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RESEARCH PAPER

Willingness of Nonindustrial Private Forest Owners in Norway to Supply Logging Residues for Wood Energy

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Abstract Norway has set ambitious targets for increasing bioenergy production. Forest residue extraction levels are currently very low, but residues have the potential to be an important component of the wood energy supply chain. A representative sample of Norwegian nonindustrial private forest owners having at least 8 ha (20 acres) of productive forest land was surveyed about their willingness to supply logging residues for wood energy production. About 59 % responded that they were willing to do so. Logistic regression analyses revealed that the following factors were positively associated with the likelihood of being willing to supply logging residues: total forest area, education level, living in a region with active timber markets and a history of forest production, and having positive perceptions of residue extraction and forestry's role in mitigating climate change. Four variables were negatively associated with the likelihood to supply residues: living on property, being older than 65 years, having family or friends who are opposed to residue extraction, and having negative perceptions of residue extraction. The study provides insight regarding nonindustrial forest owners' attitudes towards extraction of forest residues that may aid policy-makers designing effective means to meet national bioenergy production goals.

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Introduction

The European Union (EU) has an objective of increasing the share of renewable energy to 20 % of gross energy consumption by 2020 (European Commission 2009). The share was 14.1 % in 2012, of which woody biomass constituted almost half (Eurostat 2014). Biomass may become the single most important energy source in the Nordic countries by 2050 if the stated policy goal of keeping global warming below 2 °C is to be reached (IEA 2013). Currently, the contribution of forest residues to wood energy supply in most European countries is marginal. Data on current residue extraction levels are scarce, but one study estimated its use in 29 European countries at 17 million m^3 roundwood equivalent or 2 % of the total wood supply (UNECE 2007). 95 % of this harvest residue volume is supplied by Germany, France, Finland and the Czech Republic (UNECE 2007).

Despite its current marginal role, the volume of harvest residues from forestry operations could increase substantially by 2020 given country level mandates and enabling policies targeting forest biomass (Moiseyev et al. 2011; Matthews et al. 2014). The theoretical potential of forest residue supply in 27 EU countries was estimated to be 332 million m^3 in 2010; a more realistic potential considering social, environmental and technical constraints is about 100 million m^3 (Verkerk et al. 2011).

Like the EU, Norway aims to enlarge the role of renewable energy by doubling the 2007 bioenergy production level to 14 TWh by 2020 (Norwegian Ministry of Petroleum and Energy 2008). Intensified harvest residue extraction is an important component of the policy strategy (Norwegian Ministry of Petroleum and Energy 2008). A conservative resource potential estimate is 10 TWh by 2020 (Norwegian Water Resources and Energy Directorate 2014). Up to 2.7 TWh of residues could potentially be supplied at a cost of 150 NOK/MWh or less[1] under the current national harvest levels of about 10 million m^3 (Bergseng et al. 2013).

Logging residue production in Norway has shifted substantially in recent years due to changes in the subsidies granted to forest owners for extraction. In 2013, those subsidies were 27 NOK/loose m^3 of residues, or about 0.032 NOK/kWh (Norwegian Agricultural Authority 2013). The domestic production level increased from almost zero before the introduction of the subsidy to 880,000 loose m^3 in 2012, but has since decreased significantly due to the removal of the subsidies in the end of 2013 (Skog 2013).

Globally, several studies of forest owner willingness to supply forest residues have been carried out. In a Swedish study, about 60 % of the forest owners who had made a final harvest had supplied or planned to supply logging residues (Bohlin and Roos 2002). Soil preparation effects, facilitation of tree planting, and a desire by the timber purchaser to buy residues were important determinants in decisions to sell residues. In a study of Finnish forest owners, 18 % stated their willingness to supply forest residues for free and 55 % for compensation (Rämö et al. 2009). Lack of market information was considered a major obstacle for energy wood supply, and respondents were concerned about soil nutrient impacts of residue extraction.

[1] 1 USD ≈ 7.80 NOK.

Several studies of non-industrial private forest owners' attitudes towards supplying woody biomass (including low-quality trees and logging residues) for energy have been undertaken in the southern United States. Joshi and Mehmood (2011) found that 85 % of the surveyed forest owners were willing to supply woody biomass if offered an equivalent payment of pulpwood price. Willingness to supply woody biomass increased with forest area, proportion of forest consisting of pine and of mixed forest, wildlife habitat being an objective of forest management and owner's education. Willingness was lower among landowners who were older than 60 years or had timber production as a management objective. In another study the authors observed an increase in willingness to supply residues where there was a perceived economic benefit, landowners had a large share of their forests in pine plantations, resided on or close to their forest property, and were older (Joshi et al. 2013). Gruchy et al. (2012) detected landowners' interest in supplying harvest residues for bioenergy over standard clearcut to be impacted by owner's education level, financial motivations and environmental considerations. Shivan and Mehmood (2012) similarly found that the probability of an owner accepting a given bid for residues increases with timber production being an important management objective, the landowner having harvested timber during the past 10 years, large proportions of the forest consisting of small trees, and the size of forest area. Lack of knowledge was insignificant in predicting forest owners' interest to sell forest residues. In contrast to Joshi et al. (2013), residency on or close to the forest property negatively affected the likelihood of acceptance, as did landowner's age being more than 60 years.

In Minnesota and Wisconsin, Becker et al. (2013) employed the Theory of Planned Behavior to estimate the social availability of forest residues from private forest owners. Payment level, landowner attitudes, social norms, positive and negative perceptions of residue removal were important predictors of stated willingness to harvest. In contrast to Shivan and Mehmood (2012), lack of knowledge was detected as an impediment to accepting payment for woody biomass. Markowski-Lindsay et al. (2012) detected biomass price, positive perceptions of residue removal and forest owners being male to impact positively on the interest in supplying logging residues among family forest owners in Massachusetts.

In Norway, Brough (2009) and Brough et al. (2013) evaluated the interest of members of two local forest owner organizations in supplying logging residues. Perceived beneficial effects of logging residues removal on forest management and economy positively impacted on the forest owners' intention to deliver logging residues; assumed negative environmental effects significantly reduced the intentions together with age and subjective norms from personal relationships. Owner's gender did not impact the intention to deliver logging residues.

To our knowledge, no studies have analyzed the extent to which forest owners are interested in supplying logging residues in Norway using a representative sample of private forest owners covering the entire country. Insight into their willingness to supply such residues is crucial for gauging realistic potentials for their contribution to the future energy mix and for going beyond assessing the potential based solely on biological considerations, which tend to be considerably higher than what may be attainable when financial and social factors are considered (Butler et al. 2010; Becker et al. 2013). The aim of this paper is to fill this void by conducting a comprehensive study with a representative sample of Norwegian forest owners about the conditions needed to consider supplying harvest residues.

Based on the reviewed studies and economic theory, it was hypothesized that the variables included in Table 1 impact on forest owners' willingness to supply logging residues. Norwegian forestry can geographically be divided into two regions, with one having strong traditions for forestry, consisting of the counties in eastern and central Norway. In the "coastal counties" in the west and northern part, properties are small (Statistics Norway 2014), the level of knowledge of and engagement in forestry tends to be lower (Follo 2014) with relational capital and the ability to mobilize forestry activities below those in the rest of the country (Amdam et al. 2000). Accumulation of old-growth forest is the highest in these areas (Statistics Norway 2014); it was thus hypothesized that *ceteris paribus*, the interest in supplying logging residues would be lower among owners in coastal counties.

Research Data and Methods

A sample of 1500 was randomly drawn from the population of approximately 77,000 private Norwegian forest owners who own at least 8 hectares of productive

Table 1 Variables expected to affect the dependent variable of willingness to supply logging residues and hypothesized impact

Variable	Hypothesized direction of impact	Reference
Total forest area	+	Bohlin and Roos (2002); Shivan and Mehmood (2012)
Living on forest property	?	Shivan and Mehmood (2012); Joshi et al. (2013)
Age	−	Joshi et al. (2013); Joshi and Mehmood (2011)
Education	+	Joshi and Mehmood (2011); Gruchy et al. (2012)
Gender	?	Markowski-Lindsay et al. (2012); Brough et al. (2013)
Living in an area with strong forestry traditions	+	See text
Family and friends are opposed to removing logging residues	−	Becker et al. (2013); Brough et al. (2013)
Previously been asked to deliver logging residues	+	Becker et al. (2013)
Perceived positive impacts of logging residue extractions	+	Markowski-Lindsay et al. (2012); Becker et al. (2013); Brough et al. (2013)
Perceived negative impacts of logging residue extractions	−	Becker et al. (2013); Brough et al. (2013)

forest land. Statistics Norway, the official Norwegian agency responsible for surveys and recording, administrated the database and drew the sample. 8 hectares (20 acres) was chosen to focus on larger landowners who have been found to be more likely to supply forest residues, and to allow comparison with similar studies in the U.S. (e.g. Becker et al. 2013). The population was divided into three subgroups according to forest landholding size, 8–49.9, 50–99.9 and >99.9 hectares (Table 2). The random sample was drawn such that the area in each stratum was proportional to the population of productive forest land in that stratum. This stratification was done to create a sample representing the productive forest land base across a population that was highly heterogeneous in forest size, but highly skewed towards large properties. The average property size across the almost 130,000 Norwegian private forest properties is 55 hectares with more than 60 % of the properties being smaller than 25 hectares (Statistics Norway 2014). Due to more missing observations of productive forest area than of total forest area (214 contrasted to 55), observations that lacked productive forest area were classified to the strata by using the output from regression of total forest area on productive forest area where both were provided. The correlation coefficient between total forest area and productive forest area was 0.97, with R^2 of this regression being 0.96.

Survey questions on land owner willingness to supply harvest residues were developed in conjunction with a mail questionnaire that queried landowners about their willingness to participate in forest carbon markets and manage their forest for carbon sequestration. The survey was partly based on Miller et al. (2012) and developed in collaboration with Statistics Norway. Statistics Norway administrated the survey following the Total Design Method (Dillman 1978). All correspondence with the respondents was done by surface mail, with the first survey sent out on April 12, 2013, the second on May 6, and the last on May 31. Each mailing included the full survey. Surveys returned by August 1, 2013 were included in the final data. The full questionnaire can be found in Appendix A in Håbesland et al. (2015).

Multiple imputation was used to restore missing values based on the variance and relations within the data (Graham 2009; Azur et al. 2011). The **mi** package in the statistical software R (version 3.1.1) was used for the imputations (Su et al. 2011). For each variable with missing observations, the observed values were regressed on the other variables in the dataset, using observed and randomly drawn values (Azur et al. 2011). This was repeated with added noise 30 times or until convergence was reached, using Gelman-Rubin convergence statistics of the stability of the iterative simulations ($\hat{R} < 1.1$) (Gelman and Rubin 1992). This *Imputed dataset* was used for

Table 2 Population and drawn samples in different size classes of productive forest land area

Sampled size class	Population	Gross sample	Net sample
8.0–49.9 ha	52,826	370	174
50.0–99.9 ha	13,651	297	149
>99.9 ha	10,685	833	424
Unknown	0	0	55
Total	77,162	1500	802

Table 3 Variables included in the analyses and descriptive statistics

Variable	Question	Type	Mean	SD[a]
AESTHETIC	Removing logging residues makes the harvesting site prettier	Ordinal (5-point)[b]	4.0	1.1
AGE	Age of respondent	Non-negative	56.7	13.4
ASKED	Ever been asked to supply logging residues	Dichotomous	0.1	0.2
BIODIV	Removing logging residues is bad for biodiversity in the forest	Ordinal (5-point)	3.6	1.1
BIOENERGY_CC	Increased use of bioenergy from forests in Norway is a useful contribution to reducing the climate problem	Ordinal (5-point)	3.5	1.2
CLIMATE	Using bioenergy from logging residues is a good greenhouse gas initiative	Ordinal (5-point)	3.6	1.2
DISEASE	Removing logging residues will reduce the risk for disease in the forest	Ordinal (5-point)	3.2	1.1
EDU	Highest completed education (Middle school, High school, Bachelor, Master)	Ordinal (4-point)	2.3	2.3
EMPLOY	Removing logging residues is good for local value-added and job creation	Ordinal (5-point)	3.3	1.2
FERTIL	Removing logging residues will require replacement fertilization	Ordinal (5-point)	3.3	1.0
FORESTRY_CC	Forestry can play an important role in reducing global warming	Ordinal (5-point)	3.9	1.1
GENDER	Gender of respondent (1 = Female)	Dichotomous	0.18	0.4
GROWTH	Removing logging residues will reduce future growth in the forest because of degradation of nutrients in the soil	Ordinal (5-point)	3.6	1.1
HUMAN_CC	Humans have contributed to changing the Earth's climate	Ordinal (5-point)	3.8	1.2
LIVE_PROP	Live on forest property	Dichotomous	0.71	0.5
OPPOSED	Family and friends are against me removing logging residues	Ordinal (5-point)	1.8	1.8
PLANT	Removing logging residues will simplify planting after harvesting	Ordinal (5-point)	4.0	1.2
REGION[c]	Live in region with strong forestry traditions	Dichotomous	0.7	0.5
TOTAL_FOREST	How much total forest land do you own in Norway?	Non-negative	161.0	1042.8
WOULD_CONS	Willingness to supply harvest residues	Dichotomous	0.59	0.5

1 USD ≈ 7.80 NOK

[a] SD is standard deviation. Dependent variable: WOULD_CONS

[b] Except for the scale of the question TIMBER_INC, where 1 = not important and 5 = very important, all ordinal 5-point scales range from 1 = completely disagree to 5 = completely agree

[c] Regions with strong forestry traditions are defined as the following counties: Østfold, Akershus, Oslo, Hedmark, Oppland, Buskerud, Vestfold, Telemark, Aust-Agder, Vest-Agder, Sør-Trøndelag and Nord-Trøndelag. Regions without strong forestry traditions are defined as the following counties: Hordaland, Rogaland, Sogn og Fjordane, Møre og Romsdal, Nordland and Troms

the analyses. To avoid biased estimators caused by the stratification, the observations were weighted with weights that equaled the inverse of the sampling fraction, divided by 100, i.e. 1.43, 0.46, 0.13 and 1 for the smallest, medium, largest and unknown size classes, correspondingly. Descriptive statistics and regression analyses were based on weighted observations for all datasets. The variables used in the analyses with descriptive statistics of the *Imputed dataset* are presented in Table 3.

Survey responses concerning the perceived positive impacts of residue extraction (AESTHETICS, DISEASE, EMPLOY, PLANT) and climate change mitigation (BIOENERGY_CC, CLIMATE, FORESTRY_CC, HUMAN_CC) were highly correlated, as were statements regarding negative impacts (BIODIV, FERTIL, GROWTH) associated with residue extraction. Despite the diversity of impacts, many respondents believed that residue extraction, and forest management in general, either contribute positively or negatively to these impacts. It thus seemed that underlying factors not captured in the questionnaire steered landowner opinion of whether forest management and residue extraction were in general beneficial or harmful. Factor analysis was thus employed to better understand views regarding the utility of residue extraction, and to capture underlying factors obscured by highly correlated variables (Johnson and Wichern 2002).

Two standardized factors, FACTOR_POS and FACTOR_NEG, were constructed from the eleven variables involving the statements of logging residue extraction, climate change and mitigation (Table 4). The null hypothesis that the

Table 4 Loadings and uniqueness of factor analysis

	Loadings		
	FACTOR_POS	FACTOR_NEG	Uniqueness
PLANT	0.55		0.70
AESTHETIC	0.56		0.68
EMPLOY	0.68		0.53
CLIMATE	0.74		0.44
BIOENERGY_CC	0.59		0.64
BIODIV		0.62	0.61
GROWTH		0.77	0.41
FERTIL		0.56	0.68
DISEASE	0.43		0.81
FORESTRY_CC	0.44		0.80
HUMAN_CC	0.36		0.86
SS loadings	2.59	1.35	
Eigenvalue	3.13	1.91	
Variance proportion	0.23	0.12	
Cumulative variance	0.23	0.35	

Cut-off for loadings is 0.15

correlation matrix is an identity matrix was rejected in Bartlett's test (χ^2: 2165; p value: $<2.2 \times 10^{-308}$; df: 55). The Kaiser–Meyer–Olkin overall MSA was 0.75 and individual MSA were in the range of 0.59–0.83, indicating that the correlation matrix was suitable for factor analysis.

While perceived beneficial impacts of residue extraction on local employment and value-added and the climate made the largest contributions to FACTOR_POS, concerns of reduced forest growth greatly influenced FACTOR_NEG. Perceptions of reducing risk of diseases, human-induced climate change and forestry's role in its mitigation were of minor importance in FACTOR_POS and only weakly correlated with other variables, as suggested by the low loadings and high uniqueness. Due to technical issues, weighting was carried out after factor analysis; however, factor analysis with weighted observations yielded similar results with the same loading patterns, uniqueness varying from 0.46 to 0.80 and the two factors together explaining 35 % of the variance. A third factor with an eigenvalue of 1.5 and proportional variance of 0.12 was considered, but only two factors were used because they could be better interpreted.

Model

The random utility model (RUM) was utilized as the basis for assessing forest owners' willingness to sell forest residues (Hanemann 1984; Bell et al. 1994). The indirect utility for a forest owner is $uj = \alpha + \Sigma\beta ixi + \varepsilon{\cdot}j$ takes the values 0 and 1, and u_1 is the indirect utility for an individual that is willing to sell logging residues and u_0 the indirect utility for an individual that is not willing. $\beta_{i's}$ are parameter estimates, and $x_{i's}$ are independent variables thought to be correlated to a landowner's decision to sell logging residues. Due to the dichotomous dependent variable, logistic modeling was used. A general logistic model of the conditional probability $\pi(x)$ that an outcome is present is given by Hosmer and Lemeshow (2000):

$$\pi(\mathbf{x}) = \frac{e^{\alpha+\vec{\beta}'\vec{x}}}{1 + e^{\alpha+\vec{\beta}'\vec{x}}},$$

where $\boldsymbol{\beta}'$ is the transposed vector of the coefficients $\beta_1, \ldots, \beta_n$, that are to be estimated together with α. The parameters were estimated with maximum likelihood. Model fit and comparison of models were performed using pseudo R^2 values [Hosmer and Lemeshow R^2 (Hosmer and Lemeshow 2000), Cox and Snell R^2 (Cox and Snell 1989) and Nagelkerke R^2 (Nagelkerke 1991) as well as Akaike Information Criterion (AIC) (Greene 2003)].

Results

Sample Description

Out of the 1500 questionnaires sent, 841 were returned. Thirty-nine respondents did not answer the question "Would you consider supplying logging residues?" These surveys were dropped from the analysis, leaving 802 usable surveys providing an adjusted (i.e. usable) response rate of 53.5 %. Of those, 59.2 % of the respondents using weighted observations would consider supplying logging residues. The *Net sample* consisted of these 802 surveys. Observation units that did not respond to all questions were deleted listwise; this *Listwise deletion dataset* included 569 respondents. The *Imputed dataset* was the main dataset used for the analyses. Except for the variables included in the factor analysis, no independent variables included in the model had correlation coefficients above 0.40 or Variance Inflation Factor (VIF) above 1.15.

Variables were compared across the three net samples with the gross sample and population (Table 5). Total forest area was larger in the gross sample than in the population due to the oversampling of large properties. In the drawn sample, forest owners in the largest area class of at least 100 hectares represented 89 % of the sampled productive forest area and 92 % in the unweighted net sample. However, this share was 65 % in the weighted net sample, similar to the share in the population, i.e. 62 % (Statistics Norway 2014). The *Imputed dataset* that was used for the main analyses was compared to the *Net sample*, but also to the *Listwise deletion dataset*, that would have been used in absence of imputation because factor analysis cannot be performed if observations are missing. The mean age of the owner was similar across the population and all samples, but the share of female owners was lower in the *Net sample* than in the drawn (gross) sample, and even lower in the *Listwise deletion dataset*. The share of owners who lived on the property was higher in all net samples than in the gross sample and population. Comparing the *Imputed dataset* with the *Net sample*, the imputation preserved well the variance and mean values, with the exception for the total forest area. There are small deviations between the *Listwise deletion dataset* and the *Net sample*; the missingness seems thus to be close to random.

Regression Analysis

Forest owners who owned large forest areas, who had higher education, lived in a region with strong forestry traditions or had positive perceptions of logging residue

Table 5 Summary statistics for population, gross sample and net samples

	Population (n = 77,162)	Gross sample (n = 1500)	Net sample (n = 802)	Listwise deletion dataset (n = 569)	Imputed dataset (n = 802)
Total forest area (mean)	85	222	118	108	161
Age (mean)	56	55	56	55	57
Gender (share female)	23	22	19	17	18
Living on property (share)	64	64	72	72	71

harvest and forestry's role in climate change mitigation were all more likely to be willing to supply harvest residues in the future than others (Table 6). However, forest owners who lived on the property, were above 65 years old, had family or friends that were opposed to the removal of harvest residues or who had negative perceptions of logging residue removal were less likely to engage in such supply. The two most important factors in terms of marginal effects were REGION and FACTOR_POS. Living in a region with strong forestry traditions or having a one unit increase of the composite variable FACTOR_POS each increased the probability of engaging in such activity by 16 or 14 %, respectively. While AGE_M65 had marginal effects of around −0.10, the corresponding value for LIVE_PROP was around −7 %. The variables GENDER and ASKED were not significant. Depending on the type of pseudo R^2, the model explained 22–33 % of the variation in the data.

The regression output of the imputed dataset was compared to the *Listwise deletion dataset* and the *Net sample* to check if the imputation could have created biases. Since factor analysis cannot be performed for datasets with missing values, the two variables with the highest loadings (Table 4), CLIMATE and GROWTH, replaced the factors. Most variables retained their influence in terms of sign and significance across the three datasets, with a few exceptions (Table 7). OPPOSED was a significant variable in the *Imputed dataset*, but not in the other two datasets, while the opposite was true for ASKED and GENDER.

Comparing the two models using the *Imputed dataset* (Tables 6, 7), the replacement of the variable CLIMATE for FACTOR_POS and GROWTH for FACTOR_NEG did not considerably change the coefficients or reduce the pseudo

Table 6 Results from logistic regression, dependent variable: willingness to supply harvest residues

	Coeff.	S.E.	Pr(>|z|)	Marg. effect
(Intercept)	−0.090	0.391	0.817	−0.015
TOTAL_FOREST	0.001	0.000	0.002***	2×10^{-4}
LIVE_PROP	−0.423	0.209	0.043**	−0.068
AGE_M65	−0.596	0.204	0.003***	−0.096
EDU	0.373	0.109	0.001****	0.060
GENDER	0.065	0.248	0.793	0.011
REGION	1.006	0.203	7×10^{-7}****	0.163
OPPOSED	−0.265	0.077	0.001****	−0.043
ASKED	0.608	0.409	0.138	0.098
FACTOR_POS	0.856	0.097	$<2 \times 10^{-16}$****	0.138
FACTOR_NEG	−0.319	0.090	4×10^{-4}****	−0.052

Region: non-forest region = 0, forest region = 1. Gender: male = 0, female = 1

Null deviance: 1001.48 on 801 df; Residual deviance: 784.96 on 791 df; AIC: 806.96; χ^2 (216.51411, df: 10): $<2 \times 10^{-16}$

Hosmer and Lemeshow R^2: 0.22; Cox and Snell: 0.24; Nagelkerke R^2: 0.33

R^2 values. However, the estimated coefficients were higher for the composed factors than for CLIMATE and GROWTH with the latter variable insignificant, suggesting that the composed variables exerted larger influence on the probability that a forest owner was willing to consider supplying forest residues.

Discussion

The regression analyses suggest that the willingness to supply harvest residues among Norwegian private non-industrial forest owners increases with forest area size, owner's education level, if the owner lives a region with strong forestry traditions or has positive perceptions of residue extraction and use. The likelihood that an owner will provide harvest residues was lower among forest owners living on the property, were above 65 years of age, had negative perceptions of the extraction and use of residue or had family or friends who were opposed to residue extraction and uses.

Most of the tested variables were found to be significant and of expected sign. Market experience in the sense of previously being asked to supply residues, was however not significant. This is contrary to previous studies such as Becker et al. (2013), but in accordance with e.g. Shivan and Mehmood (2012) that found this factor not to be significant. Biomass market access and knowledge may be high among Norwegian landowners rendering the variable insignificant. However, the question of minimum compensation level (not included in the model because of too many missing values) could suggest that many owners are not aware of the normal price range for harvest residues or are only willing to supply residues at

Table 7 Estimated coefficient and significance level from logistic regression on the three datasets

	Imputed dataset (n = 802)	Listwise deletion dataset (n = 569)	Net sample (n = 802)
(Intercept)	0.227	−0.038	0.048
TOTAL_FOREST	2×10^{-5}**	4×10^{-5}**	1×10^{-5}
LIVE_PROP	−0.172****	−0.148***	−0.156***
AGE_M65	−0.153***	−0.183***	−0.193***
EDU	0.054**	0.066**	0.049*
GENDER	0.067	0.196***	0.114*
REGION	0.268****	0.335****	0.302****
OPPOSED	−0.047**	−0.001	−0.002
ASKED	0.115	0.206**	0.167*
CLIMATE	0.111****	0.133****	0.133****
GROWTH	−0.031	−0.026	−0.029

Dependent variable: willingness to supply harvest residues

Significance levels: * 10 %, ** 5 %, *** 1 %, **** 0.1 %

considerably higher prices. The median of minimum accepted price of forest residues was 50 NOK/loose m^3 and the mean 106 NOK/loose m^3 (data not shown), considerably higher than the previous years' market prices of 1–15 NOK/loose m^3 (calculated from Dahl 2010; Skog 2013; Skog 2013; Vennesland et al. 2013; Norwegian Water Resources and Energy Directorate 2014).

Listwise deletion of multiple imputation did not substantially impact the regression output, as suggested by relatively stable coefficients across the datasets. The uncertainty seems to be the highest regarding the variables GENDER, OPPOSED and ASKED, that varied in their impacts across the datasets. There are mixed results of gender effects from previous studies (Markowski-Lindsay et al. 2012; Brough et al. 2013; Kuuluvainen et al. 2014), as well as the importance of other peoples' opinions (Becker et al. 2013; Brough et al. 2013).

The share of female forest owners was lower in all three net samples than the population. Furthermore, being female impacted positively on the willingness to supply forest residues based on the *Listwise deletion dataset*, but not on the other datasets. In this dataset, 82 % of female owners stated willingness to supply harvest residues compared with 59 % of male owners. In the *Net sample* and *Imputed dataset*, the numbers were 69–71 % among female owners and 57–58 % among male owners. Self-selection among female forest owners could potentially lead only those who were especially motivated or interested in the subject to respond to the entire questionnaire. Lower response rates among women have been found in other studies of Norwegian family forest owners, which could partially be explained by the higher share of elders among female than male forest owners (Follo 2008). More research regarding patterns of engagement and interest among females contrasted to male owners would be of interest.

Forest owners living on the property were oversampled with higher shares in all three net samples than in the gross sample and population. Forest owners who lived on the property may have been more involved in or had more knowledge of the management of their forest and therefore more willing to complete the survey. These forest owners were clearly less likely to supply logging residues. They could possibly be more informed of the research that has pointed to the risk of productivity loss after residue removal in some forests, e.g. Clarke (2012). Conclusions from the literature regarding the effects of living on property on supplying logging residues are mixed, with detected impacts being positive (Joshi et al. 2013), negative (Shivan and Mehmood 2012) and none (Becker et al. 2013). More research is needed on this point to detect the underlying factors that contribute to the effects of living on property. It is possible that social factors specific to a state or country may reduce the transportability of the results. In line with previous findings (Joshi and Mehmood 2011; Brough et al. 2013), younger forest owners are more interested in selling residues, which potentially can be explained by more debt in early life stages.

The main implication of the findings in light of the policy goals to increase wood energy production, are that the Norwegian family forest owner population is highly diverse with greatly varying perceptions of forest residue extraction. This is consistent with previous studies in the US (Becker et al. 2013) and Scandinavia (Bohlin and Roos 2002; Rämö et al. 2009). If policies were designed for groups of forest owners, they could potentially stimulate individuals that otherwise refrain from market participation that include small forest owners, who live on property or outside traditional forestry areas, are above 65 years of age or are negative towards the extraction of forest residues. More committed forest-owner adapted activities to reach these owners or organization of cross-boundary forestry could help these owners becoming more interested and active; in the long run, modifying legislation that changes property structure towards larger properties and adjusting the taxation system could trigger forest owners to become more active (Follo 2011).

Conclusions

Norwegian private forest owners who have large properties, do not live on the property, are younger than 65 years old, have higher education, live in regions with strong forestry traditions, and have positive perceptions of residue extraction impacts are the most likely to consider supplying forest harvest residues. Current residue extraction levels in Norway are very low. Yet there appears to be considerable potential for increasing the supply of logging residues, which could contribute substantially to achieving Norway's bioenergy targets. To that end, policy-makers could design policies based on this insight to stimulate forest owners that are less interested in market participation, including owners that live on the property, that are above 65 years of age, or who themselves, friends or family are negative towards the use of forest residues. Implementing safeguards to protect soils could also help owners to supply residues. Market agents, on the other hand, could make use of the information regarding different groups of owners to target those most likely to be willing to sell residues, such as large landowners with higher education that live in regions with strong forestry traditions, that own forest land that is less sensitive to negative soil impacts of residue extraction.

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