

Information and Preferences for Post-Fire Restoration Techniques in Protective Forests: A Choice Experiment Approach

Supplementary material

A. Overview of post-fire restoration approaches

Post-disturbance management requires decisions and strategies to be based on a clear understanding of disturbance severity (i.e. the magnitude of the disturbance impact on the ecosystem) and its spatial pattern within the affected area, coupled with a sound knowledge of species ecology and regeneration strategies (Morresi et al., 2022). While biophysical and ecological assessments provide the foundation for post-disturbance management, intervention priorities should also incorporate socio-economic considerations, such as the main functions and ecosystem services, previously provided by the forest, public safety, land ownership, and funding availability. Despite this approach being widely advocated, land managers and policy-makers quite often still rely on past habits, promoting similar responses across different situations without a tailored management plan, with a preference for salvage logging (Müller et al., 2019). This practice involves the removal of damaged or dead trees following a large, high-severity disturbance and is often justified on economic grounds (e.g. timber recovery), although research suggests it may negatively affect biodiversity and hinder natural regeneration processes (Donato et al., 2006; Leverkus et al., 2018a; Lindenmayer et al., 2008b). When mountain forests with a direct protective function are involved, the need for post-disturbance restoration should be carefully assessed to mitigate the impairment of the stand protective role, limit degradation phenomena, and foster ecosystem recovery (Lingua et al., 2020; Moos et al., 2023). Among the available techniques, salvage logging is one of the most controversial as it can reduce ecological heterogeneity, limit habitat availability, and alter ecological cycles (Stein et al., 2014). Therefore, several studies

26 suggest that its implementation should be carefully considered in order to reduce its negative
27 impacts on ecosystems (Leverkus et al., 2020; Marzano et al., 2013).

28 Indeed, removing deadwood elements from protective forests after a high-severity or stand-
29 replacing event can further reduce the residual protection still offered after the disturbance
30 (Lingua et al., 2020). Lying deadwood has been shown to increase the surface roughness
31 of the forest floor (Fuhr et al., 2015), exerting a protective function that could be even higher
32 than in the pre-disturbance stand (e.g. Costa et al., 2021) and that could last for a very long
33 time (Wohlgemuth et al., 2017).

34 If deadwood is salvaged in protective forests, regardless of the rationale (e.g. partial
35 economic recovery; phytosanitary felling, public safety), the need to install artificial
36 infrastructure and rockfall nets should be considered to minimise the risk for stakeholders
37 and guarantee the protection previously offered by the forest (Costa et al., 2021), with further
38 costs to be considered, beside those of salvage logging.

39 Thus, an alternative approach to salvage logging is to take advantage of deadwood, with
40 potential beneficial effects also from the ecological point of view: leaving standing and lying
41 deadwood on-site can result in a double positive effect in the management of protection
42 forests, providing both eco-engineering structures and enhanced microsites for regeneration
43 (Lingua et al., 2020). This practice has been shown to improve vegetation recovery and
44 young seedling survival (Lingua et al., 2023), with preferential recruitment often occurring
45 near deadwood elements, particularly under harsh post-disturbance conditions and in
46 climatically stressed sites (e.g. Beghin et al., 2010; Castro et al., 2011; Marzano et al., 2013;
47 Swanson et al., 2023; Tacaliti et al., 2025). These effects are explained for instance by the
48 creation of safe sites with enhanced microsite conditions facilitating regeneration
49 establishment and survival due to the presence of a shield object (i.e. the deadwood
50 element) in close proximity (Callaway, 2007; Castro et al., 2011).

Intermediate techniques, such as partial salvage logging, with strategic felling of dead trees without their removal, may represent a compromise between ecological and economic needs (Marzano et al., 2018). Despite scientific evidence, public opinion often demands immediate action to remove standing and lying deadwood to restore order and 'cleanliness' in disturbed areas.

B. Full model explication

In the MXL model, the parameters α and β_j can be random and individual-specific (i.e. α_n and β_{nj}). Therefore, the utility function can be rewritten as:

$$U_{njt} = -\lambda_n^* p_{njt} + w_n' x_{njt} + \eta_{njt} \quad (1)$$

where $\lambda_n^* = \frac{\alpha_n}{\mu_n}$ is the preference-space coefficient for the cost attribute (α_n is the marginal utility of income and μ_n is the logit scale parameter); w_n is the vector of the ratios $\frac{\beta_{nj}}{\mu_n}$; and $\eta_{njt} = \frac{\varepsilon_{njt}}{\mu_n}$ is the i.i.d. error term.

To account for respondents' individual characteristics, we interacted the ASC with the individual-specific variables to ensure parameters' identifiability. Within the RUM framework, the absolute utility level is irrelevant, as choice probabilities depend only on utility differences. Consequently, only parameters reflecting differences among alternatives can be estimated. For this reason, the individual characteristics - invariant with respect to alternatives - must be incorporated in the model through interactions with the ASC. In addition, to capture potential changes in respondents' preferences after the intervention, we include an interaction between the ASC and the attributes with a post-treatment indicator. This specification allows preferences to vary between the pre- and post-treatment conditions. Finally, to investigate whether the treatment effect varies across individuals with different socio-demographic characteristics, we introduce triple interaction terms between

the ASC, individual characteristics, and the post-treatment indicator. These interactions capture heterogeneous treatment effects across respondent groups. With the inclusion of these interaction terms, the indirect utility function can be written as:

$$U_{njt} = -\alpha p_{njt} + \mathbf{w}' \mathbf{x}_{njt} + ASC_j(\gamma + \mathbf{r}' \mathbf{z}_n + \delta post_t + \boldsymbol{\theta}'(x_{njt} post_t) + \boldsymbol{\varphi}'(z_n post_t)) + \varepsilon_{njt} \quad (3)$$

where p_{njt} denotes the monetary attribute associated with alternative j , $\mathbf{x}_{njt}$ is the vector of non-monetary attributes, and ASC_j is the alternative-specific constant capturing the intrinsic utility of the policy alternative relative to the *status quo*. The vector $\mathbf{z}_n$ represents individual-specific characteristics (e.g. socio-demographic variables), which enter the model through interactions with the ASC. The parameter vectors $\mathbf{w}$, $\mathbf{r}$, and δ capture the marginal utilities of attributes, the effects of individual characteristics on the baseline utility of the policy alternative, and the shift in utility associated with the post-treatment condition, respectively. The error term ε_{njt} captures unobserved factors affecting utility.

Assuming that the error term follows a Type I extreme value distribution, the probability that individual n chooses alternative i in choice situation t , conditional on the vector of preference parameters β_n , is given by the multinomial logit formula:

$$P_{nit}(\beta_n) = \frac{\exp(V_{nit})}{\sum_{j=1}^J \exp(V_{njt})} \quad (2)$$

where V_{nit} represents the deterministic component of the indirect utility function (equation 3).

Assuming a continuous cumulative distribution function of parameters ($F(\beta|\vartheta)$), we obtain:

$$P_{nit} = \int P_{nit}(\beta) f(\vartheta) d\beta \quad (3)$$

where f is the density associated with F , and ϑ the vector of parameters. The coefficients in preference space are estimated using maximum simulated likelihood (Train, 2009), based

on the indirect utility function in equation 3. Using the indirect utility function of equations, the marginal rate of substitution between the DCE attributes and income is a proxy of the marginal WTP of the attribute, and it is simply the ratio of the estimated coefficient of each attribute and the estimated coefficient of the monetary attribute (Hanemann, 1984).

C. Model estimation results

Table C1. Mixed Logit Model (MXL) estimates, whole sample.

Attributes	Levels	Baseline	Post-treatment effect	Change
ASC		2.555*** (0.127)	-1.397*** (0.172)	1.158*** (0.130)
Deadwood management	Cut and release	0.006 (0.088)	0.026 (0.131)	0.032 (0.098)
	Partial salvage logging	0.558*** (0.103)	-0.991*** (0.157)	-0.433*** (0.132)
	Salvage logging	0.407*** (0.037)	-1.011*** (0.057)	-0.604*** (0.044)
Installation of rockfall nets	Yes	0.361*** (0.035)	-0.226*** (0.052)	0.135*** (0.039)
Reforestation	With cluster planting scheme	0.824*** (0.105)	-0.528*** (0.159)	0.295** (0.119)
	With regular planting scheme	0.925*** (0.106)	-0.663*** (0.160)	0.261** (0.119)
Tax		-0.013*** (0.0004)		
Standard Deviations Random Normal Coefficients				
ASC		3.075*** (0.076)		
	Partial salvage logging	0.929*** (0.215)		
	Salvage logging	0.795*** (0.041)		
Reforestation	With cluster planting scheme	0.543*** (0.052)		
	With regular planting scheme	0.394*** (0.069)		
Log Likelihood		-11,739		
N. Observations		1,210		

Standard errors in parenthesis, * p < 0.1; ** p < 0.05; *** p < 0.01

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104 **Table C2.** WTP estimated from the Mixed Logit Model (MXL), whole sample (€)

Attributes	Levels	Baseline	Post-treatment	Difference
ASC		185.80 (165.45;207.16)	84.24 (65.30;103.37)	-76.10***
Deadwood management	Cut and release	0.46 (-12.12;13.07)	2.33 (-11.82;16.33)	1.86
	Partial salvage logging	40.45 (25.92;54.91)	-31.51 (-50.20; -12.47)	-71.96***
	Salvage logging	29.56 (24.13;35.07)	-43.95 (-50.75; -37.42)	-73.53***
Installation of rockfall nets	Yes	26.24 (21.08;31.44)	9.85 (4.19;15.45)	-16.42***
Reforestation	With cluster planting scheme	59.86 (44.85;75.31)	21.40 (4.29;38.82)	-38.44***
	With regular planting scheme	67.19 (51.80;83.10)	18.95 (1.96; 36.25)	-48.23***

105 Confidence intervals at 95% in parentheses. The statistical significance of WTP differences between baseline
106 and post-treatment estimates was assessed using the Poe test (Poe et al., 1997). * $p < 0.1$; ** $p < 0.05$; *** p
107 < 0.01

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109 **Table C3.** Mixed Logit Model (MXL) with interaction terms.

Attributes	Levels	Baseline	Post-treatment effect	Change
ASC		-1.818** (0.648)	2.958*** (0.885)	1.139*
Deadwood management	Cut and release	0.007 (0.088)	0.018 (0.131)	0.024
	Partial salvage logging	0.550** (0.104)	-0.982*** (0.106)	-0.431***
	Salvage logging	0.410*** (0.037)	-1.014*** (0.058)	-0.603***
Installation of rockfall nets	Yes	0.360*** (0.035)	-0.223*** (0.053)	0.136***
Reforestation	With cluster planting scheme	0.827*** (0.105)	-0.532*** (0.159)	0.295**
	With regular planting scheme	0.928*** (0.106)	-0.665*** (0.160)	0.263**

Tax	-0.013*** (0.000)
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Interactions of ASC with Socio-demographic Variables

ASC*Female	-0.535*** (0.110)	0.510*** (0.138)	0.024
ASC*Age	0.003 (0.003)	-0.025*** (0.004)	-0.022***
ASC*Hill Areas	0.138 (0.140)	0.040 (0.175)	-0.178*
ASC*Mountain Areas	-0.191 (0.155)	0.036 (0.200)	-0.155
ASC*Middle school	3.536*** (0.580)	-2.569*** (0.802)	0.967**
ASC*High school	3.189*** (0.574)	-2.564*** (0.798)	0.624
ASC*bachelor's degree	3.069*** (0.600)	-2.563*** (0.830)	0.505
ASC*master's degree	2.568*** (0.583)	-2.430*** (0.802)	0.138
ASC*Postgraduate	2.074*** (0.657)	-1.642* (0.911)	0.432
ASC*: North-East	0.201* (0.120)	-0.251* (0.150)	-0.05
ASC*Net household income 1,000-2,000 euro/month (1 = yes)	1.092*** (0.207)	-0.685*** (0.268)	0.406**
ASC*Net household income 2,000-3,000 euro/month (1 = yes)	1.614*** (0.216)	-0.669*** (0.275)	0.944**
ASC*Net household income 3,000-4,000 euro/month (1 = yes)	1.891*** (0.238)	-1.379*** (0.303)	0.512***
ASC*Net household income 4,000-6,000 euro/month (1 = yes)	2.435*** (0.314)	-2.274*** (0.382)	0.160
ASC*Net household income > 6,000 euro/month (1 = yes)	3.051*** (0.477)	-1.597*** (0.596)	1.454***
ASC*Net household income does not answer (1=yes)	0.658*** (0.229)	-0.337 (0.295)	0.321

Standard Deviations Random Normal Coefficients

ASC	3.085*** (0.078)
Partial salvage logging	0.931*** (0.219)
Salvage logging	0.788*** (0.041)
Reforestation	With cluster planting scheme 0.576*** (0.050)
	With regular planting scheme 0.348*** (0.073)

Log Likelihood	11,663
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Supplementary Materials