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Forest Fuel Reduction and Biomass Supply: Perspectives from Southern Private Landowners

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Removing excess biomass from fire-hazardous forests can serve dual purposes: enhancing the health and sustainability of forest ecosystems and supplying feedstock for energy production. The physical availability of this biomass is fairly well-known, yet availability does not necessarily translate into actual supply. We assess the perception and behavior of private forestland owners in the southern United States with respect to thinning overstocked forests for bioenergy production. Landowner perception is then integrated with the USDA Forest Service's Fuel Treatment Evaluator to estimate the biomass supply from fuel treatments on non-industrial private timberlands in the region. Due to competing uses for lumber and pulp/paper products, only about one-third of this biomass could be used as bioenergy feedstock. Between 6 and 66% of landowners would consider thinning overstocked forests for bioenergy purposes depending upon whether financial incentives and technical assistance are provided. Accounting for competing uses, landowner willingness, accessibility, and recovery loss, annual feedstock supply from Southern private treatable timberlands is estimated between 0.9- and 11-million dry tonnes (dt). The average production cost is proximately $48/dt. Government cost shares, biomass market development, and technical assistance could

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significantly stimulate private landowners to procure biomass from fire-hazardous forests while mitigating wildfire risk.

KEYWORDS forest biomass, wildfire, private landowner, southern United States

INTRODUCTION

Excess biomass accumulation on forestlands has created wildfire hazards, posing a threat to properties, human life, and the sustainability and health of forest ecosystems. Such threats have prompted both private and government sectors to take measures to reduce fuel loads on forestlands in the United States. Woody biomass generated from forest fuel treatments is a potential source of bioenergy feedstock. Considerable efforts have been made to estimate the availability of this biomass (Perlack et al., 2005), especially on public forestlands in western states (Skog et al., 2006). Yet its realistic supply from private forestlands remains relatively unknown or uncertain. In fact, there is a lack of large-scale action by private forestland owners on mitigating wildfire risk via forest thinning.

Several factors may be attributable to the challenge in accurately estimating this biomass source and the lack of action by private landowners. First, there are many private forestland owners in the region, who on average possess a small track of forestland and have diverse ownership objectives. Second, incentive for individual landowners to take wildfire prevention initiatives is lacking because of possible free ride in terms of mitigation benefits and the ineffectiveness of individual and uncoordinated efforts in terms of fire prevention. Third, many landowners do not have adequate knowledge of and resources for wildfire prevention. Fourth, costs associated with thinning overstocked forest stands are often high, making it economically unviable. Hence, more accurate estimation of this biomass entails a better understanding of landowner willingness to participate in this fire mitigation and biomass production process.

This study aims at: (a) identifying the perception of private landowners on wildfire risk, (b) assessing how the perception translates into their willingness to remove excess biomass to reduce fire hazards and produce biomass for energy production, and (c) estimating the bioenergy feedstock supply from this biomass source. In addition to feedstock supply estimation, we also attempt to identify key drivers and impediments for private forestland owners to engage themselves in this process. Such information will be of value for guiding bioenergy development and deployment as well as future policy formulation to simultaneously enhance the production and utilization of this biomass source and the health of forest ecosystems.

METHODS

Study Area and Data

This study focuses on the southern United States, which consists of 13 states from Virginia in the north to East Texas in the southwest. The South is one of the most productive forest regions in the United States and the world. Its 80 million ha of timberlands accumulate 990 million m^3 of growing stock, providing 60% of the nation's total timber supply annually. About 72% of the timberlands in the region are owned by non-industrial private owners (Smith, Miles, Vissage, & Pugh, 2004). Like other regions in the United States, wildfire has become an increasing threat to the health of forest ecosystems and even to properties and human life with rising urbanization (Wear & Greis, 2005).

The data on landowner perception were collected from a landowner survey conducted in five states including Alabama, Georgia, Florida, Mississippi, and South Carolina (Jarrett, 2008). Emphasis was placed on 21 counties where there are rich forest resources, looming wildfire threat, and diverse landowner composition. A carefully designed survey questionnaire was mailed to a randomly selected sample of 2,500 non-industrial and non-institutional private forestland owners who possessed at least 4 ha of forestland using the Dillman (2000) method. Five hundred and eighty-five valid responses were received, with a response rate of 24.7% (excluding 127 landowners who could not be contacted due to wrong addresses or did not want to participate in the survey).

The average age of these respondents was 61 yr. They, in general, were well-educated with a median of college education and had a relatively high annual household income with a median between $70,000 and $89,999. They were dominated by white (91%) and male (72%). These characteristics of respondents closely resemble those of the population of non-industrial private forestland owners in the South (Birch, 1996, Butler et al., 2004). Although the survey focused on five states (because of our original intention to study wildfire), but the information collected on landowner perception and willingness in forest fuel treatment and biomass production would be applicable to the entire southern region due to similarities in landowner characteristics, forest resources, and market conditions.

Biomass Supply Estimation

Several factors such as biomass available on the ground, competing uses, accessibility and recovery limitations, and landowner willingness determine the biomass supply for energy production from private treatable timberlands in the South. All these factors were accounted for in our biomass supply estimation. The RPA Fuel Reduction Treatment Tabler (USDA Forest Service, 2002), which is based on the Fuel Treatment Evaluator, was used to estimate treatable timberland area and available biomass. Treatable area and biomass quantity were derived for each fire regime condition class that measures the degree of deviation from the historical fire regime. From Class 1 to Class 3, the departure from the historical fire regime increases and a higher level of restoration treatments is needed (National Wildfire Coordinating Group, 2003). Available biomass was calculated in terms of total amount on the ground and the portions of sawlogs and total merchantable wood (including sawlogs and pulpwood logs). Competing use of forest biomass can reduce its availability for bioenergy production. Only the difference between the total available and merchantable amount could be used for bioenergy production as long as the biomass feedstock price is below the pulpwood price. Feedstock supply for bioenergy production can increase to the amount equivalent to the total less the sawlog portion when the biomass price rises to a level between the pulpwood price and the sawlog price. When the biomass feedstock price reaches or surpasses the sawlog price (unlikely in the foreseeable future), all available biomass could be used for energy production.

Not all timberlands are accessible due to terrain and road constraints. Also, not all forest biomass can or should be recovered because of machinery limitations and concerns about the impact on long-term soil productivity by excessive biomass removals. Based on existing studies (Perlack et al., 2005), 80% of private timberlands in the South was assumed to be accessible, and the biomass recovery rate in fuel treatment thinning was estimated at 85%.

Another factor that needs to be considered in estimating biomass supply from private timberlands is to identify and incorporate landowner willingness to participate in production. From our landowner survey data, we derived the percentage of landowners who would carry out forest fuel treatments under various policy scenarios. These policy options include none (no incentive or assistance), establishment of biomass markets, government cost shares, and technical assistance.

Combining these considerations leads to the estimation of biomass supply (S) from southern private treatable timberlands as follows:

$$S = \theta\lambda w(A - M),$$

where θ is the accessibility rate, λ is the biomass recovery rate, w is the proportion of landowners who are willing to participate in procuring biomass for energy production from fire-hazardous timberland, A is the amount of biomass available on the ground, and M is the amount of the merchantable portion (competing uses).

Linkage Between Landowner Interest in Bioenergy and Their Demographics

We also attempted to link landowner interest in pursuing biomass/bioenergy opportunities to their perception, experience, and demographics. Such relationships could help design more effective landowner outreach programs and policies to enhance forest fuel treatment and bioenergy production. Binary logistic regression was used in modeling. The model takes the following form (Greene, 2008):

$$Logit(p) = \ln\left(\frac{p}{1-p}\right) = \alpha + X'\beta$$

where p is the probability for a landowner to show his/her interest in pursuing biomass/bioenergy opportunities; ln is the natural log operator; X is a vector of independent variables representing landowner perception, experience, and demographics; and α and β (vector) are regression coefficients.

The stepwise backward (Wald) selection method in the Statistical Package for the Social Sciences, version 16 (SPSS, Inc., Chicago, IL, USA) was employed to estimate the model. The model was validated using several statistical tests including the Wald test for significance of individual variables and the log likelihood and Hosmer and Lemeshow tests for overall goodness-of-fit.

RESULTS

Landowner Willingness to Participate in Bioenergy Production

Survey respondents overwhelmingly perceived wildlife risk. Ninety-two percent of them believed that wildlife posed a threat to their forest resources. As a result, many (71%) had taken various fire prevention measures—including constructing fire line, removing excess biomass, using prescribed burning, and purchasing fire insurance (Table 1). Yet, without additional incentives and assistance, less than 6% of private landowners would thin overstocked forest stands (Table 2). The most effective incentives to encourage private landowners in the region to thin fire-hazardous stands would be the development of biomass markets and government cost shares, which each alone would induce over 13% of landowners and both together would

TABLE 1 Landowner Perception, Experience, and Mitigation of Wildfire

Variable	% of landowners
Believe wildfire is a threat to their forests	92.1
Have experienced wildfire on property (last 10 yr)	24.6
Have experienced property loss to wildfire (last 10 yr)	21.4
Have taken some wildfire prevention measures	71.1
Are aware of bioenergy incentive programs	5.1
Are interested in learning more about biomass/bioenergy opportunity	82.8

TABLE 2 Landowner Preferences of Forest Fuel Treatment Stimuli

Stimulus	% of landowners
None (no stimulus will be needed)	5.7
Technical assistance (TA)	6.0
Ability to sell biomass (ASB)	13.3
Government cost share (CS)	13.3
TA + ASB	2.6
TA + CS	3.3
ASB + CS	13.3
TA + ASB + CS	8.8
Other stimuli	0.2
No stimulus will help	33.7

stimulate 40% of landowners in total (including individual and joint effects) to carry out forest fuel treatments. Another policy option, though less effective when implemented alone, is to provide technical assistance to landowners. With the provision of cost shares and technical assistance and the emergence of biomass markets, about two-thirds of landowners would be willing to engage themselves in thinning fire-hazardous forest stands.

Approximately one-third of landowners did not think the development of biomass markets, governmental cost shares, and technical assistance would be sufficient to encourage them to initiate forest fuel treatment on their properties. These landowners tend to use other fire prevention measures like constructing fire line, adopting prescribed burning, purchasing fire insurance, or just doing nothing.

Estimated Biomass Supply

There are 56-million ha of private treatable timberland in the southern 13 states, accounting for 89% of the total treatable timberland in the region (Table 3). Alabama has the most treatable area, followed by Georgia, North Carolina, Arkansas, Mississippi, Virginia, Tennessee, Kentucky, Louisiana, Texas, South Carolina, Florida, and Oklahoma. The total biomass (merchantable and non-merchantable) available on the ground from southern private treatable timberlands was estimated at 2,226-million dry tonnes (dt)—including all live, rough, and rotten trees (Table 4). Wildland-urban interface (WUI) areas account for 26% of the total available biomass. Additional 9 and 14% are, respectively, on the timberlands classified as Fire Regime Condition Classes 3 and 2. Fire regimes on these three groups of lands have either been significantly or moderately altered from their historical ranges and/or posed a significant threat to life and properties, and restoration treatments are urgently needed. The remaindering 51% is on the timberland of Fire Regime Condition Class 1 (Figure 1), where the deviation from the historical fire regime is less severe and prescribed burning instead of mechanical thinning could be a treatment option (National Wildfire Coordinating Group,

TABLE 3 Private Treatable Timberland Area in the Southern United States (1,000 ha)

State	Total	Condition class 1	Condition class 2	Condition class 3	Other (WUI)
Alabama	6,314 (94)[a]	2,217	1,624	1,025	1,447
Arkansas	5,244 (81)	2,649	541	643	1,412
Florida	2,685 (79)	1,818	179	0	688
Georgia	6,236 (91)	3,278	1,440	119	1,399
Kentucky	4,050 (92)	2,605	136	141	1,168
Louisiana	3,891 (91)	2,697	420	40	733
Mississippi	4,870 (89)	2,052	1,281	389	1, 149
North Carolina	5,445 (90)	2,310	886	733	1,516
Oklahoma	1,980 (91)	753	291	152	784
South Carolina	3,302 (89)	1,945	299	51	1,007
Tennessee	4,337 (88)	2,716	169	13	1,440
Texas	3,354 (93)	2,149	219	443	543
Virginia	4,663 (87)	1,773	638	789	1,463
Total[b]	56,371 (89)	28,964	8,123	4,538	14,749

[a]Numbers inside parentheses are percentage of private treatable timberland area in the total treatable timberland area across all ownerships. [b]Figures may not sum to total due to rounding.

TABLE 4 Available Biomass from Private Treatable Timberlands in the Southern United States (Million Dry Tonnes)

State	Live trees	Rough	Rotten	Total (live + rough + rotten)	Total-sawlog	Total-merchantable
Alabama	231.04	11.69	0.62	243.35	170.97	85.67
Arkansas	172.05	6.15	0.34	178.53	143.88	75.19
Florida	92.43	4.59	0.36	97.38	73.20	34.56
Georgia	182.36	6.92	1.17	190.45	97.09	8.09
Kentucky	131.73	1.31	0.58	133.62	109.08	60.66
Louisiana	136.40	5.80	0.48	142.68	101.59	53.87
Mississippi	150.40	5.25	0.61	156.26	122.78	67.24
North Carolina	289.50	8.24	1.22	298.97	199.60	90.37
Oklahoma	54.42	4.83	0.43	59.68	53.60	30.69
South Carolina	128.50	6.55	0.63	135.69	81.70	30.10
Tennessee	208.58	16.82	1.04	226.44	155.31	74.05
Texas	104.88	4.01	0.33	109.21	82.61	43.45
Virginia	243.31	9.26	0.85	253.42	179.21	78.92
Total[a]	2,125.61	91.42	8.66	2,225.69	1,570.63	732.86

[a]Figures might not sum to total due to rounding.

2003). However, more biomass will be accumulated on Class 1's lands if treatments are delayed. With a treatment cycle of 30 yr (Perlack et al., 2005), some 1.9-million ha (75-million dt) can be treated annually.

Yet, not all biomass available on the ground would be supplied as bioenergy feedstock. Due to constraints on accessibility and biomass recovery, only about 68% of the biomass available on the ground could be procured. Competing uses for sawtimber and pulpwood would further reduce biomass available for energy production. Of biomass available on

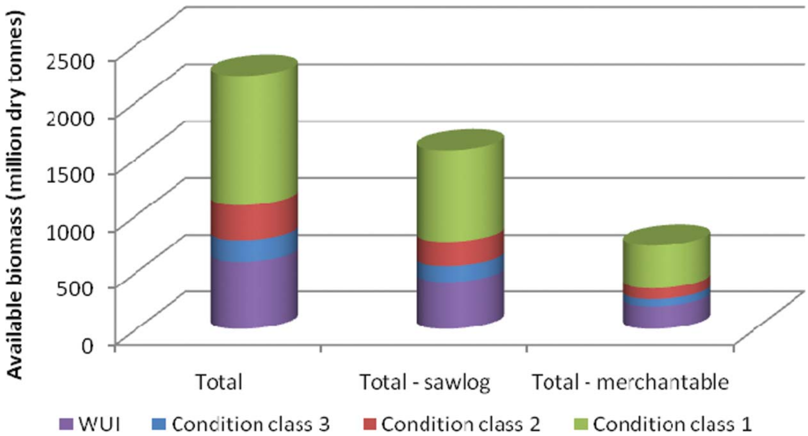

FIGURE 1 Available biomass on southern private treatable timberlands by competing use and fire condition class (color figure available online).

the ground, 650-million dt are classified as sawlogs and 835-million dt can be used as pulpwood. Excluding these competing uses and accounting for accessibility and recovery limitations leave a maximum of 500-million dt that could potentially used as bioenergy feedstock.

The actual feedstock supply from this biomass source could be further reduced due to the lack of incentives for private landowners to participate in this production process. Without technical and financial assistance, only about 28-million dt in total can be supplied as bioenergy feedstock. Assuming the fuel treatment frequency is 30 yr (Perlack et al., 2005), this is equivalent to an annual supply of 0.9-million dt. Government cost shares, biomass market development, and technical assistance can significantly stimulate landowner interest in thinning overstocked forests for bioenergy production. With these incentives and established biomass markets, 330-million dt can be supplied in total with an estimated annual supply of 11-million dt (Figure 2).

The estimated supply is also price sensitive. If the feedstock price is comparable with the pulpwood price, even without technical and financial assistance, feedstock supply from southern private treatable timberlands would increase to 61-million dt in total (2-million dt annually). With technical assistance and governmental cost shares, the supply would rise to 708-million dt in total (23.6-million dt annually; Figure 2).

Production Cost

The costs of forest fuel treatments are influenced by terrain slope, diameters and diameter distribution of trees to be removed, volume of different diameter trees, and road networks (Skog et al., 2006, Prestemon, Abt, & Huggett, 2008). The estimated treatment costs in the South range from $42/ha to $9,140/ha with a mean of $1,905/ha (Prestemon et al., 2008). Assuming that

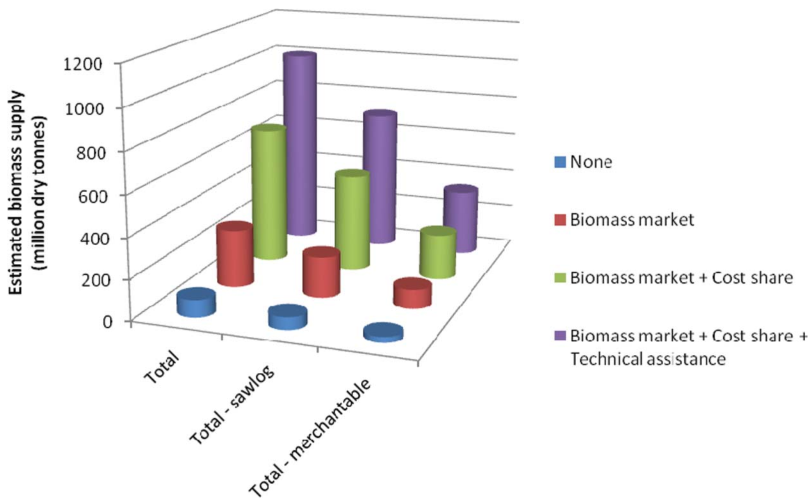

FIGURE 2 Estimated biomass supply from southern private treatable timberlands (color figure available online).

biomass is evenly distributed across all treatable timberlands, the average procurable biomass (including merchantable wood, small diameter trees, and residues) on southern private timberlands is 39.5 dt/ha. Considering a biomass recovery rate of 85%, on average some 33.6 dt/ha can be produced. Thus, the average production cost is estimated at about $48/dt ($2.5/GJ) for all merchantable and non-merchantable biomass. This cost is quite comparable to the production costs of many other plant-based feedstocks (Gan & Smith, 2006). If the benefits associated with fire risk reductions are accounted for, it appears to be a viable feedstock source.

Landowner Interest in Biomass for Energy Production

Landowner interest in learning more about forest biomass for energy production is attributable to several factors including their information sources for wildfire prevention; perception about the roles of governments, markets, and technical assistance; possession of forest management plans; and experience with natural disturbances; among others (Table 5). Landowners who had received fire prevention information from state agencies, used the federal government as a major information source, thought state governments should provide them with fire education or other assistance, perceived biomass market development would stimulate fuel treatment, resided on forestland, managed their forest for recreational purposes, and possessed a forest management plan tend to be more likely to engage themselves in producing biomass from energy production from treatable timberlands. On the other hand, those who usually got fire prevention information from county extension agents; purchased fire insurances; did not think cost shares, biomass market development, or technical assistance would

TABLE 5 Logistic Regression Results of Landowner Interest in Biomass for Energy Production

Independent variable	Estimated coefficient	Odds ratio	Wald	*p*-value
Have received wildfire prevention information from state agencies	2.242	9.42	8.533	.003
Usually received wildfire prevention information from extension agents	−5.568	0.01	10.283	.001
Usually received wildfire prevention information from federal agencies	5.461	235.23	6.398	.011
Have purchased fire insurance	−7.215	0.01	10.875	.001
Perceive that the state government should provide fire education to landowners	2.781	16.14	8.021	.005
Perceive that the state government should provide landowners with fire prevention assistances other than education, technical assistance, and cost share	3.091	22.00	6.660	.010
Perceive that biomass market development would encourage forest fuel treatment	6.174	480.00	12.484	.000
Perceive that none of technical assistance, government cost share, and biomass market development would encourage forest fuel treatment	−4.721	0.01	4.108	.043
Reside on rural land	2.301	9.99	4.937	.026
Manage forestland for recreation purposes	1.704	5.50	3.766	.052
Have a forest management plan	5.219	184.74	10.979	.001
Have not experienced any natural major disturbance on the property	−2.465	0.09	6.810	.009
−2 log likelihood	48.83			
p-value of Hosmer-Lemeshow test	.937			
Percentage of correct prediction	91.5			

enhance biomass for energy production; and had not experienced any major natural disturbance on their properties are less likely to seek bioenergy opportunities.

Among those factors that have a positive impact on landowner interest, having a positive attitude toward biomass market development, choosing federal agencies as their major information source for fire prevention, and possessing a forest management plan have large odds ratios. This suggests that landowners with these characteristics will be more inclined to produce biomass from treatable timberlands for energy production. Interestingly, the odds ratios associated with the variables that have negative impacts are generally small. Thus, their impact on discouraging landowner interest in biomass/bioenergy production would be modest.

CONCLUSION

There is a significant amount of biomass on private treatable timberlands in the South, yet competing uses for sawtimber and pulpwood and landowner willingness to participate in production could dramatically reduce its supply as bioenergy feedstock. Of the total amount of available biomass from private treatable timberlands in the South, 29% can be used for sawtimber and additional 38% for pulpwood. This leaves only one-third of the total available amount for possible use for energy production.

Landowner unwillingness to produce biomass from treatable timberlands for energy production would further reduce its potential as bioenergy feedstock. Without financial incentives and technical assistance, less than 6% of landowners would be willing to thin fire-hazardous forest stands for energy production. With biomass market establishment, government cost shares, and technical assistance, two-thirds of landowners would consider producing biomass from treatable timberlands for bioenergy purposes. Among these stimuli, cost shares and biomass market development would be much more important and effective than technical assistance. The estimated annual biomass supply from southern private treatable timberlands ranges from 0.9- to 11-million dt (with an assumed fuel treatment cycle of 30 yr) depending upon whether government cost shares and technical assistance are provided. These estimates could be more than doubled if the feedstock price is competitive with the pulpwood price.

Although only a handful of private forestland owners show their readiness for thinning overstocked forest to supply feedstock for bioenergy production, the dominant majority of these landowners are interested in seeking and learning more about bioenergy opportunities. Landowner interest in forest bioenergy is clearly related to their perception, information sources, and possession of forest management plans.

Our findings have several implications for bioenergy development and deployment as well as for future policy formulation. First, in terms of feedstock supply from forests, biomass available on the ground might not necessarily translate into what can be actually supplied. For bioenergy deployment decision making, it is the actual feedstock supply that matters. Second, competing uses for forest biomass and landowner willingness to participate in production could significantly reduce the amount of forest biomass from treatable timberlands that can be used for bioenergy production. Thus, landowner attitudes and market interactions between bioenergy and traditional forest products cannot be neglected. Though feedstock prices can play a pivotal role in allocating forest biomass among different uses, provision of financial incentives and technical assistance to landowners seems to be more critical to boost landowner participation in thinning overstocked forests to supply feedstock for energy production under current conditions. Such incentives would not only promote biomass for energy production but also enhance the heath of private forests, which in turn would secure sustainable ecosystem services to society. Third, targeting specific landowner groups—particularly those who believe the helpfulness of biomass market development, turn to federal agencies for fire prevention information, and hold a forest management plan—would be more effective than broad efforts to work with all landowners. Finally, there are few landowners who are aware of biomass/bioenergy incentive programs, yet the majority of landowners show interests in learning more about bioenergy opportunities. This calls for expanded and more effective landowner outreach efforts on disseminating incentive and technical information on biomass for energy production as well as wildfire prevention and mitigation.

This study can be expanded in several aspects. Our landowner survey was concentrated in five states. Though our work sheds light on landowner perception in the five states and possibly for the South, a call for a region-wide survey is in order. Additionally, given the complexity in estimating biomass production costs for each treatable site and separating the costs between merchantable timber and biomass feedstock, we leave more comprehensive cost estimation for future work. Such work will be able to derive a biomass supply curve from forest fuel treatments, revealing a more detailed relationship between the quantity of feedstock supply and production costs. Nevertheless, because timberland is generally quite accessible in the South (much more accessible than in the West), with the exclusion of inaccessible timberlands (20% of the total treatable area) in the analysis, our feedstock supply and average production cost estimates should be of value for planning purposes while serving a foundation for further studies.

REFERENCES

Birch, T. W. (1996). *Private forest-land owners of the United States, 1994* (USDA Forest Service Resource Bulletin NE-134). Radnor, PA: Northeastern Forest Experiment Station.

Butler, B. J., Leatherberry, E. C., Best, C., Kilgore, M. A., Sampson, R. N., & Larson, K. (2004). America's family forest owners. *Journal of Forestry*, *102*(7), 4–14.

Dillman, D. A. (2000). *Mail and Internet surveys: The tailored design method* (2nd ed.). New York, NY: Wiley & Sons.

Gan, J., & Smith, C. T. (2006). A comparative analysis of woody biomass and coal for electricity generation under various CO_2 emission reductions and taxes. *Biomass and Bioenergy*, *30*, 296–303.

Greene, W. (2008). *Econometric analysis* (6th ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.

Jarrett, A. (2008). *Landowner perception, awareness and adoption of wildfire programs in the southern United States* (Unpublished master's thesis). Texas A&M University, College Station, TX.

National Wildfire Coordinating Group. (2003). *Fire regime condition class definition*. Retrieved from http://www.nwcg.gov/teams/wfewt/archive/message/FrccDefinitions.pdf

Perlack, R., Wright, L., Turhollow, A., Graham, R., Stokes, B., & Erbach, D. (2005). *Biomass as feedstock for a bioenergy and bioproducts industry: The technical* *feasibility of a billion-ton annual supply* (DOE/GO-102995-2135). Washington, DC: U.S. Departments of Energy and Agriculture.

Prestemon, J. P., Abt, K. L., & Huggett, R. J., Jr. (2008). Market impacts of a multiyear mechanical fuel treatment program in the U.S. *Forest Policy and Economics*,*10*, 386–399.

Skog, K. E., Barbour, R. J., Abt, K. L., Bilek, E. M., Burch, F., Fight, R. D., . . . Shepperd, W. D. (2006). *Evaluation of silvicultural treatments and biomass use for reducing fire hazard in western states* (Research Paper FPL-RP-634). Madison, WI: USDA Forest Service, Forest Products Laboratory.

Smith, W. B., Miles, P. D., Vissage, J. S., & Pugh, S. A. (2004). *Forest resources of the United States, 2002* (USDA Forest Service Gen. Tech. Rep. NC-241). St. Paul, MN: North Central Research Station.

USDA Forest Service. (2002). *RPA 2002 fuel reduction treatment tabler*. Retrieved from http://www.fia.fs.fed.us/program-features/rpa/

Wear, D., & Greis, J. (2005). *Southern forest resource assessment: Summary report* (USDA Forest Service Gen. Tech. Rep. SRS-54). Asheville, NC: Southern Research Station.