RECARE
Preventing and Remediating degradation of soils in Europe through Land Care

Assessment of the effectiveness of implemented measures regarding combating soil degradation and to restore soil functions and ecosystem services.

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RECARE PROJECT REPORT

universidade de aveiro

RECARE
Preventing and Remediating degradation of soils in Europe through Land Care

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RECARE partner list

No	Name	Short name	Country	Country
1	WAGENINGEN UNIVERSITY	WU	Netherlands	NL
2	TECHNICAL UNIVERSITY OF CRETE	TUC	Greece	GR
3	AARHUS UNIVERSITET	AU	Denmark	DK
4	UNIVERSITAT DE VALENCIA	UVEG	Spain	ES
5	THE CYPRUS INSTITUTE LIMITED	CyI	Cyprus	CY
6	NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH	NIBIO	Norway	NO
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10	UNIVERSITAET BERN	UNIBE	Switzerland	CH
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12	STICHTING INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE	ISRIC	Netherlands	NL
13	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	JRC	Belgium	IT
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17	CONSULT AND RESEARCH ON PARTICIPATION AND GENDER - COREPAGE - CLARINGBOULD HELEEN ELSA	COREPAGE	Netherlands	NL
18	SVERIGES LANTBRUKSUNIVERSITET	SLU	Sweden	SE
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RECARE

Deliverable D6.2

Assessment of the effectiveness of the tested measures to combat soil degradation or restore soil functions

Keizer J.J., Hessel R. and case study partners

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Contents

1. INTRODUCTION

The present deliverable has as overarching aim to report on the results obtained in the field and glasshouse experiments carried out in the framework of the RECARE's WP6 in the project's 17 case study sites to test the prevention, remediation or restoration measures that had been selected/validated by stakeholders through a formal workshop-based procedure developed in WP4. As is common in experimental research and especially for field trials, however, for a variety of reasons it proved impossible to test all measures referred in deliverable D6.1, to implement all experiments according to the set-up envisaged in deliverable D6.1, or to obtain sufficient data to duly evaluate all measures. Therefore, the next section will provide an overview of the measures that could, in fact, be evaluated successfully (whether as ineffective, negatively or positively) by the WP6 experiments.

To guide the actual evaluation of the measures, a distinction was proposed between the measures' effectiveness in terms of targeted variables as well as principal soil threat, on the one hand, and, on the other, their impacts (or, side effects) on non-targeted variables as well as additional soil threats. This distinction was also the basis for the proposed structure of the contributions by the case study partners to this deliverable (see Appendix I). An example of the case studies in which this distinction was particularly useful is that of Portugal. Mulching with forest logging residues aimed to reduce soil erosion by water through increasing the protective litter cover but, at the same time, could be expected to decrease soil organic matter losses, increase soil moisture content or affect the abundance and/or diversity of ground-dwelling macro-invertebrates. Although the proposed structure was not followed in the contributions of all case study partners, the separate impacts of the measures on targeted and non-targeted variables, and on principal and additional soil threats and will be addressed here in sections 3 to 6, respectively.

The contributions of the individual case study partners to this deliverable are listed in Table 1 and included in Appendix II. The majority of these contributions is in the form of scientific papers published (10), under revision by authors (3) and under review (1) in/for/to a dedicated, virtual special issue of CATENA (www.sciencedirect.com/journal/ catena/special-issue/ 1063L2HD49J). CATENA was selected for being a well-reputed interdisciplinary journal of soil science - hydrology - geomorphology focusing on geo-ecology and landscape evolution (www.journals. elsevier.com/catena). This special issue is being guest-edited by the first two authors of the present document. Because of author rights transference to the journal, Appendix II includes the versions of the papers that were originally submitted. However, links to the papers that have already been published (on-line) are listed in Table 1. Since the whole process from submitting to publishing papers in scientific journals with peer review typically takes considerable time, the link provided in Table 1 for the 4 papers that are still in the review process is that of the special issue itself.

Table 1. Overview of the contributions of the case study partners to this deliverable.

cs	country	principal soil threat	type of contribution	status CATENA vsi	link to papers published in CATENA vsi
1	CH	erosion by water	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.10.038
2	PT	erosion by water	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.05.029
3	CY	erosion by water	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.07.017
4	GR	salinization	CATENA vsi	under review	www.sciencedirect.com/journal/catena/special-issue/ 1063L2HD49J
5	DK	compaction	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.05.015
6	PL	sealing	report	na	
7	ES_V	desertification	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.11.007
8	IS	desertification	report	na	
9	NO	floods & land slides	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.08.014
10	SK	floods & land slides	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.09.027
11	NL_B	om losses org. soils	report	na	
12	SE	om losses org. soils	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.10.007
13	NL_E	om losses min. soils	report	na	
14	IT	om losses min. soils	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.05.006
15	ES_G	contamination - CSIC	CATENA vsi	published	https://doi.org/10.1016/j.catena.2018.03.016
		contamination - EVENOR	CATENA vsi	under revision	www.sciencedirect.com/journal/catena/special-issue/ 1063L2HD49J
16	RO	contamination	CATENA vsi	under revision	www.sciencedirect.com/journal/catena/special-issue/ 1063L2HD49J
17	GB	soil biodiversity	CATENA vsi	under revision	www.sciencedirect.com/journal/catena/special-issue/ 1063L2HD49J

2. OVERVIEW OF THE EXPERIMENTS

Table 2 gives an overview of the 19 WP6 experiments that were reported by the case study partners in the contributions listed in Table 1. In the majority of experiments (11), two up to seven prevention, mitigation or restoration were tested, in accordance with the overall strategy as envisaged in RECARE's DOW. In one of the other cases (cs5), additional measures were in fact tested but the findings are being reported in a separate article (Pulido-Moncada et al., under review). In the remaining cases, either only one measure had been foreseen from the start, or the measures foreseen in deliverable D6.1

could not be (duly) tested, for a variety of case study-specific reasons. The latter can be exemplified by the second measure that was selected by the Portuguese stakeholders, i.e. post-fire contour plowing. Within the entire burnt area of some 700 ha, no ploughing was observed during the entire first post-fire year. Towards the end of that year, one of the landowners could be persuaded to plough a small part of one of his terrains, just for the sake of setting up a second WP6 experiment. However, since the second post-fire year was relatively dry, the obtained results were considered not to be sufficiently representative for assessing the measure's effectiveness.

The inclusion of target or reference – i.e. unthreatened or non-degraded - conditions in the WP6 experiments proved impossible in almost all experiments, except that of case studies 6 and 17. This reflected the fact that the bulk of the experiments were carried out on agricultural lands without nearby (semi-)natural ecosystems with comparable physical-environmental conditions. The only case study dealing with forest concerned planted forest with an exotic fast-growing species (eucalypt), without native forest in the wide vicinity. The ensuing sections will therefore not address the comparison with target or reference conditions.

3. TREATMENT EFFECTIVENESS IN TERMS OF TARGETED VARIABLES

Table 3 gives a summary of the impacts that the different measures had on the variables that these measures aimed to change directly or, as termed here, that these measures targeted. The concept of targeted variables was introduced to make sure that a measure's lack of effectiveness in terms of principal soil threat could not be explained by its lack of impact on the targeted variable. The concept's relevance can be illustrated by a well-known case in which post-fire mulching with straw in the USA was not effective because the straw had largely been blown away before the start of an extreme erosion event. Admittedly, however, the concept is not (easily) applicable to all WP6 experiments. This is perhaps best exemplified by the experiments of cs1 and cs3, in which the measures aimed to change surface storage capacity and resistance against flow (cs1) and to restore terraces (cs3).

Targeted variables were defined and quantified for 14 of the RECARE WP6 experiments. In three of these experiments (cs4, cs7, cs10), the experimenters had full control over the target variable, or, in other words, could select its (approximate) value during the course of experiment. In five of the remaining 11 experiments, one or more treatments seemed to have produced a significant as well as noticeable difference in the targeted variable compared to under threatened or degraded conditions. Three of these five cases concerned soil amendments targeting soil pH, with treatments aiming to either increase it (cs15 – amending; cs16) or decrease it (cs17). In contrast, three experiments revealed either insignificant (cs15 – treeing) or unsubstantial (cs12, cs13) differences in the target variables between the control and the treatment(s). Worth stressing, however, is that in the case of the c13 experiment this lack of marked differences indicated that the two mitigation measures were, in fact, successful.

4. TREATMENT EFFECTIVENESS IN TERMS OF PRINCIPAL SOIL THREATS

Table 4 gives a summary of the impacts that the different measures had on the principal soil threats, i.e. the soil threats that these measures were aimed to prevent, mitigate or restore from. In almost all experiments, these impacts could be quantified through one or more key indicators of the state of the soil threat for the threatened/degraded conditions as well as for one or more treatments. In two case studies, this proved impossible during the execution of WP6, either because of measurement problems (cs1 and cs8).

Worth stressing is that from the 30 different indicators listed in Table 4, only two were directly comparable in the sense of having been measured with equivalent methods. In cs1 as well as cs3, soil erosion by water was measured with sediment fences under natural rainfall conditions and over a period of at least one hydrological year. In contrast, soil erosion was measured in cs7 under simulated rainfall conditions of 1h duration. Besides in cs7, runoff coefficient was measured in cs10 through field rainfall simulation experiments. Arguably, however, the results of both cs's are not directly comparable due to the marked differences in rainfall intensity and duration, as indicated in Table 4, as well as in the size of the runoff plots (cs7: 0.28 m2; cs10: 0.0625 m2). As further detailed in deliverable D6.1, a lack of harmonization across case studies assessing the same soil threats was due to various reasons. The main reasons were the advantages of sticking to methods and techniques that cs partners had been applying untill RECARE, on the one hand, and, on the other, the nature of assessing measures' effectiveness, in essence involving paired comparisons with untreated but otherwise (presumably) identical conditions.

In roughly half of the experiments (7 out of 18), the principal soil threat indicator differed significantly between one or more of the tested measures and the untreated conditions. In only one of these cases (cs12), these significant differences did not correspond to an improvement compared to the current, threatened situation, as CO_2 emissions by soil respiration were significantly higher for the alternative grass species (reed canary and tall fescue) than for the control grass species (timothy). Even so, these differences in CO_2 emissions were considered to be too small to be of much relevance for organic matter losses in organic soils, while both reed canary and tall fescue were regarded as promising alternatives to timothy in terms of yield, nutrient removal and carbon capture efficiency.

Besides the experiment of cs12, three more experiments revealed just minor differences in the indicator or any of the multiple indicators of the principal soil threat between the selected measures and the threatened/degraded conditions. In cs9, neither planting shrubs nor trees seemed to markedly change stream bank instability, at least under the experimental conditions. Even so, model simulations did suggest relevant impacts of the proposed measures for steeper stream banks. In the case of the tree planting experiment of cs15, a marked reduction in soil contamination levels apparently depended more on individual tree specimens than on tree species per se and, in particular, on their capacity to change soil pH. In the case of cs13, the soil organic matter content was slight higher six years into the treatment than at its start.

The two types of measures that were tested in more than one case study site appeared to be highly effective in both cases. Mulching strongly reduced soil erosion by water in a recently burnt eucalypt plantation (cs2) as well as in an intensively managed clementine orchard (cs7), in spite different types of mulch were used (logging residues and straw, respectively). Likewise, inorganic soil amendments that effectively changed soil pH levels, were highly effective in immobilizing metals in contaminated soils in cs15 as well as cs16, in spite different types of amendments were applied.

5. TREATMENT IMPACTS ON ADDITIONAL SOIL THREATS

Table 5 gives a summary of the impacts that the different measures had on other than the principal soil threats, i.e. soil threats that these measures were not (necessarily) aimed to prevent, mitigate or restore from. Six experiments addressed such a second soil threat, covering five distinct threats.

In five out of six experiments, the impacts on the additional soil threat closely matched those on the principal one. As such, four experiments gave evidence for synergistic effects. Post-fire mulching not only reduced soil erosion by water but also organic matter losses (cs2). Cover crops not only reduced the rainfall-runoff response but also soil erosion by water (cs10). Conservation farming not only increased topsoil organic carbon sequestration but also decreased nitrate concentration in subsoil water (cs14). Applying organic as well as inorganic amendments not only reduced available metal contents but also increased total soil organic carbon contents (cs15). In contrast, alternative grass species neither impacted soil respiration nor susceptibility to soil compaction to an important degree (cs12), while tree species did not have a clear-cut effect on the topsoil content of either available metals or total organic carbon (cs15).

In the remaining case (cs13), the mitigation measures did not result in a consistent decrease of the average nitrate concentration in the upper groundwater, possibly also because the measures were only applied on roughly 30% of the arable fields or 13% of the total area.

Table 2. Overview of the field and greenhouse experiments testing selected prevention, mitigation and restoration measures ("treatments") for threatened or degraded soils, as reported by the RECARE case study partners as contribution to this deliverable.

cs	country	principal soil threat	designation experiment	threatened	degraded	treatment1	treatment2	treatment3-n
1	CH	erosion by water	Dykering	potatoe field	-	damming furrows	-	-
2	PT	erosion by water	mulching	recently burnt forest	-	standard mulching	reduced mulching	-
3	CY	erosion by water	terracing	-	collapsed t. walls	maintained t. walls	-	-
4	GR	salinization	irrigating	salinized water (sw)	-	sw + tomato inocculation	"rain" water (rw)	rw + tomato inocculation
5	DK	compaction	trafficking	using tires	-	using tracks	-	-
6	PL	sealing	feeing	without legal protection (2007/08-2017)		with legal protection (1992/94-2006/07)		-
7	ES_V	desertification	mulching	intensive orchard	-	straw mulching	-	-
8	IS	desertification	vegetating	-	eroded grassland	seeding (grass/leguminosae)	tree planting (birch/willow)	seeding + fertilizing
9	NO	floods & land slides	vegetating	grass-cov. stream bank	-	shrub planting	tree planting	-
10	SK	floods & land slides	covering	bare cropland	-	seeding winter crop	rapeseeding (3 stages)	-
11	NL_B	om losses org. soils	draining	permanent pasture	-	submerged drains	-	-
12	SE	om losses org. soils	grassing	timothy grassland	-	reed canary seeding	tall fescue seeding	-
13	NL_E	om losses min. soils	farming	-	maize field	grass undersowing in maize	biomass incorporation	-
14	IT	om losses min. soils	farming	convential cropland	-	conservation farming	cover cropping	-
15	ES_G	contamination-CSIC	treeing	-	post-remediation "control"	everg. tree planting (4 spp)	decid. tree planting (3 spp)	-
			amending	-	post-remediation "control"	sugar beet liming	biosolid composting	-
		,, -EVENOR	amending	-	post-remediation "control"	sugar beet liming (sbl)	sbl + composting (co)	sbl + claying (cl)/sbl+co+cl
16	RO	contamination	amending	-	grassland	natural "zeoliting"	"bentoniting"	"dolomiting"; manuring
17	GB	soil biodiversity	amending	-	"improved" pasture	ferrous sulphating	elemental sulphuring	-

Treatments being compared: threatened, degraded, treatment1, treatment2, treatment3-n.

Table 3. Summary of the effectiveness of the selected treatments on the target variables as reported in the contributions of the case study partners to this deliverable. The underlined values indicate significant differences of the treatment with the control (see contributions of the individual partners for the detail on the statistical test results).

cs	country	principal soil threat	designation experiment	targetted variable	measurement unit	degrad./ threat.	treatments t1	t2	t3	t4
2	PT	erosion by water	mulching	litter cover (incl. mulch)	%	2	79	50		
4	GR	salinization	irrigating	T. harzianum colonization	%	0	100	0	100	
				EC irrigation water	dS m-1	3,5	3.5	1.1	1.1	
5	DK	compaction	trafficking	vertical soil stress (at 0.35m)	kPa	228	139			
7	ES_V	desertification	mulching	mulch cover	%	0	50			
8	IS	desertification	vegetating	vegetation biomass	Mg ha-1	0-0.1	<0.1/1.7	0.7/<0.1	0.7-1.0	
9	NO	floods & land slides	vegetating	root cohesion	kPa	0.35	0.35-1.37	7.18		
10	SK	floods & land slides	covering	vegetation cover	%	0	80	40-50		
11	NL_B	om losses org. soils	draining	groundwater level	mNAP	variable	dry period: t1 = t0+(10-15 cm)			
12	SE	om losses org. soils	grassing	grass yields	Mg ha-1 y-1	11.7	14.3	13.5		
13	NL_E	om losses min. soils	farming	vegetation cover	NDVI	0.53-0.57	0.50-0.55			
15	ES_G	contamination-CSIC	treeing	soil pH	1/2.5 KCl	4.0	3.4-4.0	4.1-4.9		
			amending	soil pH	1/2.5 KCl	3.5	7.0	5.0		
16	RO	contamination	amending	soil pH	1/2.5 H2O	5.5	6.1	6.8	7.2	6.1
17	GB	soil biodiversity	amending	soil pH	1/2.5 H2O	5.5-5.6	5.4-5.5	4.8-5.1		

Table 4. Summary of the impacts of the selected treatments on the indicators of the principal soil threats as reported in the contributions of the case study partners to this deliverable. Underlined values indicate significant differences of treatment with control.

cs	country	principal soil threat	designation experiment	soil threat indicator	measurement unit	degrad./ threat.	treatments t1	t2	t3	t4
2	PT	erosion by water	mulching	sediment losses (1st post-fire year)	Mg ha-1 y-1	8.0	0.3	1.1		
3	CY	erosion by water	terracing	soil losses	Mg ha-1 y-1	3.9	1.0			
4	GR	salinization	irrigating	Δ soil pH	pH units	0.8	0.7	0.4	0.2	
				Δ soil saturated extract EC	dS m-1	-7	-4	-14	-4	
				Δ soil Sodium Adsorption Ratio	mmoles L-1	22.2	14.4	6.8	4.8	
				salinity class (van Beek and Tóth, 2012)	nominal	sodic-saline (ss)	ss to saline	saline	saline	
5	DK	compaction	trafficking	dry bulk density (0.33-0.37m depth)	g cm-3	1.56	1.55			
				air permeability (0.33-0.37m depth)	µm2	20.3	7.9			
				volumetric water content (0.33-0-37m depth)	m3 m-3	0.25	0.25			
6	PL	sealing	feeing	Poznan - annual rate of agricultural land conversion	ha y-1	101	216			
				Wroclaw - annual rate of agricultural land conversion	ha y-1	125	232			
7	ES_V	desertification	mulching	runoff coefficient (1h 38mm h-1 simulated rain)	%	66	51			
				sediment losses (1h 38mmh-1 simulated rain)	g m-2 mm-1	41.3	6.8			
9	NO	floods & land slides	vegetating	Δ x/y-position erosion pins (bank failure indicator)	m	0.01-0.09	0.01-0.06	0.01-0.07		
				stream bank stability (simulated with BESTER)	safety factor (Fs)	>1.3	>1.3	>1.3		
10	SK	floods & land slides	covering	runoff coeff. (3min 3-7mm min-1 simulated rain)	%	0-30	0	5-15		
				peak flow surface runoff (SMODERP simul. 10y rp)	L sec-1	3.9	<0.1	nq		
11	NL_B	om losses org. soils	draining	Δ ground level (subsidence indicator)	mm y-1	3.0-5.2	0.9-2.5			
				soil organic matter losses (Δ ground level derived)	Mg ha-1 y-1	3.4-5.8	1.0-3.1			
12	SE	om losses org. soils	grassing	soil respiration CO2 emisions (2h data snow-free season)	mg m-2 h-1	730	795	825		
13	NL_E	om losses min. soils	farming	soil organic matter content (0-25 cm depth)	% (m/m)	3.0 (2012)	3.3 (2018)			
14	IT	om losses min. soils	farming	Δ 0-5 cm soil organic carbon stocks t_start to t_end	Mg C ha-1 **7**y-1	0.3	4.4	-0.4		
				Δ 0-50 cm soil organic carbon stocks t_start to t_end	Mg C ha-1 **7**y-1	12	11	8		
				Δ CO2 efflux-influx (DNDC simul. 2018-2112 B1 scenario)	kg C ha-1 yr-1	-173	-309	-228		
15	ES_G	contamination-CSIC	treeing	CaCl2-extractable soil cadmium (Cd) concentration	mg kg-1	?	?	?		
				CaCl2-extractable soil copper (Cu) concentation	mg kg-1	?	?	?		
			amending	CaCl2-extractable soil cadmium (Cd) concentration	mg kg-1	0.19	<0.01	0.10		
				CaCl2-extractable soil copper (Cu) concentration	mg kg-1	2.9	0.1	0.2		
		,, -EVENOR	amending	pseudototal soil cadmium (Cd) concentration	mg kg-1	3.33	0.97	0.81		
16	RO	contamination	amending	DTPA-extractable soil cadmium (Cd) concentration	mg kg-1	11.2	10.0	9.9	8.3	9.6
				DTPA-extractable soil zink (Zn) concentration	mg kg-1	280	180	150	80	210
17	GB	soil biodiversity	amending	fluorescein released (microbial activity indicator)	µg fluor. g-1 h-1	170	nq	90		
				earthworm fresh biomass	g 8dm-3	2.6	2.2	1,3		
				nematodes abundance	nr individuals	770	500	250		

Table 5. Summary of the impacts of the selected treatments on the indicators of the additional soil threats as reported in contributions of the case study partners to this deliverable. Underlined values indicate significant differences of treatment with control.

cs	coun-try	additional soil threats	designation experiment	soil threat indicator	measurement unit	degrad./ threat.	treatments t1	treatments t2
2	PT	om losses min. soils	mulching	organic matter losses by runoff (1st post-fire year)	Mg ha-1 y-1	1.7	<u>0.1</u>	<u>0.2</u>
10	SK	erosion by water	covering	soil losses (3min 3-7mm min-1 simulated rain)	g m-2	42-67	2	?
12	SE	compaction	grassing	penetration resistance (10-20cm depth)	MPa	1.06	0.89	0.91
13	NL	contamination	farming	nitrate concentration groundwater	mg NO3 L-1	67 (2014)	72 (2017)	
14	IT	contamination	farming	nitrate concentration soil water (60cm depth)	mg NO3 L-1	85	<u>15</u>	75
				nitrate concentration groundwater	mg NO3 L-1	<1	<1	<1
15	ES_G	om losses org. soils	treeing	total organic carbon (TOC) concentration	g kg-1	14	12-17	16-18
			amending	total organic carbon (TOC) concentration	g kg-1	10	<u>16</u>	<u>16</u>

APPENDIX I.

Template for the case study contributions to this Deliverable

RECARE
Preventing and Remediating degradation of soils in Europe through Land Care

Case study number: xxx

Country: xxx

Author(s): family name, initial1.initial2;

Affiliation(s): a) xxxx; b) xxxx

Principal soil threat: xxx

Additional soil threats: xxx

Selected treatments for WP6 testing and demonstration:

1. xxx
2. xxx
3. xxx

CONTRIBUTION TO Deliverable 6.2

version: xx

date: dd-mm-201x

1. Introduction (1-1.5 pages)

Short background on the principal soil threat, both in general and in the case of your case study site.

Short background on prevention or remediation measures against the principal soil threats.

General and specific objectives of the WP6 experiment in your specific case study site.

2. Case Study area and monitoring sites (0.5-1 page)

General description of the case study area and monitoring sites, addressing location (e.g. using map of the country), climate, terrain, geology, soils, vegetation and land cover/use.

3. Materials and methods (1.5-2 pages)

3.1. Experimental design and treatments

Description of the experimental design that was implemented, whenever possible in map or schematic format, and of the treatments.

3.2. Field data and sample collection

Description of field data and sample collection, whenever possible using references to methods and techniques, and just describing relevant modifications.

3.3. Laboratory analyses

Description of laboratory analyses, whenever possible using references to methods and techniques, and just describing relevant modifications.

3.4. Data analyses

Description of data analysis methods and techniques.

4. Results (2-4 pages)

4.1. Treatment effectiveness in terms of targeted variable(s)

Analysis of the extent to which the treatment(s) altered the state of the variable(s) that it/they intended to change (e.g. in the Portuguese study case of post-fire mulching, the ground cover of the applied organic material in the course of the experiment).

4.2. Treatment impacts on non-targeted variable(s)

Analysis of the extent to which the treatment(s) altered the state of the variable(s) that it/they did NOT intend to change, provided they have some relevance for the principal or additional soil threats (e.g. in the Portuguese study case of post-fire mulching, soil moisture and soil water repellency).

4.3. Treatment effectiveness in terms of principal soil threat

Analysis of the extent to which the treatment(s) altered the state of the indicator variable(s) of the principal soil threat (e.g. in the Portuguese study case of post-fire mulching, the reduction in soil erosion comparing mulched vs. untreated plots and, whenever possible, its increase comparing mulched vs reference, long-unburned plots).

4.4. Treatment impacts on additional soil threats

Analysis of the extent to which the treatment(s) altered the state of the indicator variable(s) of the additional soil threats (e.g. in the Portuguese study case of post-fire mulching, the reduction in organic matter losses by runoff comparing mulched vs. untreated plots, and their increase comparing mulched plots vs. reference, long-unburned plots).

5. Discussion (1.5-3 pages)

5.1. Treatment effectiveness in terms of principal soil threat

Critical comparison of the observed treatment effectiveness, as described in sections 4.1 and 4.3, with what was expected based on theoretical considerations and/or with the effectiveness reported by prior studies using the same or comparable treatments.

5.2. Treatment impacts on additional soil threats

Critical comparison of the observed treatment impacts, as described in sections 4.2. and 4.4, with what was expected based on theoretical considerations and/or with the impacts reported by prior studies using the same or comparable treatments, and inference of implication for land management.

5.3. Overall discussion

Analysis of the possible interactions between soil threats in the case of the selected treatments, and their implications for land management.

6. Conclusions (0.5-1 page)

The main conclusions of this study were:
(i)

(ii)

(iii)

(iv)

(v)

Acknowledgements (<0.5 pages)
xxxxxxxxxxxxxxxx

References

please use referencing style by CATENA or, in case the special issue does not go ahead, that used for D2.1, i.e.:

- Text citations: Cite in the text by author(s) and year. For two authors cite both (using “&”, not “and”);
  Example when referring several sources: Stolte, 2013; Stolte & Skarbøvik, 2013; Stolte et al., 2013.
- Journals: Author(s), Year. Title of paper. Name of a journal (in Italics), number, and page numbers.
  Example: Bathurst, J.C., Sheffield, J., Leng, X., Quaranta, G., 2003. Decision support system for desertification mitigation in the Agri Basin, southern Italy. Physics and Chemistry of the Earth 28, 579-587.
- Books: Author(s), year. Title of book, name of publisher, place of publication. ISBN/ISSN-number, Number of pages.
  Example: Skarbøvik, E., 2057. Flooding and landslides in the Vansjø-Hobøl catchment. Save the world Press, Ås. 150 pp.
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APPENDIX II.

Contributions of the individual case study partners to this Deliverable