of rural lands (e.g., deforestation) could affect the capability of forestry and agricultural lands to sequester GHGs (Alig et al. 2010a). Previous FASOM-GHG analyses include examination of bioenergy feedstock supply (McCarl et al. 2000), impacts on the forest sector from climate change (Irland et al. 2001), and the carbon sequestration potential of management actions on agricultural and forestlands (Lee et al. 2005).

In its greatest detail, the model uses nine geographic forestry regions within the United States based on the US Forest Service's RPA Assessment regions. To facilitate reporting in this article, we collapsed results into three macroregions: North (including the northeast, Corn Belt, and Lake States), South (the 13 states including Virginia, Kentucky, Arkansas, and Oklahoma and states to the South), and West (comprising all other contiguous 48 states). Given data limitations and the relatively small amounts of forestland involved from a national perspective, we did not consider afforestation in the semiarid lands of the Northern and Southern Plains. Afforestation is also ignored in the Pacific Northwest Westside [2] and we do not allow afforestation on rangeland in any region.

Projections of economywide activity (e.g., gross domestic product and employment), timber inventory data, and other information about the forest sector were taken in large part from the 2005 RPA Timber Assessment Update (Adams and Haynes 2007). Timber harvests on all public timberlands are exogenous inputs in FASOM-GHG modeling of timber markets, with levels following assumptions in the 2005 RPA Timber Assessment Update (Haynes et al., 2007). This article does not report carbon stock changes on public lands. Future conversion of agriculture and forestland to developed uses is exogenous and based on US Forest Service projections (Alig et al. 2010b). Additionally, we assume that roughly 32 million ac remain in the Conservation Reserve Program; that energy prices over time are equal to those from the base Annual Energy Outlook 2008 (US Energy Information Administration 2008), and that production targets for bioenergy are in line

with the national Renewable Fuels Standard as established by the 2007 Energy Independence and Security Act.

Policy Scenarios

Current policy proposals to reduce GHG emissions in the United States include establishing a cap-and-trade program that places a cap on carbon emissions in regulated sectors and allows these sectors to purchase carbon offsets from others to meet the emissions cap. The forest sector would be excluded from the emissions cap but could sell offsets to regulated industries for CO₂ equivalents (CO₂e) that are either sequestered or avoided emissions by the forest sector. In this broad context, we examine the offset sales program described previously for impacts under a range of potential CO₂ prices, from 0 in the baseline or BAU scenario up to \$45/mt of CO₂e (prices are in \$ per metric tonne), implemented as constant price levels over the entire projection. Sequestered carbon in forest biomass and forest soils qualify for offset payments. No offset payments are provided for carbon sequestered in wood products manufactured from timber harvested previously or in future years. The agriculture sector is also able to take advantage of offset payments, including changes in the pool of carbon stored in agricultural soils.

Projection Results and Discussion

As the unit price of CO₂e rises, the economic costs of holding (rather than harvesting) standing timber fall for private landowners. Each additional unit of inventory earns some carbon revenue, so owners are encouraged to hold more inventory, either by reducing timber harvests and extending forest rotations or through afforestation. In our simulations, this process leads to increased private forest carbon flux and an expanded forestland base. Areas of both hardwood and softwood forest types increase relative to the BAU case. Harvests fall, pushing prices of logs and products higher and reducing timber product output and consumption.

Forest Carbon Flux

In our BAU case, private forest carbon stocks are projected to decline in the United States over the next 40 years, approaching stability after 2050. This is illustrated in Figure 1 by the negative national carbon flux on private timberland in the BAU case until

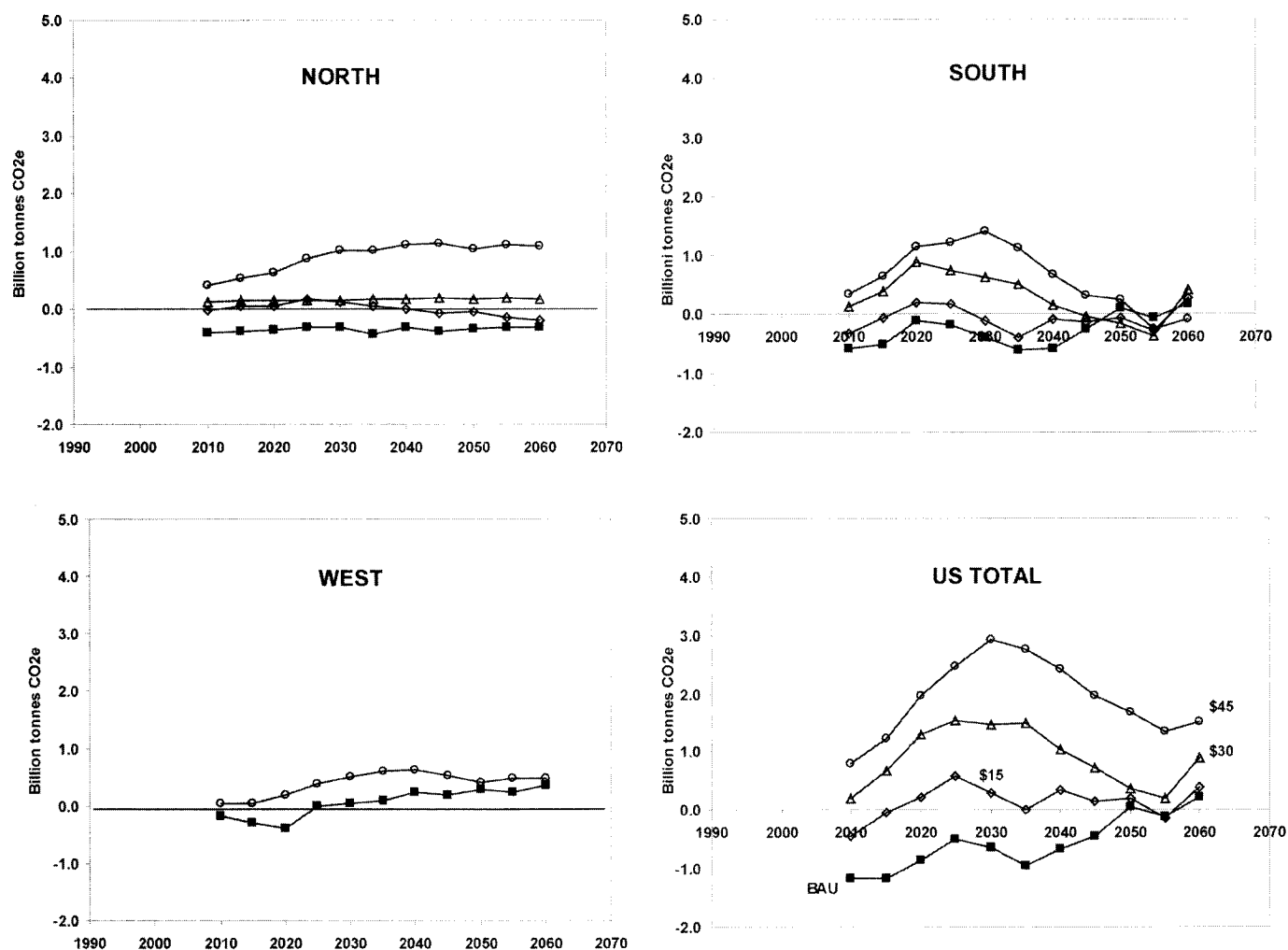


Figure 1. Carbon flux (5-year change in carbon stock) in US private forests by carbon price (CO₂e) scenario and major region: ■, BAU; ◇, \$15/mt; △, \$30/mt; ○, \$45/mt.

2050. [3] Declining carbon stocks reflect a falling private timberland base in all regions and large reductions in the areas of hardwood forest types in the East. [4] Given the higher carbon density of hardwoods, this latter shift is particularly critical. In the BAU case, the carbon stock falls because the hardwood proportion of inventory falls in the eastern regions. As the price of carbon rises, regional and national carbon flux levels rise. The declining trend in national carbon stocks (negative flux) is essentially eliminated at a carbon price of \$15. Comparing the \$45 case with BAU, total US forest carbon flux averages nearly 0.6 billion mt/year higher. This annual increase would offset roughly 10% of estimated US carbon emissions in 2007 (US EPA 2010), beyond that previously offset under BAU.

With significant options to expand the forestland base through afforestation, abso-

lute flux increments are higher in the East than in the West at all carbon prices. The largest regional expansion in afforested area occurs in the North. The regional time patterns of carbon stock changes in existing and afforested stands are illustrated in Figure 2. The most rapid sequestration response to carbon prices comes through changes in management of existing forest stands. Afforestation increments rise more gradually as plantations mature. The afforestation response differs markedly across regions. Between the \$15 and 45 CO₂e prices, afforestation's average 2010–2060 share of the total carbon increment ranges from 19 to 42% in the North, 14 to 21% in the South, 10 to 12% in the West, and 16 to 30% for the entire United States. The remaining carbon increments arise from changes in forest management on currently forested lands.

The afforestation component in the

North is highly sensitive to carbon price and expands dramatically at the \$45 level. Afforestation carbon increments also expand steadily through time in the North (Figure 2), reflecting relatively long forest rotations and continued enrollment of afforested land over the full projection. Carbon stock changes on existing forestlands in the North are overtaken by the changes on afforested land toward the end of the projections at CO₂e prices higher than \$30. In the South, in contrast, changes in management of existing forests provide a far larger portion of the total response to carbon prices. Under all CO₂e prices, the southern afforestation component rises to a peak and then declines (Figure 2). Southern landowners shift area into afforestation early in the projection and then return it to agriculture after one or two rotations. In the West, the pattern of afforestation carbon stocks is similar to the

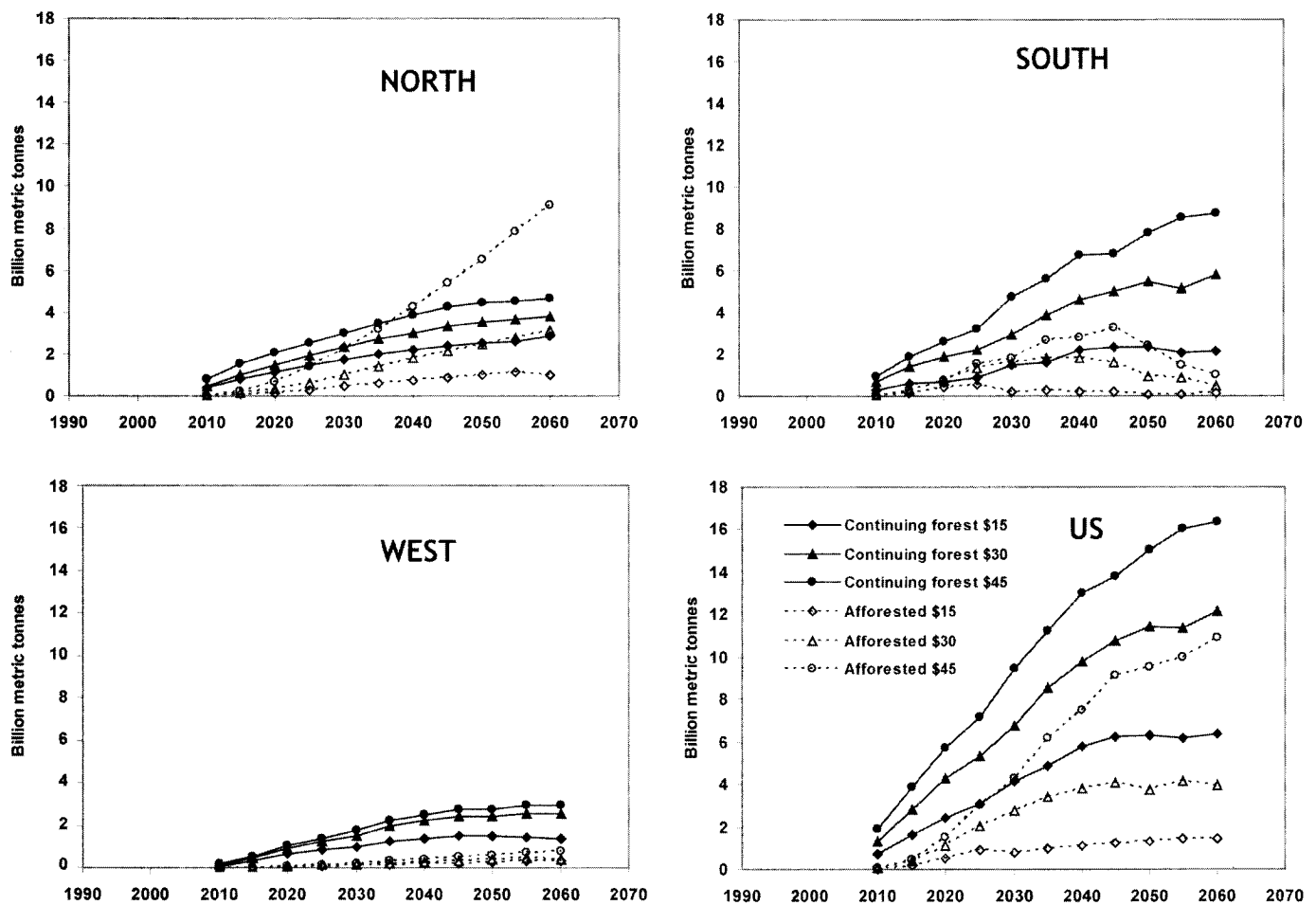


Figure 2. Change in forest carbon stocks from the BAU case for existing ("continuing") and afforested stands on private timberlands by region: \$15, 30, and 45 carbon (CO_2e) prices.

North, again with longer rotations. Carbon increments due to management changes in existing forests, however, far exceed the afforestation increments.

Afforestation, Forest Area, and Forest Type Change

Projections of private timberland area across the carbon price scenarios reflect the effects of competition for use of land with agriculture, including the effects of conversion costs and land productivity (see Figure 3). National-level private timberland area projections in the year 2060 range from 281 million ac under BAU to nearly 350 million ac with \$45 CO_2e prices. Losses to developed and other uses lead to a steady decline in US timberland area in the base (see comparable projections in Haynes et al. 2007 and Wear and Greis, 2002), it would require a price of \$30 or more to maintain the current US private timberland area. Moving from a CO_2e price of \$15–\$30 more than doubles projected afforested area, mostly in

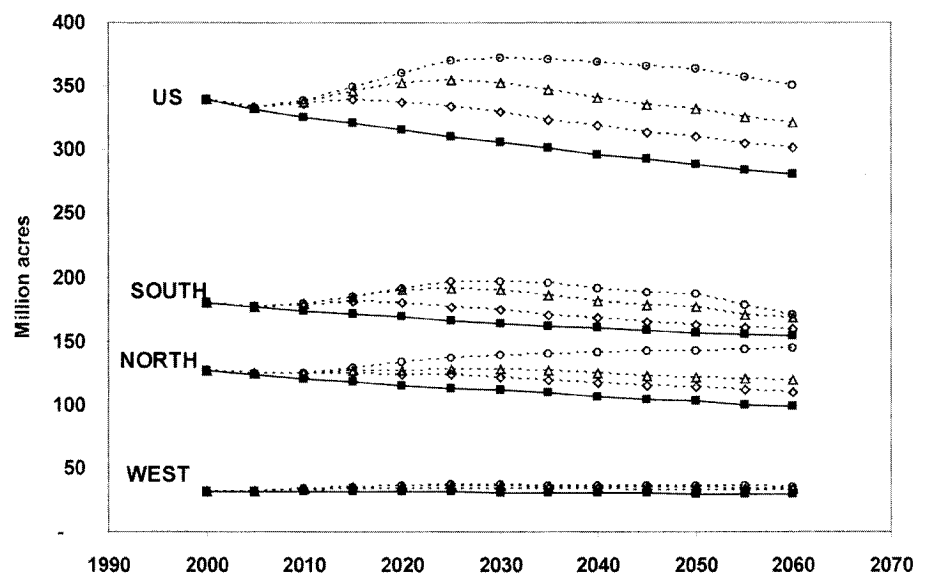


Figure 3. Private timberland area in the US by carbon (CO_2e) price scenario: ■, BAU; ◇, \$15/mt; △, \$30/mt; ○, \$45/mt.

the South and North. Historically, the forests of the eastern regions have experienced

more frequent shifts in use back and forth between agriculture and forest than has been

the case in the West. These remain the areas most responsive to carbon price changes in the projections. Smaller projected afforestation areas in the West reflect less private cropland and pastureland and fewer acres on the economic margin between the two uses. Afforested land in the South derives about equally from pasture and cropland. In the North, with proportionately more cropland acres, the source mix for cropland versus pastureland is in the ratio of roughly 4:1.

In the projections, agricultural land is afforested because expected incomes per acre under forest use rise above the expected returns per acre associated with continuing agricultural use. Increasing financial incentives to plant trees, where plantations store multiple tons of forest carbon per acre, would boost forest incomes in some cases well beyond land rental rates from agriculture. As an example, afforested cropland in mixed hardwood forest in the Corn Belt region is estimated to sequester approximately 60 mt of forest ecosystem carbon per acre by age 20 years (Birdsey 1996). A price of \$15/mt of CO₂ is equivalent to about \$55/mt of carbon. At this price the carbon payments from the hardwood stand would amount to \$3,300/ac as a lump sum at age 20 years. As an equal annual payment over the same 20-year period that would be equivalent to about \$111/ac per year (at a 4% real discount rate).

Deforestation to other land uses partially offsets the effects of afforestation and, in the case of deforestation for agricultural use, is sensitive to CO₂ price in our analysis. At a CO₂e price of \$45/mt, deforestation to agriculture over the next 30 years is projected to be about one-fourth of that in the BAU case. Similar to afforestation, shifts to agricultural use, when they occur, are heavily concentrated in the East, especially in the Corn Belt. Projected deforestation for developed uses is exogenous in our analysis and is projected to account for more than 35 million ac of diverted timberland cumulatively between 2010 and 2060 (Alig et al. 2010b).

The forest-agriculture land-use margin appears to be most sensitive to changes in carbon prices in the North. Consider the projected changes in total land-use shifts relative to the BAU case over the 50 years from 2010 to 2060. As carbon prices rise, more land in the North shifts from agriculture to forests than in other regions and the area deforested through shifts to agricultural production falls. In the South, more agricultural land shifts into forests as carbon price rises

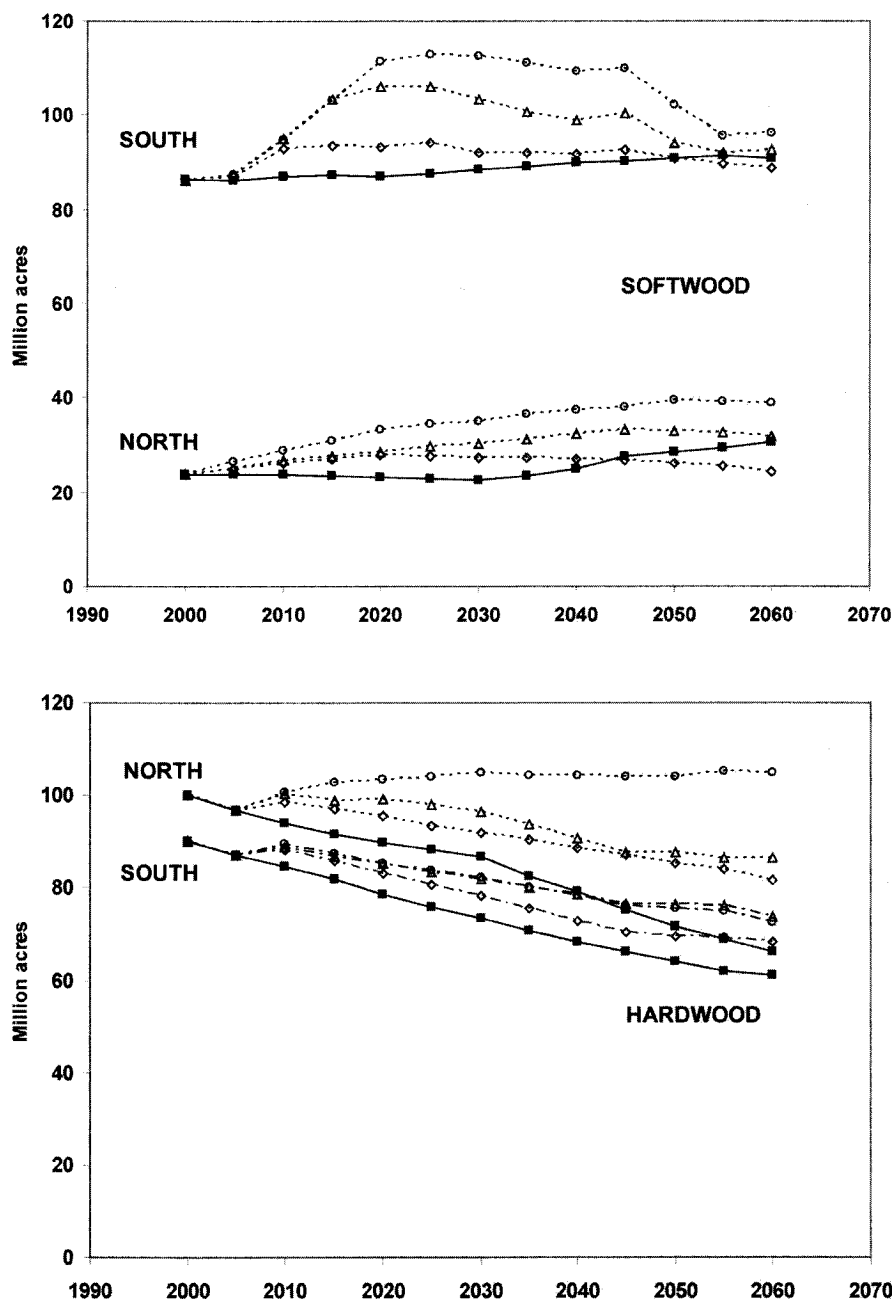


Figure 4. Private timberland area by broad forest type in the North and South by carbon (CO₂e) price scenario: ■, BAU; ◇, \$15/mt; △, \$30/mt; ○, \$45/mt.

but the area of forest shifting into agriculture also rises. This latter, countervailing, change in use is occasioned by rising commodity prices in agriculture. The net result is that forest area in the North rises much more between BAU and a \$45 C price than other regions. In the BAU case the net losses of forestland in the North come to about 7.8 million ac over the 2010–2060 period, and at a \$45 C price net forest area rises by 35.6 million ac. In the South, in contrast, BAU net forest area losses over the same period amount to some 5.3 million ac but at a \$45

C price the net forest gain rises to only 6.8 million ac.

There are two important threshold points in the projections for carbon price related to afforestation. At prices above \$15, the agricultural area shifting into forest cover becomes larger than the forest area shifting to agriculture. The second threshold is at a price of about \$30, where net afforestation exceeds the amount of land deforested to developed uses at the national level. This is the CO₂e price required to roughly maintain current private timberland area.

As illustrated in Figure 4, the BAU projection envisions a steady decline in the area of eastern hardwood forest types and stable or slightly rising areas of softwood types (consistent with projections in a study by Haynes et al. 2007). Hardwood types suffer the bulk of losses to nonforest uses. Responses to carbon offset sales vary by region in the East. In the North, significant afforestation allows both hardwood and softwood areas to expand, but the largest gains are clearly in hardwoods. Stabilization of northern hardwood types would require CO₂e prices close to \$30/mt. In the South, both softwood and hardwood areas expand for CO₂e prices up to \$15. At higher prices, further type changes are mostly concentrated in softwoods. Softwood areas gradually converge to BAU levels near the end of the projection, however, as afforested stands revert to agricultural use or are allowed to shift to development. In the West (not shown in Figure 4), areas of both softwoods and hardwoods expand due to afforestation at all carbon prices, with the largest change of about 3 million ac at a \$45 CO₂e price.

Forest Inventories and Timber Harvest

Future private growing stock inventories in the BAU case vary markedly by species and region over the period to 2060 (see Figure 5). Consistent with projections in the RPA Timber Assessment (Haynes et al. 2007) and the Southern Forest Resource Assessment (Wear and Greis 2002), hardwood inventories decline in both the North and the South. Forest management and land base adjustments under carbon prices lead to upward shifts in all regions and species groups. Growing stock inventories in the South are highly sensitive to changes in carbon price, with a projected 53% increase in hardwoods and a 46% increase in softwoods relative to the BAU case by 2060 at a CO₂e price of \$30. The South's pattern of responses to rising carbon prices also differs from other regions in that there are roughly equal or larger long-term inventory increases for each \$15 CO₂e price increment above BAU, compared with diminishing increments in other regions (see Figure 5).

Per acre timber volumes are also projected to increase on average relative to the BAU case under carbon pricing in the South and West. In the North, per acre volumes rise modestly for the \$15 and 30 CO₂e prices but decline slightly for the \$45 price. This latter result reflects the extensive acres of afforestation, and larger areas of younger

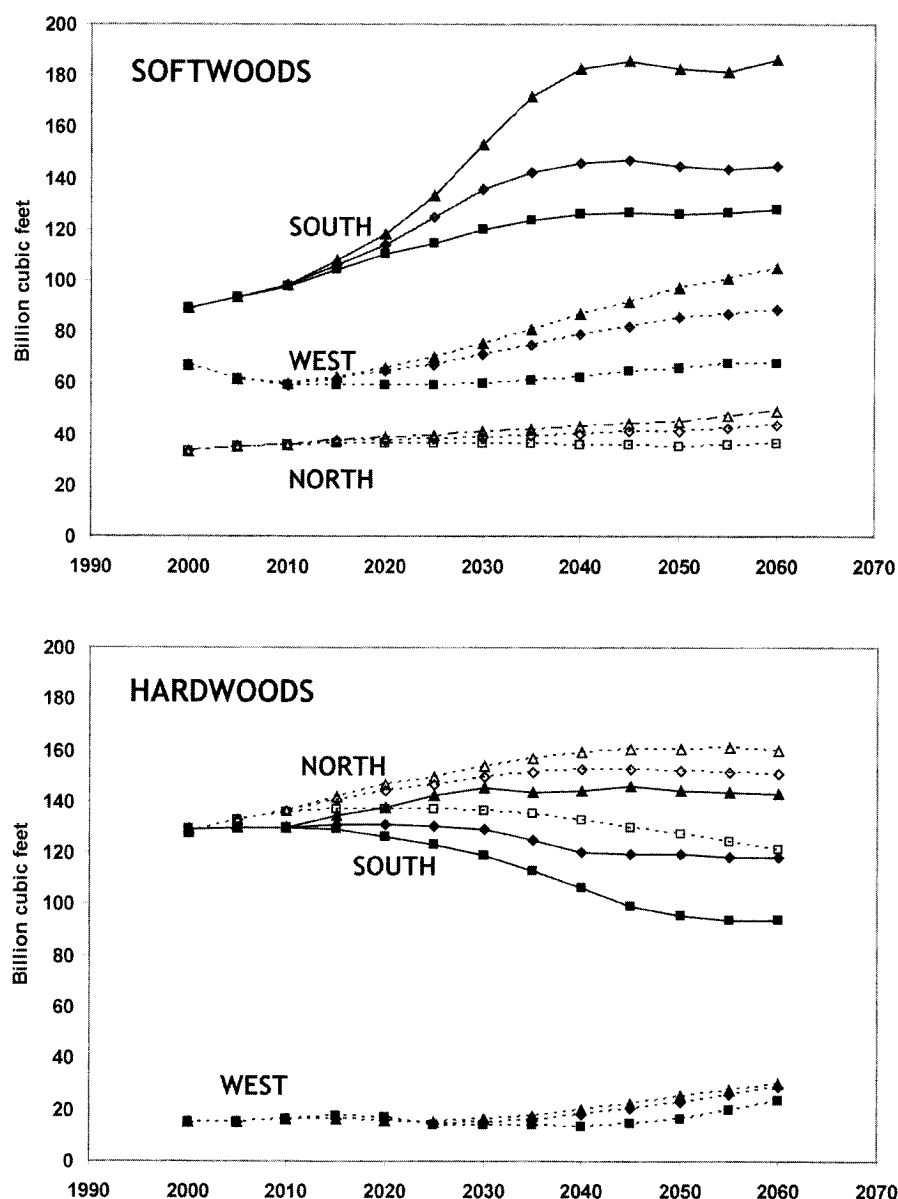


Figure 5. Private growing stock inventory by softwood and hardwood, region and carbon (CO₂e) price scenario: ■, BAU; ◇, \$15/mt; △, \$30/mt.

and lower volume per acre forest stands, projected for the North under the highest CO₂e price.

With CO₂e pricing, growing stock harvests are projected to decline relative to the BAU case, with larger reductions for higher carbon prices (see Figure 6, top frame). The largest timber harvest reductions occur in the near term, with harvest converging toward BAU levels in later decades. Nationally, hardwood harvest rates are projected to decline more than softwoods. Southern softwood is the only inventory element where harvest can be maintained near BAU levels while substantially increasing forest inventory and forest carbon storage under CO₂e

prices. In the North, hardwood harvest rates decline strongly in the near term but are projected to return to near the BAU case over time. In the West, softwood harvest volumes decline in all decades relative to the base. The relatively small amount of western hardwood harvest is generally unchanged under carbon pricing.

Changes in Forest Management

As carbon offset sales lead to increased growing stock inventories and reduced average timber harvests, the average age of stands in private forests would rise as well. When standing timber has value, owners extend rotations to realize the additional gains. We see

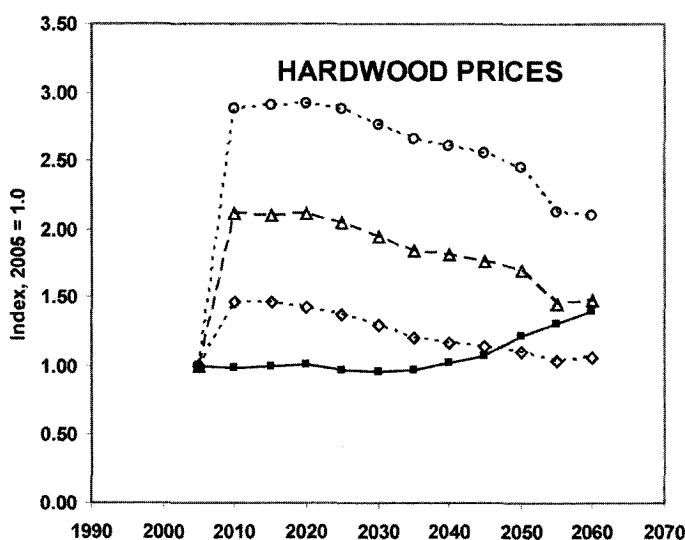
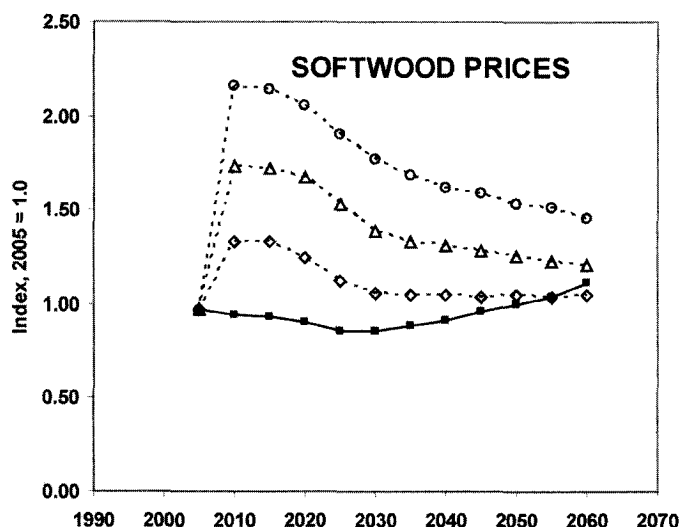
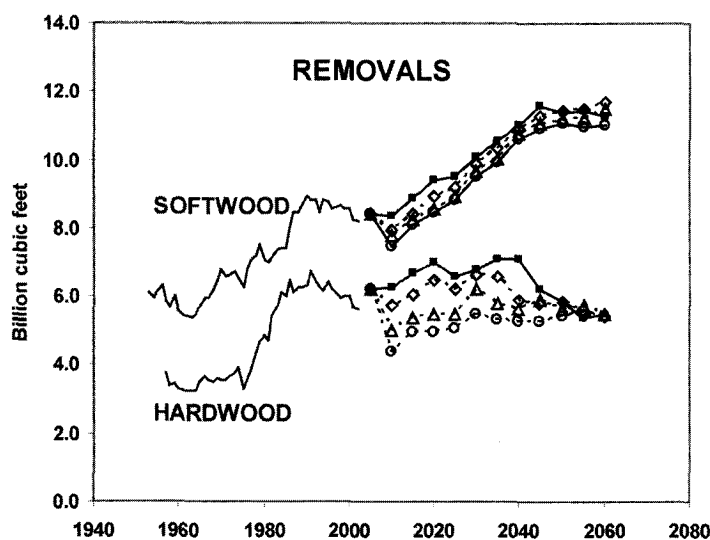


Figure 6. US private softwood and hardwood growing stock removals and indexes of softwood and hardwood delivered log prices under carbon (CO_2e) price scenarios: ■, BAU; ◇, \$15/mt; △, \$30/mt; ○, \$45/mt.

Table 1. Average age of private forest in years over the 2010–2060 projection.

	BAU	\$15	\$30	\$45
North	55	58	57	53
South	30	33	35	37
West	46	50	54	55

this impact in the tabulation of average forest ages by CO_2e price scenario in Table 1.

In the North, private forest age declines at higher carbon prices because of the large increment in young afforested stands in the inventory. This same, although less dramatic, effect damps the age increase in the South. In the West, changes in forest management, including the extension of rotation age, are the principal means for adjustment under carbon offset sales and average forest age rises by nearly a full decade between BAU and the \$45 CO_2e price scenario.

A second form of forest management adjustment is to change the mix of silvicultural regimes in ways that balance silvicultural costs with changes in prospective returns from traditional products and new returns from carbon sales. In our simulations, private timberland owners generally shift away from both the very lowest forest management intensities and the most intensive regimes, although there is some variation by region. In the West, e.g., the largest area reductions occur in simple plantations and in minimally tended natural, regeneration regimes, and the greatest gains are in naturally regenerated stands with early stocking control and plantations with thinnings. In the South, the largest change is a shift away from very low intensity management toward regimes with some stocking control, planting with subsequent competition treatment, and very short rotation regimes. In the North, again, the major change is a shift away from the least intensive regime into regimes with higher initial stocking.

Changes in Forest Products Markets

Although generating a new carbon payment revenue stream for forest landowners, the advent of carbon offset markets reduces the supply of timber for traditional forest products. This leads to higher log prices, reduced product output, higher product prices, and increased imports. Figure 6 (middle and lower panels) shows projections for US softwood and hardwood delivered sawlog prices. The price shifts are large, but

certainly not without ample precedent in past market cycles. For example, the average increase in US softwood sawlog price over the 2010–2060 period is some 51% under the \$30 CO₂e price, while harvest volume falls an average of 6% relative to BAU. Over time, price, domestic output, consumption, and imports all gradually converge to BAU levels. This reflects the gradual slowing of returns from offset sales as the private forest carbon stock rises at a decreasing rate over time. As a result, the value of an additional unit of timber harvest rises above its value when stored for an additional period, and owners raise harvest for traditional products to take advantage of higher prices in those markets.

Conclusions

Our results indicate that the largest part of increased forest carbon sequestration induced by a COSP on US private lands would come from changes in management of existing forests. Rotations would lengthen in all regions, although more in the West than elsewhere, and owners would shift away from both the most and the least intensive silvicultural regimes. The largest absolute gains from forest management change come from the South and North in our simulation. Unlike afforestation, carbon increments from forest management change can be large in the near term. This may be of value to the extent that rapid mitigation actions forestall climate change impacts more effectively than gradual ones. Despite its apparent potential, however, demonstration of additionality is most difficult for forest management change actions.

At our highest carbon (CO₂e) price, we find that afforestation could account for as much as 30% of average US incremental forest carbon sequestration over the next 50 years. The importance of afforestation at the regional and national levels rises sharply for CO₂e prices above \$30. Large forested areas are added in both the North and the South under all prices, although the North is particularly price sensitive and land remains afforested longer in that region. At a CO₂e price of \$30, the US timberland base would roughly stabilize, with afforestation offsetting both losses to developed uses and shifts to agriculture.

At prices above \$15, the South produces the largest carbon increments of any region solely from forest management change. At all prices, the North produces the most incremental carbon solely from affor-

estation and the most incremental carbon from the combination of afforestation and forest management change. Normalizing for the large disparities in timberland bases, however, the West produces more incremental carbon per acre of private timberland than either eastern region.

We estimate that a CO₂e price of \$15 would eliminate the regional and US forest carbon stock reductions anticipated in the BAU case. In the East, carbon stock growth would be accompanied by an increase in both the absolute and the relative size of the hardwood resource, with the largest hardwood response in the North. Timber inventories would grow in all regions as timber harvest falls. By far the largest inventory response would occur in the South at any carbon price. Timber harvest reductions lead to higher timber prices, reduced domestic output and consumption of traditional forest products, and growth in imports. This latter shift would represent an element of leakage, shifting carbon losses through timber harvesting to offshore and Canadian sources of product supply.

In interpreting these results it is important to keep in mind that our model projects only the market-based aspects of a response to marketable carbon offsets. Owners are assumed to adjust their forest management and afforestation decisions to optimize their returns from land holding. An array of past studies have suggested that this may overstate any observed response, because issues of uncertainty, lack of knowledge, concern for outcomes other than financial, and market imperfections can act to temper owners' actual reactions (e.g., Newell and Stavins 2000). As a consequence, we should view our findings as an indication of *potential* outcomes. One should also be mindful of the "ideal" nature of the offset policy structure we have used. Dropping any of the conditions assumed for our policy, such as use of a voluntary rather than mandatory program, would likely reduce the carbon increment response, again suggesting our results be viewed as potential outcomes or upper bounds.

Finally, we have given little attention to the on-the-ground details required to implement the offset sales program. This is significant in that the costs of administering an otherwise ideal plan may limit its effectiveness. We have also put aside other complexities in the current climate change and energy policy debate. For example, many states and the federal government are considering

(or have enacted) renewable electricity standards (RES). We have not considered the combined effects of an RES and carbon pricing—although the model does incorporate the existing federal Renewable Fuels Standard. A combined analysis of these joint policies would be useful to help policymakers identify how they might interact and modify each other's effects.

Endnotes

- [1] www.agecon2.tamu.edu/people/faculty/mccarl-bruce/FASOM.HTML; last accessed Sept. 21, 2010.
- [2] We do not model the highly specialized types of agricultural production that occur on these lands; hence, there is no basis for land value comparisons.
- [3] Detail for \$15 and 30/mt carbon prices is not shown for the West because of the small chart scale. Flux response to carbon price in the West is similar in time pattern to the South, with roughly steady expansion as price increases.
- [4] The terms "East" and "eastern" in this article refer to the combined North and South regions as distinct from the West.

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