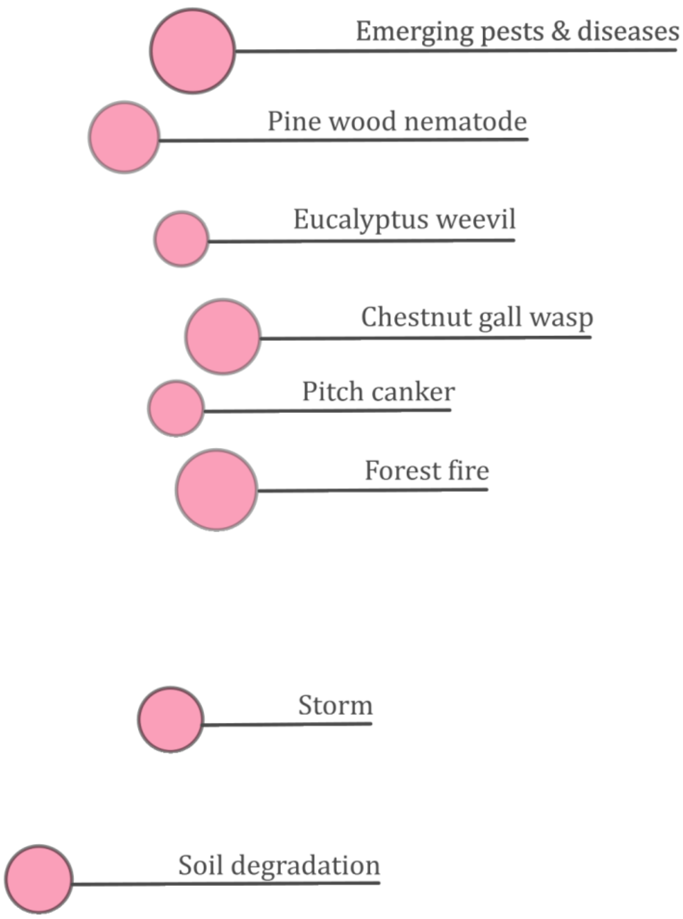
Minutes of the soil degradation risk workshop

Practical guidance for developing plans to manage soil degradation risk in forestry



Hotel Ciudad de Jerte,
Plasencia (Cáceres), Spain
28 June 2017

Author of the minutes: Eduard Mauri (EFIATLANTIC)

Reviewer of the minutes: Nahia Gartzia-Bengoetxea (NEIKER)

Workshop organisers: Ander Arias-González (NEIKER), Nahia Gartzia-Bengoetxea (NEIKER), Cristina Fernández (CIF), Elena Canga (CETEMAS), Manuel Madeira (ISA)

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Agenda

PLURIFOR PROJECT

SOIL DEGRADATION RISK WORKSHOP: PRACTICAL GUIDANCE FOR DEVELOPING PLANS TO MANAGE SOIL DEGRADATION RISK IN FORESTRY

WEDNESDAY 28 JUNE 2017	**Organisers:** Ander Arias González, NEIKER, +34 607 418 978, agonzalez@neiker.eus/ basozaintza@neiker.net Nahia Gartzia Bengoetxea, NEIKER, +34 94 403 43 21, ngartzia@neiker.eus/ basozaintza@neiker.net Cristina Fernández, CIF Lourizán, +34 986 80 50 13, cristina.fernandez.filgueira@xunta.es Elena Canga, CETEMAS, +34 984 50 00 00, ecanga@cetemas.es Manuel Madeira: Instituto Superior de Agronomia (ISA), +351 21 365 3443, mavmadeira@isa.ulisboa.pt **Language:** English **Venue:** Hotel Ciudad del Jerte, Carretera Nacional 110, Km 399,9 - 10600 PLASENCIA, Cáceres, Spain

9:15	Welcome and opening	Manuel Madeira (ISA, Portugal)
9:30	Prevention and early warning *Soil protection is better than damage detection - but both will be necessary in modern forestry*	Professor Andy Moffat (Forest Research, UK)
	Andy Moffat is a soil scientist and a chartered forester. As forest soil scientist at the UK Alice Holt Research Station, he has undertaken research exploring how to protect and conserve soil since 1985, and wrote the first Soil Conservation Guidelines for the Forestry Commission. He was in charge of forest monitoring in the UK from 1997 to 2013, including management of soil monitoring under the ICP Forests Level I and II frameworks. He has published widely on these and related subjects.	
10:30	Management of the crisis *Recovery programme after severe soil erosion: Lessons learned from the Vale Mouro case*	Mr. Henk Feith (Altri, Portugal)
	Henk Feith is a forest engineer with an academic degree from the Agricultural University of Wageningen, Netherlands. He has worked for the Portuguese forest management company Altri Florestal of the Altri Group since 1997, where he has been forest director since 2010. He is responsible for the management of 80 thousand hectares of forest, mainly occupied by eucalyptus stands (62 thousand ha). Before this position, he worked in Forest Monitoring Systems, Inventory and GIS and was later responsible for the forest management and certification systems based on ISO 9001, FSC and PEFC. Henk has also worked on forest research projects for four years at the Instituto Superior de Agronomia, Technical University of Lisbon, Portugal.	
11:30	Coffee break	

PLURIFOR PROJECT

SOIL DEGRADATION RISK WORKSHOP: PRACTICAL GUIDANCE FOR DEVELOPING PLANS TO MANAGE SOIL DEGRADATION RISK IN FORESTRY

12:00	Rehabilitation *Planning emergency response to reduce post-fire soil erosion risk under oceanic climate*	Professor José Antonio Vega (CIF Lourizán, Spain)
	José Antonio Vega is a senior forest fire scientist. He has been conducting research at the Forest Research Centre, Lourizán (Galicia, Spain) on different topics related to forest fires for the last 40 years. His main contributions have been on fire effect on vegetation and soil, fire behaviour prediction, prescribed burning, vegetation management for fire hazard reduction and wildfire impact mitigation. Since 2010 he has been leading the Galician Forest Service planning for emergency rehabilitation of burned area.	
13:00	Discussion	Cristina Fernández (CIF Lourizán, Spain)
13:30	Wrap up	Nahia Gartzia (NEIKER, Spain)
14:00	Lunch for speakers and partners	

Register for the workshop before 23 June 2017. Limited places.

Soil degradation risk WP2 objectives

Soil degradation risk partners and associated partners

Region	Organisation	Contact person	Associated partners
Euskadi	NEIKER	Ander Arias (risk coordinator)	Gobierno Vasco - Departamento de Desarrollo Económico y Competitividad
Asturias	CETEMAS	Elena Canga	Servicio de Emergencias del Principado de Asturias Celulosas de Asturias S.A. Asociación Asturiana de Empresarios Forestales, de la Madera y el Mueble Servicio Regional de Investigación y Desarrollo Agroalimentario Consejería de Agroganadería y Recursos Autóctonos de Asturias
Galicia	CIF	Cristina Fernández	Subdirección Xeral de Prevención e Defensa contra os Incendios Forestais Servicios Agrarios Galegos
Portugal	ISA	Manuel Madeira	Altri Florestal RAIZ - Instituto de Investigação da Floresta e Papel

Tools and risk management plans to be developed within PLURIFOR project

As decided by the PLURIFOR Technical committee n°2 meeting (25-26 January 2017 at NEIKER, Parque Tecnológico de Bizkaia, Parcela 812, calle Berreaga 1, Derio, Spain), the following tools and risk management plans will be developed by the soil degradation risk team in WP2:

- Set up a plan for soil protection;
- Develop maps of soil susceptibility;
- Case studies for monitoring soil protection;
- Provide a report reviewing consequences of soil degradation on productivity and environmental services.

Attendees

Attendees

Participants

First name	Last name	Organisation
Eva	Ardao Rivera	University College Dublin
Fernando	Azurmendi	BASOEKIN S.L..
Jorge	Cunha	IDARN
María Teresa	Fontúrbel	Centro de Investigación Forestal de Lourizán
Maria Elena	Gomez Sanchez	Junta de Comunidades de Castilla la Mancha
Edurne	Lacalle Galdeano	USSE
Manuel Esteban	Lucas Borja	Castilla La Mancha University
Juan	Majada	Cetemas
Eduard	Mauri Ortuno	European Forest Institute - EFIATLANTIC
Braulio	Molina Martínez	Selga, Compañía Galega de Silvicultores, S.L.
Leire	Salaberria Isasi	USSE

Organisers

First name	Last name	Organisation
Ander	Arias-González	NEIKER
Elena	Canga	CETEMAS
Cristina	Fernández	Centro de Investigación Forestal de Lourizán, Xunta de Galicia
Nahia	Gartzia-Bengoetxea	NEIKER
Manuel	Madeira	Instituto Superior de Agronomia

Guest speakers

First name	Last name	Organisation
Henk	Feith	Altri Portugal
Andy	Moffat	Forest Research UK
José Antonio	Vega	Centro de Investigación Forestal de Lourizán, Xunta de Galicia

Apologies

First name	Last name	Organisation
Mario	Michel	Gobierno Vasco
Ismael	Mondragon	Dipuatción Foral de Gipuzkoa
Aitor	Omar	Diputación Foral de Bizkaia
Ibai	Portu	Diputación Foral de Araba
Karlos	Uriagereka	Diputación Foral de Bizkaia

Absent

First name	Last name	Organisation
Rosário	Alves	IDARN
Alejandro	Cantero	Hazi
Ricardo	García	Ricardo García Santamaría

Presentation of the tools/knowledge

Introduction

By Professor Manuel Madeira, ISA

How forest management influences soil ecosystem services:

Forest management → Modification of soil properties → Modification of soil functional processes → Modification of ecosystem responses → Alteration of ecosystem services

Prevention and early warning: Soil protection is better than damage detection - but both will be necessary in modern forestry

By Professor Andy Moffat, Forest Research, UK

Goal

How to proceed with soil protection and soil monitoring.

Content

SOIL PROTECTION

Soil protection must prevent compaction and erosion, two major soil degradation forms, from human disturbance and after a forest fire event. Soil is not only important for wood production, but also for all relevant ecosystem services. Trees are intimately associated with soil and nutrient cycling. The effects of soils degradation have impacts outside the forest ecosystem, e.g. with the accumulation of sediments eroded from forest soils or nutrient exports that unbalance nutrient cycling in other ecosystems. Forestry can be, in some cases, an activity that causes soil degradation if forest operations are not adapted to soil characteristics, but it must also be taken into account that soils can be protected by forestry, e.g. by creating protective forests. In Europe it exists 110 million of such protective forests.

Many laws and governmental instruments for soil protection exist, some at a worldwide scale (e.g. the World Soil Charter), some at a continental scale (e.g. the European Soil Charter), and some at country scale and even at regional scale. Forest certification schemes also include measures to ensure soil and water protection.

Some examples of regulations include allowing grants to discourage people to perform harmful forest operations in some types of forests. For these measures to be effective, it is necessary to identify the soils, to know their vulnerabilities and how they react to different activities. People have to be trained to do so, and different training tools exist. Trained people should provide guidance for forest managers about forest activities that alter soils. The aim is that mangers know which activities can be done in each soil area. This knowledge must be provided by researchers and is their duty to demystify that soils are complex and hard to learn about. Forests practices do not have to compromise soil sustainability.

Besides forest operations that have a direct potential to degrade the soil, activities than can indirectly cause soil degradation (e.g. dead wood depletion or silvicultural systems that expose stands to high risk wind damage) must also be controlled through adequate regulations.

Soil protection must be a part of forest planning through:

- Forest management plans
- Operational plans
- Contingency plans

To incorporate soil protection in forest planning, the following information is necessary:

- Distribution of soil type (e.g. from a soil map);
- Identification of soil "limiting factors" and risks analyses (e.g. erosion, compaction and infertility);
- Implications for species choice, site preparation, silvicultural systems, mitigating measures;
- Identification of necessary soil treatment(s), if any (e.g. fertilisers, herbicides);
- Need for soil monitoring and choice of methodology (e.g. management planning documentation, discussions with forest owners and managers, soil sampling plan).

In the UK, soil degradation factors can be divided in major and minor according to their concern (Table 1). This can be used as a checklist and it must be taken into account that factors often act together.

Table 1. Factors of forest soil degradation as classified the UK according to their concern (in alphabetical order).

Major factors	Minor factors
Acidification	Salinization
Contamination	Soil biodiversity loss
Compaction	Soil loss through landslides
Disturbance	Surface sealing
Erosion	
Fertility loss	
Organic matter loss	

In the attempt to reduce soil degradation risk, sustainable forest management must aim to establish the right tree for the right place. This implies examining the relationship between different tree species (including their autoecology and silvicultural systems) and the soils present in the site. The objective is to avoid establishing tree species that, through the rotation, would require soil operations potentially causing soil degradation. Some examples are:

- **Pesticides and fertilisers application**: by establishing tree species adapted to site conditions we can minimise the use of pesticides and fertilisers. In forest contingency plans pests and diseases hazards that depend on sites and soils must be identified.
- **Compaction**: use brash mat wherever there is sufficient material during harvesting and thinning. Choose the most appropriate working method. Monitor operations and modify them or stop if soil degradation occurs. Consider weather conditions.
- How important is to **disturb soil for plantation**? In plantations, is it necessary to disturb the entire site, and how intensively? Aggressive techniques, like ploughing, can lead to soil erosion and compaction. Less aggressive techniques, like disc trenching, mounding and scarification can be used in sensitive soils by choosing appropriate tree species that can be planted using these site preparation techniques.
- **Skidding**: avoid it on soft soils. Forwarding is better and can use the brash mat techniques. On steep slopes, cable crane extraction is the preferred solution.

As soil erosion is mainly done by water, good planning on **ground water management** is crucial. The following measures should be respected:

- Collecting (cross) drains should be installed at a spacing that will control run-off in cultivation channels, including mole channels, e.g. at 40-70 m on slopes less that about 5%.
- Cut-off drains should be provided so that cultivation channels do not carry water from large areas lying above the site.
- Align drains up-valley to maintain an even gradient through their length. Drain gradient should not exceed 3.5% and should be less on easily erodible soils.
- Discharge from a drain should, as far as possible, be on flat ground so that the water can fan out rather than be allowed to emerge I a concentrated flow.
- Never end drains in natural channels, ephemeral streams or old ditches running directly into a watercourse.
- Complimentary, encourage continuous cover silvicultural systems, like shelterwood.

Road construction and maintenance is also a potential factor of soil degradation. The following considerations should be respected:

- Cut slopes greater than 2 to 3 m in height usually require a detailed geotechnical analysis.
- Situations that will warrant more in-depth analysis include: large cuts, cuts with irregular geometry, cuts with varying stratigraphy, cuts with high groundwater or seepage forces, cuts involving soils with questionable strength, cuts in old landslides or in formations known to be susceptible to land sliding.

Information required includes:

- accurate cross sections showing topography;
- proposed grade;
- soil unit profiles;
- unit weight and strength parameters:
- location of the water table and flow characteristics.

Concerning **fertilisation**, the use of fertilisers should be avoided by planting the right tree species on the right site. If fertilisation is required, it has to be planned to avoid water pollution.

Stump removal has enormous impact on soils, through soil and nutrient removal, erosion and soil disturbance. The impacts depend on the type of soil.

Finally, before establishing a forest, we first need to have a soil map, to plant the right tree species on the right soil. It is necessary to proceed to a **constraints and opportunities analysis per area of similar soil type/conditions**. Constraints include:

- soil and water quality preservation;
- wind damage risk;
- archaeology sites presentation;
- environmental preservation;
- public access;
- game management;
- future harvesting;
- and any other possible constraints

From then, the operational plan can be developed. By doing so, it will be possible to prove that sustainable forest management concerning soil is being implemented.

Conclusions about soil protection:

- Forest soils need protection under production forestry.
- Forestry authorities should put in place a range of measures to protect forest soils.
- Technical guidance on soil protection must be developed. This must include input from civil engineering and drainage expertise.
- Knowledge of soil type is essential for effective soil protection.
- Soil protection is best achieved by generating a positive ethos for protection base on an understanding of soil-forest sustainability.
- Nevertheless, good site supervision and inspection (monitoring) are vitals during and after sensitive forest operations. A risk-based approach is useful.

MONITORING

Soil monitoring is important:

- to verify compliance with sustainable forest management or certification;
- to provide basis for management planning and intervention;
- to support foresight and other strategic policy activities;
- to support scientific research;
- for national and international reporting.

Intensive, regular and long term monitoring is the key for providing insight into causes affecting the condition of forest soils and into effects of different degradation factors through time. Soil sampling is a skilled, time-consuming and expensive task. The deeper the sampling is done, the more expensive it is.

Features to monitor include direct and as well as indirect soil measures. International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP) plots (for levels I and II) provide a good manual for soil sampling: especially for chemistry. Physical measurements are less developed, difficult to compare from year to year.

Soil physical properties are no conventionally monitored in a way that facilitates national reporting. The main physical soil property is compaction. Changes in soil bulk density are usually measured on a site-specific basis. Quantitative compaction measurement techniques are sensitive to variations in soil moisture content, complicating comparison of data collected on different dates or in different regions. Current measurements of compaction are based primarily on visual estimates of compacted areas. However, subsurface compaction may not be readily visible to field crews and may be under-reported.

Soils disturbance may be more easily estate through qualitative assessments:

- Undisturbed: litter horizon undisturbed.
- Forest floor disturbance: disturbance of the forest floor, but no exposure of underlying mineral soil.
- Shallow soil disturbance: a) forest floor removed and mineral soil exposed; b) less than 5 cm of mineral soil deposited on forest floor.
- Deep disturbance: a) mixing of mineral soil evident; b) more than 5 cm of mineral soil deposited on forest floor.

Soil chemistry is highly spatially variable in the three dimensions: across the surface and in depth. Very few soil chemistry measurements generate information that can be used actively in forest management. Moreover, chemical values easily change over time and will be dependent upon underlying soil type, nature of silvicultural systems and even pest outbreaks. Moreover, it is difficult to detect a “signal” among the “noise” due to spatial and temporal variation. For these reasons, it is difficult to set a threshold value at which we assume that forest operations are having a negative impact on forest soil and have to be modified.

Alternative to “field-based” soil monitoring include:

- Headline indicators:
    - Area of forest/woodland on specific soil types
    - Area of forest/woodland on brownfield land
    - New planting
    - Area with FSC or other certification
    - Area supported by state management intervention via grants, etc.
    - Areas of forest management as Natura 2000 sites
- Surrogate indicators:
    - Forest productivity by compartment
    - Foliar analysis (for soil fertility)
    - Stream sediment via colour/turbidity (for soil erosion)
    - Forest industry fertiliser and pesticide use (gross quantities)
    - Ground vegetation (indicator species)
- Awareness indicators

  - Uptake of "Forest and Soil Guidelines" and other soil-related publications
  - Number of hits to/downloads from the appropriate website and soil-related material

Conclusions about soil monitoring:

- Forest soil health/condition is best assessed using a combination of traditional chemical and physical measures taken from permanent, unfenced, monitoring plots.
- Organic matter (carbon) content, bulk density, pH or Ca/Al ratio are perhaps the most important measures.
- Due to the complexity of forest soils and ecosystems, interpretation of indicators should be undertaken by forest production and ecosystem scientists familiar with the wide range of services and benefits forests provide.
- Despite the attractiveness of utilising biological component of forest soils as indicators of soil health, they require further development before they can be reliably used.
- Soil indicators developed for other land uses should not be used for forest soils without critical evaluation.

OVERALL CONCLUSIONS

- Promotion of a culture of soil protection as an integral part of sustainable forest management is the best way to minimise damage to soil.
- Many instruments are available but coordination and leadership are essential.
- Most soil damage is preventable and avoided by effective (and modern) forest planning and operation supervision.
- However, a program of repeated soil measurements is expensive and at risk of future closure. Better to embed soil evaluation in existing programs if possible.
- Evaluation of soil information is a skilled task and should be part of an overall assessment of forest health.

QUESTIONS

Using agriculture drainage and scale it up for forestry is not an appropriate practice. The best practice is to use small and localised drainage, and plant tree species that tolerate waterlogged soils.

Using microbes as surrogate of soils health is tricky, as we don't understand soil microbiota well enough. Their conditions can change even if soils conditions are good, e.g. according to tree species, and it is difficult to set a threshold that alert that forest operations have to be changed. Microbiota analysis is also an expensive tool.

Up to which point site preparation is good and when does it start to be harmful? It is not an easy answer and depends on case to case.

Management of the crisis: Recovery programme after severe soil erosion: Lessons learned from the Vale Mouro case

By Henk Feith, Altri, Portugal

Goal

Real case of manging a soil degradation crisis in Portugal.

Content

Context

Altri, a major Portuguese wood pulp producer, has a 670 ha forest estate at Vale de Mouro, central Portugal, dedicated to eucalyptus plantations. A forest fire burnt 290 ha. They were salvage logged the following year. Two years after the fire, soil preparation was done during autumn to renew the plantation. The following winter and spring, very heavy rains fell, causing severe erosion on slopes. Mitigation interventions started in March and lasted more than one year. The affected area was located beside a motorway easily visible, so the company received lots of complains from public. As a result, Altri's FSC certificate was suspended for a long period, thus resulting in negative impacts at commercial level. As organisation, they had to admit that their soil degradation prevention plan did not work well. Public confidence and self-confidence had to be recovered.

What went wrong? A root cause analysis

- Inadequate erosion risk assessment, due to: 1) lack of senior experience in management team, 2) ignorance of previous experiences at the site, 3) insufficient information and management support tools.
- Wrong diagnostics of the current situation: forest managers intentionally undid the previous agricultural terraces to facilitate forest operations. They uniformed the topography and create an even slope. By doing so they deconstructed the soils.
- No measures included to prevent or minimise erosion in case of erosion events.

Undertaken actions

1. **Stabilisation of slopes and prevention of further erosion in short term**: reconstruction of terraces, use of coarse woody debris to stabilise soil, filling up gullies with stumps or other debris to slow down water before it increases gullies size (it is important to slow down water, not to stop it as it would destroy the barriers), use of local available stumps to block gullies (it is not common to construct rock dams), airborne hydroseeding, planting riparian species along streams (willow cuttings).
2. **Prevent re-occurrence**: retain stumps alive in the lower parts of slopes as barriers to sediment transport, retain one line of stumps alive in mid-slope, use chemical stumps removal instead of mechanical removal, us strip harrowing instead of continuous harrowing, reduce soil preparation: soil preparation is done only on the site where each tree is planted,

not on all the surface. Constructions of ponds to buffer streams against heavy rains and naturalise riparian areas that regulate water flow. These measures were kept afterwards and applied to all forest estate.

3. **Increase knowledge on erosion risk assessment**: development and implementation of an operational planning including: 1) acquisition of information on soil characteristics and erosion prediction models to create a soil characteristics maps to assess different areas of soil vulnerability to forest operations; 2) an internal training program for forest operators. Operators must be aware of how sensitive their work is. These measures were kept afterwards and applied to all forest estate.
4. **Stakeholders' engagement**: stakeholders were invited to work on the site. Although that less than 5% of the work was executed by them, it was important to keep in touch with them and make them feel helpful and important. Meetings with stakeholders (including NGO and certification organisation) were held so Altri could know their opinions. Technical discussions took place about what could be done to prevent erosion. Stakeholders were considered as part of the solution, promoting innovative engineering techniques beyond company borders and transferring knowledge.

Lessons learnt

- Insufficient risk assessment can lead to severe soil erosion under adverse circumstances.
- Several initial recovery techniques with natural engineering are very efficient in stopping erosive processes.
- This episode at Vale de Mouro was a turning point in the company's forest policy.

Questions

Reasons for terraces in Portugal: in Portugal, compared to Galicia, eucalyptus is planted in longer growth cycles (several harvestings through coppice system), so terraces, even if they are more expensive than uniform slopes, they can be amortized more easily. Some advantages of terraces are: flat forwarding (preventing gully creation), instead of following the slope, and increased water infiltration. In thin soils, terraces increases soil depth.

Clearcut harvesting hazard: clearcutting poses no hazard in eucalyptus plantations because stumps sprout very quickly to recover the canopy. Even after a forest fire, unless it is very severe, most of the stumps survive and sprout.

Use of eucalyptus bark mulch after harvesting: eucalyptus bark cannot be used as mulch to cover the soil because debarking is done at the mill. Even if no bark spread on site, leaves, branches and tree tops are left on the site to protect the soil. When performing stump harvesting for pulp, only the nucleus of the stump is collected, preserving fine the root system.

Operator training: it was done by bringing classrooms to the forest, with lots of videos to show them good practices.

Rehabilitation: Planning emergency response to reduce post-fire soil erosion risk under oceanic climate

By Professor José Antonio Vega, CIF Lourizán, Spain

Goal

How researchers and forest managers have to interact to produce the best applicable degraded soil rehabilitation practices.

Content

Context

We can imagine that Galicia is free of soil erosion because 66% of the region is forested, because its soils have high content in organic C, conferring soil stability, because vegetation is well developed and features high growth thanks to high rainfall.

However, most flora species in Galicia are adapted to repeated fire: they sprout or regenerate through seed bank. Repeated fires all along quaternary made that 30 to 50 % of organic C content is made out of charcoal. Indeed, there is high fire risk in the region. Up to 48% of ignitions in Spain take place in Galicia, and the forest fires they produce represent 26% of the burnt area in Spain. Because of human activities, the wettest zone of the region is the one with more ignitions. Because of accumulation of fuel in abandoned forests and because of high forest productivity, ground fuel can easily represent more than 20 tons/ha.

So, theoretically, even if there should not be soil erosion in oceanic climates because high forest cover, there is erosion in Galicia due to forest fires. Moreover, soil heating produces soil water repellency, thus increasing water runoff. After fire, emergency soil stabilisation measures are required because high rainfall of this climate.

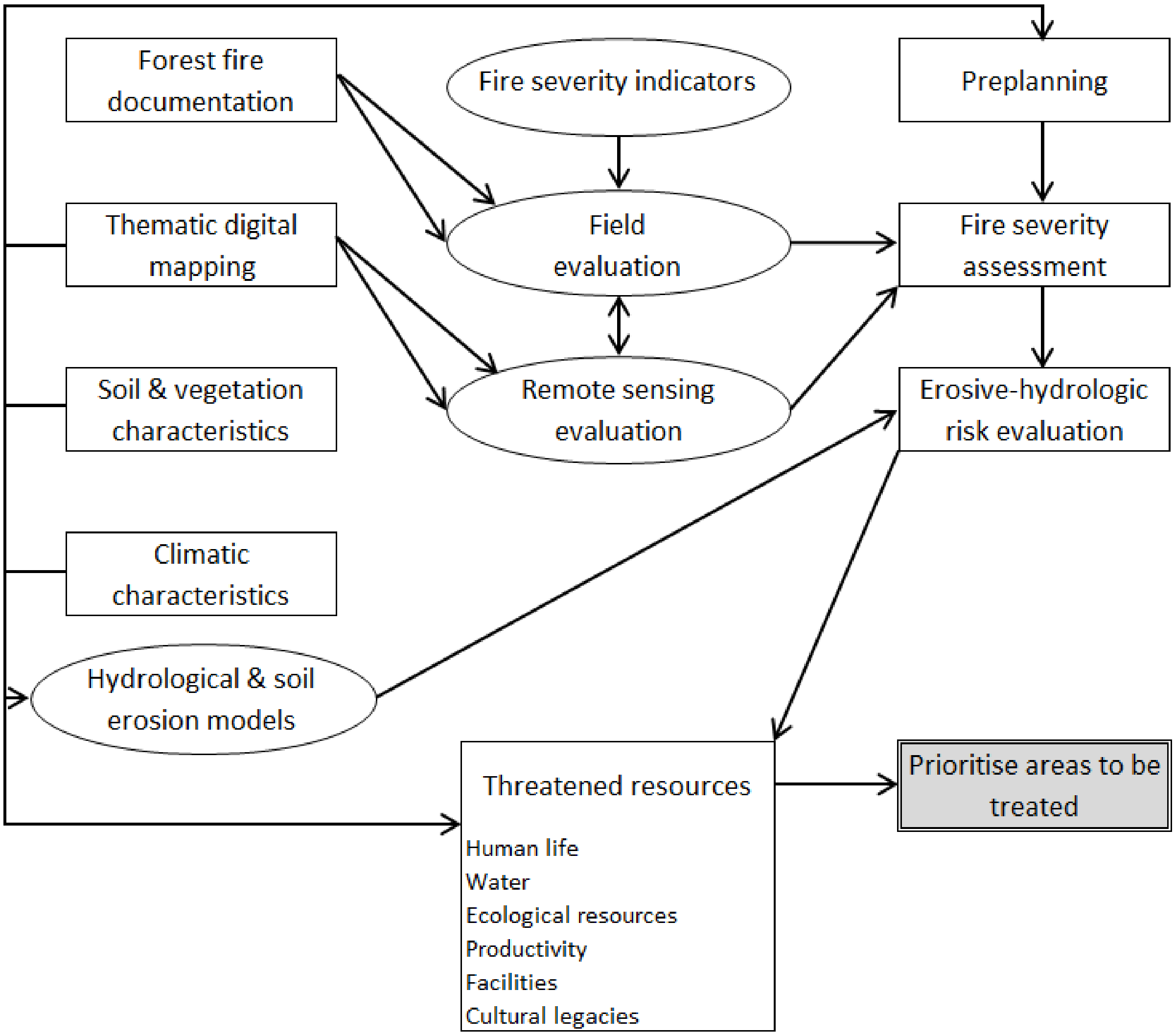
Basic principles of planning emergency response

- The highest priority for human life and safety
- Short response time
- Fast treatments implementation
- Treatments application according to priority
- Action compatible with local resources management plans
- Adequacy to values or resources to protect
- Simple and flexible planning
- Cooperation and coordination with other agencies, entities and owners are critical
- Good communication with groups affected and media

Land managers and researchers have to agree on a protocol and deal with: 1) the perception of the issue, 2) the realism of proposed solution, 3) the timing for rehabilitation actions, 4) the compatibility of soil conservation and resources use.

Steps followed in post-fire emergency stabilisation planning

Fire severity evaluation (within the burnt area) is one of the most critical point as there is short time to intervene after summer fires before autumn rains: the objective is to prioritise areas to be treated, the most sensitive, as it is not feasible to treat the whole burnt area. Fire severity evaluation can be quickly done with aerial photos and remote sensing using drones and satellites. However, it has to be validated on the ground. Organic C content, soil aggregates and water repellence are surrogates of fire severity.



When areas to be treated haven been prioritised, the following question is how to cover their soil as soon as possible, before autumn rain (that produce most of the erosion). Check dams, log barriers and hydroseeding are slow and not efficient. Check dams are costly and do not retain the soil *in situ*. Log barriers are also costly and have low soil retention capacity. Moreover, if not installed properly, they can even increase erosion. Seeding does not fix the soil immediately and can generate competition with local vegetation.

Straw mulch, wood chips mulch, shrub barriers have been tested in risk areas in Galicia after fire. Straw mulch is the most efficient measure: 2.5 to 3.5 tons/ha dramatically reduce soil erosion on the burnt area. This measure is sensitive to slope length, rain intensity and wind. Other techniques can be combined: geotextiles, straw barriers, debris fences, etc. used in targeted places with high erodible potential, like embankments or road margins.

The selection of the mitigation treatment at operational scale depends on:

- Efficiency,
- Site characteristics,
- Cost,
- Logistics,
- Compatibility with resources use.

Monitoring is essential to improve later measures applications.

Salvage logging

When salvage logging after a forest fire there is a trade-off between timber value and soil conservation. This trade-off has to be assessed! Salvage logging could cause soil erosion. Without harvesting, there is nearly no soil erosion if needle cast covers the forest soil.

Soil erosion without mulching is similar with and without salvage logging. Lowest erosion values are achieved by applying mulch when logging, as mulching attenuates the logging effect.

Conclusions

- Impact of climate change: how annual rainfall distribution and intensity shifts will affect soil losses after fire?
- Introduction of uncertainty in the models: spatial probability of high soil burn severity coinciding with post-fire adverse meteorological events occurrence.
- Vulnerability at operational scale appraisal.
- Genetic selection of soil microorganisms to be jointly used with physical treatments to accelerate post-fire recovery.
- How to improve the combination of soil protection and salvage logging.
- Faster and more precise soil burn severity assessment.
- There will be an increasingly pressing need to manage forest fire impact on drinking water quality.

Questions

Adoption of airborne straw mulching: it is difficult to convince forest managers that new techniques to protect soil, like airborne straw mulching, are more useful than business as usual. Straw mulching is very versatile and fast.

Impact of salvage logging (answered by Cristina Fernández and Braulio Molina): salvage logging impact is mainly done on hauling routes. Preventive measures should be applied on them, the rest of the soil being lowly disturbed by harvesting. Cable yarding is not worthy because of high cost. In Galicia, salvage logging is only done by harvester. The distribution and creation of hauling routes are important, as harvesters need larger trails that will be used later by other operations, as forwarding, planting and plantation treatments. If these routes are constructed properly and well drained, it is possible to spread water over the forest soil reducing its erodible impact. Otherwise, water accumulates and generates gullies. In conclusion, it is important to invest in proper and lasting hauling routes when salvage logging.

Conclusions

Wrap up session

Nahia Gartzia, Neiker

Wrap up session was a short summary of the most relevant points of each presentation.

Decisions

No decisions were taken during the workshop.

Workshop evaluation

Questions

Workshop content

	Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
1. I was well informed about the objectives of this workshop and they were clear to me.			5	8		
2. This workshop fulfilled my expectations.			5	8		
3. The content is relevant to my job tasks concerning forest risks management.			6	7		
4. The quality and depth of knowledge of this workshop were appropriate and represented state-of-the-art tools/technologies.			4	9		

Workshop design

	Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
5. The workshop activities/case studies stimulated my learning.			4	9		
6. The activities/case studies in this workshop gave me sufficient practice and feedback.		1	6	6		
7. It was easy for me to understand the messages of the professionals/lecturers, they were good communicators.			3	10		
8. The pace of this workshop was appropriate.			3	10		

Workshop instructor/facilitator/lecturer

	Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
9. The instructor/facilitator/lecturer was well prepared.				13		
10. The instructor/facilitator/lecturer was helpful.				13		

Workshop results

		Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
11.	I accomplished the objectives of this workshop.			7	6		
12.	I would be able to use the tools that I learned in this workshop on my tasks concerning forest risks management.			6	7		
13.	The exchanges with other professionals/instructors/lecturers were fruitful and will be useful for accomplishing my tasks concerning forest risks management.			2	11		

Self-paced delivery

		Strongly disagree	Partially disagree	Partially agree	Strongly agree	Not applicable	No opinion
14.	The workshop was a good way for me to learn its content.			2	11		

Improvements and values

How would you improve this workshop? (Check all that apply)

_6_Provide better information before the workshop.

_3_Clarify the workshop objectives.

___Reduce the content covered in the workshop.

_5_Increase the content covered in the workshop.

_1_Update the content covered in the workshop.

_1_Improve the instructional methods.

_1_Make workshop activities more stimulating.

_2_Improve workshop organization.

_1_Make the workshop less difficult.

___Make the workshop more difficult.

___Slow down the pace of the workshop.

___Speed up the pace of the workshop.

_4_Allot more time for the workshop.

___Shorten the time for the workshop.

___Improve the tests used in the workshop.

_2_Add (more) video to the workshop.

What other improvements would you recommend in this workshop? *The order of the answers is not relevant.*

Reserve more time for participation and allow more discussion among the attendees. Add more issues to discuss given that we have come from far just for one morning. *This improvement has been expressed by 3 participants.*

More involvement from participants, not only questions and debate, but maybe also space for sharing extra relevant information.

What is least valuable about this workshop? *The order of the answers is not relevant.*

No mention.

What is most valuable about this workshop? *The order of the answers is not relevant.*

The diversity of approaches to the topic. *This opinion has been expressed by 2 participants.*
The amount of knowledge of different aspects of soil degradation.
The usefulness of tools described and the results of experiences and cases related to soil degradation.
The Portuguese real case experience.
High quality presentations.
People and knowledge.