Supplementary material

Table S1. Identity of tree species recorded in the National Forest Inventory plots in Catalonia across different bioclimatic regions (Mediterranean, Supramediterranean, and Montane) and according to protection status (Non-Natura 2000 vs. Natura 2000 areas). Numbers indicate percentages of presence. *Total* = % of species presence per bioclimatic region. *Overall total* = % of species presence in Catalonia. A value of 0.1% indicates a presence of this or lower magnitude.

	Mediterranean			Supramediterranean			Montane			
	Non-Natura 2000	Natura 2000	Total	Non-Natura 2000	Natura 2000	Total	Non-Natura 2000	Natura 2000	Total	Overall total
Abies alba				100	0	0.1	21	79	2	1
Acer campestre	50	50	0.1	25	75	1	50	50	1	1
Acer monspessulanum	67	33	0.1	50	50	1	43	57	1	0.1
Acer opalus				0	100	0.1	62	38	1	1
Acer platanoides							0	100	0.1	0.1
Acer pseudoplatanus				0	100	0.1	40	60	0.1	0.1
Alnus glutinosa	60	40	0.1	20	80	1	100	0	0.1	0.1
Arbutus unedo	45	55	3	36	64	1	33	67	0.1	2
Betula spp.			0.1	0	100	0.1	31	69	3	1
Castanea sativa	75	25	1	8	92	1	20	80	1	1
Corylus avellana	0	100	0.1	0	100	0.1	39	61	1	0.1
Crataegus monogyna	50	50	0.1	67	33	0.1	67	33	1	0.1
Eucalyptus globulus	80	20	0.1							0.1
Fagus sylvatica				13	88	1	27	73	6	2
Fraxinus angustifolia				50	50	0.1	100	0	0.1	0.1
Fraxinus excelsior				50	50	0.1	74	26	1	0.1
Ilex aquifolium				0	100	0.1	0	100	0.1	0.1
Juniperus communis	67	33	0.1	17	83	1	73	27	1	1
Juniperus oxycedrus	75	25	0.1	50	50	0.1	100	0	0.1	0.1

Olea europaea	44	56	0.1	0	100	0.1				0.1
Pinus halepensis	69	31	29	67	33	6	95	5	2	15
Pinus nigra	72	28	8	49	51	19	74	26	9	10
Pinus pinaster	63	37	3	50	50	0.1	100	0	0.1	2
Pinus pinea	65	35	10	64	36	1	80	20	0.1	5
Pinus radiata	100	0	0.1							0.1
Pinus sylvestris	66	34	4	42	58	18	64	36	28	15
Pinus uncinata	100	0	0.1				30	70	9	4
Platanus hispanica	100	0	0.1				100	0	0.1	0.1
Populus tremula	40	60	0.1	25	75	0.1	65	35	1	1
Populus x canadensis	86	14	0.1	57	43	1	89	11	0.1	0.1
Prunus spp.	100	0	0.1	50	50	0.1	33	67	0.1	0.1
Prunus avium	13	88	0.1	0	100	0.1	50	50	0.1	0.1
Pseudotsuga menziesii				100	0	0.1	100	0	0.1	0.1
Quercus canariensis	75	25	0.1	100	0	0.1	50	50	0.1	0.1
Quercus faginea	71	29	5	70	30	12	78	22	7	7
Quercus ilex	57	43	18	29	71	23	66	34	10	15
Quercus petraea	71	29	1	32	68	4	61	40	8	4
Quercus pubescens	94	6	2	45	55	2	52	48	2	2
Quercus pyrenaica	0	100	0.1	0	100	1				0.1
Quercus robur	83	17	0.1	70	30	1	50	50	1	1
Quercus suber	53	47	12	20	80	1	75	25	0.1	6
Salix spp.	100	0	0.1	100	0	0.1	58	42	0.1	0.1
Sorbus spp.	100	0	0.1	100	0	0.1	33	67	1	0.1
Tilia spp.							33	67	0.1	0.1
Ulmus glabra							50	50	0.1	0.1
Ulmus minor	67	33	0.1	50	50	0.1	100	0	0.1	0.1
Ulmus pumila	50	50	0.1							0.1

Table S2. Method used for the analysis of spatial autocorrelation and determination of cut-off values (A) and example of R-script for the analysis of spatial autocorrelation, selection of cut-off value and GLM analysis for the occurrence of wildfires in protected and non-protected areas (B).

(A) Prior to running the statistical tests on each of the response variables, we checked for the existence of spatial autocorrelation in the dependent variables among the SNFI plots as well as the maximum distance in the occurrence of this autocorrelation effect. To do so, we implemented the following algorithm:

a) First, we applied a random spatial filter to the set of points to eliminate all locations closer than a given cutoff distance. The filter worked by first picking a location at random, then selecting another location at a distance longer than the cutoff distance, and so on. Cutoff distances started in 1 km, the minimum distance among SNFI plots and increased up to 10 km, by increasing 1 km at every step. This was carried on until all available SNFI plots had been checked.
b) Next, a join-count test was carried out on those filtered points with the help of functions from the “spdep” R package (Pebesma & Bivand 2023).
c) The p-value of the join-count test was extracted and saved.

This was repeated 100 times for each given cutoff distance and the corresponding mean p-value was calculated. The idea behind this procedure was to detect at which distance spatial data stopped showing evidence of aggregation (for a detailed explanation of the join-count test, see Dale and Fortin 2014). As shown in Figure S2, p-values would start out at very low values (evidence of spatial aggregation) for very short cutoff distances until a value p-value>0.05 was eventually reached, from which mean p-values were always >0.05. That critical distance (cut-off value) would then represent our choice for a spatial filter which would balance, on the one hand, the necessity to reduce spatial correlation in the data and, on the other hand, the obvious requirement of having a dataset as large as possible.

REFERENCES

Dale, M. R., & Fortin, M. J. (2014). Spatial analysis: a guide for ecologists. Cambridge University Press.

Pebesma, E., & Bivand, R. (2023). Spatial data science: With applications in R. Chapman and Hall/CRC.

(B) Example of R-script for the analysis of spatial autocorrelation, selection of cut-off value and GLM analysis for the occurrence of wildfires in protected and non-protected areas

```
# We need to make sure that packages are available, and if not, they are installed.
check_is_installed(c("readxl", "dplyr", "spdep", "cli"))

# Load data from Excel workbooks. Then, rename coordinates, remove NAs and set columns as factors.
df <- readxl::read_xlsx("Data_SNFI.xlsx") |>
  dplyr::rename(x = utmx, y = utmy) |>
  dplyr::rename(Forest_protection = 'Forest protection',
               Bioclimatic_region = 'Bioclimatic region',
               Forest_leaf_habit = 'Forest leaf habit',
               Basal_area = 'Basal Area',
               Unspecific_disturbances = 'Unspecific disturbances',
               Forest_decay = 'Forest decay') |>
  dplyr::mutate(Forest_protection = factor(Forest_protection),
               Bioclimatic_region = factor(Bioclimatic_region),
               Forest_leaf_habit = factor(Forest_leaf_habit),
               Unspecific_disturbances = factor(Unspecific_disturbances))

# Distance intervals (in m) for join-count test and simulation parameters.
xdist <- seq(1000, 10000, by = 1000)
nsimu <- 20
pvalue <- matrix(0, length(xdist), nsimu)

# Change depending on what variable needs to be checked.
variable <- "Wildfires"

# Increase filter distance up to 10Km.
for (i in 1:length(xdist)) {
  cli::cli_progress_bar(paste0("join-count tests, step ", i, " of ", length(xdist)), total = nsimu)
  for (j in 1:nsimu) {
    cli::cli_progress_update()
    di <- MiscGeom::distance_filter(df, xdist[i], columns = c("x", "y"), verbose = FALSE, shuffle =
TRUE, strictly = FALSE)
    pvalue[i, j] <- joincount_pvalue(di, variable, iterate = FALSE)

  }
  cli::cli_progress_done()
}

# Visual inspection to identify distance at which mean p-value > 0.05.
plot(xdist, apply(pvalue, 1, mean, na.rm = TRUE), xlab = "Distance intervals (m)", ylab = "Mean p-
value")
points(c(min(xdist), max(xdist)), c(.05, .05), type = "l", lty = 2, lwd = 2)

# Simple regression to determine distance at which mean p-value is larger than 0.05.
x <- rep(xdist, each = nsimu)
y <- as.vector(t(pvalue))
r <- lm(y ~ -1 + I(x^3))
plot(x, y)
yp <- predict(r, newdata = data.frame(x = xdist))
points(xdist, yp, pch = 16, col = "red", type = "o")
points(c(min(xdist), max(xdist)), c(.05, .05), type = "l", lty = 2, lwd = 2)
```

```
# Get distance.
cutoff <- xdist[which.min(abs(yp - 0.05))]
cli::cli_inform(paste0("Cutoff value for ", variable, " is = ", cutoff))


# Final models with cutoff from previous analysis. The big model "mstart" without distance filtering will
# help us to compute starting values for the regressions further below.

nsimu <- 200

formula <- as.formula(paste0(variable, " ~ Forest_protection + Bioclimatic_region +
                              Forest_leaf_habit + Basal_area + Slope + Aspect"))
mstart <- glm(formula = formula, family = "binomial", data = df)
coef_start <- coef(mstart)
m <- list()
cli::cli_progress_bar("Computing regressions for successive distance filters", total = nsimu)
for (i in 1:nsimu) {
  cli::cli_progress_update()
  df2 <- distance_filter(df, cutoff, columns = c("x", "y"), verbose = FALSE, shuffle = TRUE)
  m[[i]] <- glm(formula, family = "binomial", data = df2, start = coef_start)
}
cli::cli_progress_done()


# Calculate confidence intervals for coefficients.
z <- sapply(m, function(z) coef(z))
modelcoef <- data.frame(Estimate = apply(z, 1, mean),
                        'Std. Error' = apply(z, 1, sd),
                        'Perc. 2.5%' = apply(z, 1, function(z) quantile(z, .025)),
                        'Perc. 97.5%' = apply(z, 1, function(z) quantile(z, .975)))
print(modelcoef)
```

Figure S1. Images of different drought-driven forest dieback episodes recorded in the DEBOSCAT project. Images A, B and C are courtesy of the Catalonian Rural Agents Corp and D is courtesy of Jordi Bartolomé.

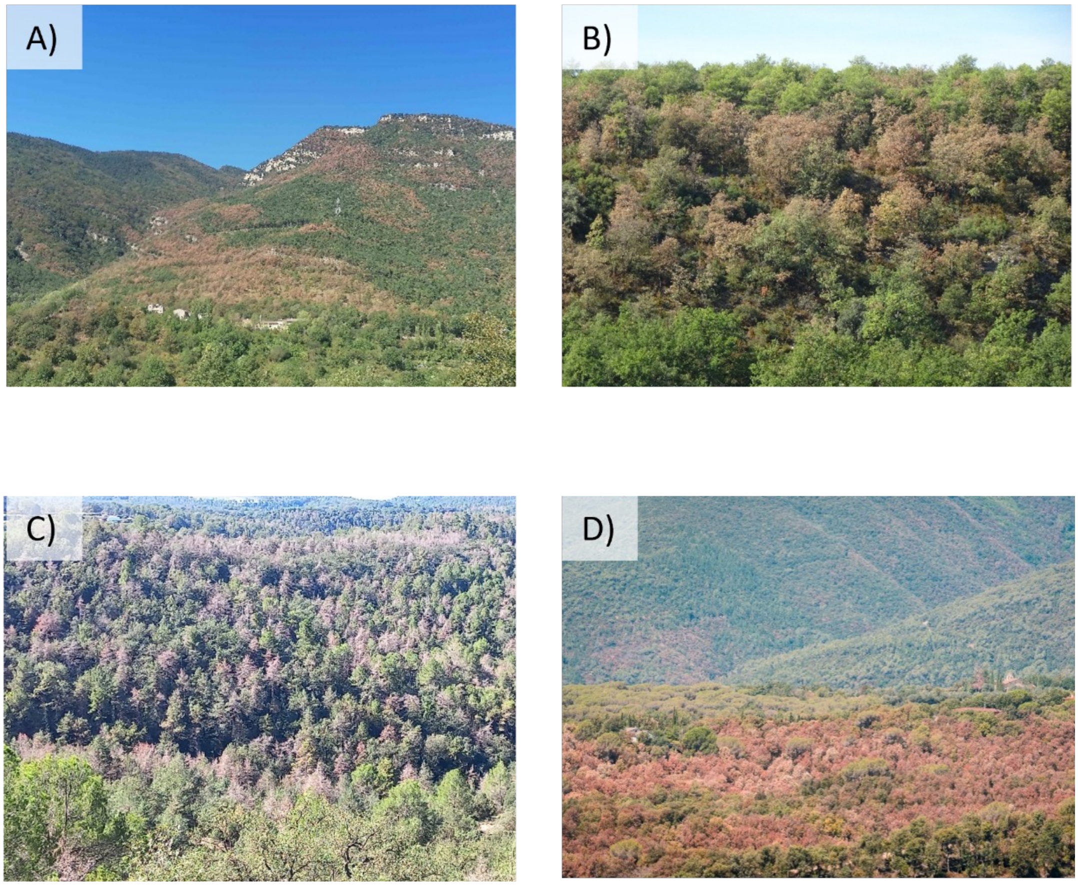


Figure S2. Mean join-count p-values as a function of cut-off distance for: A) Unspecific disturbances (wildfires + harvesting), B) Wildfires, C) Harvesting and D) Drought-driven forest dieback.

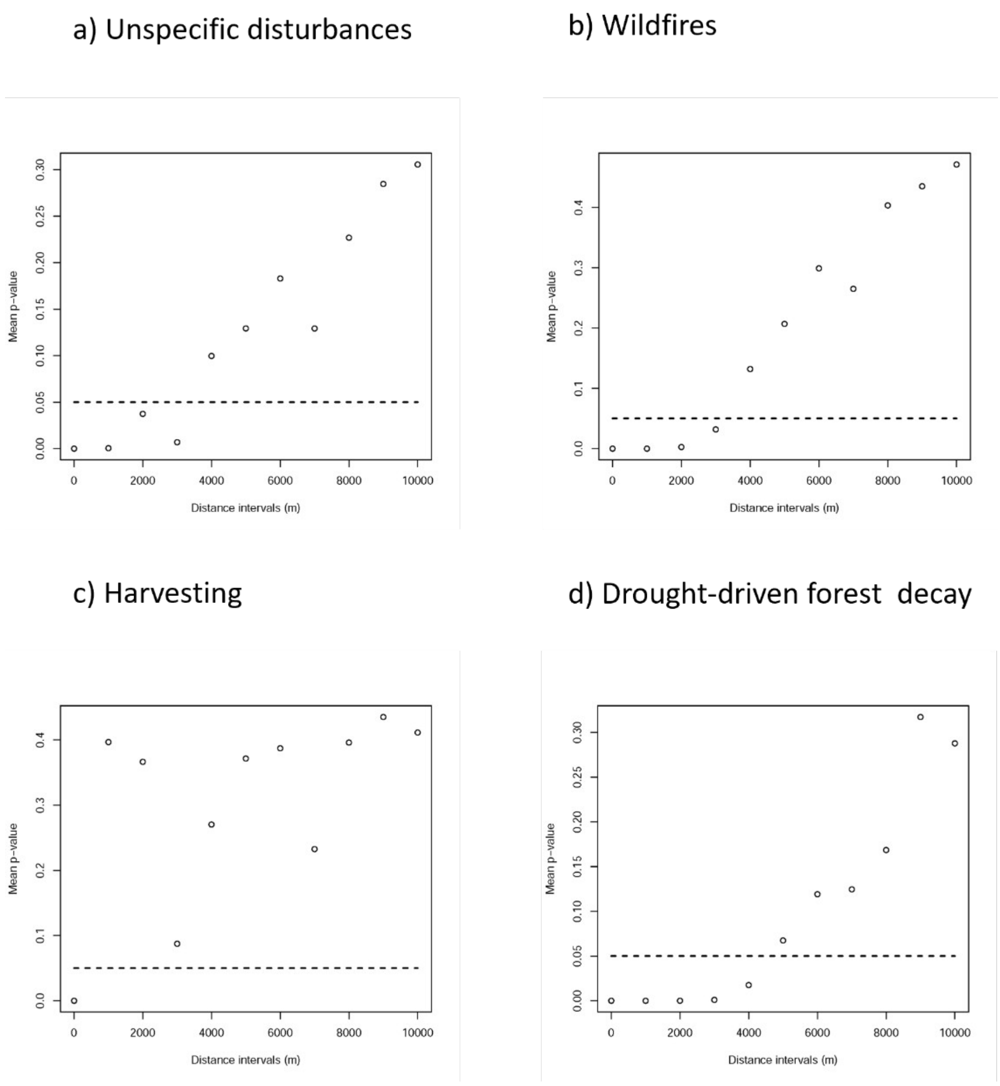
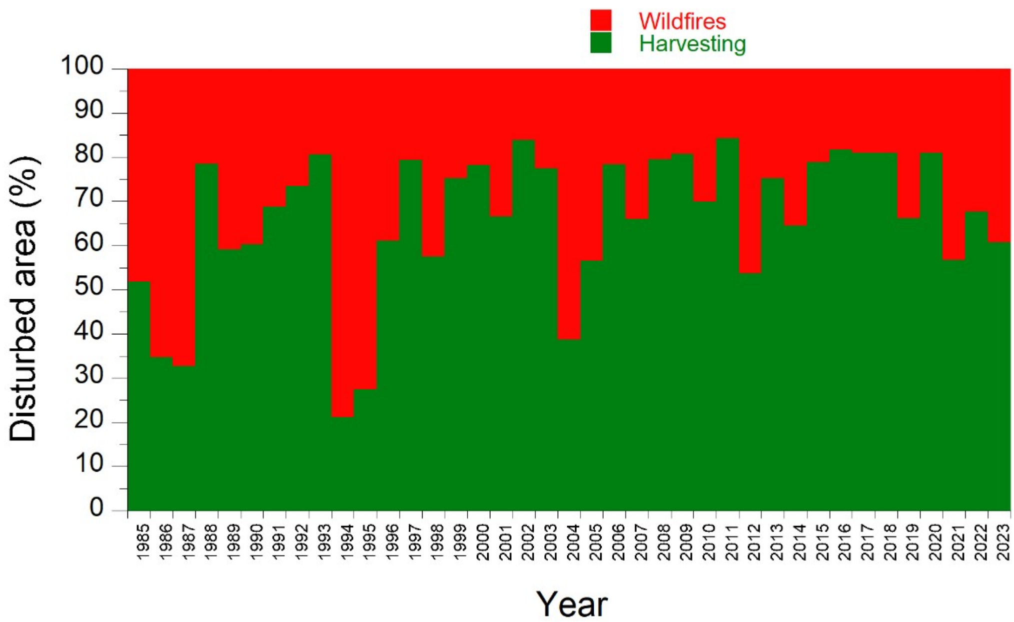


Figure S3. Yearly proportion of burned (red) and harvested (green) surface (A) and total disturbed surface (B) from 1985 to 2023, according to remote sensing-derived images-from the European Forest Disturbance Atlas.

A)



B)

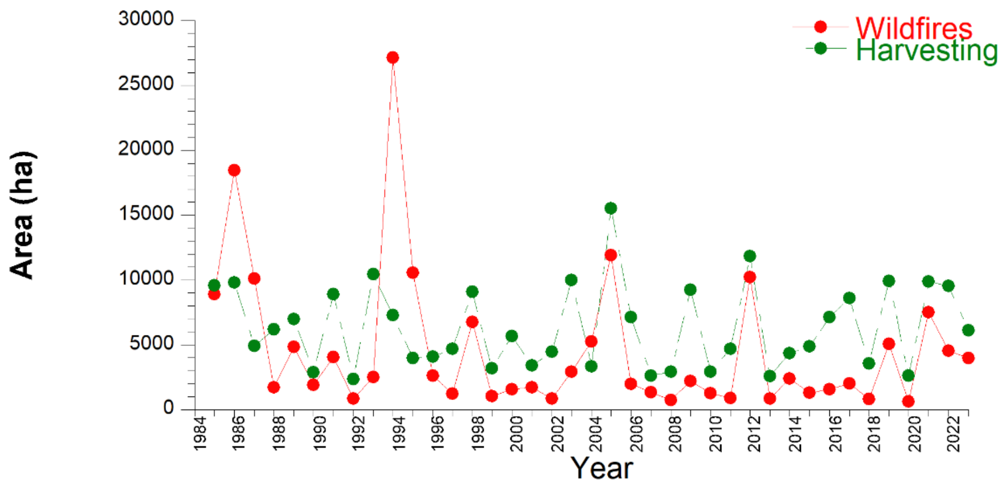
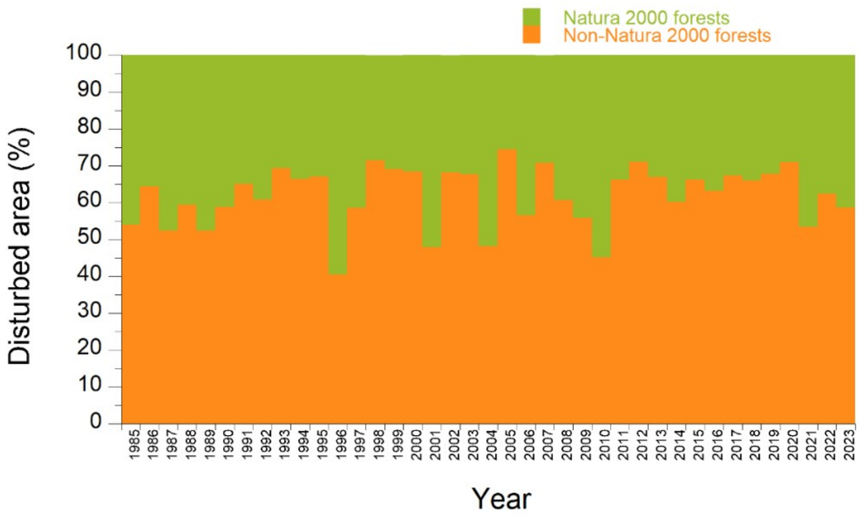


Figure S4. Yearly proportion (A) and total surface (B) of disturbed surface in Natura 2000 (green) and Non-Natura 2000 (orange) sites from 1985 to 2023, according to the analysis of remote sensing-derived images from the European Forest Disturbance Atlas.

A)



B)

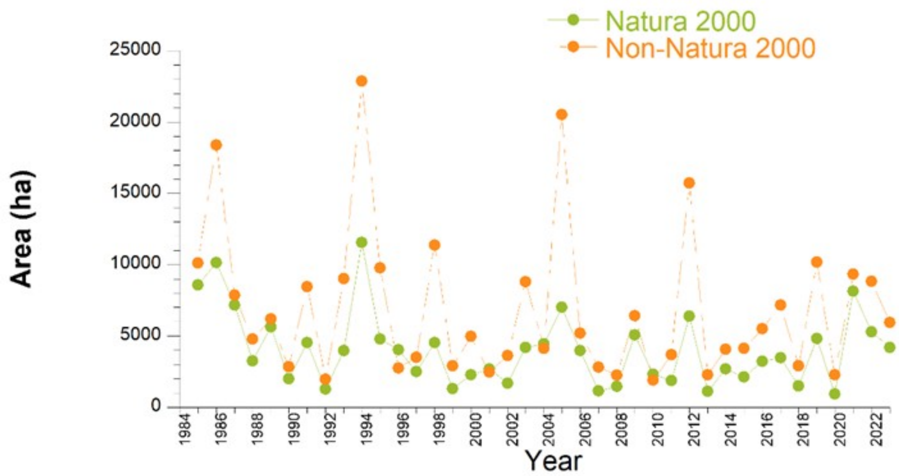


Figure S5. Yearly proportion of disturbed surface by wildfires (red) or harvesting (green) in Natura 2000 (A) and non-Natura 2000 (B) forests from 1985 to 2023, according to remote sensing-derived images from the European Forest Disturbance Atlas .

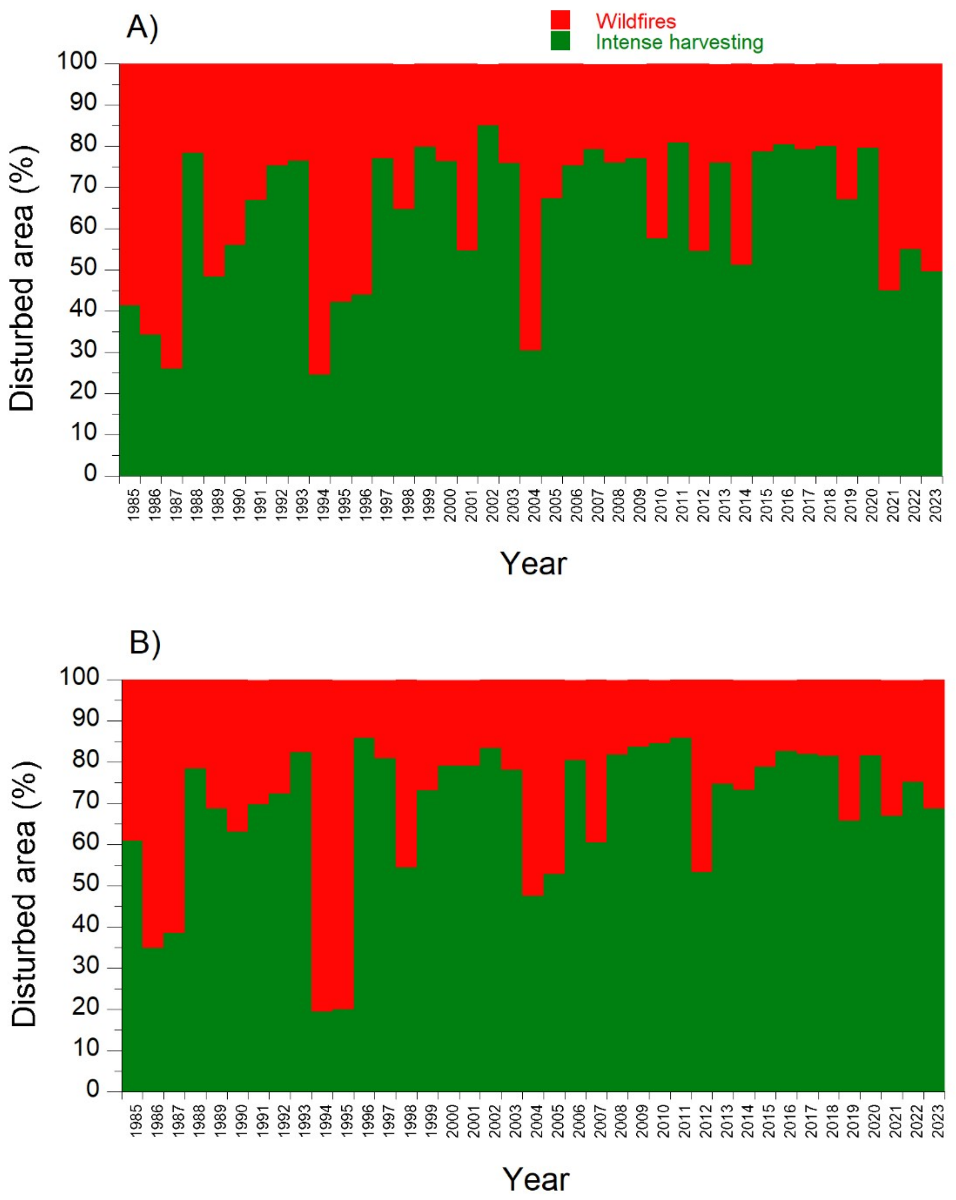
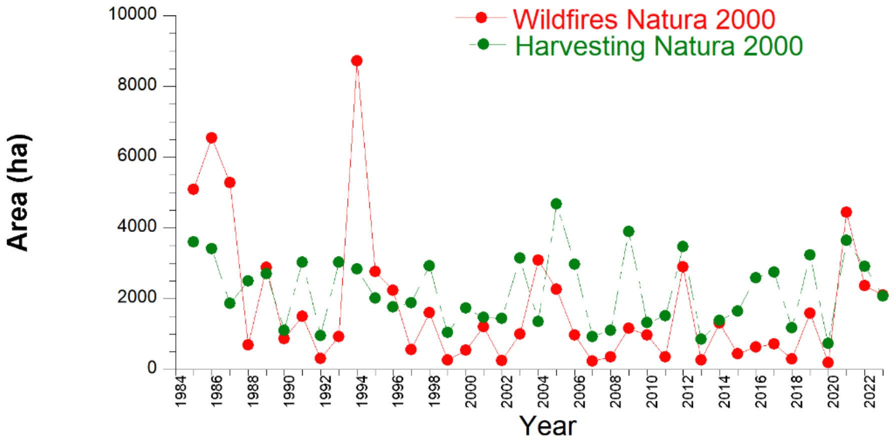


Figure S6. Yearly total disturbed surface by wildfires (red) or harvesting (green) in Natura 2000 (A) and Non-Natura 2000 (B) forests from 1985 to 2023, according to remote sensing-derived images from the European Forest Disturbance Atlas.

A)



B)

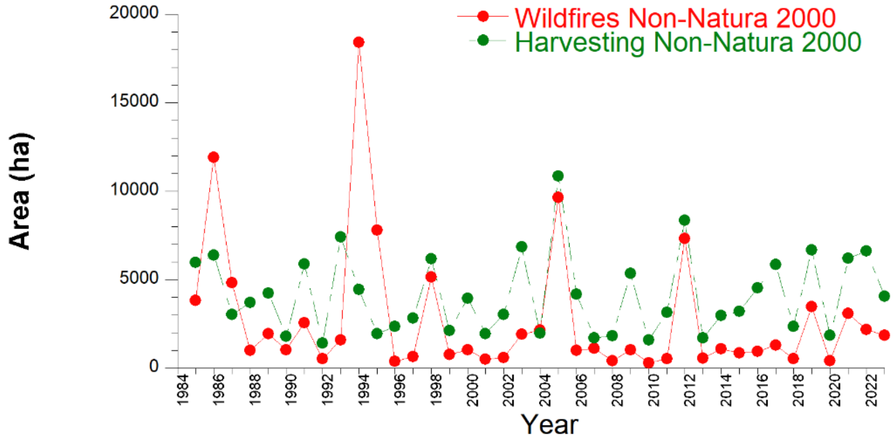


Table S3 Results of the generalized linear model for the effects of forest protection status (Natura 2000, Non-Natura 2000), bioclimatic region (mediterranean, supramediterranean, montane), basal area (m^2 ha^{-1}), forest leaf habit (broadleaf, needle leaf, mixed), slope and aspect (north, east, south, west) on the occurrence of unspecific disturbances (wildfires or harvesting) detected by remote sensing-derived images from the European Forest Disturbance Atlas from 1985 to 2023. Significant effects are highlighted in bold

	Estimate	Std.Error	Perc.2.5	Perc.97.5
(Intercept)	**-2.05426477**	**0.3823094**	**-2.74506649**	**-1.3602194**
Natura 2000	**-0.53197034**	**0.2562095**	**-1.02945884**	**-0.0372012**
Montane	**-1.13733056**	**0.3311749**	**-1.78380925**	**-0.6008468**
Supramediterranean	-0.03409957	0.2879226	-0.57277635	0.5082014
Basal Area	0.28428826	0.1234635	0.07293661	0.4856994
Mixed	0.26907320	0.3175164	-0.34558077	0.8199575
Needleleaf Forests	0.07738792	0.3079288	-0.43543534	0.7042614
Slope	**-0.32426311**	**0.1058717**	**-0.50841458**	**-0.1267310**
East	0.29892253	0.2888230	-0.23350297	0.8306383
South	0.34298637	0.2762298	-0.18587784	0.7799423
West	0.12785898	0.2398828	-0.34018084	0.5479923

Table S4 Results of the generalized linear model for the effects of forest protection status (Natura 2000, Non-Natura 2000), bioclimatic region (mediterranean, supramediterranean, montane), basal area (m^2 ha^{-1}), forest leaf habit (broadleaf, needle leaf, mixed), slope and aspect (north, east, south, west) on the occurrence of wildfires detected by remote sensing-derived images from the European Forest Disturbance Atlas from 1985 to 2023. Significant effects are highlighted in bold

	Estimate	Std.Error	Perc.2.5	Perc.97.5
(Intercept)	**-3.42674539**	**0.6339562**	**-4.8412327**	**-2.3929624**
Natura 2000	-0.41260400	0.4142032	-1.1288298	0.2946936
Montane	**-5.69110304**	**6.4039125**	**-17.5158981**	**-1.2899553**
Suprамediterranean	0.10257107	0.4215188	-0.6782901	0.8978993
Basal Area	0.01791545	0.1843070	-0.4176059	0.3250386
Mixed	0.37459112	0.5342018	-0.5912773	1.4240126
Needleleaf	0.38731888	0.5225392	-0.5956584	1.4844523
Slope	-0.11491289	0.1854157	-0.4589405	0.2383303
East	0.39602452	0.4353930	-0.3119439	1.2918732
South	0.58962826	0.4254759	-0.2008728	1.4154480
West	0.21383239	0.5179068	-0.7795726	1.2080977

Table S5 Results of the generalized linear model for the effects of forest protection status (Natura 2000, Non-Natura 2000), bioclimatic region (mediterranean, supramediterranean, montane), basal area (m^2 ha^{-1}), forest leaf habit (broadleaf, needle leaf, mixed), slope and aspect (north, east, south, west) on the occurrence of harvesting detected by remote sensing-derived images from the European Forest Disturbance Atlas from 1985 to 2023. Asterisks indicate significant effects (*** < 0.001, **< 0.01, * < 0.05)

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	**-2.70871**	**0.27807**	**-9.741**	**< 2e-16** ***
Natura 2000	**-0.35345**	**0.16197**	**-2.182**	**0.02910** *
Montane	-0.31307	0.22742	-1.377	0.16863
Supramediterranean	-0.07897	0.25091	-0.315	0.75295
Basal Area	**0.23700**	**0.07330**	**3.233**	**0.00122** **
Mixed	0.26385	0.20516	1.286	0.19843
Needleleaf	0.26059	0.22846	1.141	0.25401
Slope	**-0.29438**	**0.08217**	**-3.582**	**0.00034** ***
North	**-0.40402**	**0.20019**	**-2.018**	**0.04357** *
South	-0.10732	0.18884	-0.568	0.56982
West	-0.34772	0.19638	-1.771	0.07662 .

Table S6 Results of the general linear model for the effects of forest protection status (Natura 2000, Non-Natura 2000), bioclimatic region (mediterranean, supramediterranean, montane), basal area (m^2 ha^{-1}), period inventoried (1990-2000, 2000-2015) forest leaf habit (broadleaf, needle leaf, mixed), slope and aspect (north, east, south, west) on (A) harvesting occurrence and (B) harvesting intensity (% basal area removed) obtained by the comparison of the three national forest inventories conducted in the study area (SNFI2, SNFI3, SNFI4) in 1990, 2000 and 2015. Asterisks indicate significant effects (*** < 0.001, **< 0.01, * < 0.05)

A)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	**-0.93103**	**0.13070**	**-7.123**	**1.05e-12**	***
Natura 2000	**-0.35637**	**0.13511**	**-2.638**	**0.008348**	**
Montane	**-0.26923**	**0.10806**	**-2.492**	**0.012719**	*
Supramediterranean	0.05265	0.15933	0.330	0.741041	
Basal Area	**0.66561**	**0.05760**	**11.555**	**< 2e-16**	***
Period	**-0.36526**	**0.08744**	**-4.177**	**2.95e-05**	***
Mixed	**0.33338**	**0.10111**	**3.297**	**0.000977**	***
Needleleaf	-0.18865	0.10381	-1.817	0.069175	.
Slope	**-0.38654**	**0.04264**	**-9.065**	**< 2e-16**	***
North	-0.15748	0.10318	-1.526	0.126925	
South	-0.15506	0.10684	-1.451	0.146689	
West	-0.14125	0.10445	-1.352	0.176276	
Natura 2000 x Basal Area	**-0.23355**	**0.07946**	**-2.939**	**0.003291**	**
Natura 2000 x Period (I34)	**-0.32471**	**0.14172**	**-2.291**	**0.021947**	*

R2 marginal = 0.14, R2 conditional = 0.29

B)

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**10.6041**	**0.8182**	**3803.9**	**12.960**	**< 2e-16**	***
Natura 2000	**-3.9391**	**0.8534**	**4795.8**	**-4.616**	**4.02e-06**	***
Montane	-0.9494	0.6834	3065.8	-1.389	0.165	
Supramediterranean	0.5603	1.0594	3029.3	0.529	0.597	
Basal Area	**3.5222**	**0.3420**	**3880.8**	**10.299**	**< 2e-16**	***
Period	**-2.4616**	**0.5462**	**3378.0**	**-4.507**	**6.81e-06**	***
Mixed	0.5777	0.6221	3040.3	0.929	0.353	
Needleleaf	**-1.6670**	**0.6177**	**3037.8**	**-2.699**	**0.007**	**
Slope	**-2.1023**	**0.2500**	**3037.8**	**-8.409**	**< 2e-16**	***
North	0.1261	0.6474	3033.3	0.195	0.846	

South	0.2608	0.6644	3041.1	0.393	0.695
West	-0.2540	0.6543	3035.1	-0.388	0.698

R2 marginal = 0.04, R2 conditional = 0.18

Figure S7 Results of the interaction between the effect of forest protection status (Natura 2000, Non-Natura 2000) and the inventory period (SNF2-SNFI3, SNFI3-SNFI4) on the occurrence of harvesting (0,1) according to the data from the comparison of the three successive Spanish National Forest Inventories (SNFI2, SNFI3, SNFI4).

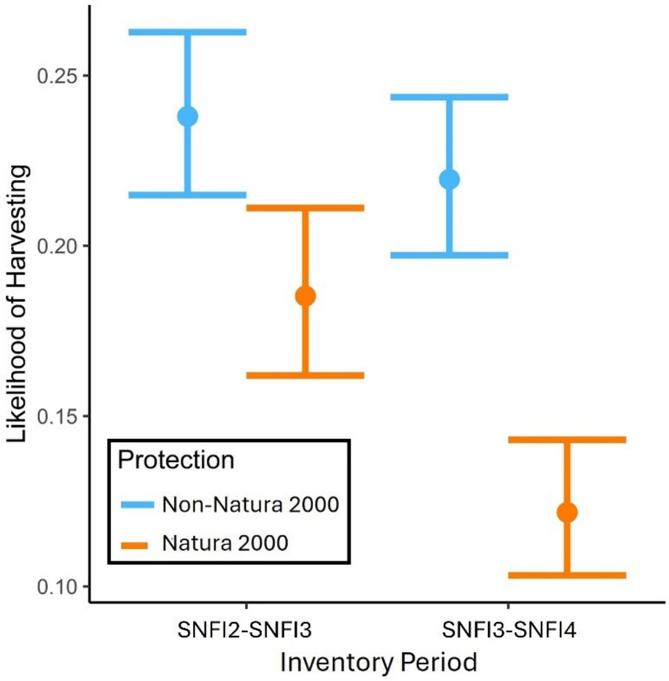


Table S7 Results of the generalized linear model for the effects of forest protection status (Natura 2000, Non-Natura 2000), bioclimatic region (mediterranean, supramediterranean, montane), basal area (m^2 ha^{-1}), basal area harvested, forest leaf habit (broadleaf, needle leaf, mixed), slope and aspect (north, east, south, west) on the likelihood of the occurrence of drought-driven forest dieback from 2016 to 2023 . Significant effects are highlighted in bold

	Estimate	Std.Error	Perc.2.5.	Perc.97.5.
(Intercept)	**-2.30937851**	**0.4583736**	**-3.17395014**	**-1.56306154**
Natura 2000	0.10735165	0.2682183	-0.35533731	0.67723438
Montane	**0.82820499**	**0.3429669**	**0.07809365**	**1.54593417**
Supramediterranean	0.13855266	0.4836704	-0.83448814	0.94103476
Basal Area (SNFI4)	-0.03257230	0.1722266	-0.38626487	0.25375936
Basal area harvested	-0.11867721	0.3155498	-0.11745891	0.14472312
Mixed	-0.62900640	0.3999644	-1.33433733	0.04949186
Needleleaf	**-1.27567506**	**0.4764286**	**-2.17763187**	**-0.49179849**
Slope	-0.12191661	0.1677691	-0.40124771	0.25168539
East	-0.13146678	0.4818717	-1.03672944	0.69049586
South	-0.13836569	0.4059980	-0.96653339	0.55777665
West	0.23738303	0.3952444	-0.53488432	0.97332083