Public Acceptance of Pre-Commercial Thinning and Energy and Soil Amendment Products from Post-Harvest Residues in Western Forests of the United States

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Abstract. *The goals of the Waste-to-Wisdom project is to produce bioenergy products and biochar from post-harvest forest residues and thus understanding public acceptance of the forest management and utilizing forest residues for biomass-based products is critical. This research explores the public perceptions of producing bioenergy products and biochar from forest thinning activities in the western Pacific Northwest region. A web-based survey was conducted in Washington, Oregon, and Northern California generating 1,202 responses. Multinomial regression techniques and simulation-based approach were applied to analyze how demographic and socio-economic factors influence public perceptions. People living in less populated areas are more likely to support forest thinning. Higher levels of education and household income also lead to higher levels of support for forest thinning. On the other hand, supports for forest thinning results in supports for using forest residuals to produce bioenergy products. These results suggest that different strategies are necessary to effectively communicate the environmental and ecological benefits of using forest residuals derived from forest thinning activities to produce biomass-based products.*

Keywords. *Environmental Perceptions, Multinomial Logistic Regression, Natural Resource Management, Rural vs. Urban, Simulation-Based Approach.*

One challenge of conducting forest management activities that involve biomass removal is the efficient disposal of unused forest residues (e.g., branches and tops). While there are many potential markets for forest residuals (Han et al., 2004), high collection and transportation costs mean that most forest residuals are left in the forest where they are burned in slash piles (Malmsheimer et al., 2008). In addition, ongoing consolidation within the forest products industry has altered the traditional utilization of forest resources (Sasatani and Zhang, 2015). The closure of many pulp mills, which were historically the main buyers of low grade logs, has forced nearby forestland owners to find alternative markets for low quality pulpwood (Li et al., 2004). Developing markets for currently unmerchantable forest residues would encourage forest owners to conduct pre-commercial thinning operations, which would help to improve the health and fire resilience of U.S. western forests (Becker et al., 2009).

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One aspect of the Waste-to-Wisdom project; hereafter referred to as W2W in this article, was to identify and test in-woods processing technologies that could effectively address the collection and transportation challenges associated with using woody biomass. Newly developed in-woods mobile biomass conversion technologies can reduce the production costs in the manufacture of value-added products including woody biomass-based products, such as wood briquettes and biochar. While markets for these products have not been established yet, they could be substitutes for existing bioenergy or soil amendment products (Sasatani and Eastin, 2017). Wood briquettes are produced from wood chips that have been densified under high pressure and heat to increase the energy content of the briquette. The energy content of wood briquettes can be increased substantially by torrefying the wood chips prior to producing the wood briquettes. Wood briquettes are mainly used as a heating fuel in residential and industrial markets. In addition, woody biomass can be used to produce biochar via a pyrolysis or thermal degradation process. Biochar is often used as a soil amendment due to its highly porous structure which helps in the retention of water and water-soluble nutrients which can be slowly released back to the soil (Spokas et al., 2012).

Identifying potential societal concerns associated with the use of woody biomass in the manufacture of wood biomass-based products early in a project can help to minimize concerns and help identify strategies to avoid potential conflicts (Nielsen-Pincus and Moseley, 2009). The western Pacific Northwest (PNW) region (consisting

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of Western Washington, Western Oregon and Northern California) includes several major metropolitan areas (e.g., Seattle, Portland, Sacramento, and the San Francisco Bay area) that are major hubs for innovation and technology. These urban areas with a higher average income per capita attract a diverse group of people and companies with a diverse range of environmental values.

Seemingly at the doorstep of these major urban areas are extensive forestlands that have traditionally provided economic sustenance for many small forest-dependent communities. In many of these rural forest-dependent communities' economic conditions, including the unemployment rate, employment growth, and household incomes, pale in comparison to major urban areas (USDA, 2016). There are significant differences between these urban and rural areas in terms of economic diversity, economic growth, industrial structure, social well-being and political viewpoints (Sasatani and Eastin, 2017). The inhabitants of rural and urban areas often hold very different views about forest management practices and woody biomass-based energy ("bioenergy") utilization (Marciano et al., 2014). Utilizing forest residuals for the manufacturing of bioenergy products must take into account the varied perceptions of both rural and urban communities since they often influence those who make important forest policy decisions (Selfa et al., 2011). Consequently, understanding the public perceptions of converting woody biomass into bio-based products is critically important to gaining public support for this type of project. In this research, a web-based survey was used to target urban and rural residents in the western PNW region to explore their attitudes and perceptions regarding forest biomass removal and the use of forest residuals in the production of woody bioenergy products and biochar. Socio-economic and demographic factors were then analyzed to verify if there are particular factors that showed a significant impact on public perceptions.

Literature Review

It is widely accepted that active forest management programs, including forest thinning, can be effective in helping to restore forest health and improve fire resilience of forests. This is particularly true in the case of National Forests where deferred forest management activities place these forests at a high risk for beetle infestation and catastrophic wildfire. However, experience has shown that active forest management programs that include forest thinning, particularly those conducted within public forests, can be controversial, particularly with local environmental groups suspicious that these activities are thinly disguised programs designed to increase the supply of timber for local wood processing facilities. Given this situation, it is important that bioenergy projects be sensitive to the varied perceptions of local and regional communities who can influence the decision making process on timber harvesting and bioenergy policies that could determine the success of these projects (Selfa et al., 2011). In addition, from a marketing perspective it is important to understand the perceptions of potential consumers of bioenergy products in order to avoid market failure (Wegener and Kelly, 2008).

Public Acceptability of Bioenergy

Studies that explore the social acceptance and public perceptions of bioenergy have increased since the beginning of the 21st century (Radics et al., 2015). Overall, most studies that investigate the social acceptability of bioenergy in the United States have found that most people have moderate to favorable attitudes toward the use of bioenergy (Singer, 2013). However, it is interesting to note that many of those who express moderate support for bioenergy are sometimes unfamiliar with the concept of bioenergy or how it is produced (Upham and Shackley, 2007). These studies have also noted that the public often has inherently negative perceptions toward some types of bioenergy projects. For example, researchers have noted that some people are skeptical about the carbon neutrality of wood based bioenergy (Savvanidou et al., 2010), while other people dislike the policies and subsidies that favor renewable energy over fossil fuel based energy (Bailey et al., 2011).

Based on an intensive review of the literature, Radics et al. (2015) failed to find any geographic or socio-economic differences in the level of support for bioenergy, noting that acceptability of bioenergy depends more on a variety of social and demographic factors. For example, some research suggests that gender has a strong influence on perceptions of bioenergy. Mariasiu (2013) reported that while men are more knowledgeable about bioenergy, women tend to be more likely to support and pay a premium on bioenergy if they perceive the environmental benefits as being positive. Similarly, age also strongly influences public perceptions of bioenergy. Zarnikau (2003) found that younger people are more likely to hold positive opinions toward bioenergy than older people. Education has a more nuanced influence on people's perceptions of bioenergy, with higher levels of education resulting in higher levels of support for bioenergy, although more highly educated people also perceive a higher risk associated with the production and use of bioenergy products (Popp et al., 2009). Researchers have also noted a difference in perceptions and attitudes about bioenergy between people living in rural areas versus urban locations. Part of this difference can be attributed to the fact that rural people live closer to the forest resource and view forests from both an environmental and economic perspective. For example, therural public believes that bioenergy production based on biomass derived from active forest management can improve forest health while helping to support economic development within rural, timber-dependent communities, and therefore they are more likely to support the increased use of bioenergy (Radics et al., 2015). Finally, political views have a strong influence on public perceptions and support of bioenergy. Research has found that Democrats are more likely to have a favorable view of bioenergy and a stronger concern about the environment than do Republicans (Cacciatore et al., 2012).

Public Acceptability of Pre-Commercial Thinning in National Forests

Decades of fire suppression and other management practices have created dense forest stands in National Forests that have adversely affected forest health, structure and resilience to insect infestation and fire (Shindler and Toman, 2003). These poor forest conditions equate to a dramatic increase in areas destroyed by beetle infestations and contributed to a significant increase in the incidence of catastrophic wildfires, particularly in the western United States and Canada (Shindler and Toman, 2003). The combination of increased fatalities, property damage, firefighting costs and ecological destruction make fire management a top priority in western forests of the United States (Weible et al., 2005). Mechanical thinning of dense forest stands is one of the management options available to reduce wildfire risk. However, increased demands for recreation and protection of biodiversity and endangered species have been driving forest management decisions in National Forests in the western United States, especially after the northern spotted owl was listed as threatened under the Endangered Species Act in 1990 (Charnley et al., 2008). Most federal forest lands in the western United States currently allow minimal timber harvesting with most of these proposed timber sales being immediately challenged in court by environmental groups opposed to any timber harvest activities in National Forests (Stuart, 2006). This opposition is often not looking at the overall benefits given the fact that thinning activities increase forest health and fire resilience in western forests.

Numerous studies have looked at the public support for forest thinning. For example, public support for forest thinning is generally strong on public lands where fire risk is perceived to be high (McCaffrey et al., 2013). Yet, public support for active forest management can vary geographically and is often dependent on an individual's experience and beliefs (Brunson and Shindler, 2004). For example, Ribe and Matterson (2002) found that people who held an eco-centric perspective of forests were more likely to mistrust forest managers and active forest management programs. Other studies have found that demographic characteristics, such as age, education, income and resident location influence public perceptions of forest thinning, although the results are inconclusive (McCaffrey et al., 2013). For example, while Weibl et al. (2005) found that holding an advanced degree positively influenced support for forest thinning, Shindler and Toman (2003) failed to find a statistically significant relationship between support for forest thinning and gender, education or income.

Rural vs. Urban Perception

Rural, timber-dependent communities are generally more supportive of active forest management and using forest residuals for bioenergy products (Radics et al., 2015). In contrast, people in urban areas tend to be less supportive of active forest management. However, since both of these groups can influence the decision-making process as it relates to forest management and forest thinning, it is important to understand the different perceptions and attitudes of these groups. The literature makes it clear that there is substantial disagreement between rural and urban Americans with regard to natural resource management and environmental policy (Salka, 2001). The decision of whether to continue exploiting forests for economic gain or to preserve these forests to enhance quality of life is a classic conflict. This often fails to adequately take into consideration the role of sustainability as a core principle of active forest management and forest health. In general, those living in urban areas are more likely to support the protection and preservation of forests than are those living in rural areas (Salka, 2001). Furthermore, urban residents (who view forests as a place to visit) are more likely to emphasize the amenity values of forests (e.g., recreation and scenic beauty of the forest landscape) than do rural residents who live in close proximity to forests (Tahvanainen et al., 2001). Another problem associated with urban perceptions of forest management practices may be attributed to their lack of familiarity with forestry practices such as thinning. The fact that some urban residents are unfamiliar with the terminology used by the forestry professionals to describe forest management activities can lead to emotional conflicts with respect to any type of management in National Forests (Tyrväinen et al., 2003). Interestingly, other research shows that urban residents who are unfamiliar with forest management practices tend to display moderate support for the use of bioenergy (Upham and Shackley, 2007). However, it is important to emphasize that some of the discrepancies between urban and rural residents can be explained by demographic and socio-economic variables (Kahn and Matsusaka, 1997), and thus it is very important to apply appropriate statistical techniques to reveal the correlation between public perceptions and the demographic and socio-economic factors that influence those perceptions.

Performing forest thinning operations has always been challenging because the woody biomass produced from these activities is often uneconomical to remove from the forest. The W2W project considers the challenge of how to economically conduct forest thinning operations and best utilize the woody biomass within the forested landscape. W2W may be able to help resolve this issue by generating revenue from the production and sale of value-added bioenergy products (wood briquettes and biochar) manufactured from forest residues. This revenue stream could then be used to fund the thinning activities being used to improve forest health and reduce the risk of catastrophic fire on both public and private forestlands in the western United States. However, public resistance to active forest management (particularly in urban areas) will inevitably result in policy conflicts that will increase the costs of implementing these policies and restrict efforts to improve forest health and increase fire resilience (Manfredo et al., 1990). When the public views a forest management strategy unfavorably, it becomes extremely difficult to implement this policy on public forestlands no matter how ecologically sound it may be (Stidham and Simon-Brown, 2011). Thus, the goal of this research is to develop a better understanding of the factors that influence public perceptions and attitudes towards active forest management and the use of woody biomass derived from forest thinning activities in the production of bioenergy products.

METHODOLOGY

SAMPLING METHOD

A web-based survey was conducted to collect primary data during March 2016. The objective of the survey was to explore public perceptions about forest resource management and utilization. With regard to the forest resource management component, we were interested in assessing public perceptions of active forest management (especially forest thinning) in public forests. With respect to the issue of forest utilization, we were looking to assess public attitudes and perceptions towards using woody biomass from forest thinning operations to make wood briquettes and biochar. The goal of the survey was to understand how perceptions would change as other demographic factors vary. Based on the objectives of the research project, we defined the geographic scope of the study as being Western/Central Washington, Western/Central Oregon, and Northern California. Many people in rural areas in Eastern Washington, Eastern Oregon and Central/Southern California manage their land for agriculture and do not engage in forest operations, and thus may have quite different views than those who live or reside in forested regions. Accordingly, they were excluded from this study.

Urban/rural influence on perceptions is the main independent variable of interest, and comparing these different population zones can provide a baseline of how respondents in this study feel about the forest. However, there are many ways to determine urban and rural dwellers. The assumption is that the population density of a zip code where respondents live well represents an urban/rural classification. Since the great majority of people in the U.S. West Coast live in urban areas, we still want to engage stakeholders in rural forest areas. In order to overcome this problem, we oversampled rural respondents by a stratified sampling technique using 500 persons per square mile as a threshold to categorize zip codes into urban and rural areas. The web-based survey was conducted using the Qualtrics survey platform (Qualtrics LLC, 2017) during March 2016. The study population was first divided into six stratum based on 2010 census data: urban Washington (158 zip codes; 3.99 million people), rural Washington (249 zip codes; 1.95 million people), urban Oregon (75 zip codes; 2.03 million people), rural Oregon (247 zip codes; 1.58 million people), urban Northern California (287 zip codes; 8.90 million people), and rural Northern California (349 zip codes; 2.36 million people). Following Dillman (2000), the survey was pre-tested to ensure the comprehensiveness, clarity and ease of use of the survey instrument. Qualtrics randomized the distribution of surveys to zip codes in the strata of interest and only survey respondents from age 21 to 75 from their email database and sent emails. When all strata reached a minimum of 150 responses, Qualtrics stopped collecting responses. This quota sampling method is efficient, especially when utilizing online survey software, such as Qualtrics. This is not a pure probabilistic sampling method, and thus the descriptive statistics of the respondents may not be representative of the population of interest. However, this sampling method can efficiently collect a more diverse sample from large geographic areas including sparsely populated rural areas. Subsequent statistical models can then be developed to estimate the perception of a counterfactual person with certain demographic factors in the PNW.

QUESTIONNAIRES AND VARIABLES

Questionnaires used in this study were part of a larger survey that asked respondents about their opinions on the current impacts of bioenergy on the economy and forest industry, the effects of forest thinning and treatments of slash piles, and their perceptions on forest management and the protection of national forests. The introduction to the survey included a brief explanation on the purpose of the survey and informed the respondent on the types of bio-based products asked about in the questionnaire and how they are produced. The dependent variables were derived from three questions. The first question asked if the respondent supported the thinning of dense forests. The second question asked if the respondent would support the production of woody bioenergy products, such as wood briquettes, from forest residuals. The third question asked if the respondent would support the production of biochar as a soil amendment from forest residues. Each question provides three response options; 1) yes, 2) no, and 3) no opinion. The “no opinion” response option was included based on previous studies which found that people with little knowledge of these issues tend to indicate that they support them (e.g., Upham and Shackley, 2007). By providing the option to respond “no opinion”, we hoped to be able to distinguish between respondents who really support these activities from those who are less knowledgeable. The question related to support for forest thinning was also used as an independent variable to help model the support for woody bioenergy products and biochar.

In order to control the independent variables of the statistical model, the survey also collected demographic information about each respondent including: gender (male or female), household income (based on seven ordinal categories), and the highest level of education completed (based on five ordinal categories). In addition, the survey asked each respondent to indicate whether or not they often spend time in National Forests. As mentioned before, the population density of the respondent’s zip code was included to serve as a proxy for the rural/urban classification. Both household income and population density display a right-skewed distribution. Those indicators often increase relatively (i.e., exponentially) rather than absolutely (i.e., linearly), and thus a natural logarithm was used to transform both variables.

MULTINOMIAL LOGISTIC REGRESSION

The response variables obtained in this study are unordered categorical variables with three response categories. Multinomial logistic regression (MNL) is often used to model nominal outcome variables (Agresti and Kateri, 2011). The probability distribution of the response variables y (yes: j=1, no opinion: j=2, no: j=3) is assumed to be multinomial. The latent systematic component, μ_{ij}, for the *j*-th outcome of the *i*-th respondent can be represented as:

$$\mu_{ij} = x_i\beta_{ij} \tag{1}$$

where x_i is the vector of the explanatory variables of respondent *i,* and β_{ij} is the vector of the regression coefficient estimates. In other words, the systematic components are explained by the linear combinations of the products of *x*s and βs. Assuming the link function between the systematic (1) and the random components is logit, the probability model of the MNL can be expressed as:

$$Pr\left(y_i = j|x_i\right) = \frac{e^{\left(x_i\beta_j\right)}}{\sum_{k=1}^{3} e^{\left(x_i\beta_k\right)}}\text{ , j=1,2,3} \tag{2}$$

In order to identify the coefficients, we used y_i=3 (i.e., oppose) as the baseline category and thus β_3 is the vector of zeros. The natural logarithm of the likelihood function was maximized by utilizing the "optim" function in R (R Core Team, 2015) to obtain the coefficient parameters for the model. The most parsimonious model was selected as the best model based on the Akaike Information Criteria (AIC) (Buckland et al., 1997).

Simulation-based approach (King et al., 2000) can provide a unique view into the data. Because this approach can visually discover interesting structures of statistically complex non-linear models, applying this has recently became popular in the forest sciences literature as well (e.g., Ganguly et al., 2011; Sasatani and Eastin, 2015). In this analysis, the coefficient estimates of the best model can be transformed into counterfactual probabilities to help interpret the relative magnitude of each type of effect on a hypothetical person. In this analysis, 10,000 draws were taken from the multivariate-normal distribution with means at the point estimates from the model and a variance matrix as the estimated variance-covariance matrix from the Hessian matrix. The 10,000 simulated sets of coefficients were placed into vectors and used to calculate the counterfactual probability for a hypothetical individual who has a set of given explanatory variables. We then graphically report some of the predicted probabilities by utilizing the "tile" function (Adolph, 2012) of R (R Core Team, 2015).

RESULTS

A total 1,202 responses were collected in this project: 436 responses (36.3%) were collected from Washington (including 271 from urban areas and 165 from rural areas); 320 responses (26.6%) were collected from Oregon (including 158 from urban areas and 162 from rural areas); and 446 responses (37.1%) were collected from Northern California (including 296 from urban areas and 150 from rural areas). The overall descriptive statistics of the respondents are summarized in table 1. With regard to the response variables, overall 58.1% of the respondents support thinning activities, ranging from 53.6% in Northern California to 67.2% in Oregon, while 27.4% of the respondents do not support thinning activities, and 14.6% do not have an opinion. Overall, 79.5% of the survey respondents support the use of forest residuals to make bioenergy products whereas 73.0% support the use of forest residuals to produce biochar. Just 9.1% and 9.0% respondents oppose the use of forest residuals to make bioenergy products and biochar products, respectively.

A summary of the explanatory variables from each state is also shown in table 1. Among all respondents, 62.1% were female. Also, 63.5% of the respondents often spend time in National Forests; the highest was Oregon (67.5%) and the lowest was Northern California (59.6%). With regard to the highest education received, 3.9% of the respondents had some high school or less, 15.1% received a high school diploma, 34.1% spent some time in college,

Table 1. Descriptive statistics of survey results by state.

	Total	Washington	Oregon	N. California
Number of Respondents	**1,202**	436	320	446
Response Variables				
Support Thinning (%)				
Yes	**58.1%**	56.0%	67.2%	53.6%
No	**27.4%**	26.4%	24.4%	30.5%
No Opinion	**14.6%**	17.7%	8.4%	15.9%
Support Bioenergy Products (%)				
Yes	**79.5%**	81.4%	85.3%	73.5%
No	**9.1%**	7.6%	6.3%	12.6%
No Opinion	**11.4%**	11.0%	8.4%	13.9%
Support Biochar (%)				
Yes	**73.0%**	72.0%	77.5%	70.6%
No	**9.0%**	8.3%	7.5%	10.8%
No Opinion	**18.1%**	19.7%	15.0%	18.6%
Explanatory Variables				
Female (%)	**62.1%**	67.0%	58.4%	60.1%
Spend in Forest (%)	**63.5%**	64.4%	67.5%	59.6%
Median Education	**Some college**	College	Some college	Some college
Mean HH Income ($)	**$67,795**	$65,442	$60,460	$75,358
Std. Dev	*($51,734)*	*($51,620)*	*($42,430)*	*($56,803)*
Mean Population Density(persons per square mile)	**2,998**	2,824	1,505	4,240
Std. Dev	***(5,161)***	*(4,015)*	*(1,919)*	*(7,093)*

33.7% received a college degree, and 13.1% received a graduate degree. The mean household income was estimated to be $67,795 from the aggregated category, ranging from a high of $75,358 for Northern California to a low of $60,460 for Oregon. The standard deviation for the household income data was very large ($51,734), which suggests the household income data was widely spread. The mean population density for the respondents was 2,998 persons per square mile ranging from a high of 4,240 persons per square mile in Northern California to a low of 1,505 persons per square mile in Oregon. The high standard deviation (5,161 persons per square mile) reflects the large range in population density between the urban and rural areas included in the survey. It is important to note that the descriptive statistics are of the respondents, and do not represent the central tendency of the target population, and thus further simulation analyses will be required

The estimation results for the MNL regressions are presented in table 2. The full models that include all of the variables and some important interactions were estimated first. Then, a backward stepwise procedure was used to determine which explanatory variables should be retained in the best parsimonious model. Support for thinning activities in forests was the first question that was estimated. The results show that both education level and household income were positively related to the support for thinning (and were statistically signification at the 1% level). In other words, as a respondents level of education or household income goes up, so too does their support for the use of thinning in forests. The results also show that population density was negatively related to the support for forest thinning meaning that respondents living in urban areas are significantly (at the 1% level) less likely to support thinning activities within forests. This analysis also found no statistically significant relationship between support for thinning and gender, frequent visits to National Forests or any of the interaction terms.

The effects of the independent variables are complex and non-linear and it should be noted that the odds that a respondent would oppose thinning are not shown in table 2 since we used oppose thinning as the base line for the MNL analysis. We then conducted counterfactual simulations based on the final (best) models in order to make it easier to visualize the relationships between the significant variables

Table 2. Results of multinomial logistic regression.

	Thinning on National Forests						Bioenergy Products						Biochar					
	Full Model			Best Model			Full Model			Best Model			Full Model			Best Model		
	PE	SD	Z	PE	SD	Z	PE	SD	Z	PE	SD	Z	PE	SD	Z	PE	SD	Z
Supports (vs Oppose)																		
(Intercept)	-9.300	4.251	**	-2.376	1.172	**	-7.265	6.679		-6.800	1.970	***	-0.546	6.736		0.007	0.371	
Thinning: Support†	NA			NA			1.772	0.236	***	1.757	0.233	***	2.329	0.248	***	2.288	0.243	***
Thinning: No Opinion†	NA			NA			1.808	0.423	***	1.800	0.421	***	2.685	0.606	***	2.676	0.605	***
Go to Forests†	0.049	0.579		0.146	0.144		1.658	0.836	**	0.450	0.222	**	0.181	0.862		0.287	0.226	
Female†	0.050	2.314					0.661	3.784		0.670	0.219	***	0.118	3.768				
Education	2.249	1.068	**	0.226	0.074	***	0.483	1.768		0.236	0.115	**	-0.479	1.759		0.280	0.106	***
Income	0.953	0.396	**	0.312	0.113	***	0.722	0.633		0.647	0.193	***	0.005	0.633				
Population Density	-0.136	0.047	***	-0.143	0.038	***	-0.051	0.078					0.096	0.075				
Forest x Density	0.015	0.080					-0.175	0.118					0.014	0.123				
Female x Income	-0.001	0.212					0.002	0.354					-0.012	0.348				
Education x Income	-0.188	0.099	*				-0.023	0.166					0.065	0.164				
No Opinion (vs Oppose)																		
(Intercept)	-9.388	5.740		-2.075	1.624		-4.023	8.135		-4.381	2.421		7.722	7.498		-0.102	0.411	
Thinning: Support†	NA			NA			0.416	0.316		0.390	0.313		1.053	0.290	***	0.999	0.285	***
Thinning: No Opinion†	NA			NA			2.403	0.451	***	2.384	0.450	***	3.342	0.614	***	3.289	0.612	***
Go to Forests†	-0.790	0.791		-0.861	0.193	***	1.007	1.054		-0.076	0.273		0.001	0.973		-0.390	0.252	
Female†	-2.362	3.300					2.229	4.809		1.054	0.284	***	2.647	4.282				
Education	2.604	1.481	*	-0.062	0.100		-0.343	2.146		-0.028	0.141		-3.236	1.945		-0.047	0.119	
Income	0.794	0.534		0.117	0.156		0.305	0.770		0.322	0.236		-0.782	0.706				
Population Density	-0.004	0.075		-0.003	0.054		-0.031	0.101					0.041	0.088				
Forest x Density	-0.007	0.109					-0.157	0.149					-0.055	0.138				
Female x Income	0.235	0.304					-0.108	0.449					-0.212	0.396				
Education x Income	-0.247	0.137	*				0.029	0.202					0.295	0.181				
AIC	2,227			2,218			1,368			1,354			1,569			1,561		
BIC	2,317			2,269			1,480			1,426			1,681			1,611		

Note: PE, SE and Z represent point estimates, standard errors of coefficient, and the significance level of z-tests respectively; † represents dummy variable; ***, **, and * represent significant difference at the 1%, 5%, and 10% levels, respectively. The second question looked at respondent support for the production of bioenergy products from forest residuals derived from forest thinning activities. The results from the best model show that when respondents support or have no opinion regarding forest thinning (top half of table 2), they are significantly more likely to support the production of bioenergy products derived from forest residuals (at the 1% level of significance). Gender (female), frequent visits to National Forests, increasing level of education and increasing household income also significantly increase the odds that a respondent will support the production of bioenergy products from forest thinnings. The results did not show any relationship between population density and support for the production of bioenergy products. The third question looked at respondent support for the production of biochar products from forest residuals derived from forest thinning activities. The results from the best model show that when respondents support or had no opinion regarding thinning, they are significantly more likely to support the production of biochar from forest thinnings (at the 1% level of significance). The education level of respondents was significantly and positively related to support for the production of biochar from forest residuals derived from forest thinning activities (at the 1% level of significance). Neither gender, level of household income nor population density were significantly related to support (positive or negative) for the production of biochar products.

identified for each of the three questions of interest (figs. 1-3). In the first simulation (fig. 1), we consider how household income and population density influence the probability that respondents would be supportive of forest thinning activities. As discussed previously, support for forest thinning activities was significantly and positively related to level of education, household income, population density, and time spent in National Forests. In this first simulation, we compare three hypothetical locations within the coastal Pacific Northwest where the population densities are 5,000, 900, and 55 persons per square mile. These locations are categorized in figure 1 as "metro suburbs", "small city", and "rural", respectively. In the first simulation, household income varied from \$15,000 to \$500,000 while holding constant the other significant variables: time spent in National Forests (some) and level of education (some college). Figure 1 shows the results of the counterfactual probability simulations under this scenario. Considering figure 1, the probability that a person would support forest thinning activities increases as their household income increases (support increases from left to right within each figure). Similarly, their support for forest thinning increases as the population density of where they live decreases. In other words, support for thinning activities is greatest in rural areas followed by small cities and urban areas (support increases across the three figures moving from left to right). For example, if a counterfactual person lives in an urban city (fig. 1a) with an annual household income of \$60,000, the probability s/he would support forest thinning activities is 55.0% ± 2.5%, while the probability that s/he would oppose forest thinning is 32.9% ± 2.3% and the probability that s/he would not have any opinion about forest thinning is 12.1% ± 1.5%. If the annual household income of the same person were increased to \$250,000, ceteris paribus, the probabilities that s/he would support, oppose and have no opinion about forest thinning change to 64.8% ± 4.4%, 24.6% ±3.5%, and 10.6% ± 2.7%, respectively. If the same person with an annual household income of \$60,000 were to live in a rural area (fig. 1c), the probability that s/he would support, oppose or have no opinion about forest thinning is 69.8% ± 2.6%, 21.9% ± 2.2%, and 8.1% ± 1.3%, respectively.

The second simulation (fig. 2) considers the question of whether people support or oppose the use of forest residuals derived from forest thinning activities for bioenergy products based on the significant variables

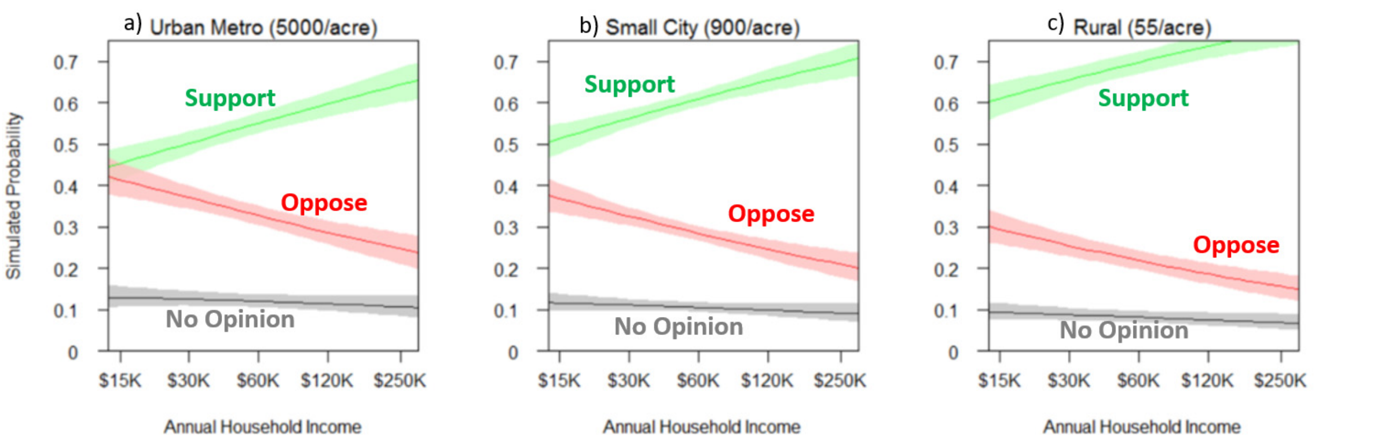

Figure 1. Counterfactual probabilities regarding forest thinning by a hypothetical person based on location using a simulation-based approach. In this scenario, annual household income is varied while all other factors are held constant. The central lines in each distribution represent the point estimates and the shading represents the one standard deviation confidence interval around the mean.

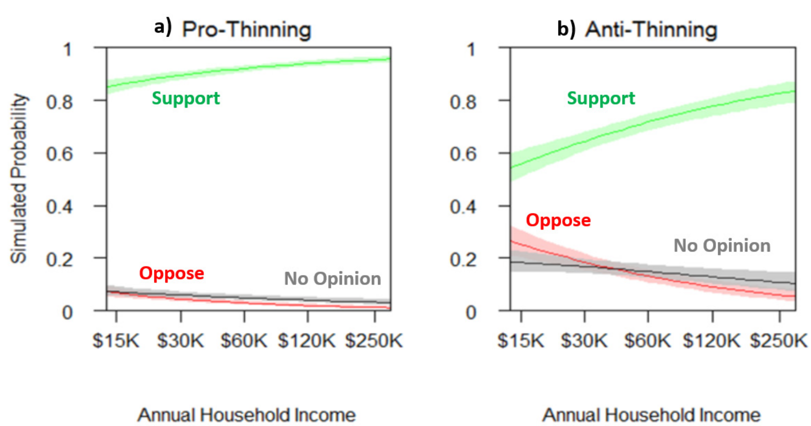

Figure 2. Counterfactual probabilities regarding support for the production of bioenergy products from post-harvest forest residuals by a hypothetical person who supports or opposes forest thinning using a simulation-based approach. In this scenario, annual household income is varied while all other factors are held constant. The central lines represent the point estimates and the shading represents the one standard deviation confidence interval around the mean.

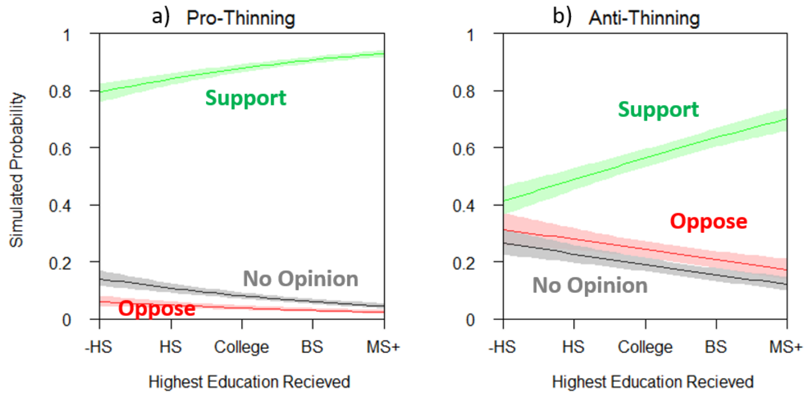

Figure 3. Counterfactual probabilities regarding support for the production of biochar from post-harvest forest residuals by a hypothetical person who supports or opposes forest thinning using a simulation-based approach. In this scenario, the level of education is varied while all other factors are held constant. The central lines represent the point estimates and the shading represents the one standard deviation confidence interval around the mean.

identified in table 2. In this simulation, we assume two identical persons (male, finished some college, do not visit National Forests often, and who live in an urban area), where one supports forest thinning activities (fig. 2a: pro-thinning) and the other opposes forest thinning activities (fig. 2b: anti-thinning) and where their household income changes from \$15,000 to \$250,000. Figure 2 shows the results of the counterfactual probability simulation for this scenario. In this simulation the pro-thinning person has a significantly higher probability of supporting the production of bioenergy products generated from forest residuals. As we vary his annual household income from \$30,000 to \$100,000 in figure 2a, the probability that he would support bioenergy products increases from 89.5% ± 1.7% to 93.6% ± 1.3%. While the simulation results show that the anti-thinning person is significantly less likely to support the production of bioenergy products from forest residuals, his support for bioenergy products does increase significantly as their household income increases from \$30,000 (support is just 64.4% ± 3.7%) to \$100,000 (support increases to 76.2% ± 3.6%). Similarly, the opposition to bioenergy products from woody biomass declines significantly as the household income of the anti-thinning person increases.

The third simulation (fig. 3) considers the question of whether a person supports or opposes the conversion of forest residuals derived from forest thinning activities into biochar based on the significant variables identified in table 2. In this simulation, we assume two identical persons (men with an annual household income of \$50,000, who do not visit National Forests often, and who live in an urban area). In this scenario, one person supports forest thinning activities (fig. 3a: pro-thinning) and the other opposes forest thinning activities (fig. 3b: anti-thinning) and their highest level of education changes from "some high school" to "obtained a graduate degree from college". Figure 3 shows the results of the counterfactual probability simulation for this scenario. A comparison of figures 3a and 3b show that the pro-thinning person is significantly more likely to support the production of biochar from forest residuals than is a person who opposes thinning in forests (fig. 3a vs. 3b). Both figures 3a and 3b show the positive relationship between the support for the production of biochar from forest residuals and level of education. If a person who supports forest thinning has had some high school, the probability that he would support the production of biochar from forest residuals is 79.5% ± 3.6%., whereas for the same person with a graduate degree, the probability that he would support the production of biochar from forest residuals increases significantly to 93.1% ± 1.3% (fig. 3a). On the other hand, if a person was anti-thinning and had completed some high school, the probability that he would support biochar production from forest residuals would drop significantly to just 41.5% ± 4.9% (fig. 3b). If the same person had completed a graduate degree in college, then his support for the production of biochar from forest residuals would be expected to increase significantly to 70.1% ± 4.1%.

Discussion and Conclusions

In this research, we explore the public support for thinning activities in U.S. western forests and the use of the resultant forest residuals in the production of bioenergy products and biochar. It was important for this study to give the option of "have no opinion" because past studies suggest that folks who do not have a strong understanding of an issue (e.g., biochar) are more likely to indicate their support for the issue. The responses were treated as nominal variables and MNL regression was applied to estimate how demographic and social factors influence public acceptance of forest thinning activities and the use of forest residuals to produce bioenergy products and biochar. The majority of respondents support thinning of forests and using the forest residuals generated during those thinning activities to produce bioenergy products and biochar. Public acceptance of forest thinning, bioenergy products and biochar show different results based on a variety of variables, including where to reside, level of education, household income, gender, location, and frequency of visits to National Forests. These results suggest that different communication strategies and messages are needed in order to educate the public about the role of forest thinning in improving the health and fire resilience of western forests and the economic benefits.

Simulation results indicated strong support for producing bioenergy products and biochar from forest residuals derived from forest thinning operations. More importantly, very few people opposed the production of bioenergy products or biochar from forest residuals and the opposition to bioenergy products does not appear to be related to population density. The single most important factor that determined if people supported the production of biomass-based products is whether s/he supports forest thinning. The simulation results also show that a sizable proportion of respondents had no opinion about using forest residuals for bioenergy/biochar. Utilizing the woody residuals derived from forest thinning can help improve the ecological sustainability of forest while producing bioenergy products and biochar could help to support rural economic development. Investing time in identifying those who oppose forest thinning can help industries' promoting products from forest residuals. By educating people that are opposed to thinning can help them to understand the numerous benefits of well-designed thinning activities and could be an important strategy for showing the positive impacts on forest health and fire resilience within western forests.

Although the majority of people would support forest thinning, it is important to note that quite a few people would oppose thinning activities. The model results show that opposition to forest thinning increases as urban density increases (from rural areas, to small cities to large urban areas). Rural residents living in the PNW region are surrounded by forests and they are more aware of the direct positive relationship between sustainable forest management (including forest thinning) and forest health, fire resilience and rural economic development. In contrast, most urban residents only visit forests occasionally and they generally do not have a strong understanding of how unmanaged dense forest conditions can adversely impact forest health and increase the chances of insect infestations and catastrophic wildfires. Previous research has found that many urban residents tend to overemphasize the amenity values of forests while being more likely to view forest management activities as being destructive to forests and wildlife (Tahvanainen et al., 2001). However, given the asymmetrical influence of people living in urban areas on natural resource policies (relative to people living in rural areas), these results suggest that it is important to ensure that urban people better understand that sustainable forest management, including thinning of forests, is critical to maintaining healthy forests that are resilient to both insect infestations and catastrophic wildfires.

In addition, this study reveals that higher income and educational level contribute to a higher percentage of support for forest thinning, and vice versa. People who live in urban areas with a lower household income and lower education level are more likely to oppose active forest management. People who visit National Forests often tend to hold positive opinions on forest thinning, so engagement and education to those demographics that are less inclined to support forest management could help them to understand the benefits of forest thinning and products utilized from forest residuals. However, it is also very important to note that decisions made in the process of natural resource management do not necessarily reflect the voices of the majority. Strong voices from an active few sometimes heavily influence policy. Unfortunately, this result does not reveal those who are the positive active voices toward forest management activities, but it is clear that a majority of people support forest thinning regardless if they actively voice their opinion or not.

This study has certain limitation. Although a large sample was collected, it was not a pure probability based sample. A quota sampling method utilizing a database of survey participants may generate some bias; though, this method suited the purpose of the research since the primary objective was to see how opinions vary depending on demographic factors. However, caution needs to be taken in the interpretation of these descriptive statistics since they are from samples that are not necessarily representative of entire populations in these regions. These results can contribute to future studies by helping researchers further discern demographic factors that could potentially affect the public's perceptions of forest management activities and products that could utilize post-harvest residuals on-site. This manuscript is a part of a large survey, and the full results of the survey will be included with the final report of the W2W project.

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