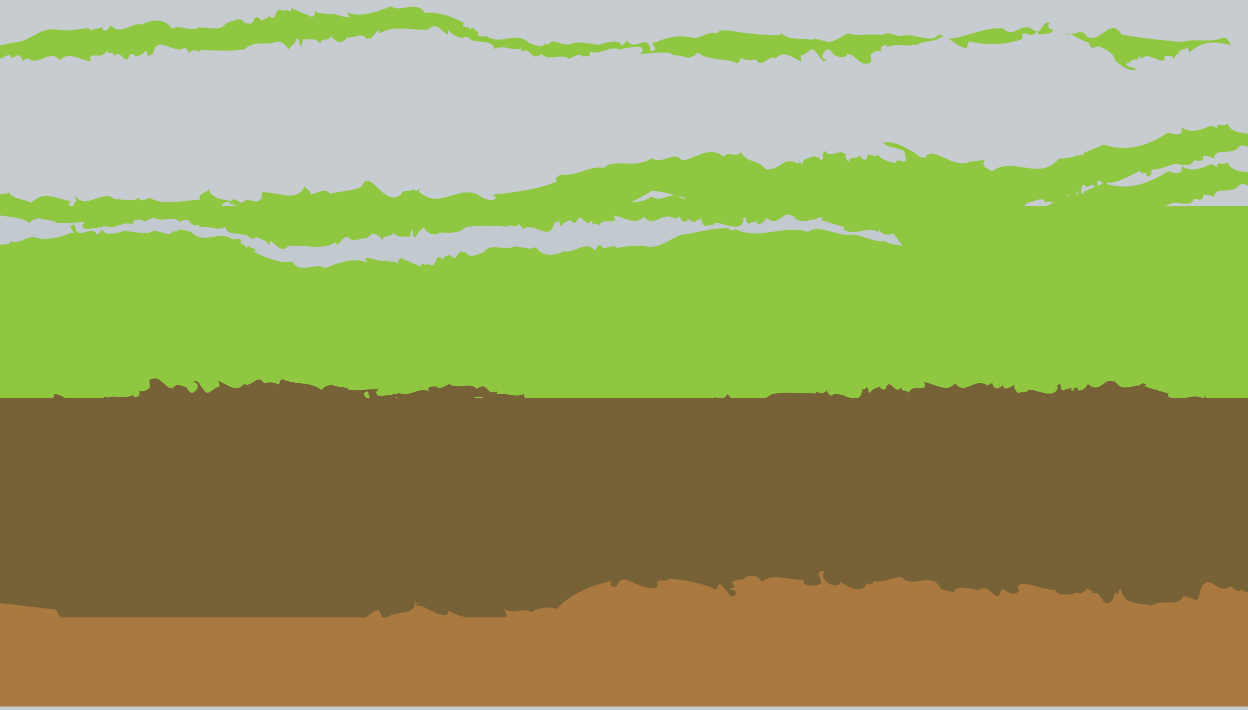
Soil management practices in the Alps

A selection of good practices - Case Study 2



Edited by · Andreja Nève Repe · Aleš Poljanec · Borut Vrščaj

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Editors
Dr. Andreja Nève Repe, Dr. Aleš Poljanec,
Dr. Borut Vrščaj

Reviewers
Dr. Aleš Poljanec, Elena Cocuzza,
Sašo Gorjanc, Elisabeth Schaber,
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Dr. Andreja Nève Repe

Slovenia Forest Service, Office of the Tyrolean Regional Government, Agricultural Institute of Slovenia, University of Innsbruck, Institute of Geography, University of Torino, Department of Agricultural, Forest and Food Sciences

English review
Miha Odar

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CS2.
Preventing hydrogeological risk in Aosta Valley Region, Italy

TiHoDA for Regione Autonoma Valle d'Aosta:
Michele E. D'Amico
Emanuele Pintaldi
Emanuele Sapino
Regione Autonoma Valle d'Aosta:
Evelyne Navillod
Contact:
Evelyne Navillod
+39 165-272643
e.navillod@regione.vda.it

Country, Region: *Italy – Aosta Valley*

Organisation: *Regional administration of Aosta Valley*

Sector: *hydrogeological risk prevention*

Land uses: *agriculture, forest, pasture, urban centres, ski resorts*

Main soil threat: *erosion, loss of soil habitat and biodiversity, loss of fertility*

Key soil ecosystem services: *surface runoff regulation, water filtration and purification*

Summary: *Soils in mountainous regions, such as Aosta Valley, are intrinsically vulnerable and sensitive to degradation processes such as water erosion, shallow landslides and loss of chemical and physical quality. Thus, the integration of knowledge concerning soil that is based on soil maps and soil vulnerability, specific for every environmental condition and type of soil, is necessary for land planning and hydrogeological risk prevention. The main results of the work package (maps showing soil erosion and vulnerability of soil regarding shallow landslides) are shown and explained.*

Keywords: *land planning, RUSLE, shallow landslides, soil erosion*

Background and description of the problem

Following the floods of October 2000, the Region has proved to be vulnerable to different types of natural disasters including shallow landslides affecting the topsoil horizons. Alpine soils are particularly vulnerable to water erosion processes, where the significant amounts of fertile soils are lost. In order to find out more about these issues, several studies have been conducted in the last decade that helped increase the knowledge of the soil properties in the Region, in particular with respect to hydrogeological risk. The purpose of previous studies was to assess the vulnerability of soils to pedo-environmental hazards at the regional level, and the main goal was to provide practical tools to prevent these phenomena from occurring. The obtained information provides an indispensable in-depth analysis to support the preventive action and prevention of disasters, as well as to promote a balanced territorial development. The study aimed at identifying the areas within the regional territory that are most prone to this type of phenomena. The study involved the entire regional territory in order to produce soil vulnerability and soil erosion maps at 1:100,000 scale.

Expected improvements / contribution to better soil management

The main expected impact of the project is raising of awareness on the importance of Alpine soils, not only in the forestry and agricultural sectors, but also in terms of global heritage that is threatened by urban pressures around the inhabited centres. The land conformation, i.e. the narrow central valley with steep lateral slopes, strongly affected the distribution of productive soils.

The management of sludge drainage from hydrogeological reservoirs and the continuous extension of agricultural land is reshaping naturally endangered soil surfaces, which are often covered by materials with poor geotechnical, physical and fertility properties. The development of appropriate soil management techniques should also take into consideration the specific climatic characteristics of the region, which significantly differ between the border areas or the central area (dryer precipitation regimes). Erosion risk should be taken into account.

The report and the map were designed to get better understanding of soil functions, threats and soil ecosystem services and thereby improve land management in the region.

Workshops concerning soil characteristics and vulnerability have been organised, as well as workshops regarding the use of the new maps. The map results that were obtained from scientific data are broadly applicable, understandable and therefore useful for field operatives.

Stakeholders and knowledge transfer

Our main stakeholders are regional administrators in the following sectors:

- Agriculture
- Regional rural development policies
- Agricultural territorial planning and business structures
- Crop productions, quality systems and plant protection products
- Forests and natural resources
- Protected areas
- Forestry and forest roads

- Environment
- Land planning
- Transportation
- Cableways infrastructure
- Civil protection and fire department
- Education, training and research (Institut Agricole Régional)

The following professional members were also identified:

- Architects
- Engineers
- Forest engineers, agronomist
- Geologists

The following Public Administrators of natural parks and protected areas in the regional territory have been identified as stakeholders:

- Gran Paradiso National Park
- Mont Avic Natural Park
- C.E.L.V.A. ("Consorzio degli Enti Locali della Valle d'Aosta") Association of Municipalities of Aosta Valley.

Considering the heterogeneity of stakeholders, in order to overcome differences in attitude, find shared and appropriate solutions and spread the awareness of soils, meetings have been organised during the Links4Soils project. Based on existing environmental data and the recent soil maps (created within the project), soil erosion maps were created, and their use was presented to the stakeholders. In addition, the participants' opinions and suggestions were further used to improve the usability of the new maps and related datasets.

Data and methods

After the collection of all the available soil data and new soil sampling, 712 soil profiles were used to create the soil map (1:100,000), and the subsequent erosion and shallow landslide vulnerability maps.

Six cartographic layers were used for the creation of the soil map (which is the obvious base for erosion risk maps s.l.), and they were provided by the regional administration. In particular, we used the vegetation map ("Carta della Natura"), geological map (1:100,000, modified to better characterise soil parent material lithology), slope steepness, aspect and altitude (derived from the DTM, 10 m) and the spatialisation of measured rainfall data. These data were statistically assembled using a maximum likelihood algorithm to produce the soil type map, where each soil type is characterised by specific chemical, physical and fertility properties, and by specific erodibility and shallow erosion vulnerability. The characterised soil properties included soil morphology, chemical (pH, organic carbon, total nitrogen, carbonates, CSC, Fe and Al), and physical data (texture, index of vulnerability of structure, WAS (Wet Aggregate Stability), Atterberg limits.

The RUSLE equation was then applied (Renard et al. 1997), in which soil erosion (A, t ha^{-1} $year^{-1}$) is the product of rainfall erosivity (R), soil erodibility factor (K), land cover protective action factor (C), slope steepness and length (LS) factor and protective infrastructures factor (P, normally not considered at 1:100,000 or larger scales):

$$A = R * K * C * LS * P$$

Soil erodibility, in particular, is related to soil structure, organic matter content and soil texture, and it is thus easily derived from the soil type map. In this case, we considered A as potential erosion, since humus types on the surface are not considered in the RUSLE equation and are only partially included in the C factor. Therefore, we added an expert-based classification of the H factor, differentially reducing the actual erosion under natural vegetation according to the humus form, considering that the presence of OH organic horizons requires many decades to form and they have a highly protective effect on the underlying mineral soil.

All soil profile properties have also been correlated with WAS and Atterberg limits that are available for a more limited number of sites; moreover, the frequency of shallow landslides of 16 soil types has been calculated in order to improve the existing shallow landslide susceptibility map.

Results

The soil type map of the entire Aosta Valley region has been created (1:100,000, Fig. 4).

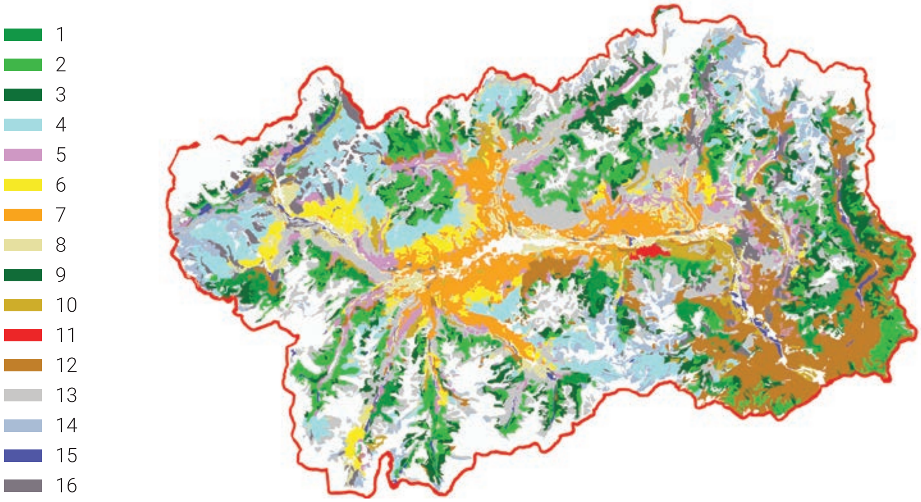

Figure 4: The soil map of the Aosta Valley Region; the 16 soil types are explained in Table 1.

As a first derivation, the soil erodibility map (K value in the RUSLE model, 1:100,000, Fig. 5) and the soil erosion map (t/ha/year, 1:100,000, Fig. 6) were created.

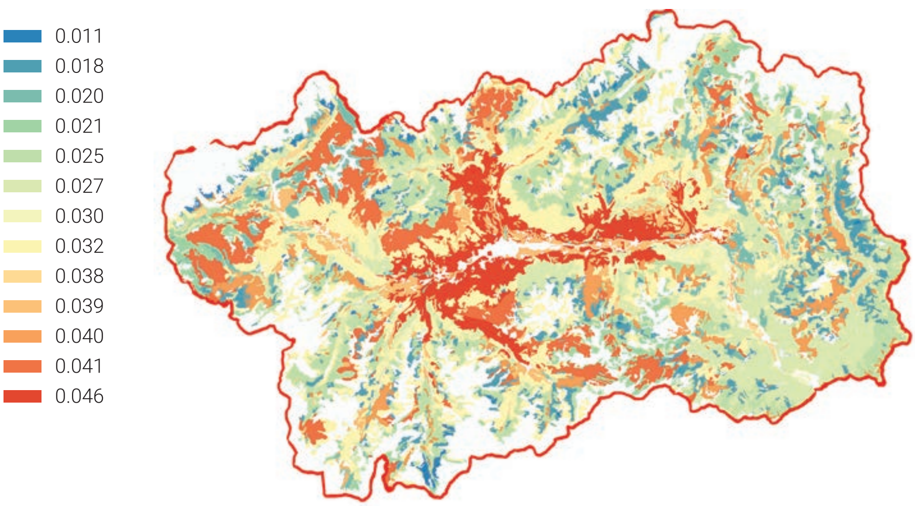

Figure 5: K (erodibility) factor calculated for the 16 soil types (t ha $MJ^{-1}mm^{-1}$); the soils developed in the most xeric area are most susceptible to erosion, followed by high altitude soils on calcschists.

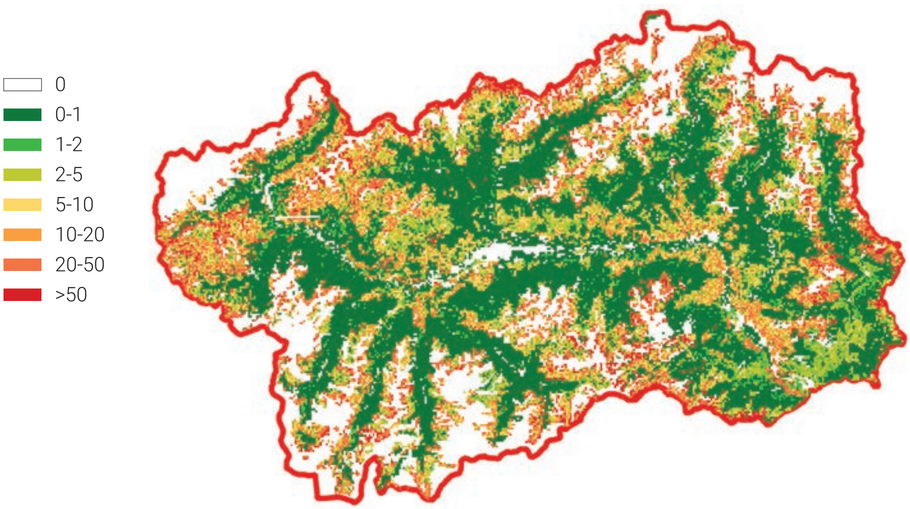

Figure 6: Soil erosion values in the Aosta Valley Region (t ha^{-1} y^{-1}).

The density of shallow landslides (Fig. 7) basically follows the K factor map evidencing an intrinsic weakness of the soils developed in the inner Alpine area that is related to a less developed surface structure and degree of weathering in the subsoil, which also have a quite good correlation with the Atterberg Liquid Limit (not shown).

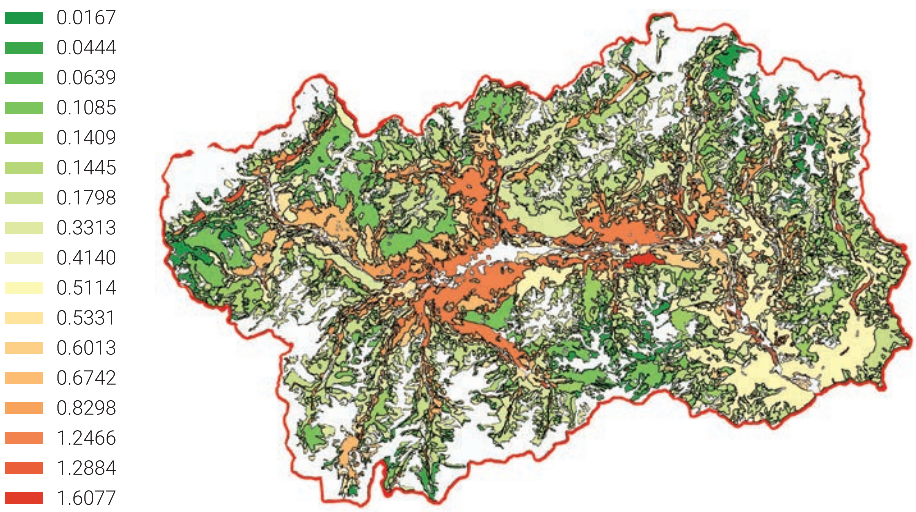

Figure 7: The density of shallow landslides in the different soil types (N km^{-2}).

Table 1: Soil type classification, erodibility and main erodibility factors in topsoil mineral horizon

SOIL TYPE	WRB2015	K	MAIN SOIL ERODIBILITY FACTORS
1	Albic Podzol	0.040	Lack of structure, texture
2	Skeletic Entic Podzol	0.025	Weak structure
3	Umbric Entic Podzol	0.011	Texture
4	Dystric Cambisol (Protospodic, Arenic; Alpine grassland on calcschists)	0.041	Lack of structure, texture
5	Haplic/Cambic/Gleyic Phaeozem	0.027	Texture, occasional loose consistence
6	Haplic Kastanozem	0.032	Loose consistence
7	Petric/Haplic Calcisol	0.046	Lack of structure, little TOC, loose consistence
8	Calcaric Regosol	0.039	Lack of structure, little TOC, loose consistence
9	Haplic Umbrisol	0.018	Texture
10	Eutric Cambisol	0.030	Texture, thin A horizon
11	Hypocalcic Rhodic Cambisol	0.046	Texture, lack of structure, thin organic horizons
12	Dystric Cambisol	0.027	Texture, thin A horizon
13	Hyperskeletic/Skeletic Regosol	0.032	Weak structure, little TOC, loose consistence
14	Skeletic Eutric Regosol (Turbic)	0.021	Little TOC, cryoturbation
15	Fluvisol	0.038	Weak structure, little TOC, loose consistence
16	Skeletic Dystric Leptosol	0.020	Shallowness

In the central part of the region, change of land use from natural vegetation to cultivation that implies the removal of the organic layer and topsoil reworking should be considered carefully, particularly on soil types 6 (Fig.8), 7, 16. The removal of natural vegetation, particularly of the protective shrub layer and of the litter layer should also be avoided on soil type 3 (Fig. 9), during forestry operations or, above treeline, because of intense grazing.

Overgrazing should be avoided, particularly on Alpine grasslands on calcschists, on the soil type 1, which has a surface mineral horizon characterised by an extremely weak structure and high erodibility when exposed to rainfall and runoff without the protective effect of the thin organic horizons. One peculiarity of soil types 4, 13 and 14 is the large carbon stock included in the mineral horizons, caused by grassland vegetation characterising the soil cover. Therefore, preservation of pastures and grasslands is important to preserve the large C content and limit CO_2 emissions.

In the stakeholder meetings, specific types of management to be considered when working on soils have been shown.

Transferability and applicability to best soil management practice

The soil map approach, with derived maps regarding erosion, soil functions etc., is applicable to any context in mountainous environments and can be calibrated in relation to the environmental specificity.

However, the method is widely applicable only for the areas where soil maps exist and the basic data for soil types are available. Such maps are an important basis for better decision-making at local level and can thereby improve land planning and agro-forestry heritage management, allowing a better soil protection which is especially important in mountainous areas.

Environmental and climate change impact

In general, mountain soils evolve slowly because low temperatures and erosion-related processes limit their formation and evolution. They are also highly diverse and vary significantly within limited areas due to different exposure and steepness. With increased elevation, they usually become less productive and developed. Mountain soils are frequently less productive than plain soils and agricultural activities are more difficult, as well as less productive. To better exploit the surfaces on steep slopes, farmers build terraces and other structures to limit erosion and land degradation. Their evolution is a product of unstable and delicate equilibrium between formation and erosion processes and time. On steep slopes, soil can be eroded and transported away very easily, particularly under increased rainfall erodibility which is likely one of the effects of climate change in Alpine regions. A correct soil management is therefore required.

Photos / illustrations / maps

Figure 8: A common soil in the inner Alpine area of the Region: soil type 6, characterised by $CaCO_3$ accumulation in the deep subsoil but with a very weakly developed structure and loose consistence, extremely vulnerable to all kinds of erosive processes. Pont d'Aël, Cogne Valley *(Photo: M. D'Amico).*

Figure 9: A common soil under subalpine forest or heathland, soil type 3 (Albic Podzol). The light E horizon below the dark organic layers is loose, structureless and sandy and, thus, sensitive to erosion. In Valsavaranche, past grazing activities probably caused the disruption of the heath vege-tation and the removal of organic horizons, causing the widespread soil slips and erosion of the E horizon.

References and further reading

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Caring for Soils
- Where Our Roots Grow