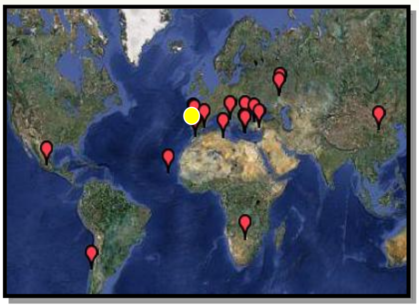
Góis study site, Portugal



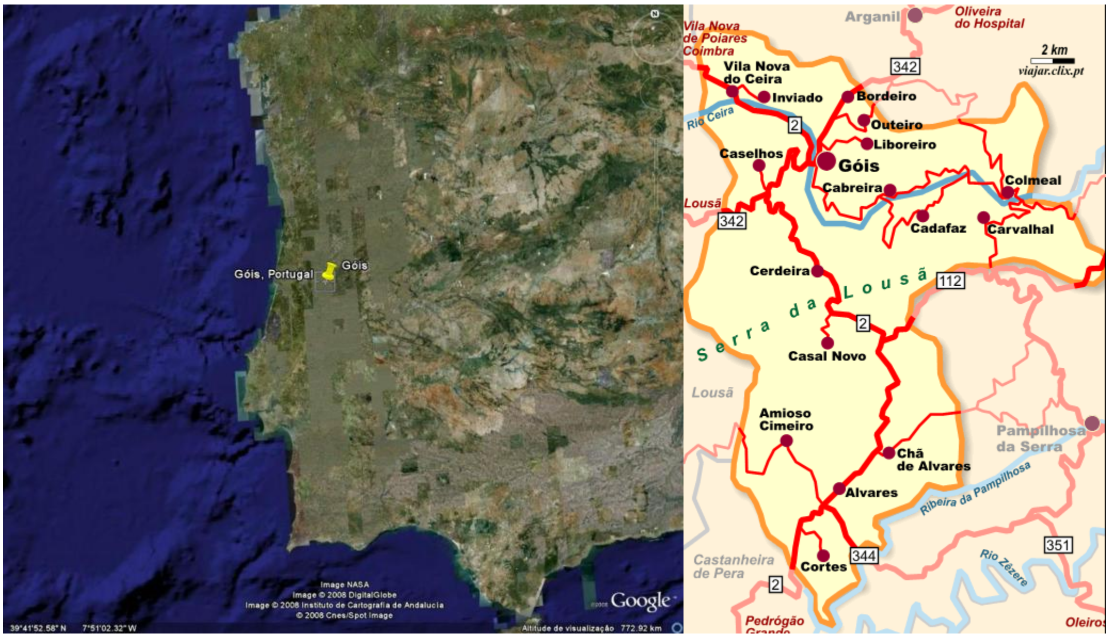
Highlights of work carried out in the DESIRE Project

Based on work by ESAC, Portugal

The study site

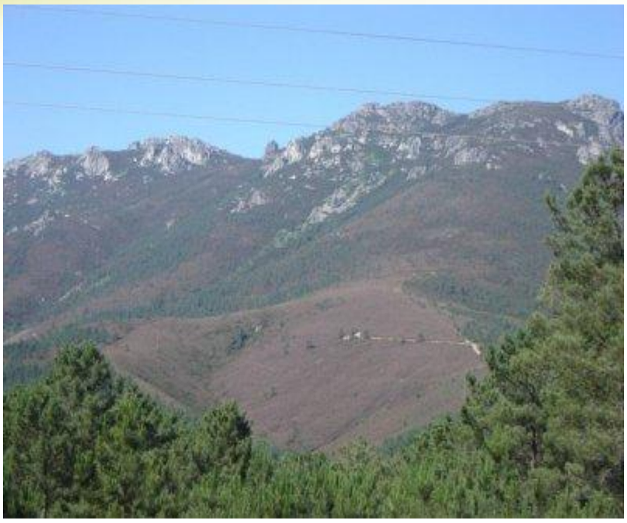
Gois is a municipality situated on the northern slopes of the Lousã Mountains in Central Portugal. Prescribed fire is used to prevent the spread of wildfires.

- **Coordinates of central point:** Latitude: 40°06’26.28” N; Longitude: 8°06’57.19” W
- **Size:** 263 km²; **Altitude:** 145 – 1200 m
- **Precipitation:** ca. 1200 mm
- **Land use:** pine and eucalyptus forests, arable land, unproductive land and settlements
- **Main degradation processes:** forest fires, land abandonment through depopulation
- **Major drivers of degradation:** depopulation and ageing population, land abandonment, monocultural forestry, inadequate laws and lack of enforcement, financial constraints
- **Inhabitants:** 4,499 (2006)



Study site location

The Vale Torto catchment, Góis , Portugal, (in the foreground) was instrumented to record soil loss before and after controlled fires. Photo by R. Shakesby

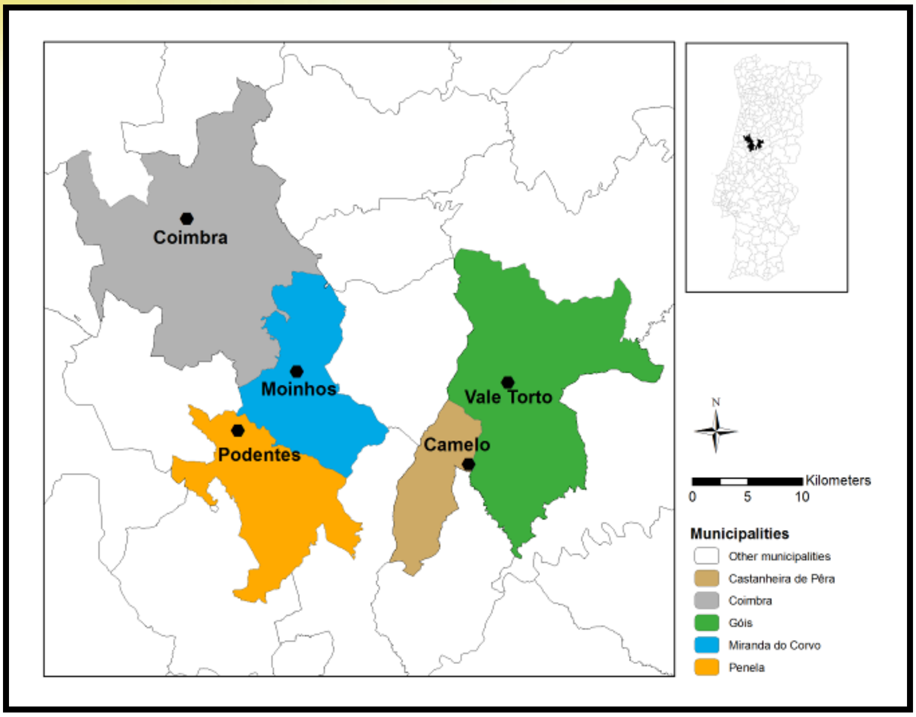


Like many Mediterranean countries Portugal suffers from forest fire due to a dry and hot climate. The problem is not only degradation of forest and the emission of carbon dioxide to the atmosphere but it also increases soil losses and pollution of water and air. The Vale Torto area near Góis in Portugal was burned by several fires in the 1970s and the early 1980s. Similarly the Camelo catchment near Góis also suffers from forest fire with a recent fire taking place in July 2008. In order to reduce soil losses caused by wild fire and to minimise the amount of flammable materials an experiment was applied which uses a technology called prescribed fire.

The main objective was to assess soil degradation due to erosion and associated nutrients losses in the period after the fire. The main aim was to evaluate prescribed burning techniques currently used as a landscape management technique to prevent fire. To this end, wildfire areas and prescribed burnt areas were assessed to measure the differences between the two types of fire.

Sustainability goals	
Goal 1	Conservation of biological diversity;
Goal 2	Maintenance of productive capacity of forest ecosystem;
Goal 3	Maintenance of forest ecosystem health and vitality;
Goal 4	Conservation and maintenance of soil and water resources;
Goal 5	Maintenance of forest contribution to global carbon cycles and climate change mitigation;
Goal 6	Maintenance and enhancement of long-term multiple social and economic benefits;
Goal 7	Streamlining and simplification of policy and legal instruments;
Goal 8	Provide agricultural lands to balance opportunities with the protection of ecological systems;

Sustainability goals for the Portuguese study sites



Location of four ESAC study sites, near Coimbra

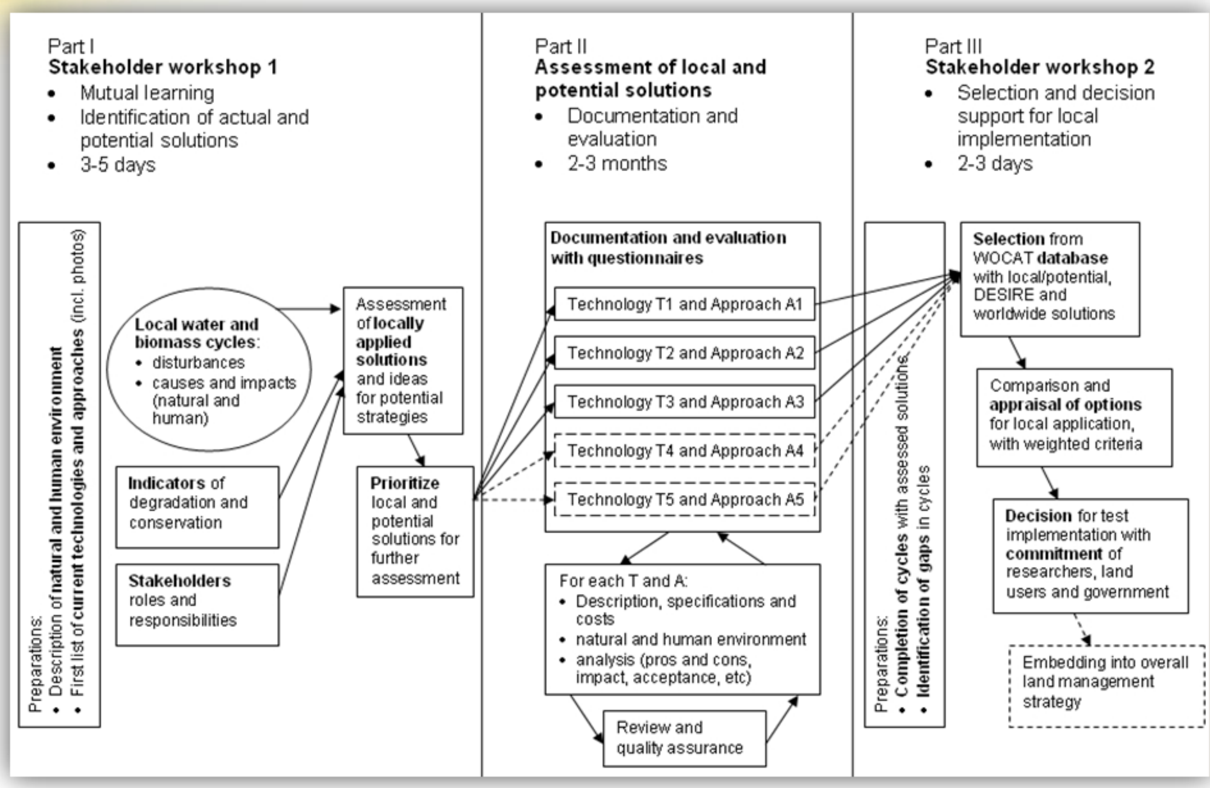
The Camelo site, affected by wildfire in July 2008

The Vale Torto catchment during experimental burning on February 20th 2009

The Podentes prescribed fire, in April 2009

The Moinhos study site, after September 2009 wildfire

Workshops for researchers and stakeholders to select sustainable land management technologies

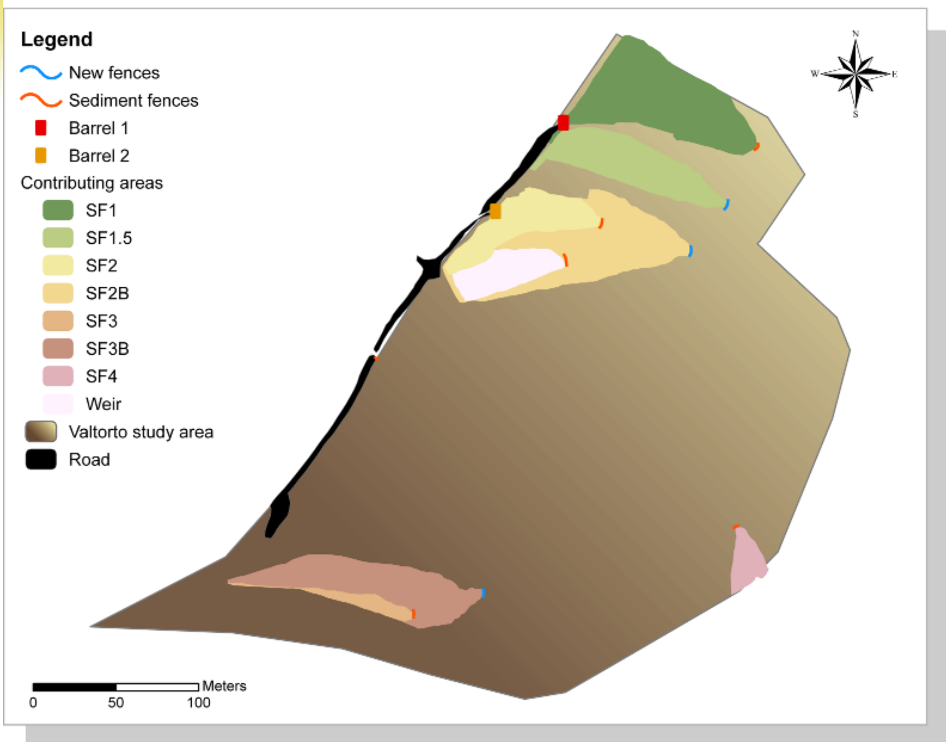


Researchers talked with local people and policy makers, and together they decided on the best options for sustainable land use. In the DESIRE Project the three Parts to WOCAT methodology were developed as outlined above. This provides decision support for choosing technologies suited to the local environment that includes social, cultural and economic factors as well as physical science.

In every DESIRE study site researchers and stakeholders held two workshops to arrive at their selection of approaches and technologies. At the first workshop stakeholders learned about how degradation happens, and how to avoid it.

Meetings of researchers with stakeholders were used to help break the cycle of desertification. Together they discussed and tried out suggestions to find the best ways of reducing the incidence and impact of forest fires while addressing goals for sustainability. If forest fires become less of a problem and do less damage, then 1)erosion will be decreased, 2)it will be easier to make a living off the land, and 3)land users will be less likely to abandon their farms and look for more reliable employment prospects in the towns.

At the **Vale Torto** study site, several soil samples were collected and analysed for nutrients before the prescribed fire, immediately after and one year after. Six rainfall simulations were performed in different time periods before and after the fire. Five sediment fences were installed to assess the erosion rates before the fire and reinstalled with three additional ones after the fire. A micro-catchment weir was used for runoff and sediments data collection, and measurements were also performed at catchment level, to provide the spatial integration of hydrological and erosion processes. The vegetation recovery was also monitored through repeat-vertical-photography in plots with $0.25m^2$ and visually through $4m^2$ plots.

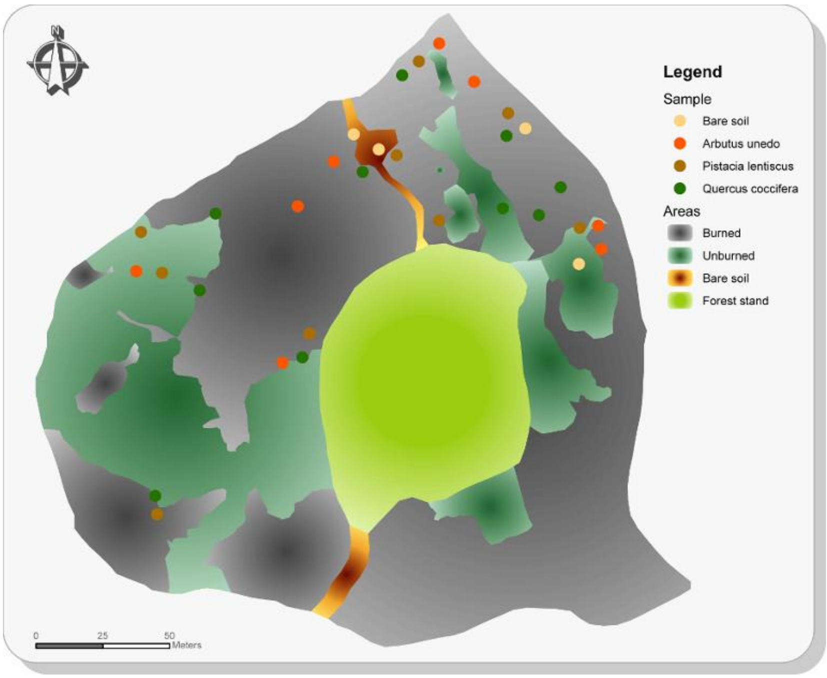


Vale Torto catchment: location of sediment fences and of weir pool sub-catchment and their contributing areas

Sediment fences, Vale Torto

Weir pool sub-catchment, Vale Torto

In **Podentes**, several techniques were used to monitor degradation processes following prescribed fires, namely point assessment of soil properties, such as infiltration capacity and soil water repellency. Soil water repellency was assessed depending on the shrubland type, slope orientation and soil depth.



Map of the prescribed fire area in Podentes

In **Moinhos**, the land degradation was assessed through sediment fences installation and periodic monitoring. Logging wastes from a burned (wildfire) and slashed eucalyptus area were also applied in a terrace plot, as another erosion mitigation technique. An area of 95 ha was burnt in September 2009 where eucalyptus were planted. To study the effect of forest fire, field study was carried out to collect data on soil moisture, infiltration, suspended sediments and nutrient contents. In addition to collecting data on soil, Vegetation recovery monitoring was also carried out using vertical-photography of plots of size 0.25m. In addition, a lysimeter was also used to assess fire impact on soils started during 2010. During the experimental lysimeter fire flame temperature was assessed using an infrared heat sensor, that shows temperatures values of over 700ºC.

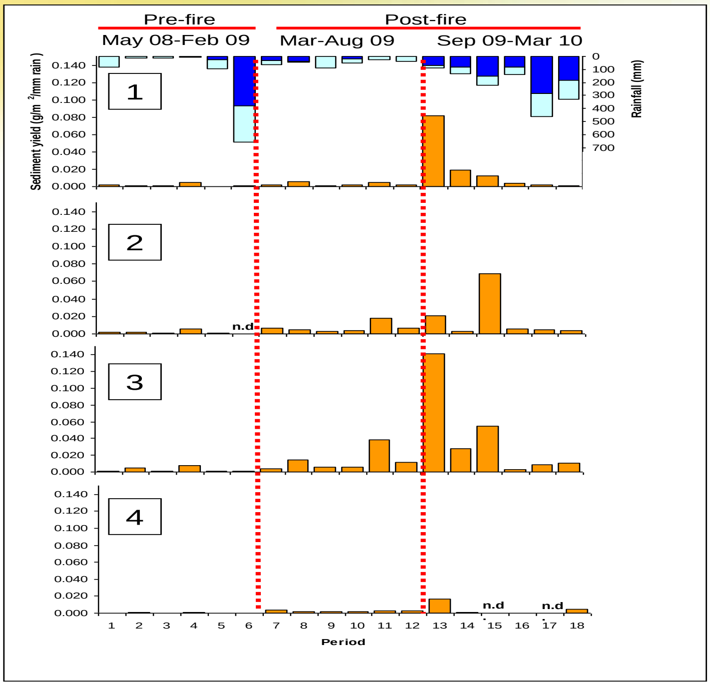
On the left the initial lysimeter during preparation and, on the right, during the burning

Results of research carried out in the field sites

The results showed an increase in soil water repellence after burning which is not shown by the unburned area. Burning intensified soil hydrophobicity (compared with the unburned site) probably due to enhanced drying and high temperatures during the fire. Studies carried out in the effects of ash in Podentes study site revealed that water repellence depends on plant species and to some extent also on slope aspect. The ash from *A. Unedo* shows major water repellence behaviour as compared to ash from other shrub species (*Quercus coccifera, Pistacia lentiscus*).

	Infiltration rate (mm/h)			Infiltration capacity (mm/h)		
	Burnt	**Unburnt**	**ratio**	**Burnt**	**Unburnt**	**ratio**
Bare soil		7.50			13.85	
Q. coccifera S	10.45	13.80	0.76	30.26	30.56	0.99
P. lentiscus S	15.05	22.39	0.67	29.64	31.13	0.95
A. unedo S	7.99	12.09	0.66	11.89	32.45	0.37
Average	**11.16**	**16.09**	**0.69**	**23.93**	**31.38**	**0.76**
Q. coccifera N	25.47	41.03	0.62	26.87	46.13	0.58
P. lentiscus N	28.94	29.42	0.98	30.25	31.76	0.95
A. unedo N	16.23	24.57	0.66	16.62	30.10	0.55
Average	**23.55**	**31.67**	**0.74**	**24.58**	**36.00**	**0.68**
Whole area	**15.81**	**21.14**	**0.75**	**21.94**	**29.14**	**0.76**

Fire also influenced soil infiltration. The study showed reduction of soil infiltration by about 25 per cent. Highest decline of infiltration capacity was observed in the burnt shrub species, *A. unedo*, which has also high soil water repellence value. This could be related to different surface litter and root systems of plant species. The results also showed higher infiltration capacities on limestone area as compared to the area with schist bedrock. On schist sites, the fire had no discernible impact on runoff, and the average runoff coefficients for the burned sites were 24% Camelo, 29% Vale Torto and 8% Podentes.



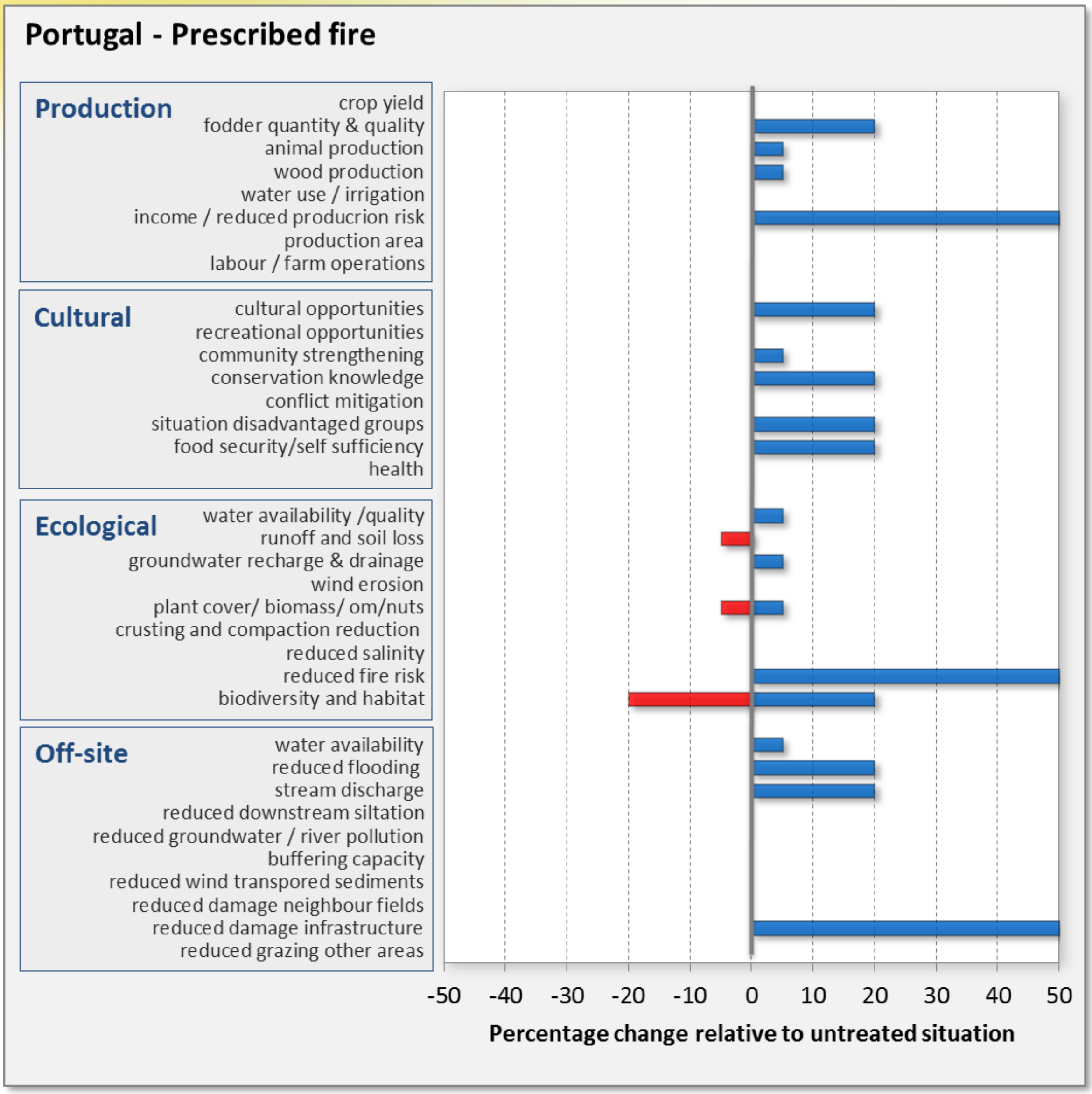
Soil erosion expressed as sediment per m² of contributing area collected from the sediment fences in Vale Torto for periods of different lengths (orange bars) together with rainfall amounts (dark blue and light blue compound bars), for the period of May 2008 – March 2010. For rainfall, dark blue represents the amount falling as daily events ≥ 20 mm, and light blue as rain falling in daily amounts <20 mm. (n.d. = no data)

In the case of soil losses, the schist study site showed a significant increase of soil loss for both cases: wild fire versus un-burned area (3.8 g m^{-2} vs 0.1 g m^{-2}), and prescribed fire versus un-burned area (1.6 g m^{-2} vs 1.2 g m^{-2}). In Vale Torto the increase in soil erosion after the fire was so significant. Soil loss results in Vale Torto site showed a distinct increase (upto 8 -15 times) as compared to pre fire periods. In the Camelo site, soil losses per unit contributing area were on average 1-2 orders of magnitude higher (2.2 t/ha for the first year after the wildfire, and 3.6 t/ha for the whole 19-month monitoring interval up to March 2010) compared with prescribed fire.

The lysimeter data showed that the top soil (0-2cm depth) temperature during fire varied spatially, average temperature was around 250ºC, but in some places it reached 450ºC. At the sub-surface layer (2-5cm), soil temperature during the fire was around 60ºC which indicates that organic matter will be burnt only in the top 2 cm of soil.

Evaluation of results

The results are evaluated from a production, socio-cultural and economic point of view. The bars in the graph below express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



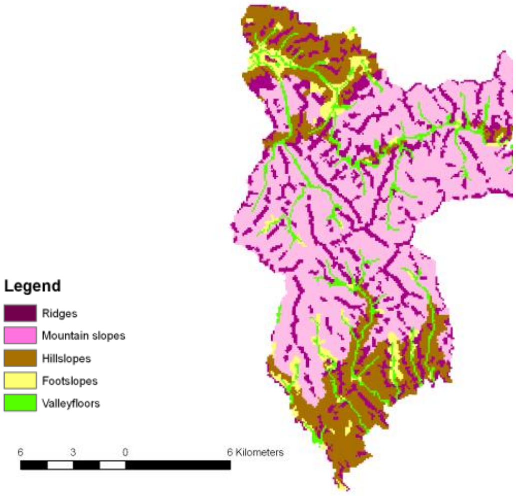
Opinions of stakeholders

- ☺ Prescribed burning is increasingly useful as a tool for landscape management, in order to increase diversity and reduce forest fire risk.
- ☺ To perform prescribed burning, one has to be approved on a special fire management course. The means to perform it are only possible with the involvement of local authorities, which became involved in the Vale Torto experimental fire.
- ☺ The stakeholders were responsible for getting all the permits and performed the prescribed burning. They followed up the recovery of the burned area.
- ☺ The Benefits are the improvement of pastures for grazing and the reduction of forest fire risk.
- ☺ Prescribed fire is probably the most cost effective technique for landscape management, it is an old practice that was forbidden for 60 years, and has the approval of local stakeholders.
- ☺ We expect a reduction on fire frequency and the diversification of local economy due to an increase in grazing, bee keeping, cheese production, etc.

Conclusions from scenario modelling

PESERA baseline run

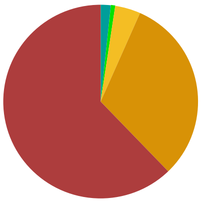
Landforms

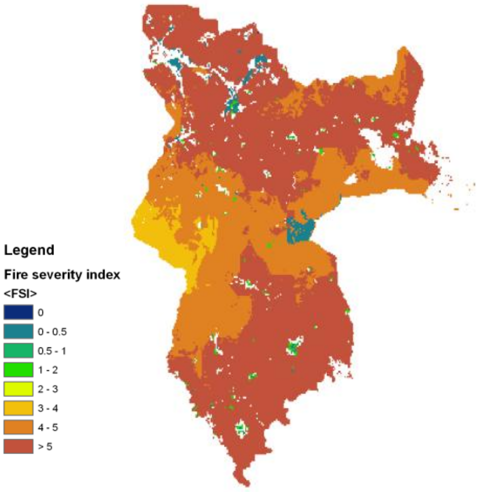


Two baseline indicators were calculated, the fire severity index as a measure of fire susceptibility and biomass production as a measure of fuel load. The main influencing variable controlling both indicators is land use. Output shown is limited to forest areas as these are the areas where fire ignitions occur. The fire severity index is very high in 90% of the study area. Three-quarters of the forest area contains more than 20 tons of biomass per ha, followed by ca. 20% having between 15-20 ton per ha.

Fire susceptibility

Fire Severity Index (FSI)





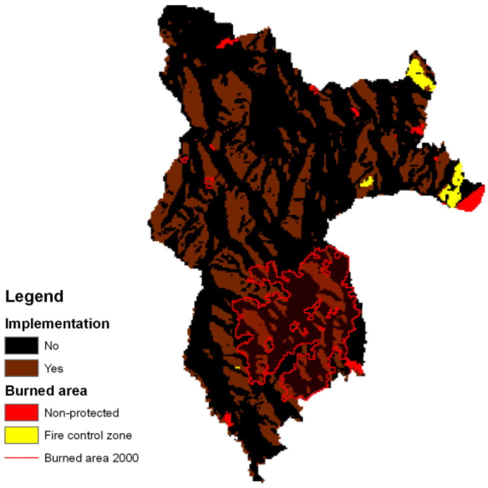
Technology Scenario: Prescribed fire

- Areas burned in a controlled way are assumed to act as a 100% effective fire break. Repeated burning every 2 years is assumed.
- The cost of prescribed fire is assumed to be fixed at €270/ha; planning and fire brigade stand-by are the main cost factors.
- A discount rate of 10% has been applied
- Analysis is carried out for an implementation period of 10 years, with the benefits derived from analysis of avoidable damage from observed fire-affected areas over the period 2001-2009.

Applicability

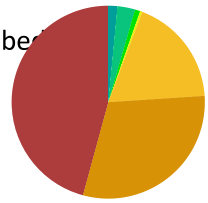
- Prescribed fire needs to be carefully planned in relation to wind speed, humidity and temperature. Slope aspect is another important aspect to take into account. Shown here is the area with NE-E facing slopes, which was assessed to have the highest potential impact on forest fire reduction.

Applicability

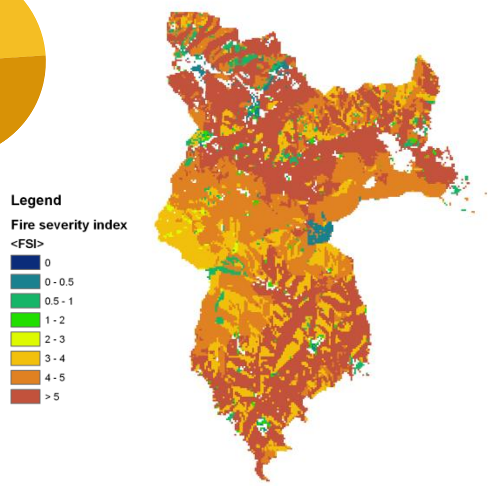


Biophysical impact: fire susceptibility

- Fire severity index is reduced when prescribed fire is implemented. The FSI values shown here are representative for the situation 2 years after controlled burning of NE-E facing slopes (FSI values in other slope aspects are not affected).

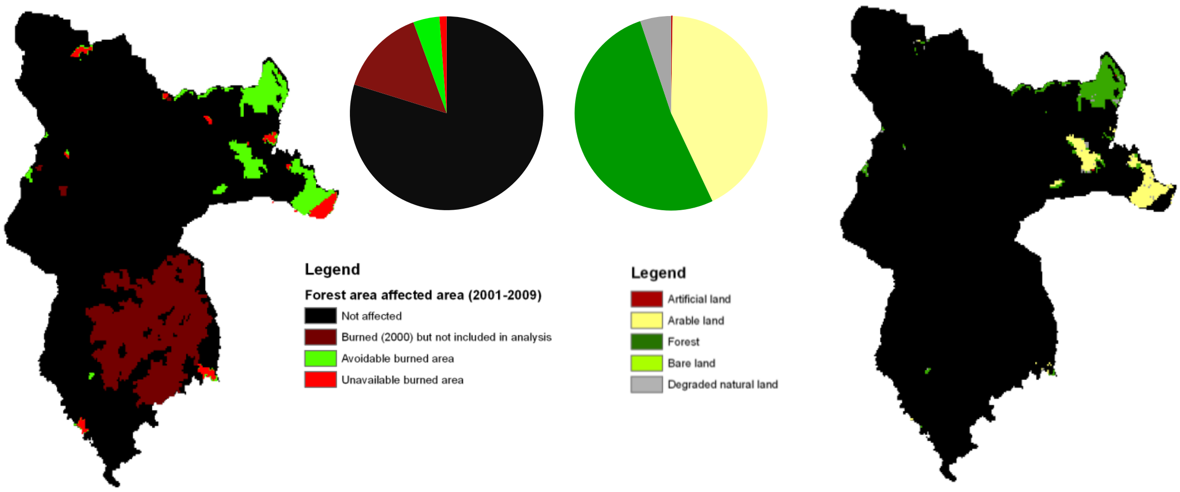


Fire Severity Index (FSI)



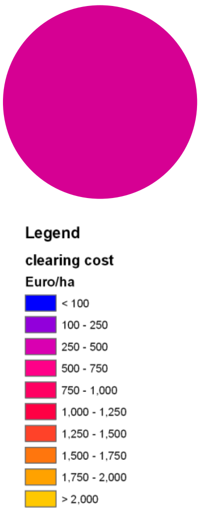
Biophysical impact: forest fire prevention

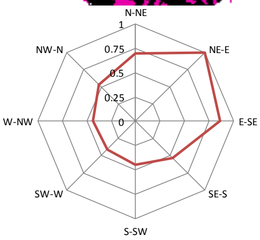
Fire-affected area **Avoided burning**



Economic viability

Clearing costs





Relative effectiveness of slope aspect for fire containment

Net Present Value

Year	Clearing cost	Avoided dam
0	€ 1,886,220	
1		€ 238,744
2	€ 1,886,220	€ 238,744
3		€ 238,744
4	€ 1,886,220	€ 238,744
5		€ 238,744
6	€ 1,886,220	€ 238,744
7		€ 238,744
8	€ 1,886,220	€ 238,744
9		€ 238,744
10		€ 238,744
Total	€ 9,431,100	€ 2,387,444

Discount factor	10%
Net present value	€ -6,398,302

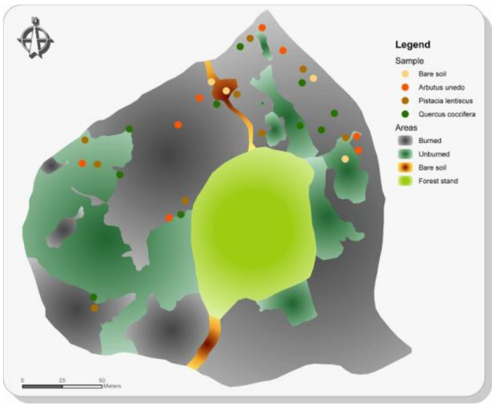
Scenario analysis of implementation zone

Implementation area	Size of area (ha)		NPV (Euro)		
	Preventive	Avoided fire	Clearing cost	Avoided damage	Nett
1. N-NE Aspect	5412	930	€ 6,093,174	€ 975,416	-€ 5,117
2. NE-E Aspect	6986	1332	€ 7,865,284	€ 1,466,981	-€ 6,398
3. E-SE Aspect	6425	1139	€ 7,233,674	€ 1,269,604	-€ 5,964
4. SE-S Aspect	5360	702	€ 6,034,629	€ 698,569	-€ 5,336
5. S-SW Aspect	6223	589	€ 7,006,250	€ 735,163	-€ 6,271
6. SW-W Aspect	6851	541	€ 7,713,292	€ 634,324	-€ 7,078
7. W-NW Aspect	5763	579	€ 6,488,352	€ 483,031	-€ 6,005
8. NW-N Aspect	4626	706	€ 5,208,245	€ 743,015	-€ 4,465
9. Ridges	4560	1121	€ 5,133,938	€ 1,090,797	-€ 4,043

An economic analysis of prescribed fire is difficult due to lack of clarity over the optimal scale of implementation. Clearing costs if indiscriminately applied across areas of similar slope aspect (or ridges) appear to be too high to justify investment based on damage by forest fires in the period 2001-2009. However, the damage in this time frame has been limited, and extending the analysis with the year 2000, when 15% of the municipality was burned would give a different picture. That said, more informed application of prescribed fire could decimate the clearing (burning) costs without compromising effectiveness. Slopes with N-NE aspects appear to be the most effective in terms of containing wildfires but might not be the most cost-effective.

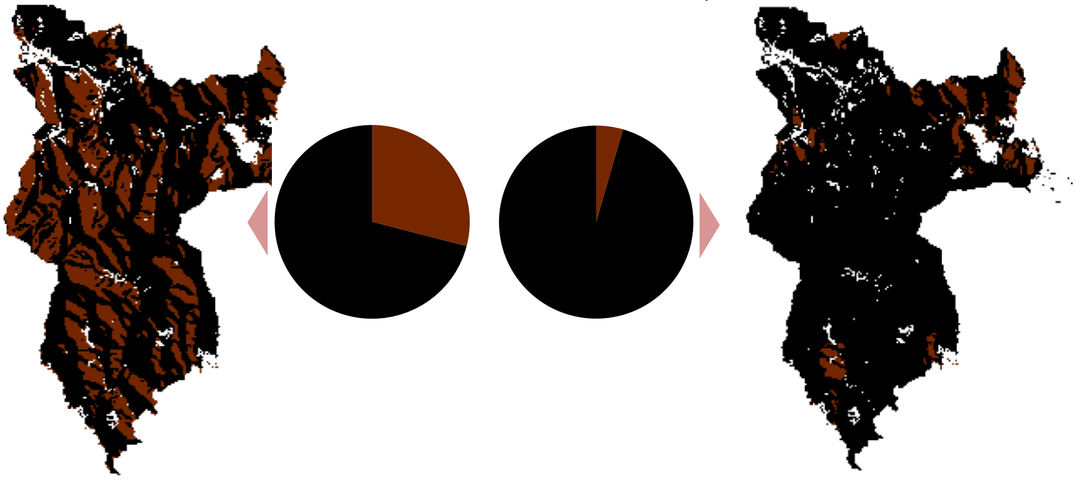
Policy Scenario: Targeted implementation of prescribed fire

The extent of application of prescribed burning analysed in the Technology Scenario is exaggerated, with ratios of preventively burned to protected areas ranging from 4.1 – 12.7. If areas most at risk of wildfires are better known and the prescribed fire technology more restrictively applied, costs can be reduced while maintaining high level of wildfire control. In this policy scenario we consider only implementing prescribed fire with 1km from burned areas on land with high susceptibility to fire (FSI > 5).



Profitability:

Implementation area: A. Slopes NE-E aspect **B. Idem, with SFI > 5 and burned area < 1km**



Net Present Value

Implementation area	Size of area (ha)		NPV (Euro)		
	Preventive	Avoided fire	Clearing cost	Avoided damage	Nett
I. Targeted application with calculated effect (reduced effectiveness due to patchy application)					
N-NE Aspect	745	488	€ 838,768	€ 672,489	-€ 166,280
NE-E Aspect	1177	944	€ 1,325,142	€ 1,213,962	-€ 111,180
NW-N Aspect	613	453	€ 690,154	€ 495,730	-€ 194,424
II. Targeted application with assumed micro-management to retain effectiveness					
N-NE Aspect	745	930	€ 838,768	€ 975,416	€ 136,647
NE-E Aspect	1177	1332	€ 1,325,142	€ 1,466,981	€ 141,840
NW-N Aspect	613	706	€ 690,154	€ 743,015	€ 52,860

Targeted implementation reduces the implementation area (and hence costs) by 83% (for NE-E slope aspect). Two analyses are performed: in the first (calculated) analysis the annual area avoided from burning is reduced from 133 to 94 ha due to more patchy application; in the second the same cost is assumed to suffice to safeguard the originally protected area (i.e. more micro-management). The NPV is slightly negative in the first but positive in the second analysis. In applying prescribed fire, there is a trade-off between targeting high-risk areas and accepting wildfire risk in remaining areas.

Cost-effectiveness indicators:

- The cost per hectare of land where burning is avoided is between €902 and €1720.
- The cost per inhabitant would be between €37 and €71 per year.
-

Global Scenario:
Food production

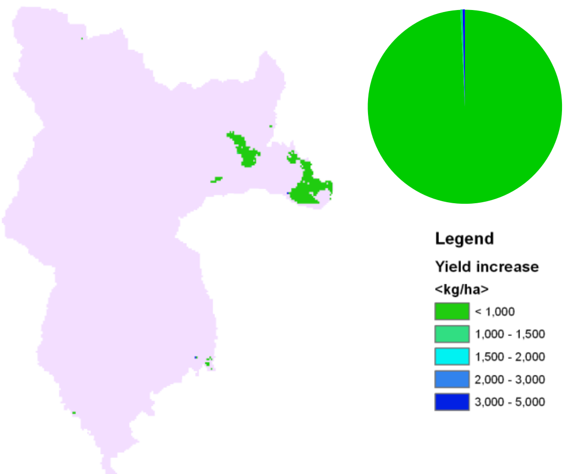
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+958 kg/ha

+130 kg/inhabitant

Scope for increased (i.e. not lost) production

Yield increase



Biophysical impact: yield increase

- Yield increase in 39% of applicable area (all arable land)
- Average absolute yield increase: 958 kg/ha
- Average yield increase: na (avoided burning)

Economic indicators

Average costs (arable land as share of total):

- Investment cost: €1,571/ha*
- Unitary cost year 1: €1,640/ton(yr)*
- Unitary cost lifetime: €820/ton*

Aggregate indicators:

- Study site: €0.96 million*
- Augmented annual production: 583 ton
- Augmented total production: 5,833 ton

* Note that costs can be reduced with more targeted application of the technology (see Policy scenario), to: Investment cost: €216/ha; unitary cost year 1: €226/ton(yr); unitary cost lifetime: €113/ton; Aggregate investment study site: €0.13 million.

Conclusions from scenario modelling

- ✓ The baseline simulation shows a very high fire susceptibility in about 70% of the forest and unmanaged area. Biomass production is more than 15 ton/ha in 90% of the forest area.
- ✓ Prescribed fire was prioritised by scientists and local stakeholders to control wildfires. Field experiments were conducted to assess the effects of controlled fire in comparison to wildfires. The analyses included post-fire hydrology, measuring erosion and nutrient losses. It was concluded that prescribed fires result in less degradation effects than wildfires, confirming it can be used as a landscape planning tool. Modelling concentrated on an analysis of the potential of using prescribed fire as a fire break at landscape scale, using data on burned areas and ignitions over the period 2001-2009. Slope aspect was considered as a basic management factor, as fire is more easily controlled on relatively homogeneous slopes. Applying controlled fire on slopes with NE-E aspect was found to result in the highest reduction of wildfire. The average annual area burned by wildfires could be reduced from 1703 to 317 ha (a 78% reduction). From an economic point of view a crucial factor is how much area should be burned in a controlled fashion to achieve this effect. Indiscriminate application is too expensive but there is likely to be much room for improvement, which was explored as a policy scenario. It should also be pointed out that the rate of burning was relatively low over the period assessed (e.g. wildfires in the year 2000 burned 3842 ha, or 15% of the municipality).
- ✓ In the workshop to evaluate monitoring and modelling results, stakeholders confirmed their preference for prescribed fires (and the fuel strips network), evaluating it slightly higher than in the second workshop – perhaps because of increased knowledge derived from pilot implementation of the technology. In order to promote the technology, recommended actions in four domains (regulation, awareness, forest intervention areas, and funding) were agreed by the participants.
- ✓ A policy scenario explored whether the benefit-cost ratio could be improved by more contextual knowledge leading to a more targeted application of the technology. Two additional management factors were taken into account: the fire severity index (FSI) in the baseline situation and the distance from burned areas over the past decade. Both factors could potentially weaken the firebreak effect of prescribed fires: the FSI because introducing a treshold FSI creates a more scattered pattern of areas with low susceptibility, and proximity to known fire hotspots because there is no guarantee that ignitions would not occur in an area where no recent wildfires occurred. The patchiness due to FSI treshold was modelled to reduce protection against wildfires. Due to less effective firebreak function, the greatly reduced investment costs were still too high to warrant application of prescribed fire. However, if we assume field knowledge is sufficient to avoid reduction of effectiveness, the technology turned positive. Application accross NW-N slopes was most cost-effective in this

analysis.

- ✓ The global scenario for food production shows that although the technology is not primarily intented to protect cropland (which is a limited land use in the area), its impact in avoiding the burning of crops is noticeable. For simplicity the analysis assumes that all fires would affect crops in the field (i.e. occur before harvesting). The investment costs to protect crop production, when attributed equally to all areas where burning would have been avoided, range from €1,640 to potentially €113/ton grain.
- ✓ The analyses show that the required scale of application of prescribed fire is a crucial factor in assessing its economic viability. Targeted application is essential in order not to apply the technology too widely, perhaps introducing degradation impacts that are not serving to offset more devastating wildfires. Results obtained were based on several assumptions and based on an analysis of areas burned in the period 2001-2009. While the long-term average area burned could deviate from the observed burned areas in this period, it is under future climate change likely that wildfires will increase rather than decrease, in which case the viability of implementing prescribed fire could be improved. For example, would the 2000 burned areas have entered the analysis and the effectiveness of prescribed fire would have been the same as observed over the period 2001-2009, even the large scale application of wildfires accross all ridges would have been economically attractive.

General Conclusions

- ✓ Prescribed burning, during the wet period seems to have less impacts on the soil and vegetation than the summer wildfires, therefore it is suitable as a land management technique.
- ✓ It has a reduce cost/effect rate, especially when compared with other techniques.
- ✓ Can be used to promote higher landscape diversity and therefore promote biodiversity.
- ✓ The landscape diversity can induce a higher diversity of economic activities, therefore increasing the appeal of mountain areas, by improving the local community's livelihoods.

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