Lariviere D., Djupström L., Nilsson O. (2025). Impact of varying retention proportions on Scots pine (*Pinus sylvestris*) establishment across planting, direct seeding, and natural regeneration. Silva Fennica vol. 59 no. 3 article id 25007. https://doi.org/10.14214/sf.25007

Supplementary file S2 – Survival, Germination and Recruitment by Inventory

Survival (planted) and germination (direct seeding) were expressed as the proportion of seedlings that survived (planted) or germinated (direct seeded) per sample plot at each inventory ($prop_i$). Because proportions could include zeros, the response was log-transformed after adding a constant. Fixed and random effects were specified as for the height models. The significance of fixed effects was assessed using Type II Wald F-tests with the Kenward–Roger approximation from the *car* package. For each regeneration method and inventory time *i*, models were fitted in the form:

Equation 2 in R

$$Log(prop(i) + 1) \sim ret\_lvl \times Markb \ + (1 \mid StandID \ /Block)$$

PLANTED

```
mod1_P_S <-  lmer(log(prop.surv1+1) ~ ret_lvl * Markb + (1 | BeID/Block), data = PLANTED_df)
mod2_P_S  <- lmer(log(prop.surv2+1) ~ ret_lvl * Markb + (1 | BeID/Block), data = PLANTED_df)
mod3_P_S  <- lmer(log(prop.surv3+1) ~ ret_lvl * Markb + (1 | BeID/Block), data = PLANTED_df)
mod4_P_S  <- lmer(log(prop.surv4+1) ~ ret_lvl * Markb + (1 | BeID/Block), data = PLANTED_df)
mod5_P_S  <- lmer(log(prop.surv5+1) ~ ret_lvl * Markb + (1 | BeID/Block), data = PLANTED_df)
```

DIRECT SEEDED

```
mod1_S_G <- lmer(log(prop.surv1+1) ~ ret_lvl * Markb + (1 | BeID/Block), data = SEEDED_df)
mod2_S_G <- lmer(log(prop.surv2+1) ~ ret_lvl* Markb + (1 | BeID/Block), data = SEEDED_df)
mod3_S_G <- lmer(log(prop.surv3+1) ~ ret_lvl* Markb + (1 | BeID/Block), data = SEEDED_df)
mod4_S_G <- lmer(log(prop.surv4+1) ~ ret_lvl* Markb + (1 | BeID/Block), data = SEEDED_df)
mod5_S_G <- lmer(log(prop.surv5+1) ~ ret_lvl* Markb + (1 | BeID/Block), data = SEEDED_df)
```

NATURAL REGENERATION

```
mod1_NR_R_nb <- glmer.nb(sum_ANTAL1 ~ ret_lvl * Markb + (1 | BeID/Block), data = NATURALR_df)
mod2_NR_R_nb <- glmer.nb(sum_ANTAL2 ~ ret_lvl * Markb + (1 | BeID/Block), data = NATURALR_df)
mod3_NR_R_nb <- glmer.nb(sum_ANTAL3 ~ ret_lvl * Markb + (1 | BeID/Block), data = NATURALR_df)
mod4_NR_R_nb <- glmer.nb(sum_ANTAL4 ~ ret_lvl * Markb + (1 | BeID/Block), data = NATURALR_df)
mod5_NR_R_nb <- glmer.nb(sum_ANTAL5 ~ ret_lvl * Markb + (1 | BeID/Block), data = NATURALR_df)
```

Mathematical Equation 2 for each inventory x (1-5)

$$log\left(Prop_{ijk} + \ 1\right) = \beta_0 + \beta_1 \cdot ret\_lvl_{ijk} + \beta_2 \cdot MSP_{ijk} + \beta_3 \cdot (ret\_lvl \times MSP)_{ijk} + u_j + v_{k(j)} + \varepsilon_{ijk}$$

Where β_0 is the intercept, β_1 to β_3 are fixed effect coefficients, $u_j \sim \mathcal{N}(0, \sigma_u^2)$ is the random effect for stand, $v_{k(j)} \sim \mathcal{N}(0, \sigma_v^2)$ is the random effect for block nested within stand, and $\varepsilon_{ijk} \sim \mathcal{N}(0, \sigma^2)$ is the residual error.

Supplementary S2 Table 1. Results from ANOVA examining the effects of Retention Level, Site Preparation, and their interaction (Retention × Site) on the log-transformed proportion of survival, germination, or recruitment for three regeneration types (Planted Seedlings, Direct Seeded, and Naturally Regenerated) across five inventories (H1–H5). For Planted Seedlings and Direct Seeded, each cell reports the F-statistic from a Type II Wald F test, with degrees of freedom estimated using the Satterthwaite approximation (formatted as F(numerator df, denominator df)), and the associated p-value. For Naturally Regenerated recruitment, each cell reports the χ^2-statistic from a Type III Wald chi-square test based on a Poisson GLMM, along with the p-value.The response variable for each inventory is the log-transformed proportion of surviving or recruited seedlings (log(mean_Hx), where x = 1 to 5).

Type	Factor	Estimates β inv1	Inventory 1 (log(prop_surv1))	Inventory 2 (log(prop_surv2))	Inventory 3 (log(prop_surv3))	Inventory 4 (log(prop_surv4))	Inventory 5 (log(prop_surv5))
Proportion survival (%)	Retention Level	β□s = 0.06 (lvl3), 0.04 (lvl30), 0.00 (lvl50), 0.01 (B50)	F=0.395 (4,9.722), p=0.808	F=0.479 (4,9.692), p=0.751	F=0.523 (4,9.712), p=0.721	F=0.438 (4,9.642), p=0.779	F=0.409 (4,9.652), p=0.798
	Site Preparation	β□ = 0.11 (Markb1)	F=3.260 (1,39.182), p=0.079 .	F=5.984 (1,47.774), **p=0.018 ***	F=8.409 (1,47.758), **p=0.006 ****	F=7.675 (1,47.694), **p=0.008 ****	F=6.991 (1,47.697), **p=0.011 ***
	Retention × Site	β□s = -0.06, -0.18, 0.00,-0.06 (interactions)	F=1.125 (4,39.182), p=0.359	F=1.484 (4,47.774), p=0.222	F=0.861 (4,47.758), p=0.494	F=0.832 (4,47.694), p=0.512	F=1.001 (4,47.697), p=0.416
Proportion germination (%)	Retention Level	β□s = 0.69 (lvl3), -0.27 (lvl30), -0.09 (lvl50), 0.03 (B50)	F=0.917 (4,9.512), p=0.493	F=1.190 (4,10.063), p=0.373	F=1.136 (4,11.634), p=0.387	F=1.010 (4,13.254), p=0.437	F=0.980 (4,11.669), p=0.455
	Site Preparation	β□ = 2.09 (Markb1)	F=177.086 (1,47.785), **p<0.001 *****	F=161.077 (1,48.497), **p<0.001 *****	F=146.347 (1,49.867), **p<0.001 *****	F=130.552 (1,50.978), **p<0.001 *****	F=134.227 (1,49.894), **p<0.001 *****
	Retention × Site	β□s = -0.46, 0.26, 0.12, 0.04 (interactions)	F=0.527 (4,47.785), p=0.716	F=0.482 (4,48.497), p=0.749	F=0.328 (4,49.867), p=0.858	F=0.187 (4,50.978), p=0.944	F=0.198 (4,49.894), p=0.938
Recruitment	Retention Level	β□s = -0.45 (lvl3), -0.58 (lvl30), -1.53 (lvl50), -0.79 (B50)	χ^2=5.209, df=4, p=0.267	χ^2=7.802, df=4, p=0.100 .	χ^2=8.440, df=4, p=0.077 .	χ^2=14.554, df=4, **p=0.006 ****	χ^2=17.430, df=4, **p=0.002 ****
	Site Preparation	β□ = -1.86 (Markb1)	χ^2=17.959, df=1, **p<0.001 *****	χ^2=0.156, df=1, p=0.693	χ^2=21.518, df=1, **p<0.001 *****	χ^2=19.795, df=1, **p<0.001 *****	χ^2=21.674, df=1, **p<0.001 *****
	Retention × Site	β□s = -0.09, 1.73, 1.66, 1.50 (interactions)	χ^2=15.159, df=4, **p=0.004 ****	χ^2=10.812, df=4, **p=0.029 ***	χ^2=13.847, df=4, **p=0.008 ****	χ^2=52.249, df=4, p<0.001 ***	χ^2=66.084, df=4, **p<0.001 *****

Notes: p* < 0.05, ** p < 0.01, *** p < 0.001, . p < 0.1.
F-values for Planted Seedlings and Direct Seeded are from Type II Wald F-tests with Satterthwaite degrees of freedom. χ^2-values for Naturally Regenerated recruitment are from Type III Wald chi-square tests (Poisson GLMM). Response variable for each inventory is the log of mean seedling proportion
“Retention level” refers to the tree retention category (five levels: 3, 10, 30, 50 % or Burn 50).
“Site preparation” = mechanical site-preparation treatment (0 = without, 1 = with).

Supplementary S2 Table 2. Model estimates for the proportion of survival (Planted), proportion of germination (Direct Seeding), and recruitment (Natural Regeneration) models for each regeneration method across five inventory times. Retention level is treated as a categorical variable with five levels; therefore, all corresponding coefficients (β□) and interaction terms (β□) are presented. The intercept represents the reference levels (e.g., retention level = 3%, MSP = 0). Values with p < 0.05 are highlighted in red to indicate statistical significance.

		Inventory 1				Inventory 2				Inventory 3				Inventory 4				Inventory 5			
Method	term	estimate	std.error	statistic	p.value	estimate	std.error	statistic	p.value	estimate	std.error	statistic	p.value	estimate	std.error	statistic	p.value	estimate	std.error	statistic	p.value
Planted	(Intercept)	4,509	0,057	78,447	0,000	4,500	0,071	63,571	0,000	4,491	0,078	57,256	0,000	4,482	0,083	54,297	0,000	4,482	0,086	52,056	0,000
	ret_lvl10	-0,059	0,081	-0,730	0,473	-0,130	0,100	-1,301	0,209	-0,121	0,111	-1,089	0,292	-0,145	0,117	-1,245	0,230	-0,155	0,122	-1,272	0,221
	ret_lvl30	-0,022	0,081	-0,272	0,788	-0,055	0,100	-0,554	0,586	-0,107	0,111	-0,961	0,350	-0,097	0,117	-0,833	0,416	-0,097	0,122	-0,798	0,436
	ret_lvl50	-0,060	0,081	-0,744	0,464	-0,106	0,100	-1,054	0,305	-0,121	0,111	-1,087	0,293	-0,121	0,117	-1,033	0,316	-0,133	0,122	-1,090	0,291
	ret_lvlB50	-0,045	0,076	-0,592	0,561	-0,088	0,095	-0,923	0,370	-0,080	0,106	-0,752	0,465	-0,080	0,111	-0,720	0,483	-0,081	0,116	-0,691	0,501
	Markb1	0,049	0,068	0,719	0,476	0,058	0,073	0,792	0,432	0,068	0,074	0,909	0,368	0,069	0,080	0,854	0,398	0,058	0,082	0,708	0,482
	ret_lvl10:Markb1	0,064	0,097	0,664	0,511	0,116	0,104	1,122	0,268	0,098	0,105	0,933	0,356	0,112	0,113	0,984	0,330	0,132	0,116	1,139	0,260
	ret_lvl30:Markb1	-0,114	0,097	-1,179	0,245	-0,120	0,104	-1,158	0,253	-0,069	0,105	-0,656	0,515	-0,070	0,113	-0,616	0,541	-0,074	0,116	-0,636	0,528
	ret_lvl50:Markb1	0,063	0,097	0,650	0,519	0,072	0,104	0,689	0,494	0,087	0,105	0,824	0,414	0,087	0,113	0,763	0,449	0,098	0,116	0,848	0,401
	ret_lvlB50:Markb1	0,001	0,087	0,016	0,988	0,018	0,093	0,194	0,847	0,009	0,094	0,092	0,927	0,008	0,102	0,075	0,940	0,018	0,103	0,177	0,860
Direct Seeding	(Intercept)	2,610	0,303	8,621	0,000	2,541	0,296	8,588	0,000	2,528	0,287	8,800	0,000	2,509	0,284	8,834	0,000	2,479	0,279	8,874	0,000
	ret_lvl10	-0,686	0,428	-1,603	0,121	-0,779	0,418	-1,862	0,072	-0,679	0,406	-1,670	0,103	-0,609	0,402	-1,517	0,137	-0,567	0,395	-1,435	0,160
	ret_lvl30	-0,953	0,428	-2,226	0,035	-0,897	0,418	-2,144	0,040	-0,879	0,406	-2,163	0,037	-0,763	0,402	-1,900	0,064	-0,761	0,395	-1,925	0,062
	ret_lvl50	-0,775	0,428	-1,811	0,082	-0,880	0,418	-2,102	0,044	-0,633	0,406	-1,557	0,128	-0,550	0,402	-1,369	0,178	-0,424	0,395	-1,072	0,290
	ret_lvlB50	-0,659	0,395	-1,666	0,112	-0,511	0,381	-1,340	0,193	-0,496	0,367	-1,350	0,188	-0,464	0,360	-1,290	0,206	-0,447	0,357	-1,252	0,221
	Markb1	1,632	0,373	4,371	0,000	1,658	0,391	4,240	0,000	1,632	0,390	4,181	0,000	1,627	0,398	4,088	0,000	1,590	0,380	4,187	0,000
	ret_lvl10:Markb1	0,456	0,528	0,863	0,392	0,574	0,553	1,038	0,304	0,425	0,552	0,770	0,445	0,337	0,563	0,599	0,552	0,284	0,537	0,529	0,599
	ret_lvl30:Markb1	0,717	0,528	1,357	0,181	0,631	0,553	1,140	0,260	0,615	0,552	1,114	0,271	0,469	0,563	0,833	0,409	0,438	0,537	0,816	0,418
	ret_lvl50:Markb1	0,579	0,528	1,097	0,278	0,627	0,553	1,133	0,263	0,324	0,552	0,587	0,560	0,299	0,563	0,531	0,598	0,186	0,537	0,347	0,730
	ret_lvlB50:Markb1	0,497	0,472	1,052	0,298	0,353	0,495	0,713	0,479	0,377	0,494	0,763	0,449	0,301	0,504	0,598	0,553	0,333	0,480	0,693	0,492
Natural Regeneration	(Intercept)	1,872	0,426	4,395	0,000	1,450	0,365	3,970	0,000	1,798	0,409	4,394	0,000	1,968	0,394	4,996	0,000	2,278	0,353	6,454	0,000
	ret_lvl10	0,025	0,602	0,042	0,966	0,599	0,476	1,257	0,209	0,565	0,560	1,008	0,314	0,811	0,541	1,500	0,134	0,761	0,521	1,460	0,144
	ret_lvl30	-0,486	0,616	-0,789	0,430	-0,137	0,499	-0,275	0,783	-0,070	0,570	-0,124	0,902	-0,153	0,545	-0,280	0,779	-0,335	0,503	-0,666	0,505
	ret_lvl50	-1,466	0,670	-2,190	0,029	-0,732	0,537	-1,364	0,173	-0,834	0,599	-1,392	0,164	-0,938	0,575	-1,629	0,103	-1,032	0,521	-1,980	0,048
	ret_lvlB50	-0,773	0,555	-1,393	0,164	-0,261	0,472	-0,553	0,580	0,307	0,526	0,584	0,559	0,377	0,493	0,765	0,444	0,275	0,441	0,623	0,533
	Markb1	-2,565	0,957	-2,681	0,007	0,172	0,469	0,368	0,713	0,664	0,542	1,225	0,221	1,085	0,546	1,989	0,047	1,078	0,520	2,071	0,038
	ret_lvl10:Markb1	0,850	1,204	0,706	0,480	-0,166	0,588	-0,282	0,778	0,253	0,695	0,364	0,716	-0,286	0,710	-0,403	0,687	-0,364	0,696	-0,523	0,601
	ret_lvl30:Markb1	2,431	1,147	2,120	0,034	0,103	0,607	0,170	0,865	0,312	0,708	0,441	0,659	0,160	0,718	0,223	0,824	0,216	0,693	0,311	0,756
	ret_lvl50:Markb1	2,342	1,239	1,890	0,059	0,979	0,645	1,518	0,129	1,041	0,737	1,411	0,158	1,358	0,754	1,802	0,072	1,302	0,727	1,792	0,073
	ret_lvlB50:Markb1	2,208	1,088	2,030	0,042	0,188	0,557	0,337	0,736	0,015	0,638	0,023	0,981	-0,329	0,650	-0,506	0,613	-0,433	0,630	-0,688	0,492