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Factors Influencing Private Forest Owners Decision-Making Rationalities to Implement Salvage Logging after Large-Scale Natural Disturbances in Slovenia

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Abstract

This study examines the factors that influence the decision-making rationality of private forest owners (PFOs) when implementing salvage logging after large-scale natural disturbances. The literature suggests two main responses to large large-scale natural disturbances: performing salvage logging and no salvage at all. When salvage logging is carried out, two different strategies can be applied: clearing, i.e. all trees are removed, including damaged trees and standing survivors; and salvaging, i.e. damaged trees are removed but the surviving trees are left and some dead trees are left standing. In an online survey conducted in Slovenia in March and April 2022, responses were collected from 1515 forest-owning households. A logistic regression model was created to analyse the data and understand how socio-demographic characteristics, characteristics of forest property, forest management activities and the market influence their decisions. The results show that previous management activities and cooperation with service providers significantly influence PFOs' decision-making rationality to implement salvage logging. The study contributes to a nuanced understanding of the complex decision-making processes in forestry. Future research opportunities lie in investigating specific aspects of past management activities and understanding the dynamics in cooperation between different actors to develop customised policies for effective forest management after large-scale natural disturbances.

Keywords: forestry, environmental disturbances, private forest owners, decision making process, post-damage management, logistic regression analysis

1. Introduction

Natural disturbances represent one of the key factors affecting the dynamics of forest development and shape forests (Camia et al. 2021, Senf and Seidl 2021, Sturtevant and Fortin 2021) but also result in socio-economic losses for forest owners and managers (Senf et al. 2019). The natural disturbances in European forests have increased in frequency and intensity over the last seventy years, with wind as the most important disturbance agent (46% of total damage), followed by fire (24%) and bark beetles (17%). Bark beetle disturbance doubled its share of the total damage in the last 20 years (Patacca et al. 2023). Natural disturbances are expected to become even more frequent and intense in the future (Seidl et al. 2017, Senf and Seidl 2021). After natural disturbances such as wildfires, windstorms, icebreaks, and insect outbreaks, salvage logging is commonly applied to reduce economic losses, mitigate subsequent disturbance risk and to improve forest health (Müller et al. 2019, Sanginés de Cárcer et al. 2021). The growing influence of natural disturbances has implications for forest management, followed by careful evaluation of salvage logging practices (Leverkus et al. 2018, Müller et al. 2019). It is therefore important that the management strategies developed by forest owners, forest experts and policy decision makers reconcile the need for short-term economic benefits with long-term sustainability and multifunctional objectives.

In the European Union (EU), about 60% of the forest area is privately owned. Small scale holdings prevail, where 88% of all forest holdings are smaller than

10 ha. Private forest owners (PFO) manage their forests based on their individual values, objectives, and their decision-making rationalities (Pezdevšek Malovrh et al. 2017, Tiebel et al. 2022, Sotirov et al. 2024). The management decisions rationalities of PFOs are diverse, varying significantly from one country to another. Like in case of forest management, the PFOs response to perform salvage logging after natural disturbances can also vary depending on their values, objectives, priorities, and resources (Markowski-Lindsay et al. 2020, Sanginés de Cárcer et al. 2021). A variety of previous studies explore why and how PFOs engage in forest management and provide important information on whether and how various factors influence the harvest behaviour and harvest rates of PFOs (Silver et al. 2015, Feliciano et. al. 2017, Sotirov et al. 2024). However, there is still a lack of research on PFOs management response to natural disturbances or they are only focusing on individual disturbance agents, e.g. disturbances from bark beetles, windstorms or drought (Sanginés de Cárcer et al. 2021).

In the literature, roughly two emerging strategies appear for post-disturbance management; the first performs salvage logging and the second does not. PFOs may choose to salvage their forests after natural disturbances in order to generate income from the salvaged timber and prevent further economic and ecological losses (Thorn et al. 2018, Sanginés de Cárcer et al. 2021, Conrad 2023). The main reasons for not performing salvage logging can be subdivided into three groups:

– PFOs may choose not to salvage their forests after natural disturbances for environmental or ecological reasons (Thorn et al. 2018, 2020, Knoke et al. 2021, Sanginés de Cárcer et al. 2021). They may believe that leaving the damaged trees in the forest can support biodiversity and provide habitat for wildlife, or that salvage logging can disrupt the natural regeneration process and cause further damage to the forest ecosystem. Senf et al. (2019) highlights high resilience of forest ecosystems to recent disturbances, and the forests of Central Europe are well able to recover naturally from large and severe disturbance events
– PFOs may choose not to salvage their forests due to lack of the resources or knowledge to undertake salvage logging operations, or may face legal barriers to salvaging their forests (Sanginés de Cárcer et al. 2021, Stare et al. 2023)
– in some cases, salvage logging may not be economically viable due to low timber prices or high logging costs (Knoke et al. 2021, Sanginés de Cárcer et al. 2021, Stare et al. 2023).

Understanding the ongoing changes in forest ecosystems and developing management strategies to increase their resilience require understanding of the PFO decision-making rationalities to perform salvage logging after natural disturbances. PFOs have a significant influence on the outcome of forest management and the implementation of salvage logging. Despite all actions and recommendations by professionals, salvage logging is still not done to a satisfactory extent, which affects the general health of the forest. Motivation, objectives, attitudes, and capacities of PFO in relation to management activities (regular and after natural disturbances) are influenced by relevant legislation and policy instruments, market, as well as their specific cultural and social background, public opinion and societal pressure (Lidskog and Sjödin 2015, Nichiforel et al. 2018, Ščap et al. 2021, Stare et al. 2023).

Slovenian system of forests management focuses on sustainable, close-to nature and multifunctional forest management, which ensures that the country has one of the highest growing stock in Europe. The growing stock in Slovenian forests is 304 m^3/ha, and the annual increment is estimated at more than 8.5 million m^3 or 7.4 m^3/ha. In 2023, the planned potential annual harvest amounted to 7.2 million m^3 and it is estimated that 74% of the potential harvest was harvested according to the forest management plans (Slovenia Forest Service 2024). In the last ten years, Slovenian forests have been hit by several large-scale natural disturbances (Mori and Poljanec 2019), which have impacted both the national economy and forest ecosystems, their structure, function and management. Disturbances pose a challenge for sustainable forest management and require effective management strategies that are adaptive and incorporate environmental, economic and social considerations to ensure that forests remain healthy, productive and resilient in the face of natural disturbances. In the years 2014 to 2019, salvage logging accounted for more than 50% of the total logging in Slovenia. However, in 2021, for the first time since 2014, it accounted for less than a third of the total harvest (and totalled 26%). In 2022, it reached 31% of the total harvest, i.e. 1.40 million m^3 of trees. Logging due to bark beetles accounted for 52%, logging due to natural events 17% (the main reason was wind). 71% of the total felling took place in private forests, 28% in state forests and 1% in municipal forests (Slovenia Forest Service 2023). In 2023, salvage logging reached 42% of the total logging, i.e. 1.82 million m^3 of trees. Logging due to bark beetles accounted for 42%, logging due to natural hazards 36% (the main reason was wind, followed by snow), logging due to forest tree diseases 10% and logging due to all other

health reasons 12%. 71% of all felling took place in private forests, 27% in state forests and 2% in municipal forests. The proportion of conifers in salvage logging was 81% (Slovenia Forest Service 2024). Since almost 80% of forests in Slovenia are privately owned, with large number of PFOs (the average size of private forest property is about 3 ha), it represents a good framework basis for researching the desicion-making rationalities of PFOs to natural disturbances and their implementation of salvage logging.

As the PFOs are a very heterogeneous group that changes over time due to ongoing processes and changes in society, such as demographic, economic and social changes that have altered the interests, values and demands of PFOs on their forests, they generally react to large-scale natural disturbances in different ways. Furthermore, the frequency and magnitude of natural disturbances will likely increase in the future, therefore the improved disturbance management is needed. In this sense, the aim of the study is to identify potential factors that can explain the PFOs decision-making rationalities for salvage logging, with the intention to determine factors that influence the PFOs' decision for salvage logging and organisation of work. Based on this, the research hypothesis is: the PFOs' decision to implement salvage logging and the way the work is carried out are influenced by the individual's socio-demographic characteristics (e.g. age and education), property and ownership conditions, economic factors of the market (prices of forest wood assortments and service prices), past management experience and cooperation with actors (service providers) and other PFOs. The results of this study may help decision makers understand the response of PFOs, which in turn may lead to improved management requirements for salvage logging and more explicit consideration of climate change in post-damage management.

2. Materials and Methods

2.1 Questionnaire Design and Data collection

In order to determine what factors influence the decision-making rationalities of PFOs to perform salvage logging after large-scale natural disturbances, an on-line survey among random households throughout Slovenia was conducted. The survey was conducted in March and April 2022. According to the sampling method, the basis of the sample was the gross sample, i.e. all households, regardless of forest ownership, for which representativeness was guaranteed with quotas by region and type of settlement. In addition, the so-called soft quotas based on the age of the respondents ensured that the online survey not only included a younger population, but that the age structure of the respondents essentially followed the age structure of forest owners in Slovenia. The survey sample consisted of households that own and know the forest and have a basic knowledge of forest management. Within the household, the questionnaire was answered by the PFOs who manage the forest. A total of 1515 household representatives who own a forest and know it, meaning at least know the location of their forest and were responsible for it to the extent that harvesting had taken place in the past, took part in the survey. The questionnaire was used to collect information on forest ownership (area), forest management characteristics and respondent demographics (gender, age, employment status, education), as well as the impact of large-scale natural disturbances on forest management. The questionnaire was pre-tested and revised by the research team to make the questions as understandable and precise as possible.

In order to analyse the effects of prices for services and forest wood assortments (market variables), we included prices in the model that are systematically collected by the Slovenian Forestry Institute and published on the WoodChainManager data portal (Stare and Ščap 2019, WCM 2024). The Slovenian Forestry Institute has been monitoring the market for services and forest wood assortments in Slovenia for almost a decade. For the logistic regression model, the average prices of the last 5 years (2017–2021) by statistical region were used, separately for conifers and deciduous trees (in the case of assortments and timber transport services) and separately for mechanised logging and chainsaw logging. The price was allocated to the PFO based on their statistical region.

2.2 Econometric Modelling Method: a Random Utility Approach for Salvage Logging Decision-Making Rationalities

The literature has identified that the factors influencing PFOs decision-making rationalities related to forest management after large-scale natural disturbances tentatively belong to four groups:

– forest property characteristics including size of forest, geographical location of the forest and forest value (Beach et al. 2005, Eggers et al. 2014, Eriksson and Fries 2020, Markowski-Lindsay et al. 2020, Juutinen et al. 2020, de Groot et al. 2021, Stockmann et al. 2024)

– forest management including past management and future management strategies, motivation,

risk, knowledge and information (Andersson and Keskitalo 2019, Eriksson and Fries 2020, Markowski-Lindsay et al. 2020, Juutinen et al. 2020, de Groot et al. 2021, Ščap et al. 2021, Triplat et al. 2023, Stockmann et al. 2024)

– PFOs socio-demographic/socio-economic characteristics including education, gender, age, income and duration of forest ownership (Beach et al. 2005, Karppinen 2012, Eggers et al. 2014, Feliciano et al. 2017, Eriksson and Fries 2020, de Groot et al. 2021, Triplat et al. 2023, Stockmann et al. 2024)

– market including wood price dynamics and prices of forest services (Beach et al. 2005, Favada et al. 2009, Sjølie et al. 2019, Triplat et al. 2023).

Identified groups of influencing factors affect the decision-making rationalities of PFOs in diverse ways, leading to two possible post-disturbance responses or management strategies:

– performing salvage logging

– no salvage at all (Figure 1).

When salvage logging is carried out (response 1), two different management strategies can be applied:

– clearing, i.e. all trees are removed, including damaged trees and standing survivors

– salvaging, i.e. damaged trees are removed but the surviving trees are left and some dead trees are left standing (Petucco at al.2020, Sanginés de Cárcer et al. 2021).

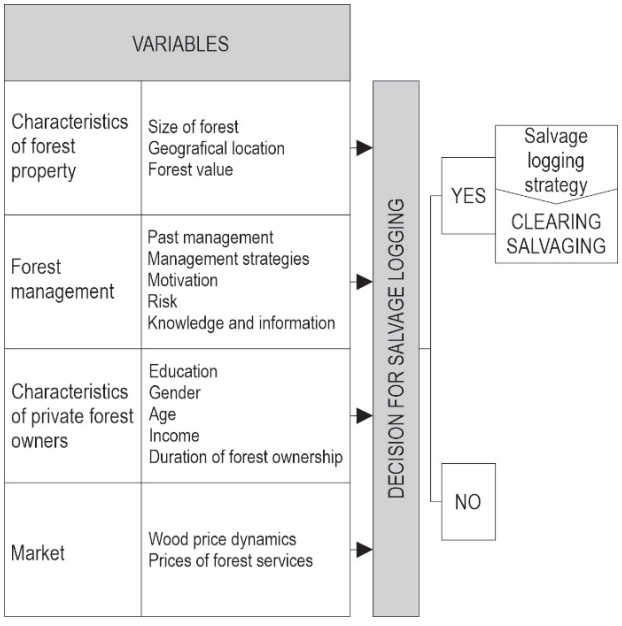

Fig. 1 Conceptual framework of private forest owners' decisions for salvage logging (adapted from Thomas et al. 2022)

The study assumes that the decision-making rationality of PFOs to implement salvage logging after large-scale natural disturbances is based on their utility maximisation. To account for the uncertainties inherent in the decision-making rationalities of PFOs due to unobserved alternatives, unobserved individual characteristics and measurement error (Manski 1977, Lynch et al. 2002), a random utility model was used to determine the factors that influence the PFO to implement salvage logging after large-scale natural disturbances. The utility function can be expressed as follows:

$$U_i = f(x_i) + \varepsilon \quad (1)$$

Where:

U_i is the decision whether PFOs will implement salvage logging or not

x_i is a vector of the socio-demographic characteristics of PFOs (SOCIODEM), characteristics of forest property (*PROP*), forest management activities (*MANACT*) and market (*MARKET*)

ε is the random error term. Since the dependent variable »PFOs performance of salvage logging after large-scale natural disturbances (*PERF*)« was transformed into a binary scale in this study, logistic regression was applicable to estimate the model parameters (Field 2009).

In binary logistic regression, the probabilities of the individual outcomes are given as follows:

$$\ln\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = logit\,(P(Y=1)) = \beta_0 + \beta_1 x_1 + \ldots + \beta_p x_p \quad (2)$$

Where:

P is the probability that a PFO is performing salvage logging after large-scale natural disturbances

x denotes the values of independent variables

β denotes the model coefficients.

Maximum likelihood estimation was used to estimate the values for model parameters from 1 to p. The specific binary logit model used in the study is:

$$PERF = \beta_0 + \beta_1 GEND + \beta_2 AGE + \beta_3 EDU + \beta_4 FPROSIZE + \beta_5 DAMAGE + \beta_6 MANPAST + \beta_7 COOPSERV + \beta_8 COOPPFO + \beta_9 PRICECON + \beta_{10} PRICEDEC + \beta_{11} MECHARV + \beta_{12} HARV + \beta_{13} TRANCON + \beta_{14} TRANDEC + \varepsilon \quad (3)$$

2.3. Variable definitions

The dependent variable (*PERF*) for the selection equation was binary and took the value »1« if PFOs perform salvage logging after large-scale natural dis-

Table 1 Definition and coding of model variables

Variable	Definition	Coding system	Expected correlation
PERF	PFOs performance of salvage logging	0 – do not perform salvage logging 1 – perform salvage logging	/
Socio-demographic characteristics of private forest owners (*SOCIODEM*)			
GEND	Gender	1 – male 2 – female	(+)
AGE	Age of PFOs in years	Continuous variable	(–)
EDU	Level of education	1 – high school or less 2 – completed bachelor, master's degree, PhD	(–)
Characteristics of forest property (*PROP*)			
FPROSIZE	Forest property size, ha	Continuous variable	(+)
DAMAGE	Damaged forest area, %		(+)
Forest management activities (*MANACT*)			
MANPAST	Management activity in the past	0 – Do not perform activities 1 – Perform activities	(+)
COOPSERV	Cooperation with service providers	0 – Do not cooperate 1 – Cooperate	(+)
COOPPFO	Cooperation with PFO		(+)
Market (*MARKET*)			
PRICECON	Price of forest wood assortments – conifers	Continuous variable	(+)
PRICEDEC	Price of forest wood assortments – deciduous trees		(+)
MECHARV	Price of fully mechanised harvesting		(–)
HARV	Price of harvesting and skidding		(–)
TRANCON	Price of transport – conifers		(–)
TRANDEC	Price of transport – deciduous trees		(–)

turbances and »0« if they did not. Based on the conceptual framework (Fig. 1) for the categorisation of variables, the independent variables used in the model were divided into four categories: socio-demographic characteristics of PFOs, characteristics of forest property, forest management activities in own forests, and market influence. A total of 15 variables were included in the model. The definitions and coding system for all variables can be found in Table 1.

The first category of variables, »Socio-demographic characteristics of PFOs (*SOCIODEM*)«, included three variables: gender (*GEND*), age of PFOs in years (*AGE*) and level of education (*EDU*). The continuous variable *AGE* was expected to be a negative predictor of PFOs decision-making rationality to implement salvage logging as older PFOs are generally less receptive to active forest management (Beach et al. 2005, Karppinen 2012, Pezdevšek Malovrh et al. 2022b, Stockmann et al. 2024). The variable *EDU* was also expected to be a negative predictor, given the presumption that more educated PFOs are not dependent on the forest and they usually implemented biodiversity management rather than wood harvesting (Feliciano et al. 2017, Eriksson and Fries 2020, Mook and Dwivedi 2022). The variable *EDU* was coded 2 for the PFOs with at least a bachelor degree and 1 with high school or less. The *GEND* variable was expected to be a positive predictor for male respondents because male PFOs are more orientated toward forest management practices (Eggers et al. 2014, Eriksson and Fries 2020, Stockmann et al. 2024).

The second category of variables »Characteristics of forest property (*PROP*)« included two variables, one related to the size of the property (*FPROSIZE*) and the other related to the proportion of damaged forest area (*DAMAGE*). The variable *FPROSIZE* was a continuous variable indicating how many hectares of forest land the respondent owned. This variable was expected to be a positive predictor since larger PFOs are usually more prepared to harvest and manage their

forests (Beach et al. 2005, Eggers et al. 2014, Eriksson and Fries 2020, Juutinen et al. 2020; Markowski-Lindsay et al. 2020, de Groot et al. 2021, Ščap et al. 2021, Pezdevšek Malovrh et al. 2022b, Stockmann et al. 2024). The variable *DAMAGE* was a continuous variable indicating a share of the damaged area due to large-scale natural disturbances in the past. This variable was also expected to be a positive predictor of PFOs decision-making rationality to implement salvage logging (de Groot et al. 2021).

The third category of variables »Forest management activities (*MANACT*)« included three variables that captured the forest management activities in the past (*MANPAST*) and two types of cooperation: cooperation with service providers (*COOPSERV*) and cooperation between PFOs (*COOPPFO*). All variables within *MANACT* category were expected to be a positive predictor of PFOs decision-making rationalities to implement salvage logging as all three variables have been recognised in the past as having a positive impact on forest management (Pezdevšek Malovrh et al. 2017, Andersson and Keskitalo 2019, Fischer et al. 2019, Eriksson and Fries 2020, Juutinen et al. 2020, Markowski-Lindsay et al. 2020, Ščap et al. 2021, Pezdevšek Malovrh et al. 2022a, Triplat et al. 2023, Stockmann et al. 2024). They were coded as 0 if PFOs did not perform activities or did not cooperate and 1 if they performed activities or cooperated.

The fourth category of variables »Market (*MARKET*)« comprised six variables associated with prices. The price of forest wood assortments included the average prices (average value) of forest wood assortments separately for coniferous trees and deciduous trees for the 5-year research period (2017–2021) by region (*PRICECON* for coniferous trees and *PRICEDEC* for deciduous trees), the price of harvesting included the average value of harvesting and skidding separately for fully mechanised harvesting and classical harvesting and skidding for the 5-year research period by region (*MECHARV* for fully mechanised harvesting and *HARV* for classical harvesting and skidding) and the price of transport included the average prices of transport separately for conifers and deciduous trees for the 5-year research period by region (*TRANCON* for conifers and *TRANDEC* for deciduous trees). Variables related to forest wood assortment prices were expected to be a positive predictor, as we hypothesised that these variables would be important for the implementation of salvage logging. In the past, they already recognised the positive influence of prices of forest wood assortment and, in connection with this, income from forestry (Beach et al. 2005, Favada et al. 2009, Sjølie et al. 2019, Triplat et al. 2023). Variables related to harvesting and transport prices were expected to have a negative influence, as a result of past findings that a higher price negatively affects the performance of services (Triplat et al. 2023).

2.4. Data Analysis

The collected data were entered and coded in MS Excel and processed in IBM SPSS Statistics 25.0 (IBM SPSS Statistics 2017). To check the quality of the data and to detect errors, outliers and missing values, all data were first checked with frequencies. Variables in the questionnaires were analysed using frequency distributions and mean values.

First, descriptive statistics were performed on the obtained database, including the relationships between the selected variables. Secondly, a binary logistic regression analysis using the Enter method was used to estimate the coefficients and standard error. The test for statistical significance of the regression coefficients in the model was performed using the Wald test at a significance level of 0.05 (Hosmer and Lemeshow 2000). Before the analysis was performed, the data were checked for logistic regression assumptions such as linearity and multicollinearity. In addition, the data were checked to reduce the problem of coefficients with unreasonably large standard errors by comparing all categorical independent variables with the dependent variable in a cross-tabulation. The linearity assumption was tested for continuous variables by examining whether the interaction term between the predictor and its log transformation was significant. All interactions had significance values greater than 0.05, indicating that the assumption of linearity of the logit was met for all continuous variables. Multicollinearity was tested using the variance inflation factors (VIFs). The VIFs for the independent variables were less than 5.

3. Results

3.1. Description of Variables Used in Logistic Regression Model

Table 2 shows the description of the variables used in the logistic regression model. It can be seen that 86% of respondents stated that they salvaged their forest, while 14% did not. The age structure with an average age of 54 years is dominated by the 60-70 age group, and more than 60% of respondents are over 50 years old. The average forest property size is 7.5 ha and the median is 3 ha. The smallest forest property was 0.1 ha and the largest 600 ha. The forest of 55.1% of respondents suffered damage in the last ten years due to large-scale natural disturbances or extreme weather

events (e.g. forest fire, ice break, windstorm, drought, bark beetle outbreaks). The damage accounted for an average of 24% of the total area of the forest they own. The smallest reported damaged area was less than 1%, and 14.4% of PFOs stated that their entire forest (100% of the area) was damaged by large-scale natural disturbances. Up to 50% of damaged areas were reported by 86% of PFOs whose forests were damaged.

3.2. Results of Logistic Regression Model

The estimates of the binary logistic regression model for the PFOs decision-making rationality to implement salvage logging after large-scale natural disturbances are presented in Table 3. The Chi-squared test on the log-likelihood ratio indicates that the model was significant (χ^2=6.751; p=0.000). The model correctly classified 87% of the cases.

The results show that only two out of 14 independent variables are statistically significant. This indicates that past management activities and cooperation with service providers are significant predictors of PFOs' decision-making rationality to implement salvage logging after large-scale natural disturbances. Odds ratio for the »Management activity in the past« variable is 2.97 with a 95% confidence interval of [1.59, 5.55]. This suggests that PFOs with past management activities are 3 times more likely to perform salvage logging than PFOs without past management activities, while PFOs cooperating with service providers in the past are 6.3 times more likely to perform salvage logging. Odds ratio for the »Cooperation with service providers« variable is 6.26 with a 95% confidence interval of [2.40, 16.33]. The direction of the relationship between the independent variables and dependent variable were consistent with the hypotheses. The di-

Table 2 Characteristics of variables in logistic regression model

Attribute		Number	%
PFOs performance of salvage logging	No		14.4
	Yes		85.6
Gender	Male		54.6
	Female		45.4
Age of PFOs in years	Average		
	Median		
	Modus		
	<30 years	54	6.5
	30–40 years	56	10.1
	40–50 years	60	20.6
	50–60 years		25.2
	60–70 years		27.6
	>70 years		10.0
Level of education	High school or less		54.6
	Completed achelor, master's degree, PhD		45.4
Forest property size, ha	Average		
	Median	7.5	
	Modus	3	
	<4.99 ha	1	65.4
	5–9.99 ha		16.6
	10–29.99 ha		13.4
	>30 ha		4.6
Damaged forest area, %	Mean		24.3
	Minimum		0.4
	Maximum		100
Management activity in the past	No		10.2
	Yes		89.8
Cooperation with service providers	No		85.7
	Yes		14.3
Cooperation with PFO	No		95.2
	Yes		4.8
Price of forest wood assortments – conifers, €/m^3 without VAT	Average	53.8	
	Standard deviation	27.1	
	Median	50	
	Minimum	15	
	Maximum	180	
Price of forest wood assortments - deciduous trees, €/m^3 without VAT	Average	55.8	
	Standard deviation	21.1	
	Median	50	
	Minimum	20	
	Maximum	150	
Price of fully mechanised harvesting, €/m^3 without VAT	Average	21.8	
	Standard deviation	4.2	
	Median	22	
	Minimum	13	
	Maximum	35	
Price of harvesting and skidding, €/m^3 without VAT	Average	20.3	
	Standard deviation	4.6	
	Median	20	
	Minimum	9	
	Maximum	40	
Price of transport – conifers, €/m^3 without VAT	Average	8.6	
	Standard deviation	2.6	
	Median	8	
	Minimum	4	
	Maximum	18	
Price of transport – deciduous trees, €/m^3 without VAT	Average	9.2	
	Standard deviation	2.9	
	Median	9	
	Minimum	5	
	Maximum	22	

rection of both statistically significant variables was positive, indicating that the decision-making rationality to implement salvage logging after large-scale natural disturbances increased with experiences in forest management activities and cooperation with service providers in the past (Table 3).

4. Discussion

This study examines the results of a survey of PFOs responses to large-scale natural disturbances in order to identify potential factors that can explain the PFOs decision-making rationalities for salvage logging. The 14 analysed variables, divided into four groups, were identified in literature as important factors influencing PFOs' forest management decision making. These factors, which guide decision-making under normal conditions, provide a valuable baseline and may also affect certain aspects of salvage logging. The results of this study show a significant influence of the PFOs' previous management activities on the implementation of salvage logging, which is coherent with previous studies that have focused on PFOs motivation for regular timber harvesting. PFOs with past experience in timber harvesting and forest management objectives related to timber production are the most likely to harvest timber (Eriksson and Fries 2020, Juutinen et al. 2020), which also translates into a greater likelihood of salvaging damaged forests after large-scale natural disturbances (Markowski-Lindsay et al. 2020).

PFOs cooperation with service providers and between PFOs has been recognised in the past as an important measure that has a significant impact on supporting the sustainable management of private forests and implementation of policy objectives (Andersson and Keskitalo 2019, Fischer et al. 2019, Pezdevšek Malovrh et al. 2022a, Pezdevšek Malovrh et al. 2022b). Cooperation with forest service providers can influence the harvesting decisions in several ways, such as providing access to information, advice and technical assistance, reducing the costs and risks of timber harvesting, strengthening the negotiating position and increasing market opportunities. Previous research has shown that PFOs cooperation with forest service providers is increasing across Europe, in diverse means, to support timber production (Andersson and

Table 3 Logit estimates for factors influencing private forest owners' performance of salvage logging

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	95% *C.I.for EXP(B)*	
							Lower	Upper
Socio–demographic characteristics of private forest owners (*SOCIODEM*)								
Gender	0.253	0.278	0.831	1	0.362	1.288	0.747	2.219
Age of PFOs	–0.011	0.010	1.189	1	0.275	0.989	0.970	1.009
Level of education	–0.434	0.271	2.570	1	0.109	0.648	0.381	1.101
Characteristics of forest property (*PROP*)								
Forest property size	0.022	0.018	1.514	1	0.219	1.023	0.987	1.060
Damaged forest area	0.001	0.007	0.049	1	0.825	1.001	0.989	1.015
Forest management activities (*MANACT*)								
Management activity in the past	1.089	0.319	11.658	1	0.001	2.971	1.590	5.552
Cooperation with service providers	1.833	0.490	14.017	1	0.000	6.255	2.395	16.332
Cooperation with PFOs	0.922	0.498	3.432	1	0.064	2.515	0.948	6.672
Market (*MARKET*)								
Price of forest wood assortments – conifers	0.000	0.240	0.000	1	0.999	1.000	0.625	1.599
Price of forest wood assortments – deciduous trees	0.005	0.018	0.091	1	0.762	1.005	0.971	1.042
Price of fully mechanised harvesting	–0.205	0.332	0.382	1	0.537	0.815	0.425	1.561
Price of harvesting and skidding	0.791	1.028	0.592	1	0.442	2.206	0.294	16.554
Price of transport – conifers	1.251	2.167	0.333	1	0.564	3.494	0.050	244.388
Price of transport – deciduous trees	–1.843	2.138	0.743	1	0.389	0.158	0.002	10.461
Constant	–5.925	14.143	0.176	1	0.675	0.003	–	–

Keskitalo 2019, Ščap et al. 2021, Stockmann et al. 2024). These findings are also supported by our research, which demonstrated a statistically significant positive impact of PFOs cooperation with forest service providers on their salvage logging decision-making rationality. Finally, it can be concluded that the selection of service providers is a crucial aspect of salvage logging and can influence the overall success and sustainability of timber harvesting operations. In the past, researchers have focussed on cooperation between PFOs as well as on their engagement with service providers. The importance of cooperation has been an important area of forest policy research in the last decade, as it is believed to positively influence forest management (Malovrh et al. 2017, Andersson and Keskitalo 2019, Fischer and 2019). However, in our study cooperation between PFOs is not statistically significant at the conventional level, although it suggests a borderline relationship (p=0,064).

The logistic regression model confirms significant predictors that contribute to a more complex understanding of PFOs' decision-making rationalities to engage in salvage logging. A large proportion of the PFOs that took part in the survey carry out salvage logging. Since clear-cutting is prohibited in Slovenia due to regulations, the only possible strategy is salvaging, so damaged trees are removed. The specific deadlines for the implementation of salvage logging is determined by the Slovenia Forest Service based on the decision submitted to PFOs (Administrative decision to carry out the necessary work). If the work is not done, foreclosure proceedings are initiated. Despite the large proportion of those who have carried out salvage logging, there are still 14.4% of those who have not done so. In these cases, the most common reason for PFOs appears to be the lack of time to carry out the salvage logging followed by excessive cost, lack of contractors and inaccessible terrain. These results correspond to the group identified in the literature review (Knoke et al. 2021, Sanginés de Cárcer et al. 2021, Stare et al. 2023) and described in the introduction »PFOs may choose not to salvage their forests due to lack of resources or knowledge«.

We found that variables from the »Forest management activities« group proved to be the most influential on PFOs in their salvage logging decission-making process. On the other hand, the results of this study showed no significant influence of variables from the »market« category on the decision-making rationalities to implement salvage logging. This implies that changes in price of forest wood assortments, costs of harvesting or transport and interest rates may not necessarily have the expected result. Silver et al. (2015), in reviewing the literature that statistically examined the intent to harvest or the actual harvesting behaviour, examined several studies that concluded that harvest price was a positive significant predictor of PFOs decision to harvest timber. Similarly, Favada et al. (2009) and Sjølie et al. (2019) found that timber price has a significant and positive impact on the willingness of active PFOs to increase harvest. On the other hand, price did not impact on inactive PFOs inclination to engage in harvest (Sjølie et al. 2019). Moreover, Kittredge and Thompson (2016) found that PFOs are unresponsive or insufficiently responsive to timber prices. Beach et al. (2005) determined that timber price had a positive influence on the harvesting decisions of PFOs in only 58% of the studies analysed. This implies that PFOs are less responsive to market signals, especially timber prices, and that factors other than price are important (Sjølie et al. 2019).

Contrary to our expectations, only two variables were shown to have a statistically significant influence on PFOs decision-making rationality to implement salvage logging. However, this can also be linked to the result of Ficko (2019), who investigated the influence of the socio-economic profile of PFOs on the conceptualisation of forest management and found only a weak influence. This leads to the important conclusion that the statistical significance of factors influencing the rationality of decision making is not always substantial, and thus represents a remarkable contribution to scientific understanding and practical applications.

4.1. Limitations of the study and Future Research

Possible limitations and uncertainties of the study include the fact that the model does not address the specific nature of past management activities or the characteristics of cooperation with service providers. A more detailed analysis of these factors could provide additional insights. Another limitation of the model is the possibility that variables were omitted in the sense that there are variables that would prove to be statistically significant but are not included in our model. The success of the logistic regression depends on the correct selection of variables. It would be advisable to expand the number of variables in future studies to better understand how forest management behaviour of PFOs is related to salvage logging. For example, our model did not include the political and technological variables that were found to influence decision-making rationalities regarding salvage logging in previous studies (Deuffic et al. 2018, Sotirov et al. 2024).

5. Conclusions

To identify potential variables influencing PFOs' decision for salvage logging, a survey wconducted among PFOs on their decision rationalities regarding salvage logging after large-scale natural disturbances. Contrary to expectations, we were only able to partially confirm the hypothesis, as only two variables were found to be statistically significant, while our starting assumption was that the variables of all four groups would be.The findings that prior management actions and cooperation with service providers are significant predictors of PFOs' decision-making rationality to implement salvage logging have practical implications for forest managers, forest management planning, and policy makers. Consequently, support should be given to PFOs to help then overcome the time pressures and logistical challenges associated with salvage logging. Promoting cooperation with forest service providers can improve resource sharing and increase the efficiency of salvage logging operations.

Future research opportunities arise from examining the specific aspects of past management activities that contribute to salvage logging decision-making rationalities and understanding the dynamics of cooperation between different actors. A multifaceted approach that avoids a one-size-fits-all strategy is required. For future research, it is necessary to develop customised measures that would address specific interests and concerns. The key question for the future is how to support PFOs most effectively in forest management following damage from large-scale natural disturbances by providing them with advice that would maintain their interest and engagement.

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Conflicts of Interest

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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