

Public and Private Forest Ownership in the Context of Carbon Sequestration and Bioenergy Feedstock Production—a Briefing Paper on Existing Research and Research Needs

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Introduction

Forests continue to be recognized as having important roles in comprehensive policies and legislation to address climate change and increase renewable energy use. Much of the discussion around forests in the context of those topics has related to better understanding key physiological processes, developing projections of future markets for carbon or bioenergy, and examining the physical and economic outcomes of alternate policies. An important layer of complexity in considering the use of forests to address climate change and renewable energy development is forestland ownership. In the U.S., at the highest aggregation, forest ownership is divided into those lands owned by private individuals and entities and public lands. This briefing paper examines some of the existing literature to highlight considerations on how public and private forest ownership may influence the use of forests to address climate change and renewable energy development.

Forests constitute about 33 percent of the U.S. landscape and are common on both public and private land (Smith et al. 2009). In many places, forested landscapes are a mix of both public and private ownerships and forests in both ownerships provide society with a variety of goods and services, from recreation opportunities to timber for the production of wood products. Public and private forests in the U.S. are also connected through a shared history. The federal National Forest System of today, which comprises the greatest extent of public forestland, was initially developed from forest reserves removed from settlement lands. Later, many national forests in the East were formed from lands that reverted to public ownership because of private land tax delinquency. In other cases, such

as the “Oregon and California” lands, publicly-owned forest lands were given to private companies in efforts to spur infrastructure development.

Just as forest landscapes can be made up of a diverse mix of forest owners, the conditions of forests in different ownership groups can differ widely. As shown later, public ownership forests tend to have a greater number of trees in older age classes relative to private forests. In general, public forests, relative to private forests, are more frequently managed for non-consumptive uses such as recreation. However, public forests are managed by a variety of agencies at different levels of government with differing objectives and the variety of conditions on public forests reflect those differences. Private forests are owned by individuals and families, traditional vertically-integrated timber companies, and investment groups. Similar to public lands, private forests range from those intensively managed for timber production to forests where little if any active management occurs and objectives are primarily non-consumptive uses of forest resources.

Today, the interactions and linkages between public and private forests range from the administrative (e.g., land parcel trades) to ecological (e.g., management of invasive species) to economic (e.g., impacts to the forest products sector) to legal (e.g., reciprocal fire suppression agreements). With the consideration of climate change policies, there is interest in considering how public and private forestlands may differ and complement one another in response to policy. Unfortunately, few studies have examined the distinctions, linkages, and interactions between public and private forestland in the context of climate

change and climate change policy. The objectives of this research are to briefly describe the current areas and spatial patterns of public and private forestland ownership, to use existing knowledge to describe the differences and commonalities of public and private forestlands within the context of climate change, and to identify future research needs. Differences and commonalities of public and private forestlands are considered for four areas: carbon sequestration, bioenergy feedstock provisioning, timber harvest relationships, and decision-making.

Public and Private Forestland Ownership

The distribution and patterns of public and private forestland serve as a backdrop in considering the interaction of those ownerships in responding to climate change and energy policies. Forestland in the U.S. is split 56 to 44 percent private and public ownership (Butler 2009). Just less than half of publicly-owned forests are managed by the USDA Forest Service. Reflecting the settlement patterns of the U.S., forestlands in the East are most commonly private owned while public forestlands are most common in the West (fig. 1). The general perception, particularly for the West, is that high elevation forests are more commonly public owned, while lowland forests are often private owned. Similar elevation patterns can also occur in the East, particularly along the Appalachian Mountains. Relative to historic levels, forestlands in the East have suffered the greatest reductions in area, largely because of conversion to agriculture and development (Smith

et al. 2009). Looking forward, eastern forests are also projected to experience the greatest amounts of future development (Stein et al. 2005, White et al. 2009).

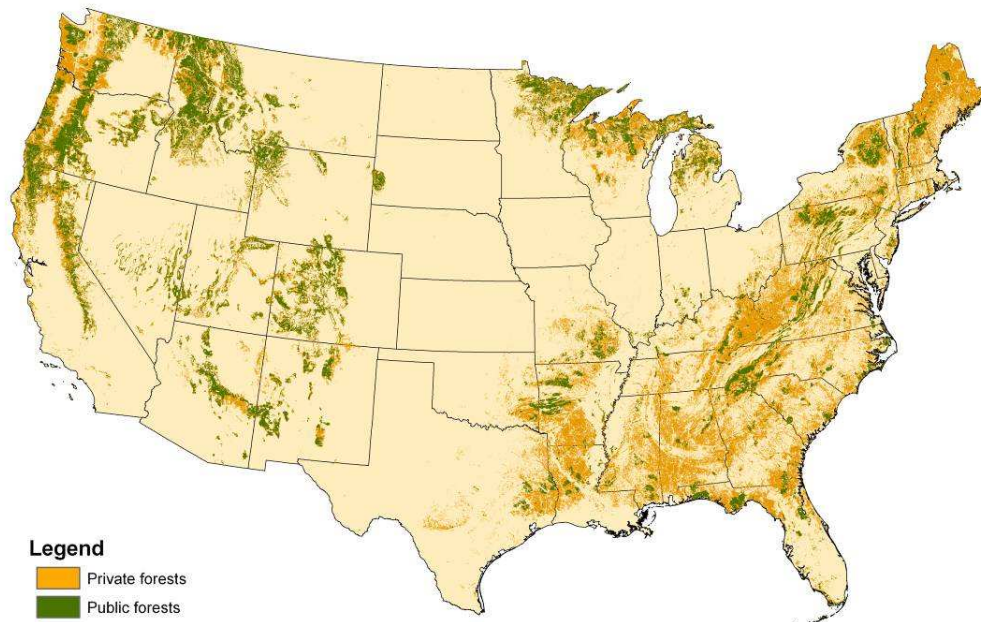


Figure 1—Public and private forestland in the United States. Data source: Theobald 2007).

The physical connections, via shared boundaries, between public and private forests are highlighted by considering two common local spatial arrangements of public and private forests. In many locales, public and private forests are held in fairly large blocks with a fairly clear delineation between the ownerships (fig. 2a). Conversely, in other areas, public and private forests are more intermingled, with forested ownerships contained in smaller contiguous blocks (fig. 2b). Because of east to west settlement of the U.S., the

former pattern is likely more common in the western U.S., while the latter is likely more common in the in East—although both patterns occur in each region. The first example arrangement suggests how public and private lands might be influenced differently by climate-related conditions that vary over space (e.g., temperature impacts that differ by elevation). In the first example, such a pattern of climate change could lead to disparate impacts by ownership group. The latter spatial arrangement is not as susceptible to disparate impacts to public and private owners from conditions that vary over space because the ownerships are intermingled. However, this intermingled arrangement highlights the degree to which forest management actions on one ownership may impact the other ownership and the extent to which the landscape provision of goods and services may be dependent on joint provisioning.

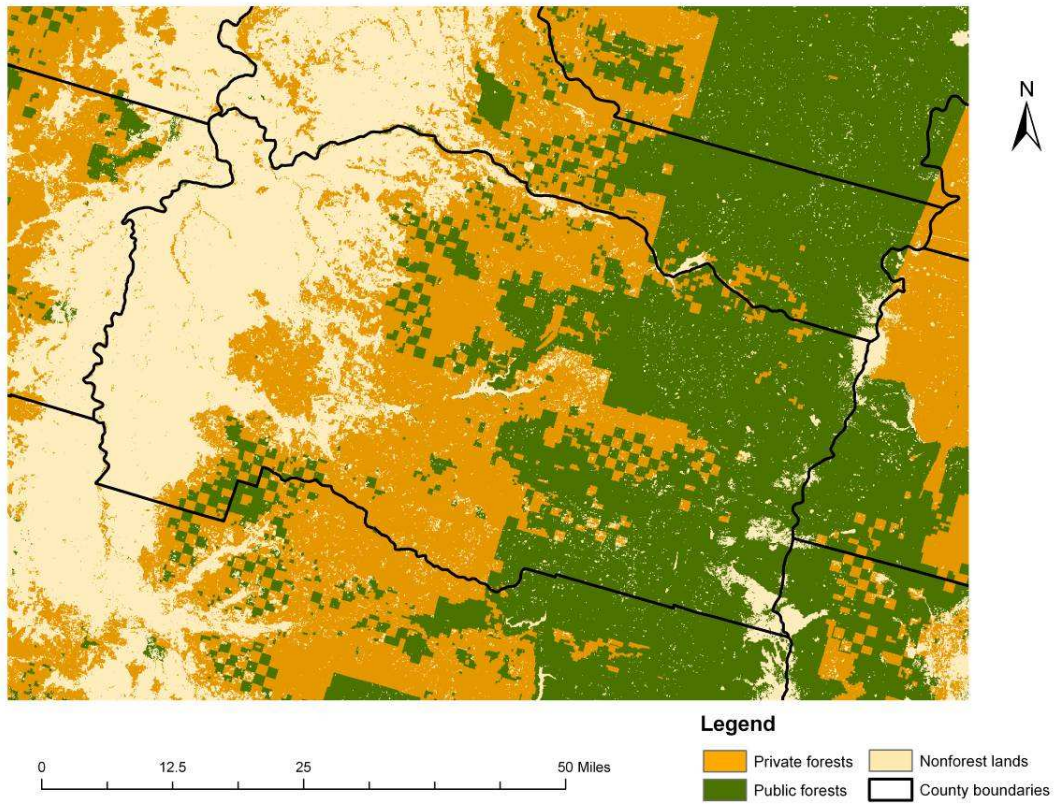


Fig 2a

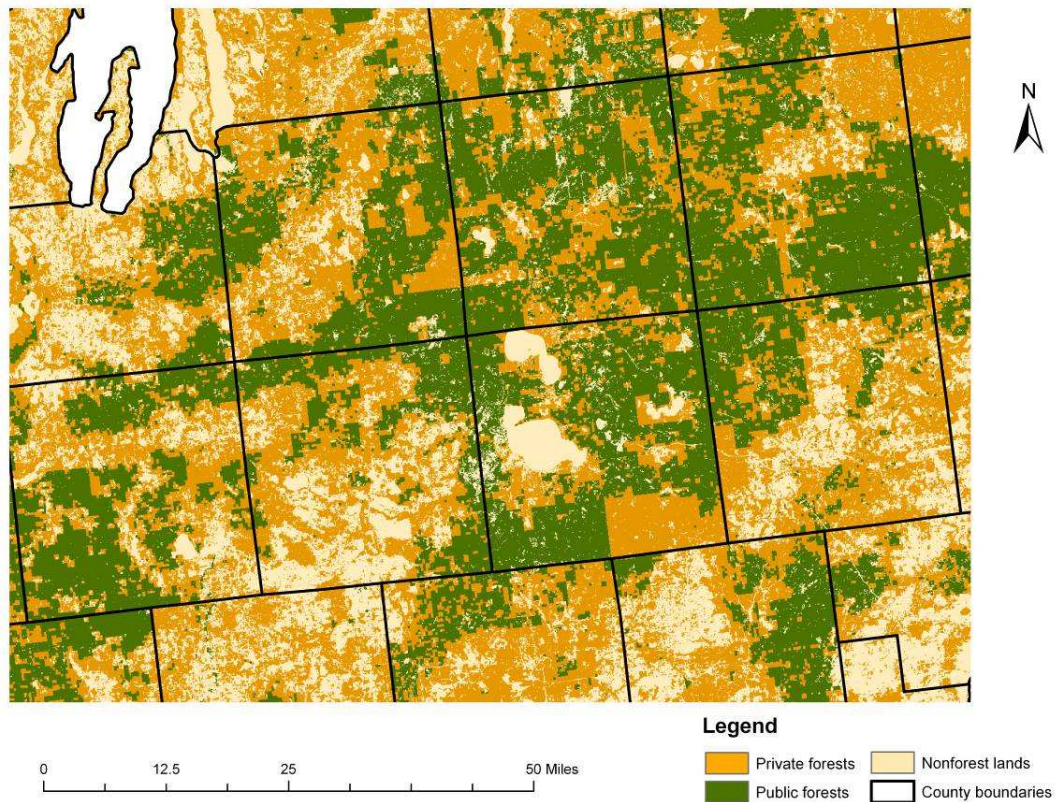


Fig 2b.

Figure 2—Two spatial patterns of U.S. public and private forestland ownership, a) Oregon and b) Michigan. Data source: Theobald (2007).

Carbon Sequestration

The sequestration of emitted carbon by forests has been discussed in the context of both reducing existing atmospheric carbon and within a program (cap and trade) to offset future carbon emissions produced by industry. In 2007, trees, agriculture soils, and other

carbon sinks offset about 15 percent of U.S. greenhouse gas emissions (US EPA 2009). In addition to the ability to use forests to sequester emitted carbon, there has also been interest in avoiding the release of carbon stored in forests (in plant matter and in forest soils), because of land use change, timber harvest, or disturbances such as fire. The release of carbon from individual forest stands reduces the flux of carbon sequestered to forests collectively (the net amount of carbon sequestered in a forest over a period) and if a release is severe enough, it can turn forests from carbon sinks to carbon sources. Because of the interest in carbon sequestration, the carbon fluxes and amount of carbon currently sequestered (i.e., carbon stocks) in public and private forests have been of interest.

Carbon flux

Based on recent data, U.S. forests sequester an estimated 595 teragrams (Tg) CO₂ equivalent of carbon (one teragram = 2.2 billion pounds) annually. Carbon sequestration in forests offset about 8 percent of total U.S. greenhouse gas emissions (7,150 Tg CO₂ equivalents) in 2007 (US EPA 2009). Over the period, 1990 to present, annual greenhouse gas emissions in the U.S. have been increasing. Over the same period, annual carbon flux to forests has also increased, being about 17 percent greater than the carbon flux estimated for 1990. Most of this increase in flux can be attributed to increases in carbon sequestered in above-ground biomass, as a result of increased area of forestland and faster growing forests (USDA 2008). Currently, public forest lands have an aggregate carbon flux that is about 50 percent greater than the aggregate carbon flux on private

forests (USDA 2008). Lower rates of flux on private forests likely result from greater land use conversions and disturbance (including timber harvest) on private forests relative to public forests.

Carbon stocks

The forests of the U.S. account for an estimated 150,000 Tg CO₂ equivalent of carbon stocks (USDA 2008). Slightly less than 40 percent of these stocks are associated with forest soils and the remainder is in live and dead plant material (USDA 2008). Forestland carbon stocks in the East (94,500 Tg CO₂ eq.) are about 70 percent greater than those in the West (55,300 Tg CO₂ eq.). In the eastern U.S., the northern states have slightly greater carbon stocks than the southern states (USDA 2008). At the state-level, carbon stocks in the live and dead biomass are greatest in California, Oregon, Washington, and Montana (fig. 3).

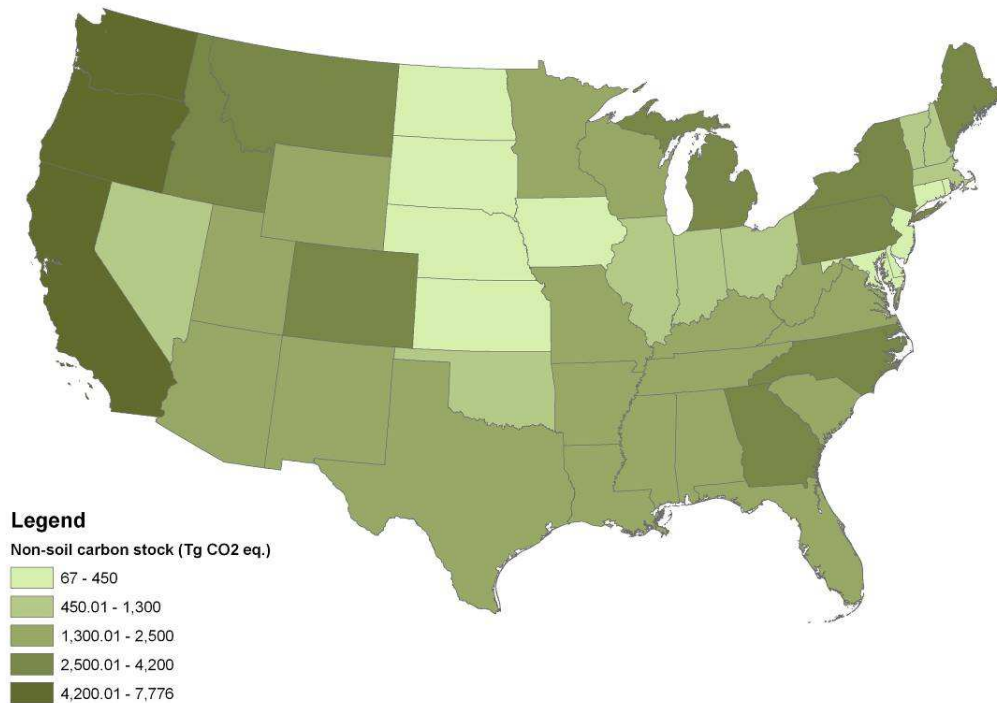


Figure 3—Estimated non-soil carbon stock on public and private forestland. Note that those states with greater forest area typically have greater aggregate carbon stocks. Data source: USDA 2008.

Currently, more forestland carbon is stored in private forests (87,710 Tg CO₂ equivalent) than in public forests (62,132 Tg CO₂) (USDA 2008). Following the spatial pattern of forest ownership, private forestland carbon stocks are greatest in the North and South regions (~ 36,000 Tg CO₂ equivalents in each region) (fig. 4). Public forestland carbon stocks are greatest in the Rocky Mountain and Pacific Coast regions. In the West, carbon stocks are greatest in public forests, mostly distributed in the older age classes. In the

East, private forests account for the majority of sequestered carbon with stocks primarily, especially in the South, in the younger age classes.

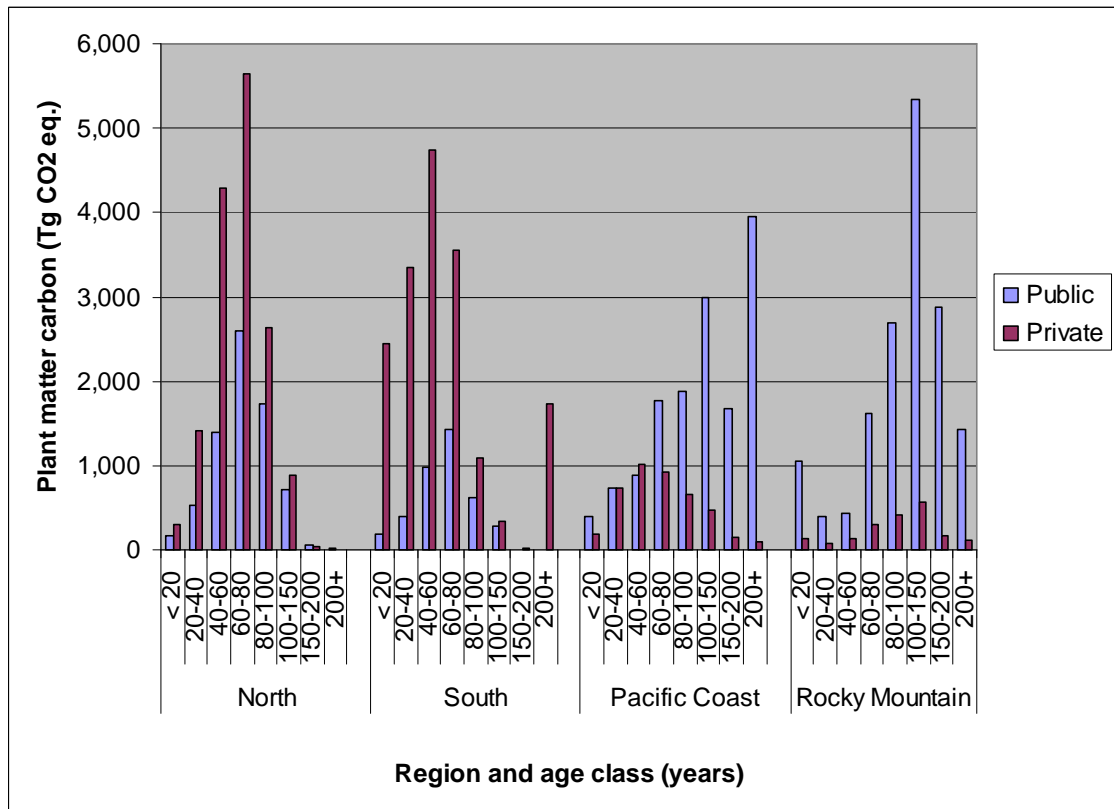


Figure 4—Distribution of forest carbon by region, ownership, and forest age class. Data source: USDA 2008.

From some of the most recent data available, carbon stocks in forest industry and non-Forest Service public ownerships have been declining slightly; stocks in federal ownership have increased slightly, and stocks in non-industrial private ownership have increased the most between 1987 and 1997 (Table 1). These changes likely reflect both forest condition changes and changes in forest ownership (Birdsey and Lewis 2003). For

forest industry lands, the greatest reductions were in the North. This likely reflects at least some divestiture of forest industry lands in that region in the early 1990s. The greatest gains for national forest land were in the North. Non-industrial private forest lands in the North and South experienced similar changes to each other.

Table 1—Carbon stock changes (percent) by ownership category and region, 1987 – 1997. Data source: Birdsey and Lewis 2003.

	North	South	West	Total
National forest	5.9	4.7	4.5	4.6
Other public	7.4	19.2	-4.3	-1.0
Forest industry	-11.6	3.6	-1.9	-2.4
Non-industrial private	7.1	6.5	5.2	6.4

Carbon is stored in the plant material of forests. When that plant material is harvested and converted to wood products (e.g., construction lumber) that carbon is then contained within the wood product (e.g., in newly constructed houses). This “fixed” carbon will remain in place until the wood products degrade, which often begins once they are discarded and subjected to decay or are burned. Carbon in wood products is not newly-sequestered carbon but should be included when accounting for forest carbon stocks and carbon flux. In 2005, carbon stocks in existing harvested wood products accounted for an estimated 8,700 Tg CO₂ equivalent of sequestered carbon. The carbon pool in wood products increases by approximately 103 Tg CO₂ equivalent of carbon per year, net of carbon stored in new wood products and carbon released from discarded wood products (USDA 2008). Little work has been completed to differentiate wood products carbon by

public or private sector forest source. However, it can be assumed that most of the hardwood products created in recent years are from timber harvested from private forests.

Projections of private carbon stock

Carbon stocks in forested ecosystems on private lands are projected to decline over the next several decades under a business as usual case (fig. 5). Declines in the amount of sequestered carbon over time trace primarily to projected deforestation. Forestlands in all private ownership types are subject to deforestation, but those lands owned by non-industrial private forest owners have historically experienced the greatest amounts of deforestation to agriculture and urban development (Alig et al. 2003). Because residential development typically includes some trees and perennial grasses in landscaping, deforestation for residential development has been assumed to have less negative consequences for carbon sequestration than agriculture land use (e.g., Cathcart et al. 2007). Under policies where carbon sequestered in trees is valued, forest ecosystem carbon stocks are projected to increase between the present and 2050. Carbon stocks are projected to increase through a combination of increased forest area (because of afforestation of agriculture land) and changes in forest management (e.g., lengthening harvest rotations and changing management intensities).

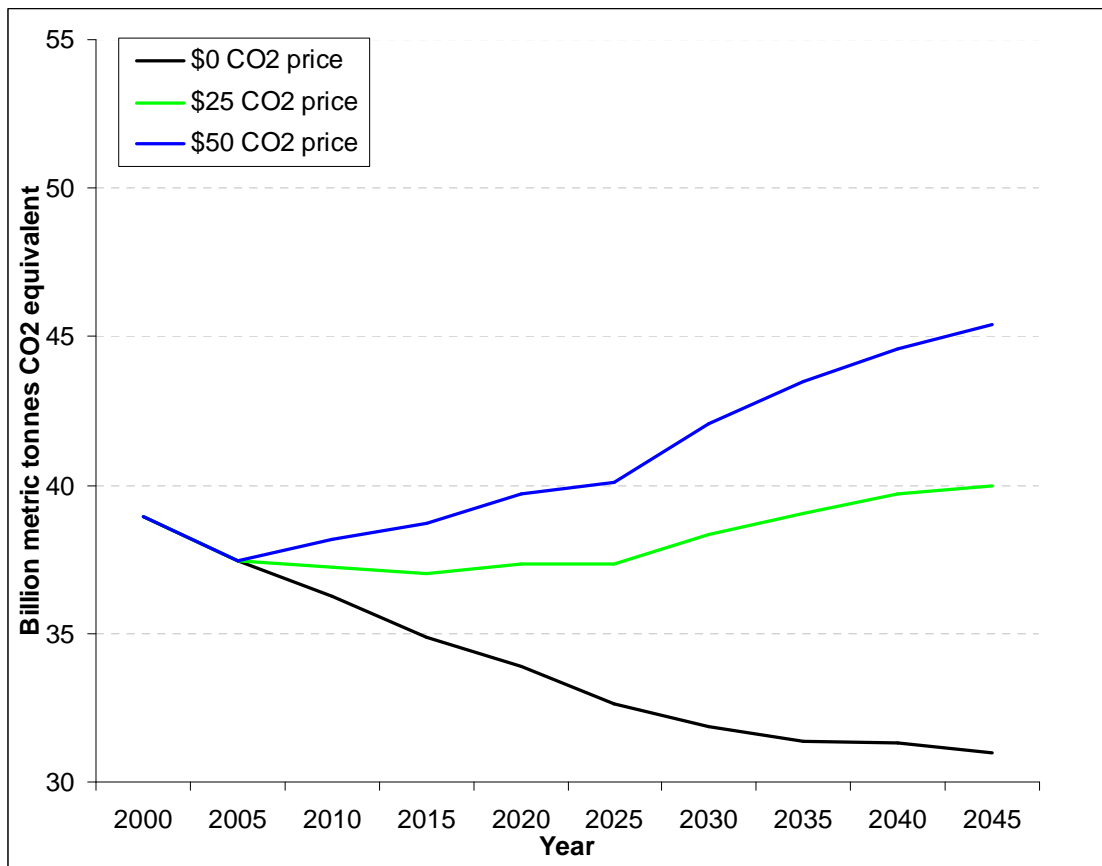


Figure 5—Projected carbon stocks in private forests under different carbon price scenarios. Adapted from Alig et al. 2010.

Projections of public carbon stock

Non-soil carbon stocks on public lands are projected to increase between 2000 and 2050 (Smith and Heath 2004). Carbon stocks on national forest land were projected to be greatest in the Rocky Mountain and Pacific Northwest Regions. Aggregate carbon stocks on public lands not managed by the USDA Forest Service were projected to be highest in the North Central and Northeast regions. The amount of carbon sequestered annually on

public lands is projected to slow slightly in the coming decades as public forests age and growth rates slow.

Depro et al. (2008) examined how public timber carbon sequestration might respond to changing timber harvest rates. Under business as usual, public forestlands in the Depro et al. study were projected to sequester, on average, 50 teragrams of carbon annually between 2010 and 2050. National forests accounted for more than 60 percent of the projected sequestration. Because of projected aging of public forests, rates of carbon sequestration were projected to decrease over time under all harvest scenarios considered. Reducing public land timber harvest hypothetically from approximately 15 billion cubic feet per decade to near zero increased carbon stored in public forests by 40 to 50 percent. Conversely, increasing annual public forest harvest levels by approximately 20 billion cubic feet per decade, to the harvest levels projected in the 1989 national timber assessment (Haynes 1990), decreased the amount of carbon sequestered in public forests by 50 to 80 percent per decade. Even accounting for carbon sequestered in wood products, under a high timber harvest scenario, public forests were projected to become carbon sources rather than carbon sinks. It should be noted that the Depro et al. (2008) analysis included baseline levels of public forest disturbance (e.g., wildfire, insects, and disease) in the growth and yield estimates. As a first generation study, the analysis of Depro et al. (2008) did not incorporate a private sector response to changes in public land timber harvest. Increased private harvesting could offset some of the additional carbon sequestered on public land under a no-public-harvest scenario. However, the vast

majority of timber production in the U.S. is already associated with private lands (Adams et al. 2006).

Bioenergy Feedstock Provisioning

Increased use of biomass for the production of renewable and low-carbon electricity and liquid fuels may be an outcome of comprehensive climate legislation and may be an outcome of carbon emissions regulation. Woody biomass for bioenergy production can be obtained from a number of feedstocks from public and private forest lands (see White 2010 for a description). The current Renewable Fuels Standard in the Energy Independence and Security Act of 2007 and draft language in some proposed legislation is typically interpreted as not recognizing, for renewable electricity credit or carbon offsets, biomass from public lands and biomass from forests of certain characteristics. That topic is outside the scope of this paper and interested readers can refer to WFLC (2009).

Woody biomass already comprises a significant component of current U.S. renewable energy consumption. Residues from timber mills are currently responsible for much of the bioenergy produced from biomass (see White 2010 for a discussion). In the future, under increased demand for woody biomass, material from timber harvest residues and hazardous fuel reduction on both public and private forests may be important feedstocks. These two feedstock sources are discussed in the next sections. Within these sections we

discuss the interactions between public and private timber harvest rates based on the existing literature. In addition to harvest residues and hazard fuel reduction material, use of biomass feedstocks from short-rotation woody crops and other residues and wastes (e.g., construction debris) will also likely increase; however, feedstocks from these sources are associated almost exclusively with private forests or private companies.

Timber harvest residues

In 2006, approximately 4.6 billion cubic feet of residues were generated from timber harvesting activities (Smith et al. 2009). This woody material, left onsite, translates into approximate 64 million dry tons of biomass material. Not all of this material would be technically or economically available for bioenergy production. In one study of harvest residue biomass, Gan and Smith (2006) estimated that about 36 million dry tons of residues on public and private lands would actually be available under likely market conditions—enough material to generate 67.5 terawatt hours (TWh) of electricity—about 1.7 percent of the electricity available to the grid in 2007 (US DOE 2010).

Based on current timber harvest patterns, private forest lands would likely supply a greater volume of harvest residues than public lands under increased bioenergy feedstock demand. In 2002, less than 10 percent of the timber harvested in the U.S. came from public lands (Adams et al. 2006). Aggregate public land timber harvests were greatest in the North Central region and areas in the states of Oregon and Washington west of the crest of the Cascade Mountains. Private timberland harvest was greatest in the South

Central region (although private harvest was also high in the Southeast, Northeast, and Pacific Northwest). The use of timber harvest residues for bioenergy feedstock would offer private landowners another revenue stream from harvests. However, the costs of handling and transporting biomass is high and feedstock values low, so revenues from this additional product stream are likely to be modest and in many cases not a driving factor in private forest management activity. For example, in Minnesota the additional value from using timber harvest residues for bioenergy in hybrid poplar stands harvested for pulp was estimated to be positive but minor (Schmidt 2006).

Slightly more residues are generated from hardwood harvest than softwood harvest (Smith et al. 2009) but much of the private timber harvested currently is from southern softwoods. The disparity in residue production between forest types could push residue usage into northern regions where hardwoods are more common. In the northern region, public land owned by states and other public entities is common and is often used for timber production (e.g., in the northern Great Lakes Region). Thus, public forestlands in the North not managed by the USDA Forest Service may be well positioned for the provision of timber harvest residues. Hardwood harvest in the northern region has declined relative to the early 1990s but is still greater than that of the 1970s (Adams et al. 2006).

There are some concerns about reduction in available site nutrients because of timber harvest residue removal, but the literature is not currently definitive (Carter et al. 2006, Walmsley et al. 2009). However, guidelines that are being developed in some states for

removing harvesting residue from logging sites (e.g., Minnesota FRC 2007) may help to mitigate any potential site productivity declines. If removal of harvest residues resulted in widespread private forest productivity declines, private land managers would need to increase management intensity (e.g., fertilizing, use of improved planting stock) to maintain the same levels of productivity. Decreased productivity and increased management intensity on private forest lands could result in greater pressure on public forestlands and nonindustrial private forests for provision of forest goods (e.g., timber) and services (e.g., wildlife habitat, clean water). This greater reliance on public lands could be complicated by the patchwork of public and private ownership, with the potential for difficulty in providing some services because of fragmented ownership (e.g., fig. 1b).

Hazard fuel reduction

Because of increased attention to large and costly wildland fires that cause damage to private property, there have been calls to implement widespread activities to reduce hazardous wildfire fuel loads on public and private lands. It is often suggested that small diameter hazard fuel material could be a key biomass feedstock for renewable energy production. Skog et al. (2006) quantified acres and volumes of material that could be removed from timberland in the western U.S. under several hazard fuel treatment scenarios. The amount of hazardous fuel volume on public lands far exceeds that on private lands. Under a representative scenario, the volume of biomass that could be removed from private lands was slightly less than $\frac{1}{2}$ the volume that could be removed

from public timberlands (Table 2). In general, the western states with the greatest forest areas have the greatest potential volumes of hazard material.

Table 2—Volume of material removed (million oven dry tons) under a simulated uneven-aged hazard fuel thinning regime by timberland ownership. Adapted from Skog et al. 2006.

State	Private	National forest	Other federal	State and local	Total
Arizona	2.0	6.9	0.0	0.0	8.9
California	50.0	65.1	0.6	1.7	117.4
Colorado	5.9	8.9	2.4	0.2	17.4
Idaho	13.2	35.7	3.5	5.3	57.7
Montana	14.8	38.2	3.2	2.6	58.9
Nevada	0.2	0.0	0.0	0.0	0.2
New Mexico	3.3	10.7	0.0	1.1	15.0
Oregon	16.3	28.3	8.4	2.1	55.1
South Dakota	0.0	1.1	0.0	0.0	1.1
Utah	1.6	3.9	0.3	1.1	6.9
Washington	12.8	18.4	1.1	6.4	38.8
<u>Wyoming</u>	<u>2.3</u>	<u>3.1</u>	<u>1.8</u>	<u>0.1</u>	<u>7.3</u>
Total	122.3	220.2	21.3	20.8	384.6

A significant challenge to widespread implementation of hazard fuel reduction is the cost of treatment. Skog et al. (2006) found that no treatment scenario was profitable if all of the removed material was sold only for bioenergy. If larger stems that were removed could be sold for pulpwood and sawtimber, some hazard fuel treatment scenarios resulted in positive net revenues. Subsidies of \$20/green ton of chips in addition to the ability to sell larger stems for pulpwood and sawtimber allowed more treatments to become economically feasible. In addition to affecting economic feasibility, Skog et al. (2006) also found that allowing harvesting of larger stems as part of hazard fuel reduction resulted in programs better able to meet targets for reducing the susceptibility of forest

stands to wildfire crowning and torching. It is unclear whether hazardous fuel removal programs on public lands would be required to cover costs. Where hazardous fuel reduction could be completed on private forests (many lands that likely do not have management plans), it seems unlikely such treatments would be implemented if costs could not be covered either by revenue from selling the material or via subsidy. As such, it is likely that public forests would be the focus of a widespread hazardous fuel reduction program and associated biomass for bioenergy. However, the ownership(s) on which hazard fuel reduction occurs will likely be most influenced by the specific focus (public or private lands) of any potential future hazardous fuel reduction program.

Public and private timber harvest linkages

In general, changes in timber harvest levels on public lands lead to countervailing changes in harvest on private lands (Adams et al. 1996). However, because only some of the material harvested under a hazard fuel reduction program would have value for traditional commercial timber production, the relationship between public land hazard fuel reduction programs and private forest harvest is not entirely clear. Building on the work reported in Skog et al. (2006), Ince et al. (2008) projected that widespread hazardous fuel treatment on western public lands would result in “significant displacement” of timber that would have been harvested from private and state-owned forest land. When there was hazard fuel treatment on public lands, timber production from private and state-owned lands was projected to be up to 30 percent less than baseline projections. Increased production of timber from a hazardous fuel reduction

program was also projected to reduce stumpage prices for western softwood timber by up to approximately 40 percent in 2015 relative to the baseline. Hazard reduction programs that removed stems of a variety of sizes yielded greater reductions in timber harvest and stumpage price than treatments that thinned only the smallest stems. Because public timber output increases and prices fall, a hazardous fuel reduction program was projected to decrease the welfare of timber producers but increase the welfare of wood product consumers. Research completed by others (Abt and Prestemon 2006, Keegan et al. 2004) is consistent with the findings of Ince et al. (2008).

Adams and Latta (2005) examined how a hypothetical federal forestland restoration program would influence the private forest sector in a rural community. In their study, small material harvested during the restoration was left onsite and larger material was sold for timber production. Logging contractors completed the treatments and were provided a variety of subsidies. The setting for the Adams and Latta (2005) study was eastern Oregon, where timber milling capacity and timber harvest levels have been in decline. In this setting, a hazard fuel reduction program increased the amount of timber harvested in the region with small reductions in timber prices, except in the most generous subsidy program. Implementation of a hazard fuel reduction program slowed the projected reduction in timber mill capacity within the region, although over the long-term capacity was projected to be nearly as low, or lower, than in the base case with no restoration program. Adams and Latta (2005) found both reductions and increases in the values of various types of private timberland owing to changes in the output of the region's industry. Timber producers (primarily private forest owners) suffered welfare

losses under the subsidy program but consumers (timber mills) gained welfare, as expected. Based on model output, timber producers were also found to change their management regimes when the fuel reduction program was in place—slightly reducing the share of acres in uneven-aged management and increasing the share of acres in even-aged management. Impacts on local mills and the forest sector from the fuel reduction program were sensitive to the type of subsidy program (including no subsidy) offered to logging contractors.

Goals and Decision-making

Differences in management goals and the process of decision making and implementation is a factor in how public and private forest owners interact with one another and respond to climate change. Within the confines of regulations, private landowners can manage their lands for goals they identify. These goals may be narrow or broad and focused on production of goods (e.g., timber) or non-consumptive uses (e.g., aesthetics). In theory, a sufficient number of private landowners are able to influence the activities on neighboring private landowners via the marketplace. In general, private landowners can influence public land policies only through the policy process. Looking forward, the general expectation is that private forestland owners have the ability to respond rapidly and optimally to changes in environmental conditions and new climate change policies and opportunities. For example, in response to changing forest growing conditions or changing policies, private landowners may adapt and choose to plant tree species better

suitable to the new conditions or to change management activities on existing forests (see White et al. 2010 for a discussion).

On the face, private lands would appear to be well positioned to respond quickly to climate change and the establishment of climate change policies. However, private forest landowners are currently experiencing widespread changes in ownership away from traditional timber industry and toward investment group ownership and small parcels owned by numerous private individuals. Pressure on forests for urbanization and residential development has been high and is projected to continue in the coming decades (Stein et al. 2005, Alig et al. 2003). The timber industry is also currently faced with decreased demand for wood and paper products. These factors may make it challenging for private forest owners to optimally respond to climate change and such things as carbon markets. For example, it may be very difficult to get private individual forest owners to increase carbon sequestration rates given that these owners have a diverse array of management goals and often have no management plan (Birch 1997).

Public forests, particularly federal forests, are typically managed for a broad suite of goals that involve a number of consumptive and non-consumptive uses. However, some public forests, such as those managed by local utilities, are managed primarily for a specific set of goals, such as the provision of water (e.g., Seattle Public Utilities 2008). Regardless, the goals for public forestlands and the management actions to achieve those goals are generally developed through processes involving numerous stakeholders. Reflecting the diversity of goals as well as the policy-making process, public forestlands

are perceived to be slow to respond to changing environmental and market conditions.

Generally, public land agencies influence management actions on private lands by providing information and technical assistance (e.g., the State and Private Forestry branch of the USDA Forest Service).

Federal public forests are less constrained than private forests by market conditions in adopting new management directions; although management decisions for many state-owned forest lands do explicitly incorporate market conditions. Some agencies, including many in the West, are responsible for providing revenue from forest resource uses such as timber harvest or grazing allotments to support state services. In addition to timber production, state and local forest agencies typically also provide a number of non-consumptive resource opportunities. Federal forest agencies have recently exhibited, through significant increases in fire and fuels management capacity, that the government is able to make fairly rapid changes in response to perceived threats in at least some cases. However, in many other cases, changes to federal land policy continue to be slow to occur.

Needed Future Research

The interactions between public and private forestlands in the context of climate change and climate change policies, as well as the provision of other ecosystem services, have not been well studied. However, these interactions are important in considering likely

future conditions and the potential impacts of new policies. Several opportunities for additional lines of research are presented below. We focus on the U.S. here, but there are also opportunities to gain insights by comparing forest resource conditions, carbon sequestration, institutional arrangements, forest ownership, and social issues across regions of the world (e.g., Alig et al. 2006).

Research is needed to better understand how public and private forestlands are likely to interact in the provision of feedstocks for bioenergy. This might help to identify opportunities to increase the joint provision of feedstocks from landscapes that have a mixture of public and private forests. Currently, much effort is being expended discussing what feedstocks should be eligible for renewable energy credit. Even with limited eligibility standards in place, there is need to better understand how increased demand for bioenergy feedstocks from private lands may influence the demands for goods and services obtained from public forestlands. Additionally, because the agriculture and forest sectors are linked and many of the feedstocks are substitutable, it is useful to consider both of those sectors in any analysis of bioenergy feedstocks (e.g., Alig et al. 2010). It is possible that increased demand for biomass from private forest harvest residues would have little impact on the management of private forests. In one existing national-level study of the forest sector (McCarl et al. 2000), logging residues from harvest of traditional forest products were never utilized for bioenergy, although the oil prices at the time were much lower than current ones. Research that quantifies how handling and transport costs differ between public and private forests would also be useful in identifying bioenergy feedstocks accessible at the lowest transportation cost.

How the forest sector responds to changes in public land timber harvest volume has been studied. However, relatively little is known about the threshold relationships that might exist between public land harvest volumes and the maintenance of adequate logging and milling infrastructure in local communities to support continued forest sector commercial activity (e.g., in eastern Oregon). In addition to traditional timber production, threshold relationships between local infrastructure and the provision of resources from public forest lands may also exist for items such as bioenergy feedstocks or other forest products. Additional research addressing these thresholds would be useful to identify potential unintended consequences from significant changes in public land management (e.g., a hypothetical halt of harvesting on public lands as modeled in Depro et al. 2008).

Private landowners, particularly individual forestland owners, are diverse. Numerous research projects have been undertaken to quantify the motivations and willingness of private individual landowners to participate in conservation programs. Research efforts to summarize this existing work as well as efforts to quantify revealed behavior in responding to conservation programs (e.g., afforestation of erodible agricultural land) would be useful to better gauge the expected response by private forestland owners to new climate change programs and associated new markets. This would help public forest agencies identify tools and information that would be useful to the private sector.

Afforestation is one of the most productive approaches to generating carbon offsets as part of any potential cap and trade program. One recent study estimates that forest area could increase by up to 25 percent, mostly owing to afforestation, when carbon is valued

(Alig et al. 2010). Research that examines the willingness of agriculture landowners (including those who lease agriculture land to agriculture operators) to plant trees for climate change programs will help to place these forest and agriculture sector modeling results into perspective and identify opportunities for technological transfer from public land agencies.

Additionality, leakage, and permanence are three concerns commonly mentioned when considering climate change policies. Leakage is likely the most germane when considering the interaction between public and private forests in the context of climate change and climate change policy. The concept of leakage relates to how offset activities in one location or market may result in countervailing emissions in another location or market (see Kline et al. 2009 for a discussion of leakage). Some existing forest sector research is pertinent. For example, Adams et al. (1996) have shown that reductions in public harvest rates are followed by increases in private harvest. Within the context of climate change and associated policies, leakage is important when considering the overall efficacy of comprehensive climate legislation. Leakage between public and private forests is probably of greatest importance when considering policies implemented on publicly-owned forests. However, leakage across regions is likely also of interest within the context of regional patterns of public and private land ownership.

Impacts on land values from climate change policies warrant further investigation. The form and extent of land value changes can depend on the type and size of the policy as well as whether taxes, subsidies, or other types of incentives are employed. For example,

subsidies to promote delays in timing of timber harvest can affect land values for some forest stands even without timber price reductions (Adams and Latta 2005). Given the relatively long-term nature of forest production, it would be useful to consider changes in value over time. These types of investigations would be facilitated by expanded and consistent data coverage for land values, including for forest land, across the United States.

Finally, partnerships in management of public and private forestlands could continue to increase in popularity in the coming decades (see National Association of State and Private Foresters 2009). Research that examines ways to maximize the joint provision of goods and services from public and private forests, in the context of climate change, will help inform ways to achieve more effective policy. Lessons learned from past efforts at joint public and private timberland management, such as sustained timber yield units in the West, could help inform current policy deliberations. Additionally, policy implementation can be improved by research that identifies effective public agency programs for private landowners and the most effective approaches to public/private partnerships.

Conclusions

The public and private forests of the U.S. have a long history of connection and interaction. As climate change progresses and comprehensive policies are developed,

consideration of public and private forest ownership will be important. Under baseline projections, carbon stocks are projected to decline on private forests but increase on public forests in the coming decades. When carbon is valued, private forest carbon is projected to increase because of afforestation and changes in forest management. Increases or reductions in public harvesting rates have been projected to lead to countervailing changes in public carbon stocks and flux relative to the baseline. Although research has confirmed that public and private forests are linked through the market by changes in timber harvest activity, additional research is needed to quantify projected responses in public and private forest management to alternate carbon market or policy formulations. Similar to the provision of bioenergy feedstocks, public lands could potentially participate in carbon markets, although public land participation is not certain. Whether carbon sequestered on public lands under a carbon market would be “additional” to carbon sequestered under “business as usual” needs to be considered, particularly on federal lands where current harvest rates are low.

Both private and public forest ownership groups have advantages in the provision of some bioenergy feedstocks. Because private lands account for most U.S. timber harvest, those forests have the greatest capacity to provide harvest residues for biomass. Current expectations are that revenues from the sale of timber harvest residues would be minor and would probably not change private forest management. There is some concern about site productivity declines because of harvest residue removal. If harvest residue usage on private industry lands lead to widespread reduction in productivity, additional pressure could be placed on public lands to increase the provision of some forest goods and

services. Public forests have the greatest volumes of material that could be treated as part of a hazard fuel reduction program. Research has projected that hazard fuel thinning programs would lead to a reduction in private timber harvest and stumpage values for softwoods. Research has consistently projected that logging contractors and timber mills benefit from hazard fuel reduction programs, although this benefit is projected to be short lived in at least one study. There is currently much discussion over whether feedstocks from public forests would qualify for renewable energy credit under existing and proposed legislation.

The general perception is that privately-owned forests are better positioned than public forests to respond rapidly to climate change and new climate change policies. However, private forests have gone through a change in traditional industry forest ownership and much of private forestland is owned by a diverse group of individual owners, many without management plans. Public forest agencies can help private forest owners respond optimally to climate change and new policies by providing information and technical assistance. Recent responses by the USDA Forest Service to increase wildland fire and fuels management capacity may indicate that public forests do in fact have the capacity to make rapid changes in management in response to climate change and new policies in some cases. Even if public forests are not the focus of new climate policies, public forest agencies will be integral in helping private forests respond by providing information and support as well as participating in public/private partnerships.

The literature examining linkages and interactions between public and private forests within the context of climate change and climate change policies is limited. There are a number of research opportunities to quantify the connections between public and private forests. It is probable that both private and public ownerships will play important roles in the mitigation of and adaptation to climate change by the forest sector. Improved knowledge regarding the linkages between the two ownership groups should improve the effectiveness of climate change policies and help resource planners identify likely future conditions.

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