Supplementary materials

Supplementary S1. Narrative Storyline of Land Use Scenario of MASCC Project

S1—Business-as-usual

There is political will for real reform of the Portuguese forest but the actual agro-forestry policies remain with the prioritization of the pyrophyte species (*Eucalyptus* and pine). Forestry area increases, with increased fuel density and consequently increased fire risk. There is a trend for the abandonment of traditional agriculture especially small-scale agriculture. Shrublands increase due to the occurrence of fires with more frequency and intensity. We observed depopulation of the mountain areas and decay of small clumps leading to a loss of landscape aesthetic value. Urban areas are expected to be slightly reduced.

Eucalyptus production remains being owned by private owners with a tendency to abandon small fields of *Eucalyptus* and pines. Paper companies are dominating the market of *Eucalyptus* plantation and production. *Eucalyptus* expansion continues with a reduction of other land uses and related activities. The landscape is monotonously dominated by monoculture of *Eucalyptus*, even in areas where the pinewood and agriculture were dominating in the past. Due to the increased uncontrolled *Eucalyptus* plantation, risks in fire increase and leads to more erosion after fires also due to the low or/and inappropriate timing for the implementation of post-fire soil management practices. The maintenance of current land uses and practices associated with climate change (e.g., prolonged droughts, pests and diseases...), will lead to an increase in shrublands, and in areas subject to erosion; to a greater risk of large fires; to a lower productivity of fast-growing species and to a reduction of biodiversity.

S2—Productivist

This scenario gives continuity to a forest that is dominated by *Eucalyptus* and forest fires, with degraded soils and loss of biodiversity. The investment in the most profitable solutions (in the social conditions of the area and of the region) leads to the expansion of the *Eucalyptus* in a similar way as expected in scenario S1. Intensification of production/expansion of areas of fast-growing species occurs. In the short term, this creates a higher income for producers, but in the medium and long term, it leads to soil and natural resource degradation, soil erosion and low productivity. There is a loss of the identity of the Serra do Caramulo (natural and cultural heritage) and the Águeda basin. Higher flood risk is predicted in the Águeda basin combined with high risk of fire, lack of water and a reduction of biodiversity. Depopulation of the mountain areas and decay of small clumps is occurring. Given the relative profitability of *Eucalyptus*, the landscape tends to be dominated by the monoculture of *Eucalyptus* managed by big pulp and paper companies. There is an increased risk of fire mainly managed by private companies. Forest management (e.g., planting and removal work) is highly aggressive to the soil.

S3—Environmental scenario

In this scenario, there is a reduction of the *Eucalyptus* area and an expansion of the pinewood area and, above all, oak forest. The risks of fire and fire intensity are lower than in the past and propagate less. Agriculture is expanded in some areas through the allocation of subsidies that allow the maintenance of this activity. Urban area increases slightly with the maintenance of agricultural activity. This scenario favors the provision of a greater diversity of ecosystem services and more in the case of biodiversity conservation, regulation (soil and water) and cultural services (landscape, nature tourism, inspiration, etc.). There is an increased area of native species and permanent crops. There is an incentive for integrated management of rural areas, with the creation of ZIFs (forest intervention areas, etc.), with the recovery of some small-scale agriculture, recovery of grazing and replacement of forest areas with species of rapid growth by hardwoods.

S4—Sustainable scenario

New environmental and effective legislation is created and promotes environmentally sustainable territories. There is an alteration of the relation of the current dominant silvicultural species (*Eucalyptus* and pine) accompanied by the reduction of their area. On the other side, there is an increase in hardwood area, in particular, Portuguese local oak species. From the agricultural side, we observed an increase in areas devoted to local grazing-breed of sheep, goats and cattle including permanent meadows. The diversity of crops is increased for the greater resilience of the forest. From a management point of view, the national government promotes sustainable practices and agricultural species that are ecologically relevant and well adapted to the changing climate. Maintaining biodiversity and crop productivity are important components of the new incentives. Finally, the creation and expansion of agro-pastoral activities are promoted in the region. The new agro-ecological system is this more resilient to droughts and to the occurrence of fires, and water managers are increasing flood protection measures in the Águeda river valley, taking into account climate change.

The owners are united in a kind of enterprise where all fields are managed by a common entity and the profits are divided by the size of each parcel in response to the abandonment of the rural world. The risk of fire is decreasing and, the forest and agriculture are managed according to the agri-environmental measures defined by the government. On the other side, large scale investors are funding new agroforestry development projects. Socially, there are incentives to counteract the tendency of depopulation in mountain areas and to attract the young population to live and work in the Caramulo region. We observed a recovery of some mountain settlements, such as Macieira de Alcoba, which, due to their natural and cultural heritage value and resident population, help to keep alive the techniques of soil and water use and conservation and the sustainable management of the landscape.

Supplementary S2. Land Use and Climate Scenarios

Table S1. Land use allocation constrains for Macieira.

Land Use	Constrains
Corn	Slope < 15%; size < 100 m^2
Horticulture	Slope < 15%; size < 100 m^2
Grassland	Slope > 10%; size > 100 m^2
Orchards	Slope < 15%; size < 100 m^2
Pines	Slope > 10%; size > 100 m^2
Shrubs	Slope > 10%; size > 100 m^2
Eucalyptus	Slope > 10%; size > 100 m^2
Young_Euc	Slope > 10%; size > 100 m^2
Oak	Slope > 10%; size > 100 m^2

Table S2. Land use allocation per scenario S0 (baseline 2000), S1, S2, S3 and S4.

Land Use	S0	S1	S2	S3	S4
Corn	8.10	3.40	4.14	8.90	4.40
Horticulture (conservation agriculture)	1.45	0.55	1.29	8.65	12.32
Grassland	14.63	12.92	5.77	13.84	18.58
Orchards	1.33	2.98	5.37	3.77	5.00
Pines	31.72	26.14	0.62	17.78	29.69
Shrubs	5.61	9.94	13.22	1.38	1.81
Eucalyptus	28.37	41.52	41.07	13.70	25.45
Young_Eucalyptus	8.78	2.54	28.51	8.65	0.60
Oaks	0.00	0.00	0.00	23.35	2.16

Table S3. Soil conservation practices ranking by six local experts during MASCC project.

Erosion Control Measures Selected From RECARE Project	Vote From 1 (Best) to 6 (Worst)
Mulching with pine residues after a fire	1
Erosion control barriers	2
Conservational extraction of ligneous material after fire	4
Traditional extraction of ligneous material after fire	6
Pasto-fire ploughing perpendicular to the slope	5
Post-fire ploughing perpendicular to the slope after fire with seedlings of local species	3

Table S4. Statistical summary of rainfall events selected on the study site during the period 1986–2005 (noCC) and 2041–2060 (CC).

Historical noCC	Rainfall (mm)	Duration (hours)	Antecedent 48h Rainfall (mm)	Imax (mm/5 min)
Min.	Min.: 45.20	Min.: 6.00	Min.: 0.00	Min.: 10.80
1st Qu	1st Qu: 66.75	1st Qu: 18.75	1st Qu: 4.15	1st Qu: 15.60
Median	Median: 92.65	Median: 28.50	Median: 27.05	Median: 23.90
Mean	Mean: 103.42	Mean: 30.48	Mean: 36.67	Mean: 32.58
3rd Qu	3rd Qu: 118.03	3rd Qu: 39.00	3rd Qu: 52.50	3rd Qu: 34.75
Max.	Max.: 319.70	Max.: 75.00	Max.: 208.00	Max.: 114.00
Future CC	Rainfall future (mm)	Duration (hours)	Antecedent 48 h rainfall (mm)	Imax (mm/5 min)
Min.	44	6	0	11
1st Qu	70	21	13	24
Median	91	33	33	32
Mean	106	38	47	39
3rd Qu	136	51	71	42
Max.	293	124	263	162

Supplementary S3. Results from Statistical Analyses of Observed Rainfall Events and Corresponding Runoff and Sediment Yield (R version 3.4.2 (28 September 2017)—"Short Summary")

1. Runoff

lm(formula = model, data = r3)
Coefficients:

(Intercept)	a3	a5	a23	a45
−20354.82	581.12	−97.28	−165.74	213.34

Call:
lm(formula = model, data = r3)
Residuals:

Min	1Q	Median	3Q	Max
−34843	−4724	−245	6474	28480

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	−20354.82	11030.78	−1.845	0.0825	.
a3	581.12	52.67	11.032	3.6e-09	***
a5	−97.28	222.49	−0.437	0.6675	
a23	−165.74	364.97	−0.454	0.6555	
a45	213.34	246.06	0.867	0.3980	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Residual standard error: 139,00 on 17 degrees of freedom
(36 observations deleted due to missingness)
Multiple R-squared: 0.8805, Adjusted R-squared: 0.8524
F-statistic: 31.32 on 4 and 17 DF, *p*-value: 1.219e-07

2. Sediment yield

lm(formula = model, data = r3)
Coefficients:

(Intercept)	a3	a5	a23	a45
−2964.59	49.46	−18.55	14.64	131.97

Call:
lm(formula = model, data = r3)
Residuals:

Min	1Q	Median	3Q	Max
−5029.2	−395.5	164.7	596.6	7475.5

Coefficients:

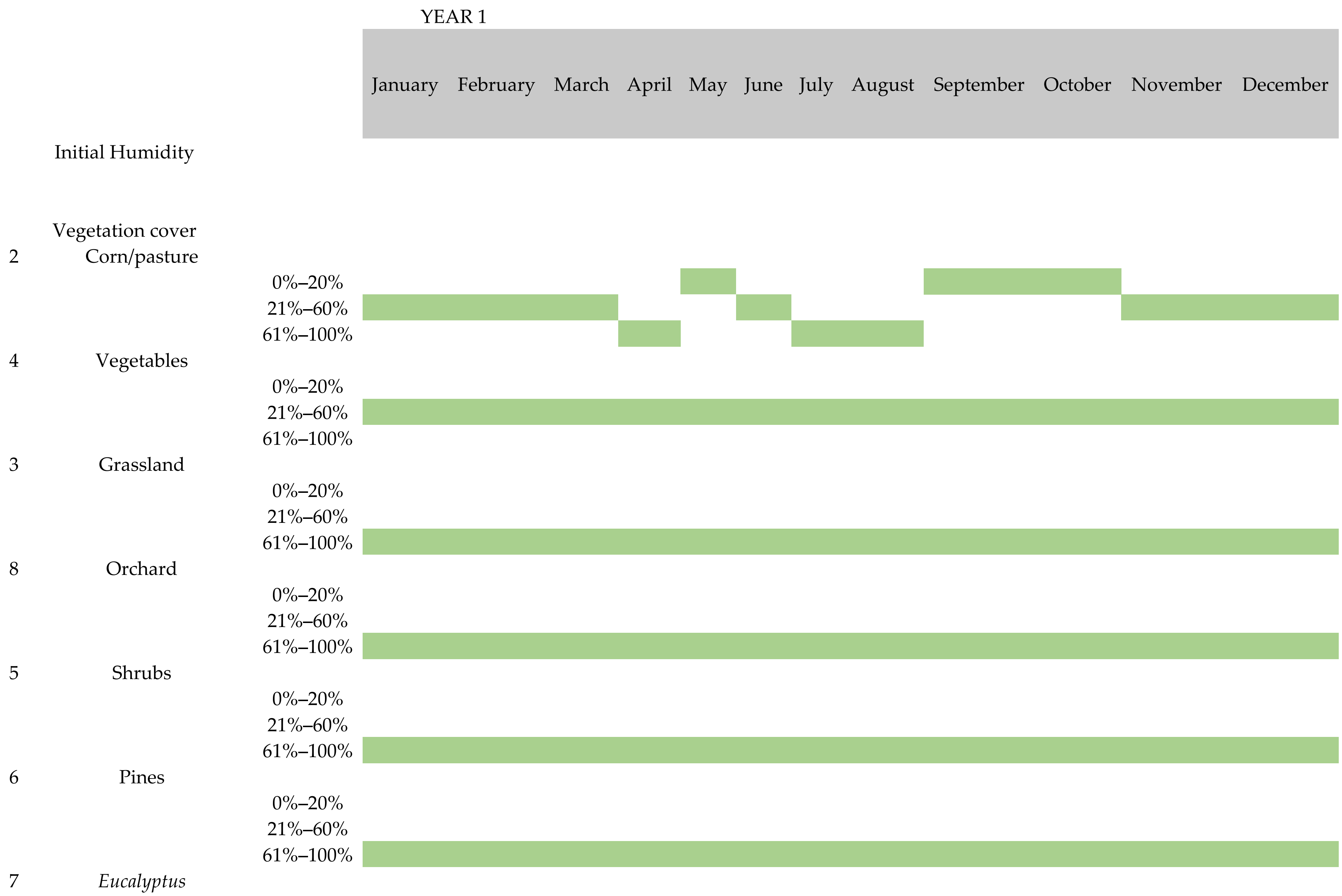
	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	−2964.59	2235.46	−1.326	0.202329	
a3	49.46	10.67	4.634	0.000237	***
a5	−18.55	45.09	−0.411	0.685879	
a23	14.64	73.96	0.198	0.845458	
a45	131.97	49.86	2.647	0.016959	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Residual standard error: 2817 on 17 degrees of freedom
(36 observations deleted due to missingness)
Multiple R-squared: 0.6398, Adjusted R-squared: 0.555
F-statistic: 7.549 on 4 and 17 DF, *p*-value: 0.001095

Supplementary S4

Table S4. Calibration of Monthly Calendars of Soil Roughness, Soil Crusting and Soil Cover per Land Use



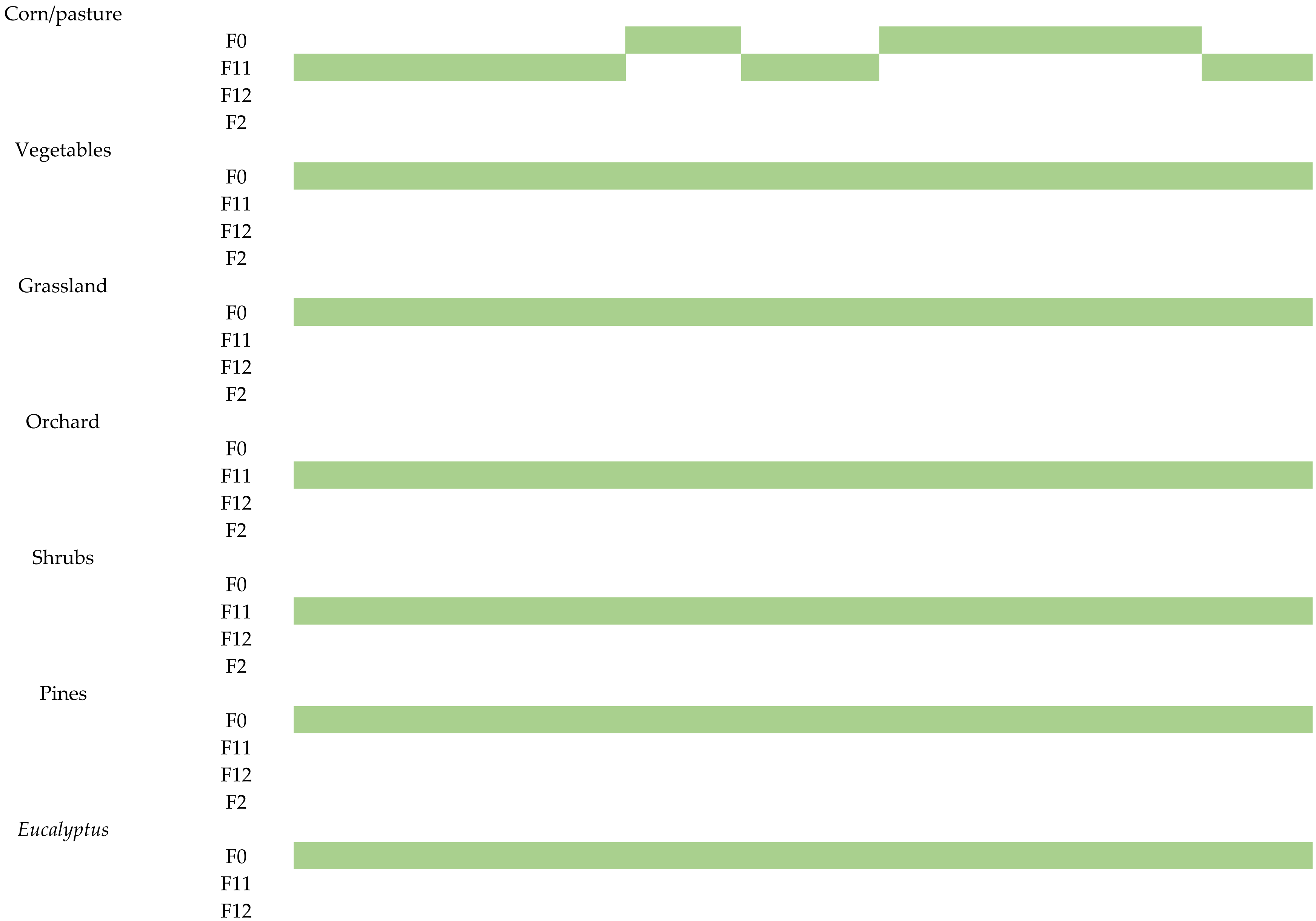
YEAR 1
January
February
March
April
May
June
July
August
September
October
November
December
Initial Humidity
Vegetation cover
2 Corn/pasture
0%–20%
21%–60%
61%–100%
4 Vegetables
0%–20%
21%–60%
61%–100%
3 Grassland
0%–20%
21%–60%
61%–100%
8 Orchard
0%–20%
21%–60%
61%–100%
5 Shrubs
0%–20%
21%–60%
61%–100%
6 Pines
0%–20%
21%–60%
61%–100%
7 Eucalyptus

		0%–20%
		21%–60%
		61%–100%
1	Build-up	
		0%–20%
		21%–60%
		61%–100%
9	Burned *Eucalyptus*	0%–20%
		21%–60%
		61%–100%
10	Burned pine	0%–20%
		21%–60%
		61%–100%
11	Bare ground	0%–20%
		21%–60%
		61%–100%
12	New forest plantations	0%–20%
		21%–60%
		61%–100%
13	Erosion features	0%–20%
		21%–60%
		61%–100%
14	Ploughed	0%–20%
		21%–60%
		61%–100%

Soil roughness	
Corn/pasture	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Vegetables	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Grassland	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Orchard	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Shrubs	
	0–1 cm
	1–2 cm
	2–5 cm

	5–10 cm
	10–15 cm
	>15 cm
Pines	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Eucalyptus	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Build-up	
	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Burned *Eucalyptus*	0–1 cm
	1–2 cm
	2–5 cm
	5–10 cm
	10–15 cm
	>15 cm
Burned pine	0–1 cm
	1–2 cm

	2–5 cm	
	5–10 cm	
	10–15 cm	
	>15 cm	
Bare ground	0–1 cm	
	1–2 cm	
	2–5 cm	
	5–10 cm	
	10–15 cm	
	>15 cm	
New forest plantation	0–1 cm	
	1–2 cm	
	2–5 cm	
	5–10 cm	
	10–15 cm	
	>15 cm	
Erosion features	0–1 cm	
	1–2 cm	
	2–5 cm	
	5–10 cm	
	10–15 cm	
	>15 cm	
Ploughed	0–1 cm	
	1–2 cm	
	2–5 cm	
	5–10 cm	
	10–15 cm	
	>15 cm	
Soil crusting		


Corn/pasture
F0
F11
F12
F2
Vegetables
F0
F11
F12
F2
Grassland
F0
F11
F12
F2
Orchard
F0
F11
F12
F2
Shrubs
F0
F11
F12
F2
Pines
F0
F11
F12
F2
Eucalyptus
F0
F11
F12

	F2	
Build-up		
	F0	
	F11	
	F12	
	F2	
Burned *Eucalyptus*	F0	
	F11	
	F12	
	F2	
Burned pine	F0	
	F11	
	F12	
	F2	
Bare ground	F0	
	F11	
	F12	
	F2	
New forest plantation	F0	
	F11	
	F12	
	F2	
Erosion features	F0	
	F11	
	F12	
	F2	
Ploughed	F0	
	F11	


F12
F2

Grade	Roughness Index (cm)*	Typical Agricultural Situation
R0	0–1	Strongly crusted
R1	1–2	Moderate crusted
R2	2–5	Crusted tilled field
R3	5–10	Cloddy surface
R4	>10	Ploughed field

* Adapted from Ludwig et al. 1995.

Evaluation of Crusting (Notation)*	Description
F0	Initially fragmentary structure
F11	Altered fragmentary state
F12	Transitional
F2	Continuous state with depositional crusts

* Adapted from Holsstein and LandSoil handbook.

Supplementary S5. Soil Tillage Calibration

	Ktill_ Min	Ktill_ Max	values of 'Van Myusen et al., 2000' and 'Govers et al., 1994'		
Corn	77	88.66667	tillage:	Combination of Manual Tillage/Harrow/Chisel	
Vegetables	77	77		77/78/111	
Grassland	0	0			
Orchard	0	0			
Shrubs	0	0			
Pines	0	0			
Eucalyptus	0	0			
Build-up	0	0	Govers et al., 1994'		
Burned *Eucalyptus*	234	330	tillage:	Moldboard	(depth: 0.28, speed: 1.25 --> k: 234)
Burned pine	234	330	direction:	up the slope	(depth: 0.24, speed: --> k: 330)
Bare ground					
New forest plantation					

Supplementary S6. LandSoil Turbidity Calibration

“Sediment concentration calibration during the post-fire disturbing period (g/L)”

“−1”,0,1,1,”0 g/L”
“0”,0,2,1,”0.10 g/L”
“1”,0.066,3,1,”0.30 g/L”
“2”,0.198,4,1,”0.5 g/L”
“3”,0.331,5,1,”0.7 g/L”
“4”,0.496,6,1,”0.9 g/L”
“5”,0.661,7,1,”1 g/L”

“Sediment concentration calibration before fire and during vegetation recovery stage (g/L)”

“−1”,0,1,1,”0 g/L”
“0”,0,2,1,”0.10 g/L”
“1”,0.132,3,1,”0.30 g/L”
“2”,0.397,4,1,”0.5 g/L”
“3”,0.661,5,1,”0.7 g/L”
“4”,0.992,6,1,”0.9 g/L”
“5”,1.323,7,1,”1 g/L”

Supplementary S7. Calibration of Rill Erosion

Class 1. Before fire occurrence and during vegetation recovery stages—median channel section value based on the incision sensitivity value.

“2000”,0,1,2,”0 à 2000”
“13000”,0.00176,2,2,”2000 à 13000”
“57000”,0.00288,3,2,”13000 à 57000”
“100000”,0.00464,4,2,”57000 à 100000”
“250000”,0.00704,5,2,”100000 à 250000”
“999999999999”,0.032,6,2,”> 250000”

Class 2. Fire period—median channel section value based on the incision sensitivity value.

“2000”,0,1,2,”0 à 2000”
“13000”,0.000061,2,2,”2000 à 13000”
“57000”,0.000135,3,2,”13000 à 57000”
“100000”,0.00345,4,2,”57000 à 100000”
“250000”,0.0097,5,2,”100000 à 250000”
“999999999999”,0.04,6,2,”> 250000”

Supplementary S8. Calibration of Infiltration Rates for Two Periods (Pre-Fire and during the Fire Disturbance Period)

"Infiltration classes pre fire disturbance period and during vegetation recovery"

"−1",0,1,1,"0 mm/h"
"0",2,2,1,"mm/h"
"1",0.7,3,1,"mm/h"
"2",0.375,4,1,"mm/h"
"3",0.125,5,1,"mm/h"
"4",0.0625,6,1,"mm/h"
"5",0,7,1,"mm/h"

"Infiltration classes during fire disturbance period"

"−1",0,1,1,"0 mm/h"
"0",7.75,2,1,"mm/h"
"1",3.5,3,1,"mm/h"
"2",2,4,1,"mm/h"
"3",1.15,5,1,"mm/h"
"4",0.7,6,1,"mm/h"
"5",0,7,1,"mm/h"

Supplementary S9. Results from the Calibration of Runoff and Sediment Yield in Pre and Post Fire Periods

NSE	Runoff	*SY*		R2	Runoff	*SY*
Before Fire	0.18	0.58		Before Fire	0.53	0.67
After Fire	0.73	0.81		After Fire	0.88	0.82
Total	0.81	0.86		Total	0.91	0.86

	Runoff (m^3)					
	Before Fire		After Fire		Total	
	Obs	Sim	Obs	Sim	Obs	Sim
Mean	1807	1840	18,284	7582	2650	2246
Median	3399	1754	28,037	31,086	11,682	12,018
Min	19	84	413	372	19	84
Max	11,555	3756	80,467	1,006,657	80,467	100,657
SD	3598	1301	28,473	37,679	20,357	25,613

	Sediment Yield (Ton)					
	Before Fire		After Fire		Total	
	Obs	Sim	Obs	Sim	Obs	Sim
Mean	0.035	0.08	2.695	1.9	0.15	0.45
Median	0.256	0.311	4.495	3.958	1.769	1.6
Min	0	0	0	0.12	0	0
Max	2.25	2.18	16.45	16.33	16.45	16.33
SD	0.565	0.56	5.07	5.54	3.837	3.465

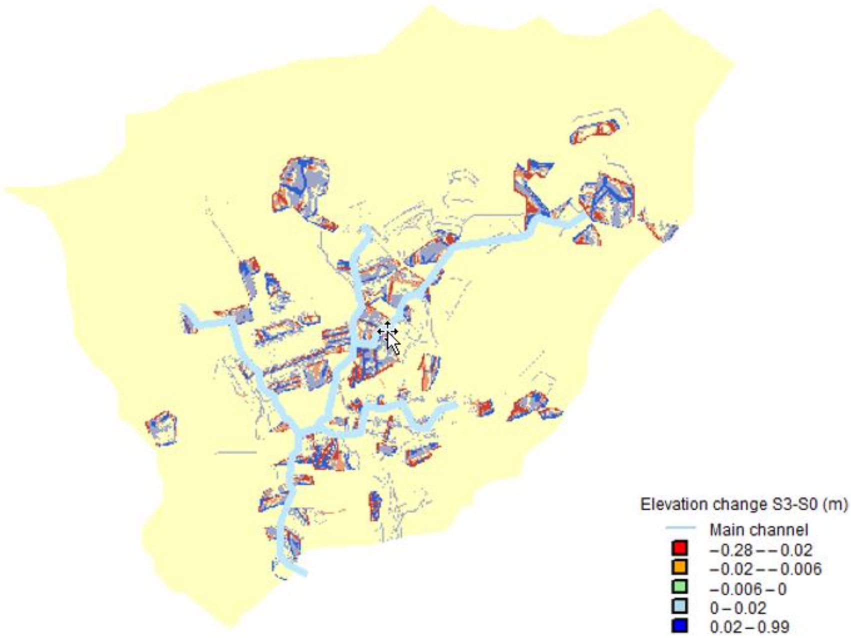


Figure S1. Difference in elevation change between scenario S3 and S0 without fire occurrence.

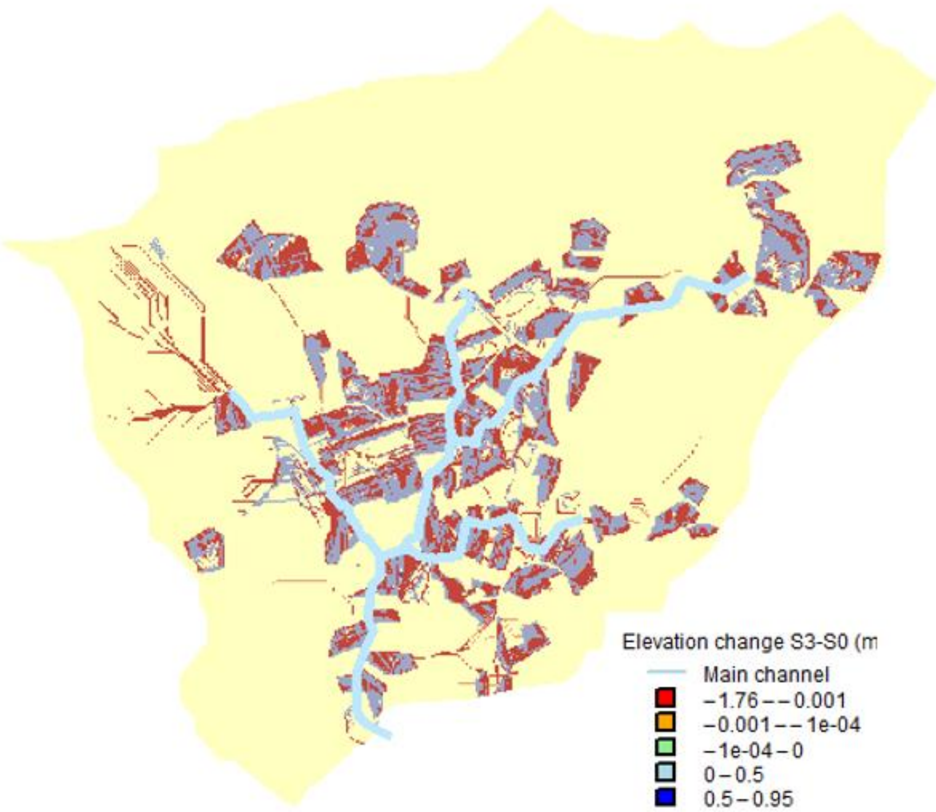


Figure S2. Elevation change in scenario S2 between 2000 and 2050.