Conventional Wisdoms of Woody Biomass Utilization on Federal Public Lands

Dennis R. Becker, Sarah M. McCaffrey, Dalia Abbas, Kathleen E. Halvorsen, Pamela Jakes, and Cassandra Moseley

ABSTRACT

The appeal of biomass utilization grows as the need for wildfire risk reduction, economic development, and renewable energy generation becomes more pressing. However, uncertainty exists regarding the factors necessary to stimulate use. We draw on in-depth interviews with local industry, agency, community, and tribal representatives from 10 study sites on federal public lands across the United States to examine persistent conventional wisdoms about what hinders biomass use. Findings indicate that the conventional wisdoms were reasonably accurate although the degree to which each impeded progress varied. Their interconnectedness also varied depending on local conditions. Supply guarantees, industry presence, transportation, and the value of the biomass were limiting factors to use, whereas agency budgets and staffing, environmental concerns, and partnerships more aggravated the problem than impeded progress. Understanding the scope and consistency of these accepted truths is important for ensuring that management efforts and ensuing policy effectively targets local use challenges.

Keywords: biomass utilization, problem framing, markets, policy

The appeal of woody biomass use grows as the need for wildfire risk reduction, economic development, and renewable energy generation becomes more pressing. In fact, biomass use in some form has been an aim of domestic energy policy since the 1973 Arab oil embargo and the subsequent Public Utility Regulatory Policies Act of 1978 (16 USC § 2601-2645). The goal of reducing dependence on foreign oil remains but the expected benefits of use have been amplified to include a variety of other critical forest management issues, greenhouse gas mitigation, and economic development objectives.

Numerous efforts have been implemented to increase biomass use anchored at the federal level by the National Fire Plan (Western Governors Association 2002) and passage of the Biomass Research and Development Act in 2000 (PL 106-224), a precursor to various funding authorities now in place. The states too have passed an array of legislation, most often directed at manufacturers (Becker et al., in press). Although progress has been made, the scope of on-the-ground accomplishments remains strikingly limited (Government Accountability Office [GAO] 2005). There are a number of possible reasons, but limited empirical knowledge impedes our understanding of the scope of challenges and, more importantly, the efficacy of efforts implemented to address those challenges.

We report on findings from a study funded by the Joint Fire Science Program examining the social dynamics of biomass use with particular attention to how a full range of factors—market, institutional, and community—contribute to or hinder project implementation. This information is used to investigate persistent conventional wisdoms about what limits biomass use. Because conventional wisdoms are widespread beliefs accepted as fact, they can influence the framing of problems and subsequent actions and, where that framing is inaccurate, it can impede progress. Understanding the scope and consistency of these accepted truths can illuminate the value of management efforts and ensuing policy.

Received November 6, 2009; accepted July 27, 2010.

Dennis R. Becker (drbecker@umn.edu) is assistant professor, Department of Forest Resources, University of Minnesota, 1530 Cleveland Avenue N, 115 Green Hall, St. Paul, MN 55108-6112. Sarah M. McCaffrey (smccaffrey@fs.fed.us) is research forester, US Forest Service, Northern Research Station, 1033 University Place, Suite 360, Evanston, IL 60201-3172. Dalia Abbas (abbasd@msu.edu) is visiting assistant professor, Department of Biosystems and Agricultural Engineering, Michigan State University, 203 Farrall Hall, East Lansing, MI 48824. Kathleen E. Halvorsen (kehalvor@mtu.edu) is professor, School of Forest Resources and Environmental Science, Michigan Technological University, Forestry and Wood Products Building, 1400 Townsend Dr., Houghton, MI 49931-1295. Pamela Jakes (pjackes@fs.fed.us) is research social scientist, US Forest Service, Northern Research Station, 1992 Folwell Ave., St. Paul, MN 55108. Cassandra Moseley (cmoseley@uoregon.edu) is director of the Ecosystem Workforce Program, University of Oregon, Institute for a Sustainable Environment, Eugene, OR 97403-5247.
This project was funded by the Joint Fire Sciences Program.

Existing Framing of Biomass Use Challenges

Many of the physical and economic challenges to woody biomass use are well documented with most attention paid to the consistency of feedstock supply (Lynch et al. 2000, GAO 2006a, Galik et al. 2009), harvest efficiency (Hartsough et al. 2001, Han et al. 2004, Rummer 2008), processing infrastructure (Wagner et al. 1998, Fight et al. 2004, Keegan et al. 2004), physical resource constraints of tree species (Erickson et al. 2000, Barbour et al. 2003), and market variation (Mason et al. 2006, Prestemon et al. 2008). Some information is known about the integration of these factors (Lowell et al. 2008). Less is known about how the broader suite of social factors hinders or enhances use (Hjerpe et al. 2009, Nielsen-Pincus and Moseley 2009) or the effects of different policy interventions (Aguilar and Garrett 2009, Becker et al., in press). These unknowns are inextricably linked to the success of the biomass enterprise and the ability to accomplish the broader objectives of wildfire risk reduction, economic development, and renewable energy development. Not considering them may mean adopting inaccurate or incomplete problem definitions in terms of how they manifest themselves in particular locales.

In terms of solutions, they are frequently framed in terms of technological advances (GAO 2006b, Shelly et al. 2006), market innovation (Malmsheimer et al. 2008, Galik et al. 2009), or the role of federal assistance (Barbour et al. 2008, GAO 2008, Becker et al. 2009b). Each is important where public lands are concerned, but integrating them into a coherent strategy is necessary, along with considering how factors such as variation in local resource conditions, ownership patterns, existing processing or transportation infrastructure, market consistency, national and state policy frameworks, and local socioeconomic attributes and capacities shape or impede success. To advance the framing of biomass use challenges and solutions, we collected interview data in 10 study sites with ongoing federal biomass use efforts. Local participants identified a range of factors hindering or facilitating their efforts, which were used to assess collective constraints and the pervasiveness of particular conventional wisdoms.

Study Methods

We chose the 10 study sites to represent distinct regions of the United States in which forest biomass harvesting was a strategy for fostering forest health, including reducing wildfire risk. We chose sites having a range of federal jurisdictions with various state and local government affiliations, forest types, and biomass processing capacity (Table 1). At each site, we interviewed key informants involved in biomass use. Interviewees were purposively sampled to represent a broad range of knowledge and perspectives (Miles and Huberman 1994). We asked local agency, business, and community stakeholders to recommend people involved in use efforts associated with US Forest Service, Bureau of Land Management, and tribal lands. The final list of participants included federal, state, tribal, and local government staff; loggers; manufacturers; community leaders; and environmentalists. Ultimately, we conducted interviews with 146 people in 10 study sites in 8 states.

Semistructured interviews were conducted with open-ended questions to elicit information and examples regarding the range of factors affecting biomass use, including questions on motivations for removal; strategies to enhanced use; and key market, institutional, and community factors affecting progress. Interviews lasted approximately 1 hour and were recorded and transcribed for consistency of analysis.

We used open and axial coding (Corbin and Strauss 2007) to identify salient themes about challenges and opportunities within and across study sites. A minimum of two investigators independently coded each interview. Using this approach, we were able to triangulate findings by identifying issues discussed by multiple interviewees (Yin 2003). An analysis of the transcribed interviews identified a number of conventional wisdoms about the barriers to biomass use. The final list of conventional wisdoms used in the analysis was systematically identified through an iterative process of reviewing the literature, public policy dialogue, and further consideration of the interview data. Eight conventional wisdoms were ultimately analyzed. Two team members then recoded each interview to identify perspectives about these conventional wisdoms, which allowed for an analysis of the applicability of the conventional wisdoms across each study site.

Importantly, we did not seek to prove or disprove particular conventional wisdoms, but rather to provide a deeper understanding of their accuracy, consistency, and relevance across diverse study sites. This allowed us to identify the nuances of local challenges, which when organized by the conventional wisdom themes illustrates their interdependency. The total number of responses per interview question was not analyzed because of the semistructured open-ended nature of questioning (Miles and Huberman 1994, Corbin and Strauss 2007). Also, our sample provided in-depth information on biomass challenges but the purposive selection of respondents makes it inappropriate to generalize these findings to the population of individuals within any one site or across federal biomass use efforts in the United States.

Findings

Guaranteed Supply

The first conventional wisdom assessed is that a guaranteed supply of biomass is needed before loggers and manufacturers will make capital investments in infrastructure and equipment. A growing body of literature quantifies the physical availability of biomass (Perlack et al. 2005, Galik et al. 2009) and it goes without saying that a business must be able to secure raw material to be successful. Our findings suggest that supply was in fact a critical element in each case, but the degree to which the lack of "guarantees" impeded development was varied. There was a strong perception among participants that securing supply was a challenge in places where federal land predominated and where consistency of supply was historically an issue. Depressed global markets, for instance, were a factor, but business owners reported that they were struggling where there was inconsistent supply.

> They will never bring any infrastructure back to the southwest until they can have a reliable supply and some guarantees. Because to bring somebody in who is going to invest $6–10 million to build a plant, they're not going to be able to get the financing and if they don't need the financing and have the capability to do it themselves, they're not going to invest their money there when they don't have a [financially sustainable supply. (Forest Industry, Southern New Mexico #33)

The focus on supply guarantees was especially salient in the western United States. In the Bitterroot Valley of Montana, for example, a local manufacturer captured the dynamics between supply from federal lands and willingness to invest.

> To put in a five-megawatt co-gen plant in the Bitterroot Valley, five megawatts means five tons per hour to produce those five megawatts, so you have five tons times 24

Table 1. Study site characteristics.

Study site	Primary communities	Dominant forest ownership	Physical setting	Key dynamics
Trinity Mountains, California	Hayfork, Redding, and Weaverville	Shasta-Trinity National Forests BLM Redding District Private industrial	Mixed elevation forests comprised of Pacific madrone, ponderosa pine, Douglas fir, and white oak	Popular recreation and tourism destination Declining industry High degree of forest management conflict
Southern Oregon	Ashland, Cave Junction, Grants Pass, Medford, and White City	Rogue River-Siskiyou National Forests BLM Medford District Private nonindustrial Private industrial	High elevation dominated by Douglas fir and cedar; lower elevations by ponderosa pine (east) and coastal species (west)	Popular recreation and tourism destination Abundant industry High degree of forest management conflict
Central Oregon	Bend, Madras, Prineville, Redmond, Sisters, and Warm Springs	Confederate Tribes of the Warm Springs Deschutes National Forest BLM Prineville District	Lodgepole and ponderosa pine in areas ranging from high elevation to arid deserts dominated by sage and juniper	Popular recreation and tourism destination Limited industry Cooperative efforts among multiple entities
Bitterroot Valley, Montana	Darby, Hamilton, Lolo, Missoula, and Stevensville	Bitterroot National Forest Private industrial	Ponderosa pine forests at lower elevations and conifer-lodgepole pine forests at high elevations	Extensive bark beetle mortality Declining industry High degree of forest management conflict
Northern Colorado Front Range	Boulder, Fort Collins, and Longmont	Arapahoe-Roosevelt National Forests Private nonindustrial	Ponderosa pine forests at lower elevations and conifer-lodgepole pine forests at high elevations	Mixed ownership in urban setting Limited industry Extensive bark beetle mortality
Southwest Colorado	-Cortez, Dolores, Durango, Ignacio, and Pagosa Springs	San Juan Public Lands (joint Forest Service-BLM administered) Southern Ute Nation Private nonindustrial	Low elevation dominated by ponderosa pine and pinyon-juniper, moving into aspen and Douglas fir at higher elevations	Limited industry Remote location Cooperative efforts among multiple entities
Southern New Mexico	Alamogordo, Capitan, Cloud Croft, Mescalero, and Ruidoso	Mescalero Apache Nation Lincoln National Forest	High plateau desert to subalpine forests with ponderosa pine, Douglas fir, spruce, aspen, and pinyon-juniper	Cooperative efforts among multiple entities Small but expanding industry
Northeast Minnesota	Ely, Duluth, Cloquet, Grand Marais, Hibbing, and Virginia	Superior National Forest Private nonindustrial Private industrial	North shore forests are dominated by aspen, fir, spruce, red pine, and mixed northern hardwoods	Popular recreation and tourism destination Abundant industry Established biomass harvest guidelines
Green Mountains, Vermont	Bristol, Burlington, Middlebury, Rutland, and Waterbury	Green Mountain National Forest Private nonindustrial	Mixed hardwood forests stretching across the state along rugged mountains and rolling valleys	Focus on “community-scaled” approaches Extensive biomass use Extensive private lands
Coastal South Carolina	Columbia, McClellanville, and Monck Corner	Francis Marion-Sumter National Forests Private industrial	Coastal plain dominated by loblolly pine, and longleaf pine in the uplands	Restoration emphasis for wildlife habitat Urban setting Abundant industry

BLM, Bureau of Land Management.

> hours means you need a 120 tons/day to run that five-megawatt co-gen, times 330 days … that requires 39,600 tons, which divided by 26, which is a normal five-axel log truck, requires 1,523 log trucks. Now if you take the entire timber sale program of the Bitterroot Forest, which means that's feathers and all from sawtimber down to the firewood that they sell, is under seven million feet. At 1,523 loads at an average of 5,000 board feet equivalent gross scale on that load, you'll require 7.6 million board feet just to feed or the equivalent in branches tops and everything else to feed a co-gen plant. There is no flipping way anybody other than the insane or the quixotic would invest a minimum of $10 million to put in a five-megawatt plant, with that little amount of wood fiber that is currently available [from federal lands] and with no knowledge if that is even a future dependable volume. (Manufacturing Industry, Bitterroot Valley Montana #132)

Participants sought to address supply challenges by focusing on two main tactics. First, they tried to minimize the volume of biomass needed from federal lands. This was accomplished by diversifying feedstock procurement or reducing the scale of operations. In the Trinity Mountains of California, e.g., participants had hoped to use local resources but inconsistent federal offerings forced businesses to source biomass from more distant nonfederal sources. In the Vermont Green Mountains, the focus on facility heating required small amounts of biomass in dispersed locations and even though located in proximity to the Green Mountain National Forest, almost all biomass was procured from nonpublic sources, much of it from outside the region, including Canada.

Second, participants sought to address supply challenges through contract "guarantees," particularly the use of the stewardship contracting authority given to the Bureau of Land Management and the US Forest Service in 2003 (PL 108-7). This authority gave the agencies the ability to apply the value of timber as an offset against the cost of services received, effectively allowing for both buying and selling in the same contract (Pinchot Institute for Conservation 2008). It also provides contractors a guaranteed supply of biomass for a set period of time that they can use to leverage loans for additional investment.

There was a high level of interest in stewardship contracting but we found limited evidence of it effectively fostering utilization. This was in part because the process was relatively new, but also perhaps because, in practice, shorter-term contracts of less than 5 years were the norm, which could impede large investments. Agency staff generally viewed short-term stewardship contracts as being more feasible than long-term contracts because they required less upfront funding, the complexity of the bidding process was reduced, and more contracts could be offered within an area thus creating more competition and ultimately allowing more businesses to participate. Some within the forest products industry were also skeptical of long-term contracts, especially where little or no timber value existed to offset biomass removal costs.

> [Stewardship contracting is] a great concept and we're certainly in favor of it. We see the potential of having some projects go forward, but until the process is taken care of whereby commercial products can be removed on a large scale, a stewardship contract for one isolated area isn't going to produce enough on a consistent basis over a long period of time, which is what you need for infrastructure. (Forest Industry, Trinity Mountains California #1)

Coastal South Carolina was one exception where long-term stewardship contracts were being used to restore wildlife habitat and had as a major component biomass removal. Other long-term contracts in the Shasta-Trinity National Forest and Central Oregon focused on nonsupply-related factors such as fostering collaborative planning. Subsequent to our interviews, additional long-term stewardship contracts have been established in our study sites and in other locations throughout the country.

Lack of Industry Infrastructure

The conventional wisdom is that biomass use is difficult in areas where there is no existing forest products industry or the industry is severely diminished. Our findings suggest that this was largely true. The development or expansion of biomass use was reported by participants to be easier where there was a viable wood products industry. Most notably, we found evidence in multiple cases of mutual dependence and market integration between users of biomass and sawlogs. Companies using the lower-value biomass reported needing the residuals of timber harvesting activities to be financially viable, and cogeneration producers often preferred the low-cost sawmill wastes generated from primary wood products manufacturing. Without the integration of markets and processers, biomass use was largely absent as a stand-alone enterprise. In fact, biomass removal without integration was thought to actually increase costs in some cases. Land managers who required biomass removal as part of fuels treatments, e.g., reported paying more by way of service contracts than if they had not required removal or instead used mastication (mechanically pulverizing the material) as a means to reduce fuel loads. Loggers similarly reported higher costs for the additional equipment needed to complete the required work and with uncertain market return for the biomass removed.

The capacity of existing industry was also part of the infrastructure equation. In places that had lost industrial capacity, the remaining infrastructure was frequently geared toward large-diameter trees. Participants found it difficult to solicit businesses with the appropriate equipment and skills to complement their resource needs, including the ability to transition to processing technologies that could efficiently use small-diameter trees. Forest restoration and wildfire risk reduction treatments generally require different harvesting equipment than used for large log operations, which precluded some loggers from making additional investments. It also precluded some manufacturers from adding biomass to their product lines.

> A lot of these guys up there are trying to do thinning of small diameter trees with logging equipment that's built for large log logging and it's just inefficient, but to upgrade to the latest equipment that can do small diameter thinning very efficiently costs a lot of money. (Community Partner, Central Oregon #66)

The capacity of the existing workforce was also a concern in places like Vermont, Colorado, California, and New Mexico. With the decline of timber markets and the closing of mills, participants reported a loss of trained workers who, as a result, moved on to other industries. Remaining workers were frequently undertrained or aging. Some participants saw this as an opportunity to rebuild workforce capacity better suited to the needs of the biomass industry, but overall it was viewed as a constraint.

Transportation Costs

A review of the empirical research suggests that transportation is a key cost factor in biomass use (Becker et al. 2009a, Fight et al. 2004, Han et al. 2004) and it was discussed in several of our interviews. We therefore assessed the conventional wisdom that use is financially difficult where transport distances exceed certain thresholds or when site access is remote or difficult. Participants

confirmed that it was clearly an issue in all cases, but not always a primary limiting factor. In most cases, either the distance to processing facilities or the difficult logging access was a limiting factor, but generally not both. Distance to processing facilities was closely linked to the level of existing infrastructure. Sawmill closings, e.g., resulted in increased distances to remaining mills by as much as 150 mi or more one way. Where the mix of tree species or quality of wood was suboptimal, the value of biomass was insufficient to justify these long transport distances. Products such as bioenergy and landscaping materials having small profit margins were particularly susceptible, which meant that only high-value material was financially viable to transport.

> As we've lost infrastructure, it's created problems in terms of transportation because for many projects, it's so far to the nearest mill. Even though there might be usable sawlogs from the project, it's not feasible or cost-effective to transport them. (State Agency, Northern Colorado Front Range #28)

In other cases, access was the main issue, which was a function of road quality, terrain, or access through private property. In places such as Southern Oregon, Montana, Vermont, and Northern Colorado, the forest road infrastructure was either seriously degraded or unable to accommodate harvesting and hauling equipment. Poor site access significantly increased transport time and/or prevented fuel treatments where road costs exceeded the value of the material removed.

> We brought a fellow out on a "show-me" trip last summer, and he just said basically, "Your road system is awful. Your ground is steep, your ground is rocky, and your road system is awful. You've got plenty of material, yes I see it, but how can I get it?" (Federal Agency, Northern Colorado Front Range #19)

Tactics to overcome transportation costs were to establish processing facilities closer to resources, pursue higher value-added products, or in the case of Oregon, enacted an income tax credit through which contractors could qualify for a $10 per green ton transportation subsidy (Oregon Renewable Fuels Standards of 2007, HB 2210). However, Oregon was alone in this approach. Participants more commonly discussed the need for appropriately scaled processing or "community scaled" as it was called in some places, which attempted to optimize the size of a facility with the volume of biomass sustainably available within an economically defined region. The size of the region and distance traveled are in turn functions of the value of the biomass removed.

> What has really helped us out is from an efficiency standpoint, is having facilities like [the paper company] nearby that makes it efficient both from a transportation standpoint and from a logging efficiency standpoint. Having a facility that close, it can use material from a biomass thinning, has to be the most important step of the process. (Federal Agency, Coastal South Carolina #50)

Value of Biomass

The conventional wisdom is that woody biomass is low-value material and that the cost of removal generally exceeds market prices. Participants confirmed this in most, but not all, cases. In places like Vermont, where fuel oil is commonly used for home heating, the value of biomass was less predictably low. However, in most cases, those interviewed focused on how to best dispose of the "waste" generated from timber harvesting and fuels reduction activities. This was especially salient in the interior and southwest United States where forests were dominated by ponderosa pine and other commercially inferior species. The cascading effects of poor physical qualities on market return created disincentives to invest in harvesting and manufacturing infrastructure.

> Contiguous forest lands, larger diameter trees, more valuable species mix, higher-grade trees converted to higher-grade logs, converted to higher-grade lumber, creating higher average selling prices. Those are all the negatives here … the trees are short, high taper, limby as hell, hard to find a straight one, and not a real good species mix. (Tribal, Southern New Mexico #34)

In response, participants identified several strategies including focusing on smaller, local markets. Financing and procurement were thought to be easier and less risky with smaller processing facilities, especially where biomass use was a relatively new or incipient activity. Another strategy was to consider biomass in the overall market framework in which a diverse and integrated sawlog market could offset low-valued biomass. Finally, participants talked about the need for market intervention to artificially increase the demand for biomass products, particularly where biomass removal provided a public benefit such as wildlife risk reduction.

> I doubt there is an instance where anyone is doing anything with biomass in a federal lands community or county where they have not accessed countless grants, federal grants, state grants, otherwise, to help them support their effort. It does not happen. (Community Partner, Trinity Mountains California #7)

Scale of the Wildfire/Forest Health Problem

The scale of processing and the scale of the problem were frequently discussed in our interviews but have not been well addressed in the literature. We therefore assessed the conventional wisdom that the magnitude of the wildfire and forest health problem was so large that equally scaled industrial efforts were needed. A number of participants argued that, indeed, large-scale processing was necessary to address the magnitude of problems, but also to maximize production efficiency and returns on investment, which were critical when dealing with small profit margins.

> I think we need a lot more industrial players to get involved to really set some of those markets. I mean, the Fuels for Schools projects are wonderful, Darby and Eureka. But you know, they're taking, you know, maybe 300-acres a year and you have enough material to run that facility. (State Agency, Bitterroot Valley Montana #138)

Interestingly, we found that few large-scale facilities had been built to address wildfire and forest health concerns. Successful use efforts that participants described were primarily geared toward supplying smaller amounts of biomass to small-scale facilities for electricity generation, firewood, animal bedding, or commercial heating. These were seen as more feasible than large processing facilities because the smaller projects enabled participants to overcome their dependency on federal biomass supplies, locate in proximity to resources thus reducing transport distances, and were more likely to be compatible with local forest health goals. The prospect of large facilities frequently raised concerns about ecological and economic sustainability.

> People are looking for that one big project, but really you can achieve some of the same ends, create viable markets that help get forest restoration done by focusing on small businesses. The post and pole business that utilizes 10,000 tons a year, the animal bedding company that is going to use 15,000 tons a year, and those sort of incremental additions to the local markets are sometimes easier to develop and less threatening to both the agencies and the environmentalists. (Community Partner, Central Oregon #66)

A corollary to this conventional wisdom is that the revenue generated from use

can offset fuels reduction costs, which would in turn allow more acres to be treated. We found little evidence that additional acres were treated because of cost savings. In fact, where there was a lack of markets, site access was difficult, or the resource was of poor quality, biomass removal and subsequent utilization was more costly than simply treating the material on site through mastication or pile burning. In only a few sites, such as in South Carolina where markets existed in proximity to fuel treatments, did it offset treatment costs.

> [The cost of mastication averaged $402 per acre], and the cost of acres treated where the wood was removed was running anywhere from $600 to $1,000 or more per acre. So unless you have enough value in the wood removed to offset that differential, the wood will stay on site. (State Agency, Northern Colorado Front Range #28)

Collaboration to Accomplish Utilization

The role of collaboration in forest and wildland fire management is often studied (Sturtevant et al. 2005) but its role vis-à-vis biomass use is less certain. We therefore assessed the conventional wisdom that the complexity of the problem meant that for utilization projects to be successful they must be developed and implemented through a collaborative process. Participants frequently identified the need for inclusive dialogue and partnering with local organizations and industries, but they did not generally think that consensus or formal collaboration was a necessary condition. Rather, relationships that ranged from formal to less-structured processes were discussed with the level of interaction depending on the type of project, mix of ownerships, and environmental impediments present. The more complex the situation, e.g., the more critical the need for structured collaboration. Furthermore, formal processes often focused on fire hazard reduction or on forest health, rather than directly on biomass use. This in turn laid the groundwork for successful use by building support for the benefits within an agreed on framework of forest management.

Although the term "collaboration" was rarely used, participants frequently identified all but the last of the six associated benefits (Sturtevant et al. 2005): (1) improved or new relationships and an understanding and support for work, (2) work accomplished on the ground, (3) working across boundaries, (4) improved effectiveness and efficiency, (5) opportunities for leveraging resources and enhancing institutional capacity, and (6) improved or increased job satisfaction. Participants most often talked about how efforts to work together resulted in new relationships and improved understanding and support for biomass removal. These relationships helped build trust among groups and industries and between communities and land-management agencies.

> Well, one thing is the Forest Service can't do it alone. We just don't have the expertise. So you need to get the state folks involved. You need to get the county folks involved. You know, it has to be a partnership. And you need to get the industry folks involved, so that, you know it's a joint effort in making it happen. (Federal Agency, Northern Colorado Front Range #18)

Despite widespread recognition of the need for cooperation, participants frequently also acknowledged that such processes were not simple and required significant effort to initiate and maintain. They also stressed the need to focus on outputs to keep the process moving and to not get bogged down.

Delays Caused by Environmental Concerns

The conventional wisdom is that the suite of environmental concerns related to federal forest planning creates an administrative burden that makes it difficult to implement biomass projects in an efficient or timely manner. Those concerns relate both to the effect of appeals and litigation and to the length of the environmental review process. Interestingly, participants describe this suite of concerns as being both barriers and facilitators to use.

Past research has identified various challenges posed by litigation in national forest planning (Portuese et al. 2009). However, in our study in places where appeals and litigation had historically been an issue, biomass use actually appeared to foster cooperation among groups in conflict. There was a sense of common purpose and mutual understanding of the linkages between the utilization of biomass and forest management goals; and although the threat of litigation was present, participants in places such as Central Oregon and Northern Colorado frequently talked about their successes working with stakeholder groups in building trust.

> I would say that environmental challenges to the projects are not a big issue. In other places it's a bigger issue, but that's part of the reason we have that collaborative process, we have this stakeholder group that has really helped to educate the public, raise awareness. (Community Partner, Central Oregon #66)

The presence of threatened and endangered species was particularly challenging because of the extent to which laws dictate management responses. However, its effect on biomass use was mixed and not always negative. In Coastal South Carolina, e.g., endangered red-cockaded woodpeckers and threatened gopher tortoises depend on open spaced old-growth longleaf and loblolly pine forests replicated through mechanical treatments. Utilization made these treatments financially viable and therefore critical to restoring habitat. Conversely, participants in Montana and Vermont reported resistance to the removal of large-diameter trees, road construction, and with air quality concerns related to bioenergy production. There was also some concern that biomass projects would serve as a backdoor attempt to justify large-scale timber harvesting.

> Whether its industry or the Forest Service, oh my god we've got all these tons out there, we've got to go get it. Wait, let's calculate the effects. Conservationists aren't going to be quiet about it. I'm supporting it, but we need to calculate those things out first so we don't end up with unsustainable industrial demand. (Environmental Organization, Central Oregon #67)

In terms of the process of conducting environmental planning, participants widely described it as time consuming and overly complex. Industry participants in places such as Montana and Northern California were further concerned that protracted planning coupled with the threat of appeals and litigation created uncertainty and delays in project implementation, which made it difficult to obtain financing to invest in needed equipment or processing infrastructure. This was particularly troublesome for startup businesses. Agency attempts to write planning documents to withstand litigation, "bullet-proofing" as it was described, were thought to inadvertently impede biomass removal by increasing the time required. An alternative discussed in Southern New Mexico and elsewhere was to conduct planning for larger units, often more than on the amount of acres for which there was funding to implement.

> Large-scale planning, I believe, is the way to go because it gives us that shelf stock. We can spin our wheels in National Environmental Policy Act of 1969 (NEPA), but if you look, and if you're going to spin your wheels on a 1,000 acres or are you going to

Table 2. Degree to which the conventional wisdoms were limiting or contributing factors impeding biomass utilization by study site.

Study site	Guaranteed supply	Lack of industry infrastructure	Transportation costs	Value of biomass
Trinity Mountains, California	*Contributing factor.* Industry has maintained limited presence without guarantees but struggled Industry lacked interest in stewardship contracts	*Limiting factor.* Logging capacity was declining and lack of industry impeded the ability of small operators to make needed investments	*Limiting factor.* Steep slopes and remote areas significantly increased removal costs Focus on local markets because of remoteness	*Contributing factor.* Low-value byproduct of timber harvesting and fuels reduction activities Increase in local small-scale processing
Southern Oregon	*Limiting factor.* Inconsistency hurting bioenergy industry, but short-term contracts were helping	*Contributing factor.* Core biomass industry existed but was in decline for lack of supply	*Contributing factor.* Distances increase as industries closed Poor access significantly increased removal costs	*Not a factor.* High competition for mill and harvest residuals increased market values
Central Oregon	*Contributing factor.* Lack of markets thwarted investment even where biomass was available Stewardship contracts helped but resistance	*Contributing factor.* Sawmill infrastructure existed but capacity was declining and lack of biomass processing impeded progress	*Contributing factor.* Long distances but easy site access, backhauls, transport subsidies, and competition for biomass increased haul distances	*Not a factor.* High competition for mill and harvest residuals increased market values
Bitterroot Valley, Montana	*Limiting factor.* Industry has maintained limited presence without guarantees but supply permeates most issues	*Contributing factor.* Processing capacity was in decline, and industry linkages were severed with each mill closing	*Contributing factor.* Facilities in proximity, but difficult site access increased costs Increased transport costs with industry decline	*Limiting factor.* Low-value byproduct of harvesting Value varied by species and a function of what was available to harvest
Northern Colorado Front Range	*Contributing factor.* Supply existed but poor quality species Stewardship contracts helped but not viewed as a solution	*Limiting factor.* Historically low industry presence Lacked biomass industry linkages and experience	*Limiting factor.* Focus was on creating local and regional demand to reduce transport distance Site access was a challenge in many places	*Limiting factor.* Low-value "waste" byproduct of fuels reduction Few market outlets
Southwest Colorado	*Contributing factor.* Supply potential and consistency varied Low-value of biomass limited application of stewardship contracting	*Limiting factor.* Some industry presence but not widely suited for biomass use from fuels reduction projects	*Limiting factor.* Isolated region; closest mill was 150 mi Focus was on creating local markets but demand was low	*Limiting factor.* Low-value byproduct of fuels reduction activities Firewood was one of few consistent markets
Southern New Mexico	*Contributing factor.* Inconsistent supply on federal lands; extensive tribal lands supply Stewardship contracting through the Tribal Forest Protection Act of 2004	*Contributing factor.* Tribal mills existed but not well suited for processing small wood Lack skilled contractors for harvesting and procurement	*Contributing factor.* Steep slopes and remote areas significantly increased removal costs Isolated from urban markets	*Contributing factor.* Low-value byproduct of fuels reduction activities Few market outlets but local markets were expanding
Northeast Minnesota	*Not a factor.* Limited federal but consistent supply from county, state, and private lands Concern for competition for roundwood	*Contributing factor.* Competition between pulp and biomass users Small number of trained contractors and manufacturers	*Contributing factor.* Increasing number of facilities but transport distances were a concern Site access limited by mild winters	*Not a factor.* Biomass was generally a low-value material and well integrated with sawlog and pulpwood markets
Green Mountains, Vermont	*Not a factor.* Supply predominately from private lands and out-of-state sources	*Contributing factor.* Processing capacity was in decline Aging workforce and equipment	*Limiting factor.* Lack of roads, difficult site access, and weight restrictions increased costs	*Contributing factor.* High price of heating oil significantly increased value for biomass and firewood
Coastal South Carolina	*Not a factor.* Abundant supply from all lands Stewardship contracting for habitat restoration increased use	*Not a factor.* Vibrant biomass processing capacity in proximity Competitive wages and skill workforce existed	*Not a factor.* Distance traveled was critical but facilities were largely in proximity to resources Well-established roads	*Contributing factor.* Generally a low-value byproduct of timber harvesting but competition existed

Continued

Table 2. (continued).

Study site	Scale of wildfire–forest health problem	Collaboration to accomplish utilization	Environmental concerns	Declining agency budgets and staffing
Trinity Mountains, California	*Contributing factor.* Focus on small industries for community benefit Recognized the need for more or larger industries to address wildfire issues	*Contributing factor.* Significant collaboration Small successes but without collaboration few projects would have been implemented	*Limiting factor.* Widespread threat of litigation routinely slowed planning and implementation for timber sales	*Limiting factor.* Limited budgets constrained project planning Agency inexperience in designing projects to facilitate use
Southern Oregon	*Contributing factor.* Wide support for large-scale investments, but also for small-scaled production	*Contributing factor.* Distrust of federal agencies but partnerships were bringing interests together	*Limiting factor.* Threats of litigation historically slowed project implementation, but less so for biomass projects	*Contributing factor.* Limited budgets constrained implementation of projects on federal lands
Central Oregon	*Contributing factor.* Support for large-scale investments, but also for small-scaled production	*Not a factor.* Partnering was key in building trust and strategies for fuels reduction and biomass removal acceptance	*Contributing factor.* Threats of litigation had slowed planning, but it was happening less with biomass projects	*Contributing factor.* Concern for funding to implement projects. Inconsistent handling of fire dollars for use
Bitterroot Valley, Montana	*Contributing factor.* Significant fire risks but mix of industries present Projects on federal lands were too small to have an impact on use	*Contributing factor.* Partnerships were critical for stakeholder negotiations, which also promoted importance of biomass use	*Limiting factor.* Litigation was seen as having a detrimental impact on procuring biomass from federal lands	*Contributing factor.* Agency and industry culture geared toward timber production impeded biomass efforts
Northern Colorado Front Range	*Contributing factor.* Support for large-scale projects to address the scope of problems, but most were small	*Contributing factor.* Complex ownership required partnering but with slowed progress Mixed opinions about collaboration	*Contributing factor.* Some evidence that EPA rules impeded combustion of biomass Minimal litigation	*Contributing factor.* Concern for fuels reduction targets and agency appropriations Partnered to develop use knowledge
Southwest Colorado	*Contributing factor.* Support for large-scale projects but most were small Use increased removal costs because of inconsistent markets	*Contributing factor.* Collaborative efforts have been limited Partnerships were largely consultative with objective of advancing use objectives	*Not a factor.* Focus was on biomass as opposed to timber sales, which generated less opposition Public opinion was not considered a barrier	*Contributing factor.* Limited budgets and staffing constrained project planning and implementation Some success securing federal grants
Southern New Mexico	*Contributing factor.* Significant fire risks but focused on local markets Use increased costs Absent markets	*Contributing factor.* Extensive collaboration in project planning and implementation	*Contributing factor.* Planning was time intensive and complex but not an impediment	*Contributing factor.* Limited budgets for implementation versus wildfire appropriations Staff turnover was high
Northeast Minnesota	*Contributing factor.* Fire was minor issue Emphasis on developing appropriate scales Thinning opportunities but slow progress	*Contributing factor.* Partnerships were viewed as important and were beginning to facilitate business development	*Contributing factor.* Public input decreased litigation, but federal supply was still minimal Concerns about soil productivity	*Contributing factor.* Agency support for biomass but inconsistent training and staffing within federal agencies
Green Mountains, Vermont	*Not a factor.* Strong focus on small-scale distributed infrastructure matched to local markets	*Contributing factor.* Agency-industry partnerships were limited but critical to use expansion	*Limiting factor.* Litigation was seen as having a significant impact on federal biomass supplies	*Contributing factor.* Limited budgets and expertise constrained project planning on federal lands
Coastal South Carolina	*Contributing factor.* Large-scale industry used for hurricane restoration work Significant use of controlled burning	*Not a factor.* Partnering viewed as important but limited in practice Stewardship contracting was advanced to improve collaboration	*Not a factor.* Some concern for litigation but it was largely absent Concern for biomass availability after hurricane recovery	*Not a factor.* Limited discussion of budget issues

EPA, Environmental Protection Agency.

> spin your wheels on 20,000 acres, you might as well spin your wheels getting the 20,000 acres through, because in the long run, I've got years worth of treatment, versus 1,000 acres. (Federal Agency, Southern New Mexico #38)

Declining Agency Budgets and Staffing

This conventional wisdom is that declining agency budgets and staffing hinder environmental planning and project implementation for biomass use. This was confirmed in every one of our study sites and was somewhat related to the previous conventional wisdom on delays caused by environmental concerns. However, although universally hindering biomass removal, nowhere was it seen as the key limiting factor. Participants from both within and outside the agencies felt that project budgets were in decline relative to the increasing cost of implementation. In the Trinity Mountains of California and Southwest Colorado, participants frequently talked about how the lack of budgets was causing delays in project planning or implementation, which stifled industry investments but also risked thwarting fuels reduction efforts. Participants were particularly concerned about what they perceived as fire suppression being funded at increasingly higher levels at the expense of fuels reduction projects, projects that could proactively reduce wildfire threats.

> Our acres from the federal side have either remained constant or maybe they're starting to slip. The local ranger district that I do a lot of work with, you know their budgets are down significantly this year. And so their acreages are down but not only are the acres down, it's the type of acres that they're doing. Instead of putting them up even for mastication, they're doing more prescribed fire, doing more what they call forest account type work. (State Agency, Northern Colorado Front Range #20)

In terms of staffing, there was concern among agency and nonagency participants alike about the perceived lack of trained personnel either to facilitate use or to perform required environmental planning. The key issue identified by nonagency participants was the loss of staff through retirement, promotion, or temporary reassignment, which was perceived as further delaying projects by increasing the time needed to foster relationships with new personnel. It also meant that priorities could change midstream or that there would be fewer staff available. Agency and nonagency participants also noted the need for basic training in biomass conversation technologies and the logistics of biomass removal. This could enhance awareness of how markets influence forest management objectives and how those objectives in turn affect the distribution and quality of biomass resources.

> None of us were really trained to facilitate development of a biomass use industry. We were trained to manage some aspect of the forest. And so, you know, while we can be supportive of that, I don't know that by and large we are really well-suited for doing the things or facilitating doing the things that need to be done to help an industry develop. (Federal Agency, Northern Colorado Front Range #18)

Despite these concerns, there was widespread recognition that the agency staff worked hard and was committed to biomass removal. For instance, in South Carolina, staff worked closely with local contractors to reduce removal costs. There was a similar perception in Southern New Mexico that agency personnel were working with their partners to make progress in conjunction with restoration objectives.

> I've seen a lot of wonderful young people coming into the Forest Service who are really educated about restoration in particular, and they seem open and excited and happy. They also seem to get the whole ecosystem function aspect of the work that we're trying to do, and I know it's at odds, a lot of times, when you have kind of a fireman mentality, and you're only looking at treating an acre and really only considering fire. So I see more, as time goes on, of concern about the other aspects of what's happening on the ground, which is, I think, a very healthy thing. (Forest Industry, Southern New Mexico #39)

Discussion

Although the use of conventional wisdoms can provide a common discussion point, they also can mislead if they are not an accurate representation of what is happening on the ground. It is therefore important to examine how a conventional wisdom does or does not hold in different situations. Our findings indicate that all but one of our conventional wisdoms was accurate at some level, although the degree and way that each impeded progress varied. The one conventional wisdom that did not hold well was the issue of matching the scale of the problem to the size of industrial facilities. The interconnectedness among conventional wisdoms also varied depending on local resource characteristics, ownership patterns, industry presence, and degree of conflict.

Limiting versus Contributing Factors

The summary of findings presented in Table 2 highlight salient themes across the eight conventional wisdoms. First, we identify the degree to which each was viewed by participants as a limiting versus a contributing factor. A *limiting factor* posed significant obstacles and would need to be addressed to achieve measured progress, and a *contributing factor* modified the problem but not always in a negative way or when negative was amenable to being mitigated or had limited impact on biomass use. Looking across the conventional wisdoms, the first four, supply guarantees, industry presence, transportation, and the value of biomass were widely considered limiting factors in our western study sites. Where these were not limiting, they still contributed to the overall problem but were not the primary issue to overcome. In Southern Oregon, e.g., biomass utilization was far more developed than in the other western study sites, but because of the lack of consistent supply, decline in markets aside, local sawmills were beginning to close. As sawmills closed, constrained access to inexpensive mill shavings forced bioenergy producers to travel greater distances to secure wood chips, thus increasing their costs. In this case, supply was arguably the limiting factor and the other conventional wisdoms were contributing problems.

The remaining conventional wisdoms —scale of the problem, collaboration, environmental concerns, and declining agency budgets and staff—were clearly salient in almost every case. However, the degree to which they impeded use was variable. Scale, as mentioned, was less consistently applicable. Many participants questioned its accuracy and were developing an alternative view that small scale, rather than large scale, was required. What was unresolved is what constituted small-scale versus large-scale enterprises. Proponents of small scale implied that the alternative was enormous processing facilities capable of denuding the landscape. Large-scale proponents implied boutique businesses having almost no impact on fuels reduction efforts and incapable of operating at a financially viable threshold. Somewhere in between was what most were actually promoting, however, it was not the focus of their framing.

The remaining three conventional wisdoms were seen as modifying the problem—sometimes even in a positive way—and something that generally could be improved or worked around. For instance, environ-

mental concerns generated significant discussion but contrary to the other issues, there was much less agreement on the extent to which factors such as appeals and litigation limited progress. Most participants agreed that environmental concerns delayed project planning, but for many the delays were more a result of conflicts surrounding timber harvesting than fuels reduction or biomass use. Declining agency budgets and staffing were likewise seen as impeding biomass removal, but were generally not seen as the fundamental obstacle. Finally, collaboration and stakeholder participation in project planning helped to bridge the gap between parties traditionally in conflict. However, formal collaboration was hardly the norm and despite widespread environmental concerns, utilization was able to progress in several sites without formal collaborative efforts.

Interconnections

As previously discussed, the factors were often interconnected. Where transportation was an issue, the lack of processing infrastructure was usually relevant, and in cases such as Northern and Southwest Colorado and Central Oregon, this was, in turn, partially a function of the value of biomass or consistency of supply. For industry to become established in Northern Colorado, e.g., there was a need for value-added markets for the poor quality tree species present (Table 1). These factors clearly impeded business development, and where one issue was present—transportation, infrastructure, or low value—the others tended to be an issue as well (Table 2). Integrated markets to offset biomass removal costs have failed to materialize in most of these cases because of the insufficient value of the resource. Where these were less of a factor or had been resolved through previous efforts, biomass utilization appeared to succeed, such as in South Carolina, Minnesota, and Vermont, although any factor could reemerge at any time.

Interactions among conventional wisdoms complicated efforts in other ways as well. For instance, where consistency of supply was a limiting factor, environmental concerns tended also to be viewed as a limiting factor. Past appeals and litigation created an atmosphere where it was difficult for parties to trust one another. Where environmental concerns persisted on federal lands, progress in planning remained slow, which subsequently impeded the consistency of supply. Interactions among institutional factors with on-the-ground accomplishments were similarly constrained. Industry participants, e.g., talked about the need for the agencies to amplify planning and to offer contracts reflecting market constraints, provide consistent supply, and some degree of value in timber to offset the cost of biomass removed. Agency planners, in turn, talked about the need for businesses to commit to expanding their operations before they could justify expanded planning.

> It's a chicken and the egg thing. You need to have the market, so you have to have the processing capacity, but you can't invest in the processing capacity and the biomass use capacity unless you have the supply, and you can't get the supply efficiently and create a reasonable price for that supply unless you have mechanical harvesting, which you can't have mechanical harvesting unless you have enough acres. (Community Partner, Trinity Mountains California #7)

Adapting to the Scale of the Problem

The magnitude of forest health problems dominated land manager concerns in interviews, but the approaches taken in response varied considerably. Participants frequently reported the need for large-scale applications, but in practice most pursued small-to-intermediate–sized projects, allowing them to better address supply and financial constraints. It also gave them a chance to build technology or market capacity before scaling up. Appropriately scaled investments reflected the desire to match the size of processing facilities with the scale of available biomass and level of community acceptance, the financial realities of harvest costs, transportation distances, quality of material removed, and market potential. The result was an incremental solution that allowed for variation and adaption, but that subsequent scaling up to address widespread forest management would take time.

Incremental solutions may also allow time for agencies and stakeholders to identify ways of addressing the interconnections among limiting and contributing factors. The question is whether adaptation and innovation will happen within an acceptable time frame; acceptable to those focused on wildfire risk reduction or forest health and to those seeking to make financial investments.

Conclusion

Although most of the conventional wisdoms held in some way, the applicability of each, the magnitude, and degree to which they impeded progress differed by study site. Many tended also to be interconnected with one factor influencing the impact of another. Strategies therefore need to account for both the interactions among factors and the local context; focusing on just one issue risks overlooking the full range of challenges and potential synergies. Furthermore, problem framing in one location may be inappropriate for another.

It is worth repeating that applicability of a conventional wisdom could change over time. The temporal aspects of the problem and fluid nature of markets could change quickly, which is why it would be incorrect to suggest that the conventional wisdoms were proved or disproved. Our findings do, however, support existing understandings of biomass challenges but are distinguished from previous research in that we examined a broader range of factors; underlying contexts; and interconnections among market, institutional, and community issues. This is an important contribution to the existing economic and technological research, and although our selection of informants limits the degree to which we can generalize findings to other locations, they may provide land managers with new ways of understanding the interactions and patterns among factors. They may also suggest new ways that barriers can be addressed through policy development at the local, state, or national level. No one approach will alleviate all the challenges or anticipate the unique issues in each location, but the consequences of these actions could contribute to the progress, or lack thereof, of woody biomass utilization.

Finally, additional research could build on these findings by assessing the degree to which social learning occurred and the role of adaption in project success. It was clear from our interviews that past experience had led to revised ways of incorporating use into forest planning, but the degree to which they improved prospects for success are largely unknown. Applying lessons learned to other locations would contribute to our knowledge of how best to stimulate utilization of biomass in places with low use capacity.

Literature Cited

AGUILAR, F., AND H.E. GARRETT. 2009. Perspectives of woody biomass for energy: survey of state foresters, state energy biomass contacts, and National Council of Forestry Association executives. *J. For.* 107(6):297–306.

BARBOUR, R.J., D.D. MARSHALL, AND E.C. LOWELL. 2003. Managing for wood quality. P. 299–336 in *Compatible forest management*,

Monserud, R.A., R.W. Haynes, and A.C. Johnson (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Barbour, R.J., X. Zhou, and J.P. Prestemon. 2008. Timber product output implications of a program of mechanical fuel treatments applied on public timberland in the western United States. *For. Policy Econ.* 10:373–385.

Becker, D.R., C. Moseley, and C. Lee. A supply chain analysis framework for assessing state-level forest biomass utilization policies in the United States. *Biomass Bioenergy* (in press). DOI: 10.1016/j.biombioe.2010.07.030. Available online at www.interfacesouth.org/resources/literature.html; last accessed May 2011.

Becker, D.R., D. Larson, and E.C., Lowell. 2009a. Financial considerations of policy options to enhance biomass utilization for reducing wildfire hazards. *For. Policy Econ.* 11(8): 628–635.

Becker, D.R., M. Nechodom, A. Barnett, T. Mason, E. Lowell, D. Graham, and J. Shelly. 2009b. Assessing the role of federal community assistance programs to develop biomass utilization capacity in the western United States. *For. Policy Econ.* 11:141–148.

Corbin, J.M., and A. Strauss. 2007. *Basics of qualitative research: Techniques and procedures for developing grounded theory*, 3rd Ed. Sage Publications, Thousand Oaks, CA. 400 p.

Erickson, R.G., T.D. Gorman, D.W. Green, and D. Graham. 2000. Mechanical grading of lumber sawn from small-diameter lodgepole pine, ponderosa pine, and grand fir trees from northern Idaho. *For. Prod. J.* 50(7/8):59–65.

Fight, R.D., G.L. Pinjuv, and P.J. Daugherty. 2004. Small-diameter wood processing in the southwestern United States: An economic case study and decision analysis tool. *For. Prod. J.* 54(5):85–89.

Galik, C.S., R. Abt, and Y. Wu. 2009. Forest biomass supply in the southeastern United States—Implications for industrial roundwood and bioenergy production. *J. For.* 107(2):69–77.

Government Accountability Office (GAO). 2005. *Natural resources: Federal agencies are engaged in various efforts to promote the utilization of woody biomass, but significant obstacles to its use remain.* General Accountability Office, GAO-05-373. 51 p.

Government Accountability Office (GAO). 2006a. *Natural resources: Woody biomass users' experiences offer insights for government efforts aimed at promoting its use.* General Accountability Office, GAO-06-336. 40 p.

Government Accountability Office (GAO). 2006b. *Wood utilization: Federal research and product development activities, support, and technology transfer.* General Accountability Office, GAO-06-624. 118 p.

Government Accountability Office (GAO). 2008. *Federal land management: Use of stewardship contracting is increasing, but agencies could benefit from better data and contracting strategies.* Government Accountability Office, GAO-09-23. 66 p.

Han, H.S., H.W. Lee, and L.R. Johnson. 2004. Economic feasibility of an integrated harvesting system for small-diameter trees in southwest Idaho. *For. Prod. J.* 54(2):21–27.

Hartsough, B.R., X. Zhang, and R.D. Fight. 2001. Harvesting cost model for small trees in natural stands in the interior Northwest. *For. Prod. J.* 51(4):54–61.

Hjerpe, E., J. Abrams, and D.R. Becker. 2009. Socioeconomic barriers and the role of biomass utilization in southwestern ponderosa pine restoration. *Restor. Ecol.* 27(2):169–177.

Keegan, C.E., T.A. Morgan, K.M. Gebert, J.P. Brandt, K.A. Blatner, and T.P. Spoelma. 2004. *Timber-processing capacity and capabilities in the western U.S.* Available online at www.wflccenter.org/ts_dynamic/edu_outreach/18file.pdf; last accessed Jan. 19, 2010.

Lowell, E.C., D.R. Becker, D. Larson, R. Rummer, and L. Wadleigh. 2008. An integrated approach to evaluating the economic costs of wildfire hazard reduction through wood utilization opportunities in the southwestern United States. *For. Sci.* 54:273–283.

Lynch, D.L., W.H. Romme, and M.L. Floyd. 2000. Forest restoration in southwestern ponderosa pine. *J. For.* 98(8):17–24.

Miles, M.B., and A.M. Huberman. 1994. *Qualitative data analysis*, 2nd Ed. Sage Publications, Thousand Oaks, CA. 352 p.

Malmsheimer, R.W., P. Heffernan, S. Brink, D. Crandall, F. Deneke, C. Galish, E. Gee, J.A. Helms, N. McClure, M. Mortimer, S. Ruddell, M. Smith, and J. Stewart. 2008. Forest management solutions for mitigating climate change in the United States. *J. For.* 106(3):115–171.

Mason, C.L., B.R. Lippke, K.W. Zobrist, T.D. Bloxton Jr., K.R. Ceder, J.M. Comnick, J.B. McCarter, and H.K. Rogers. 2006. Investments in fuel removals to avoid forest fires result in substantial benefits. *J. For.* 104(1): 27–31.

Nielsen-Pincus, M., and C. Moseley. 2009. *Social issues of woody biomass utilization: A review of the literature.* Ecosystem Workforce Program Working Pap. 20, Univ. of Oregon, Eugene, OR. 15 p.

Perlack, R.D., I.L. Wright, A.F. Thurhollow, R.L. Graham, B.J. Stokes, and D.C. Erbach. 2005. *Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply.* ORNL/TM-2005/66, Oak Ridge National Laboratory, Oak Ridge, TN. 60 p.

Pinchot Institute for Conservation. 2008. *Programmatic monitoring of the role local communities play in developing stewardship contracts.* FY 2007 Rep. to the US For. Serv., Washington, DC. Available online at www.fs.fed.us/forestmanagement/projects/stewardship/reports/documents/2007/FY07_SC_USFS_Program_Monitoring_Report_Final.pdf; last accessed Feb. 4, 2009.

Portuese, B.G., R.W. Malmsheimer, A. Anderson, D. Floyd, and D. Keele. 2009. Litigants' characteristics and outcomes in US Forest Service land-management cases 1989 to 2005. *J. For.* 107(1):16–22.

Prestemon, J.P., K.L. Abt, and R.J. Huggest Jr. 2008. Market impacts of a multiyear mechanical fuel treatment program in the U.S. *For. Policy Econ.* 10:386–399.

Rummer, R. 2008. Assessing the cost of fuel reduction treatments: A critical review. *For. Policy Econ.* 10:355–362.

Shelly, J.R., M.E. Puettmann, K.E. Skog, and H.S. Han. (eds). 2006. Woody biomass utilization: Challenges and opportunities. In *Proc. of the Forest Products Society 60th International Convention*, Newport Beach, CA. Forest Products Society, Madison, WI. 97 p.

Sturtevant, V., M.A. Moote, P.J. Jakes, and A.S. Cheng. 2005. *Social science to improve fuels management: A synthesis of research on collaboration.* US For. Serv. Gen. Tech. Rep. NC-257, North Central Res. Stn., St. Paul, MN. 84 p.

Wagner, F.G., C.E. Keegan, R.D. Fight, and S. Willits. 1998. Potential for small-diameter sawtimber utilization by the current sawmill industry in western North America. *For. Prod. J.* 48(9):30–34.

Western Governors Association (WGA). 2002. *A collaborative approach for reducing wildland fire risks to communities and the environment: 10-Year comprehensive strategy implementation plan.* Available online at www.westgov.org/wga/initiatives/fire/final_fire_rpt.pdf; last accessed Nov. 1, 2009.

Yin, R.K. 2003. *Case study research: Design and methods.* Sage Publications, Thousand Oaks, CA. 200 p.