
Linking Soil Ecosystem Services to Soil Data

Report D.T.1.3.2: Concept development of linking Alpine soil information, soil ecosystem services and ecosystem management





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D.T1.3.2 Modular Concept development of linking Alpine soil information, ecosystem services and ecosystem management consists of:

- D.T.1.3.2: Concept development of linking Alpine soil information, soil ecosystem services and ecosystem management – a report
- D.T.1.3.2: LinkingSES2SoilData_Tool.xlsx –a MS Excel application

Authors:

Dr Borut Vrščaj, Agricultural Institute of Slovenia, Department for Agroecology and Natural Resources

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www.

info@AlpineSoils.eu

Summary

The Ecosystem Services (ES), a decade ago a research subject within the scientific community, are nowadays commonly addressed and discussed in administration at all levels, nature protection organizations, local communities as well as general public. They became a kind of flagship towards protection of natural resources, nature conservation, sustainable development and environmental management.

At the same time, an important part, and, if we can afford a biased opinion, the most significant part of ecosystem services, are overlooked. Here we are discussing ecosystem services provided by soil - soil ecosystem services (SES). Not sufficiently recognised in the past, the soil is nowadays becoming equally important to air, water and biodiversity. By this, the sustainable management and development implicitly encompass sound soil management and protection.

Decisions related to environment protection / or soil management largely happen in administration of local communities (municipalities) or regional governments. Public administrations frequently face difficulties and ask questions how to safeguard soils, how to manage them properly, and especially, which ecosystem services can manage, which should be safeguarded and protected; how to do that; which are required soil management practices that keep important soil properties in good state; what measured soil parameters should be analysed and monitored.

This report presents the conceptual method of linking soil ecosystem services, management practices, soil properties and measured data. The concept largely utilizes soil expert knowledge. Once the soil parameters are set and adapted to local conditions and natural setting by a soil expert the method can be used by decision makers. The method implemented in a spread-sheet tool offers users to identify essential soil ecosystem services that should be tackled in individual sector, related sectoral sustainable soil management practices, which are important soil properties to assess and what measured soil data to provide/monitor are.

Altogether, this report presents the conceptual linking soil ecosystem services to soil management practices, and identification of soil data required for monitoring and implementation of soil management measures. The concept of the method is embedded in an automatized spreadsheet tool, which allows users to select soil ecosystem service and instantly visualize relevant soil management practices, related soil properties and soil data to collect

By this, the method and the tool are useful for planning soil protection activities and decisions for safeguarding soil ecosystem services at the local/municipal level.

Info box

Did you know?

The soil enables life on dry land – the primary human living environment.

The soil and the ecosystem services provided by soil are vital for life on dry land as well as human survival and well-being.

There is no sustainable development and environment protection without the proper management and protection of soil.

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Background and Introduction

1.1 Report goals

The primary goal of this report is to present the concept of linking soil ecosystem services and soil threats to soil protection and sustainable soil management and protection, soil properties and required soil data/information.

An additional purpose of this report is to make the reader aware that soil provides an important number of essential ecosystem services.

1 Ecosystem Services vs Soil Ecosystem Services

1.1 Ecosystem services (ES)

The Ecosystem Services (ES), nowadays a commonly used term, attract the attention of modern humans and promotes consideration of the benefits that the environment provides to them. The ecosystem services are the various benefits that humans in one way or another obtain from nature or, better stated, from ecosystems (Burkhard et al., 2014; Daily, 1997; de Groot, 2013; “TEEB,” 2015; “What is natural capital?,” 2017; Millennium Ecosystem Assessment, 2005; UNEP, 2016).

The first and some of the frequently mentioned and essential ecosystem services are provisioning services. Food for humans and fodder for domestic animals; different kinds of biomass and raw materials such as wood for heating or furniture; and medicinal plants as well as other provisioning-type ecosystem services, are apparent and well recognized.

The second group of ecosystem services, indeed much less recognized but somehow evident to modern humans, **are supporting and regulating ecosystem services.** The most important of these are Plant nutrient cycling, habitats for plants and animals, primary plant growth (primary production), below and above ground biodiversity, cleaning water such that it becomes potable, atmospheric CO₂ greenhouse gas sequestration on the soil in the form of soil organic matter, and many others, are examples of supporting services that make the ecosystem function.

The third group of soil ecosystem services are related to immaterial human needs. We much appreciate nature, the beauties of natural and cultural landscapes, and scenic natural environments and phenomena. These services satisfy the cultural, spiritual, scientific, and recreational needs of humans. They are not fundamental in terms of survival but largely contribute to physical and mental health and well-being. Ecosystem services are numerous, some obvious and well known, while others are hidden and not widely acknowledged.

1.2 Introduction to the soil ecosystem services (SES)

Besides air and water, the soil is the third fundamental ecosystem component that, in reality, enables life on dry land – the primary human living environment. For this reason, the soil needs to be better evaluated in terms of value and services provided to humans.

About 95 % of our food comes from the soil; soil filters and cleans water until it becomes potable, it cycles plant nutrients, stores carbon in soil organic matter, and preserves the remains of ancient civilizations. Soil acts as a gene pool by hosting a myriad of incredibly diverse, tiny, but useful organisms. Besides the biodiversity in soil, it defines the aboveground biodiversity – different plant communities and fascinating wildlife (Geitner and Freppaz, 2019). Many other soil ecosystem services could be discussed here.

Due to the importance of soil form terrestrial environment, the evaluation and assessment of general ecosystem services are not sufficient to successfully steer and adapt activities and development to meet sustainable goals. For human wellbeing and ecosystem health and wellbeing the question how much and to what extent soils contribute to the provision of various ecosystem services – soil ecosystem services is of particular importance.

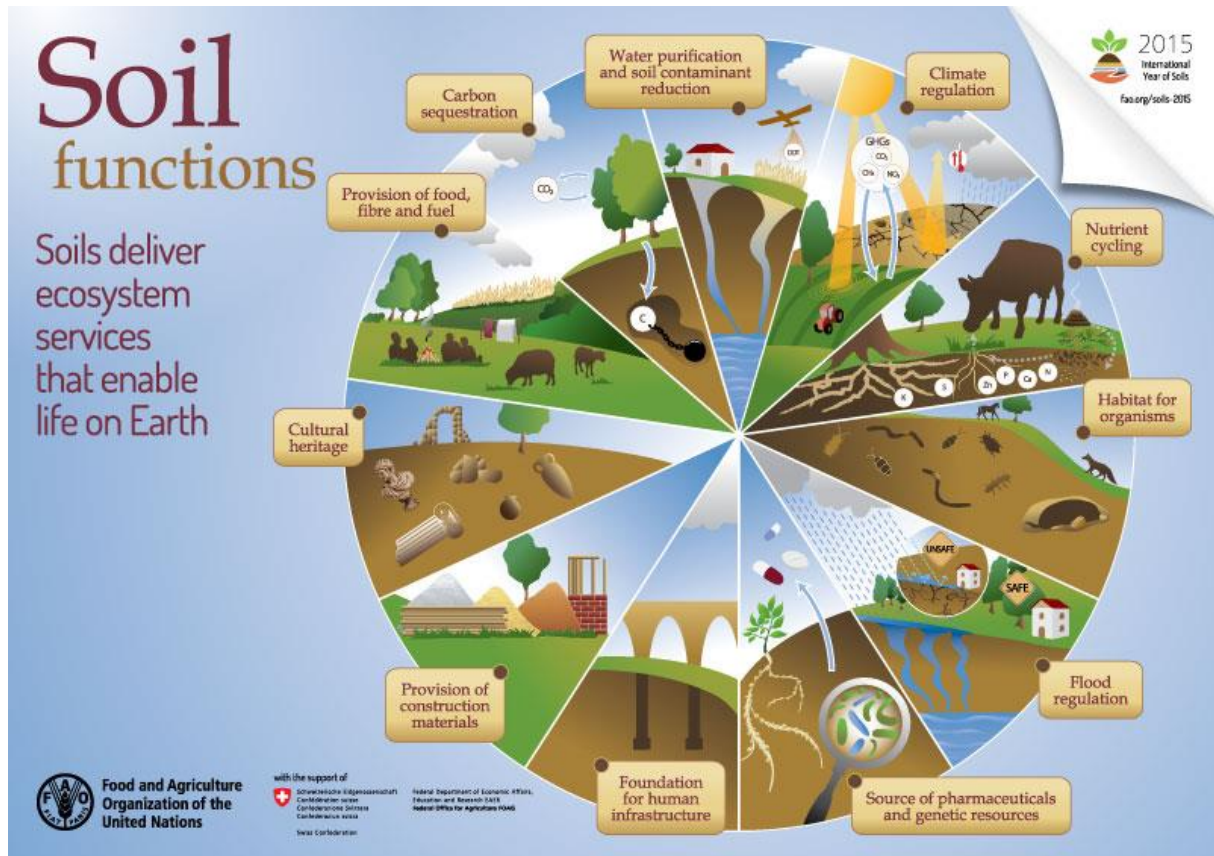


Figure 1: Soil functions / soil ecosystem services as interpreted by the Food and Agriculture Organization of the United Nations. (FAO, 2015)

What is important to know is that the soil and the ecosystem services provided by soil are vital for life on dry land as well as human survival and well-being. This is why we need to protect and adequately manage soils to be able to provide soil ecosystem services to satisfy diverse social activities and sectors for recent and future generations.

Soil ecosystem services are essential. Soil protection and sustainable management of soil, as well as other natural resources, is in particular important not because of the soils themselves, but because of the provision of soil ecosystem services.

In general, it is possible to declare that there can be no sustainable development and environment protection without the proper management and protection of soil.

2 Soil Ecosystem Services for Decision-makers

2.1 Sectors, sectoral responsibilities and needs

An important number of primary and secondary role/responsibilities of an individual sector can be directly or indirectly related to soil quality / soil suitability. The Table 1 provides a list of sectors and their primary and secondary role.

Table 1: List of sectors/industries and their primary/secondary role

Sector	Primary role	Secondary role
Agriculture	Production of food, fodder, medicinal plants, technical fibre, and materials and other biomass.	Management of cultural landscapes. Ground water protection. Erosion prevention. Carbon sequestration. Prevention of spontaneous afforestation.
Forestry	Production of wood and timber and other forestry biomass.	Ground water protection. Wildlife management. Flood and erosion protection. Nature conservation and biodiversity protection. Carbon sequestration.
Planning	Harmonising societal needs for space for construction of buildings and infrastructure. Regulating and providing physical space for construction.	Management of cultural and urban landscapes. Management of ecological and human well-being in urban environments.
Nature disaster prevention	Prevention of natural disasters and mitigation of consequences of disaster events.	Management of natural and cultural landscapes. Steering societal need towards safety against natural or human-induced disaster.
Sports and tourism	Providing facilities, organizing activities, building and maintaining infrastructure for human sports and leisure, cultural and spiritual needs.	Management of natural and cultural landscapes. Protection of natural phenomena and biodiversity.
Nature and biodiversity protection	Preservation of rare, endemic and otherwise important species. Protection and safeguarding biodiversity in nature-protection areas and open space.	Wildlife management. Management of natural areas and landscapes. Carbon sequestration in bogs.

2.2 Soil Ecosystem Services for Decision-makers

The decision-makers, experts, and practitioners in different sectors (those listed in Table 1 and others) are bind to sustainable development, management and use of natural resources, as well as environment and nature protection.

To achieve this, sectoral activities have to carry out in the way that minimizes impacts that would decrease or in any way hamper natural resources and the capacity of soils to provide soil ecosystem services. In other words, in all sectors, the activities have to be adjusted to protect the provision of soil ecosystem services.

In this report, we focus on the SES presented in the book *“Soil Ecosystem services in Alps – An introduction for decision-makers.”*

2.3 Soil ecosystem services are rather abstract to decision makers

Significant literature and media sources discuss ecosystem services nowadays, yet the soil ecosystem services remain unrecognised or poorly explained and rather abstract to end-users. Decision makers are often not sure:

- Which soil ecosystem services are primary within a sectoral land use?
- Which soil ecosystem services are important for a sector?
- Which soil properties are relevant for certain soil ecosystem service? and
- What data is needed to assess soil quality and the capacity of soil to provide soil ecosystem services?

Sectoral priorities (such as food production in agriculture, timber in forestry, etc.) largely steer the prioritization and importance of individual soil ecosystem services in each individual sector.

3 Soil ecosystem services and sectors

3.1 Selection and definition of SES in the Links4Soils project

Although very similar, the descriptions of ecosystem services in various reports (EEA, 2012; Millennium Ecosystem Assessment, 2005; UNEP, 2016) and scientific literature (Bo Jellesmark Thorsen et al., 2014; Daily, 1997; Fisher and Kerry Turner, 2008; Lamarque et al., 2011; Wallace, 2008, 2007).

Similarly to the ES, the description and interpretation of SES differ in scientific and public sources, mainly scientific articles (Baveye et al., 2016; Blouin et al., 2013; Jónsson and Davíðsdóttir, 2016; Kapur and Erşahin, 2014; Samarasinghe et al., 2013), and selected soil awareness-raising publications (Vrščaj, 2018).

In the Links4Soils project, the project partners decided to address primarily the soil ecosystem services that are described and illustrated in the book “**Soil Ecosystem services in Alps – An introduction for decision-makers** (Geitner et al., 2019). The book focuses on the following SES:

- **Agricultural biomass production** which refers to the production of plants for food, fodder, and technical fibres, as well as medicinal plants and plant biomass for (green) energy production ;)
- **Forest biomass production.** The forest biomass production refers to the production of biomass from forests. Besides wood and timber, forest-derived edible products can also be considered.);
- **Water retention** tackles the ability of soils to retain, store, and gradually release water for plant uptake: upwards for evaporation from the soil surface, as well as downwards percolation to replenish groundwater.
- **Surface runoff regulation** focuses on the surface runoff reduction through the water infiltration in soil - uptake of water from rain, snowmelt, or flooding.
- **Local climate regulation (“the cooling effect”).** This SES refers to the air-cooling effect of soil-vegetation complexes due to transpiration and evaporation.
- **Global climate regulation (“the carbon cycle”).** refers to the ability of soil to store (sequester terrestrial carbon (C) storage, and by this, regulate climate and mitigate climate change on a global scale.
- **Water filtration and purification** stand for the ability for water filtration and purification. It refers to the filtering of solid particles and retaining, degrading, and changing pollutants from water percolating through the soil. The result is clean ground and spring water that is fit for a specific use, e.g. for human consumption as drinking water.
- **Nutrient cycle regulation.** This SES is about the nutrient cycle regulation - i.a. - the storage, exchange, and cycling of macro- and micronutrients and other elements with plants. The nutrient cycling soil ecosystem service stands for several fundamental processes in the soil such as nitrogen fixation, phosphorus supply, and litter decomposition and mineralization.
- **Soil habitat and biodiversity.** This SES refers to the ability of soils to provide an environment for many diverse organisms, where they can live and grow. There is a

vast variability among soil organisms. It ranges from microorganisms (e.g. bacteria, protozoa), which are not visible to the naked eye, to mesofauna (e.g. collembola), and macro-fauna (e.g. earthworms, insects).

- **Cultural and natural archives** refer to the ability of soils to preserve particular nature- or culture-related evidence that is invaluable as heritage. This also covers the existence of rare soils, as they allow the derivation of unique natural or cultural soil-forming conditions.
- **Recreational and spiritual services.** Soil can serve as a ground for outdoor sports and tourism, enabling a wide range of activities and providing cultural, spiritual, religious, and aesthetic experiences.

Not all soil ecosystem services can be easily measured or in some cases measured at all. For instance, the *Recreational and spiritual services* are highly subjective, and therefore, the evaluation and measurement approached highly differ and change in time and location. Table 2 presents the selected SES and related status – measured or note easily measured soil properties. The general interpretation of the measurement status in Table 2 suits the purpose of this report and can be different in other uses.

Table 2: Soil ecosystem services

Soil ecosystem service	Measurement status
Agricultural biomass production	P
Forest biomass production	P
Water retention	S
Surface runoff regulation	I
Local climate regulation ("the cooling effect")	I
Global climate regulation ("the carbon cycle")	I
Water filtration and purification	I, S
Nutrient cycle regulation	S
Soil Habitat and Biodiversity	O
Cultural and natural archives	N
Recreational and spiritual services	N

Legend: Measurement status

P – Easily measurable by-product (e.g. crop yield/timber biomass)

S – Directly measured soil properties or parameters

I – Inferable from measured soil properties

O – Field observations, field and laboratory measurements

N – SES allows varies interpretation and is practically ‘not’ measurable

3.2 Setting role and priorities of sectors vs soil ecosystem services

Primary role or responsibility as the task of each sector (agriculture, forestry, spatial planning, environment protection, etc.) is to satisfy specific human and environmental needs to provide a particular service.

Depending on the primary role/responsibility of sector, the sectoral use/exploitation of soils and the impact on the soils as a natural resource are different. Concerning the main sectoral output, each sector has different/specific priorities and consequently needs and requirements in relation to natural resources and therefore tackles soil ecosystem services in a different manner and extent.

3.2.1 Sectors and their primary role

Each sector has its own primary role as well as the secondary role/responsibility.

The primary role/responsibility of the sector is to satisfy basic human or environmental needs related to or expected from the sector.

The secondary needs and responsibilities, sometimes even equally important role, are to satisfy additional requirements that are related to (or provided by) the land possessed by the sector.

For example:

Agriculture:

The primary responsibility of the agricultural sector is the production of food/fodder or any other agricultural biomass.

The secondary responsibility is maintaining landscape biodiversity, soil biodiversity, and cultural landscapes.

Therefore, the sectors are responsible for providing specific outputs to humans within the extent of the land dedicated to the sector.

3.2.2 Sectors and dedicated land uses

Each sector has its own land use:

Agriculture: agricultural land such as fields, meadows, vineyards, orchards, and specific crops (such as hops), etc.

Forestry: productive forests, protection forests (floods, landslides, erosion), protected natural forests often in a pristine condition (biodiversity protection), etc.

3.3 Prioritization of soil ecosystem services by sector

3.3.1 *Soil Ecosystem Services in Agriculture*

Essential soil ecosystem services tackled in the sector:

Primary SES in the agricultural sector

- Agricultural biomass production

Secondary SES

- Water retention
- Nutrient cycle regulation
- Surface runoff regulation
- Water filtration and purification
- Global climate regulation (“the carbon cycle”)
- Local climate regulation (“the cooling effect”)
- Soil habitat and biodiversity

Marginal, location-specific or subjective soil ecosystem services under agricultural land use are:

- Cultural and natural archives
- Recreational and spiritual services

Soil ecosystem services not applicable / excluding by the land use:

- Forest biomass production

3.3.2 *Soil Ecosystem Services in Forestry*

Primary SES in the forestry sector

- Forest biomass production

Secondary SES

- Water retention
- Surface runoff regulation
- Water filtration and purification
- Global climate regulation (“the carbon cycle”)
- Local climate regulation (“the cooling effect”)
- Soil Habitat and Biodiversity
- Nutrient cycle regulation
- Recreational and spiritual services

Marginal or subjective

- Cultural and natural archives

Not applicable: Agricultural biomass production

3.3.3 Soil Ecosystem Services in Planning and Urban management (housing, infrastructure)

Primary SES

The following SES are obvious not listed in the Table 2:

- *Providing physical space for housing and infrastructure;*
- *Soil as a support /fundament for buildings and other infrastructure*

Secondary SES in the sector

- Surface runoff regulation
- Local climate regulation (“the cooling effect”)
- Water filtration and purification
- Recreational and spiritual services
- Cultural and natural archives

Marginal or subjective

- Agricultural biomass production
- Soil Habitat and Biodiversity
- Water retention
- Global climate regulation (“the carbon cycle”)
- Forest biomass production
- Nutrient cycle regulation

3.3.4 Soil Ecosystem Services in the Nature Disaster Prevention Sector

Primary SES:

- Surface runoff regulation

Secondary SES:

- Water filtration and purification
- Water retention

Marginal or subjective

- Global climate regulation (“the carbon cycle”)
- Local climate regulation (“the cooling effect”)
- Cultural and natural archives
- Forest biomass production
- Agricultural biomass production
- Soil Habitat and Biodiversity
- Nutrient cycle regulation

Not applicable:

- Recreational and spiritual services

Not applicable: <none>

3.3.5 Soil Ecosystem Services in Nature Protection Sector

Primary SES in the sector

- Soil Habitat and Biodiversity

Secondary SES in the sector

- Cultural and natural archives
- Recreational and spiritual services

Marginal or subjective

- Water retention
- Surface runoff regulation
- Water filtration and purification
- Global climate regulation (“the carbon cycle”)
- Local climate regulation (“the cooling effect”)
- Nutrient cycle regulation
- Agricultural biomass production
- Forest biomass production

Not applicable: <none>

3.3.6 Soil Ecosystem Services in Sports and Tourism Sector

Primary SES in the sector

- Soil Habitat and Biodiversity

Secondary SES in the sector

- Cultural and natural archives
- Recreational and spiritual services

Marginal or subjective

- Water retention
- Surface runoff regulation
- Water filtration and purification
- Global climate regulation (“the carbon cycle”)
- Local climate regulation (“the cooling effect”)
- Nutrient cycle regulation
- Agricultural biomass production
- Forest biomass production

Not applicable: <none>

3.4 Linking soil ecosystem services and soil threats to soil properties and measured soil data/observations

Each soil ecosystem service can be linked in several steps to the measured soil data or field observations and information. The linking process is primarily based on the following postulates:

1. **The capacity of soil to provide individual soil ecosystem service depends on soil properties.** They can be relatively simple (e.g. acidity, etc.) or complex (e.g. soil fertility, filtering capacities, soil water holding capacity, etc.)
2. **Individual soil properties are assessed based on soil parameters** (e.g. topsoil pH value, concentrations of the main nutrient in topsoil (i.a. Nitrogen, Phosphorus, Potassium, Boron, etc.) soil texture, electrical conductivity, bulk density, soil structure, porosity, and others.
3. Individual soil parameters are measured, inferred, estimated or assessed from measurements - laboratory data and/or field observation.

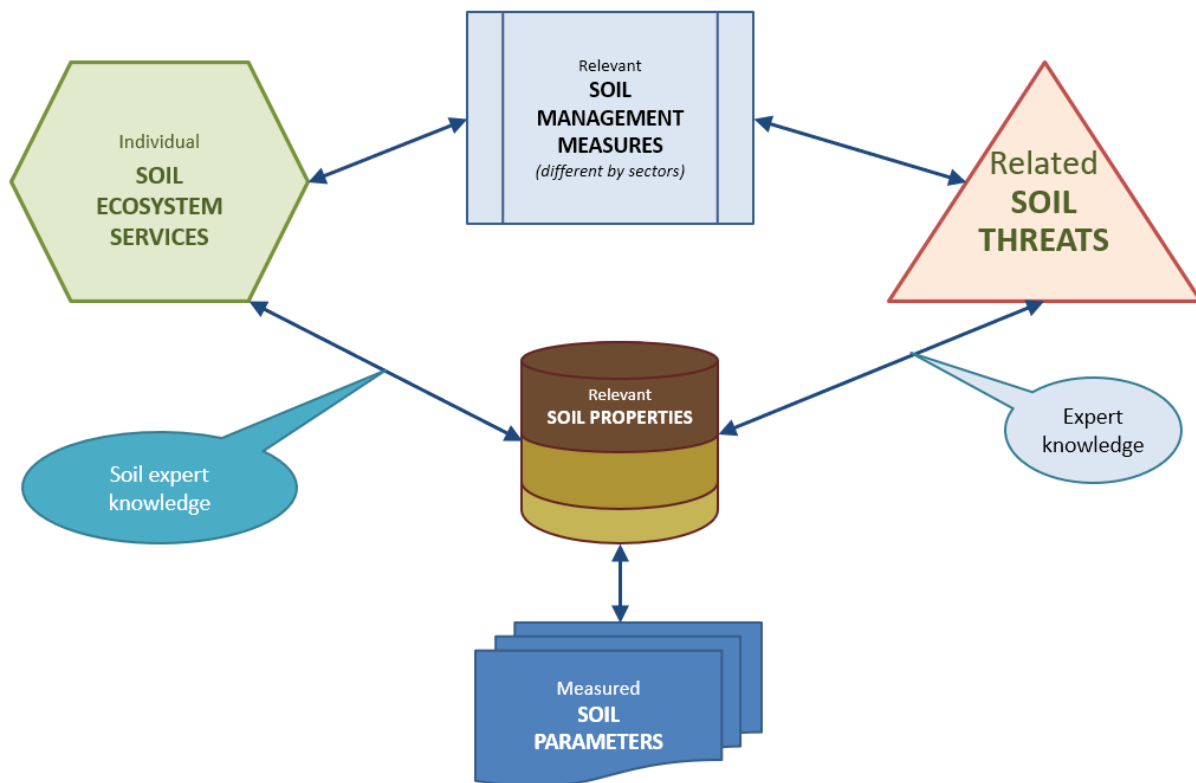


Figure 2: Relationship between soil ecosystem services, soil properties, soil parameters and measurements/observations.

3.5 Linking measured soil data properties to assess soil ecosystem services and soil threats

The idea of linking soil ecosystem services relevant for the sector is carried out in 5 steps

Selection of valuable soil ecosystem service appropriate/necessary for sustainable soil management in the sector:

1. Selection of the sector
2. Identification of soil ecosystem service from the list of primary/secondary soil ecosystem service
3. Identification of one or more relevant soil management practice or measures
4. Identification of soil properties that are evaluated to carry out the SES
5. Selection of measured soil data
6. Design the monitoring / data collection

4 Results

4.1 The 'SoilData2SES' MS Excel tool

Linking soil ecosystem service to soil management measures, soil properties and soil data is a decision-making process based on expert knowledge. The soil expert knowledge is, unfortunately, often not available when decisions related to sustainable management and protection of soil have to be made.

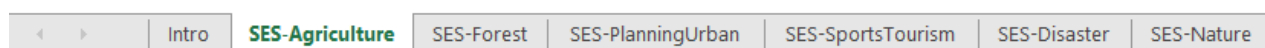
The *Concept of linking of soil ecosystem services and sustainable management of soil resources* was developed, and tested in the MS Excel tool (Vrščaj, 2017).

The MS Excel spreadsheet tool offers to assess soil ecosystem services data and management for six sectors/land uses:

- Agriculture
- Forestry
- Planning and urban management
- Sports and tourism
- Nature disaster prevention and mitigation
- Nature and biodiversity protection

Each land use/sector has its own sheet: SES-Agriculture, SES-Forest, SES-PlaningUrban, SES-SportsTourism, SES-Disaster and SES-Nature.

In the continuation the structure and the tool workflow is explained using the sheet SES-Agriculture as an example.



4.1.1 The composition of individual sheet

Each sheet is divided in two parts:

A) The upper part presents key soil ecosystem services relevant for the sector (left) and soil threats (Figure 3). The priority of SES for given sector is illustrated with the polar plot chart.

In addition, the most frequent/serious and to a certain extent expected soil threats that may occur in within the sectoral land use are listed on the right and frequency/importance is illustrated with the polar plot chart.

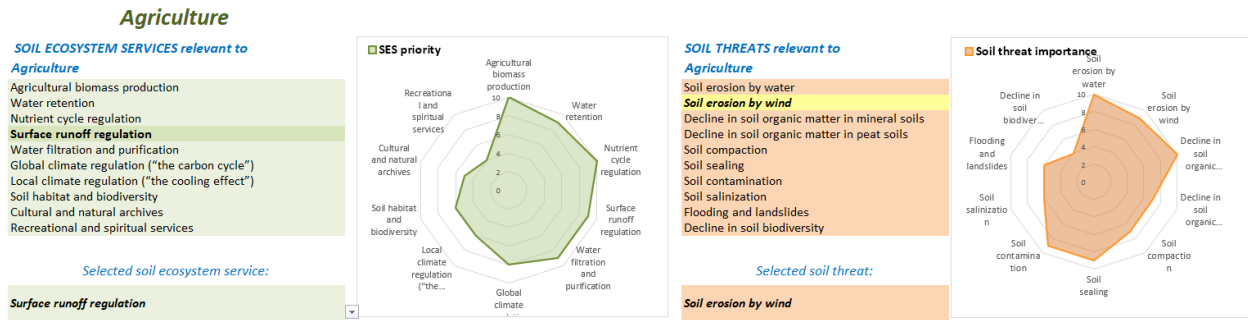


Figure 3: Upper part of sheet: important soil ecosystem services and relevant soil threats (example-agriculture)

b) The bottom part is composed of three lists: Sector-relevant soil management practices, key soil properties to monitor and required soil data to collect (Figure 4).

KEY SOIL MANAGEMENT, PRACTICES & MEASURES	SOIL PROPERTIES TO MONITOR	REQUIRED SOIL DATA																																																																																																																								
<p>Apply soil management practices: No-till, conservation tillage and similar soil management. Practice crop rotation and increase crop diversity. Use of cover crops. Decreasing traffic on soils/use of heavy machinery.</p> <p>Relevant management practices</p> <p>Soil carbon sequestration agricultural practices</p> <p>No-till, conservation tillage and similar soil management</p> <p>Practice crop rotation and increase crop diversity</p> <p>Precision nutrient management, regular periodic soil analyses</p> <p>Managing soil nutrients, replacing taken-away nutrients</p> <p>Lime acidic soils</p> <p>Use of cover crops</p> <p>Decreasing traffic on soils/use of heavy machinery</p> <p>Low/wise/rational use of pesticides & fertilizers, precision chemical application</p> <p>Avoid/prevent agricultural soil contamination</p> <p>Utilize erosion prevention land management practices</p> <p>Contour farming, water and wind erosion prevention measures</p> <p>Apply terracing on slopes</p> <p>Apply land-sliding and soil creeping protective measures</p> <p>Careful and rational water irrigation</p> <p>Creation of biodiversity hot-spots in agricultural landscapes</p> <p>Limit/prevent soil sealing and urbanization</p> <p>Prevention of spontaneous afforestation</p> <p>Prevent soil salinization</p> <p>Safeguarding natural/cultural phenomena and diversity</p>	<p>Monitor soil properties: Topsoil texture. Topsoil structure. Topsoil Corg content. Soil depth. Soil permeability.</p> <p>Relevant soil properties</p> <p>Topsoil acidity</p> <p>Topsoil texture</p> <p>Topsoil structure</p> <p>Topsoil consistency</p> <p>Topsoil Corg content</p> <p>Topsoil biodiversity</p> <p>Topsoil nutrient status</p> <p>General soil fertility</p> <p>Topsoil buffering capacity</p> <p>Soil depth</p> <p>Soil permeability</p> <p>Soil water filtering capacity</p> <p>Soil water retention capacity</p> <p>Soil compaction status</p> <p>Topsoil water erodibility status</p> <p>Soil bearing capacity</p> <p>Topsoil stoniness</p> <p>Soil surface rockiness</p> <p>Topsoil pesticide residue contamination</p> <p>Topsoil heavy metal contamination</p> <p>Topsoil organic pollutants contamination</p> <p>Topsoil contamination status</p> <p>Industrial soil contamination</p> <p>Urban soil contamination</p> <p>Agricultural soil contamination</p> <p>Forest soil contamination</p> <p>General soil contamination status</p> <p>Soil biodiversity</p> <p>Topsoil salinity</p>	<p>Measure topsoil data: Clay total. Silt total. Sand total. Texture class. Nitrogen (N) total. Organic matter content (Corg). Total carbon (C). Structure. Coarse fragments gravimetric total.</p> <p>Evaluate soil body data: Soil depth total. Soil depth to impermeable layer. Permeability rate.</p> <table border="1"> <thead> <tr> <th>Topsoil and subsoil data</th> <th>Units</th> <th>Soil body / Subsoil data</th> <th>Units</th> </tr> </thead> <tbody> <tr> <td>Clay total</td> <td>%</td> <td>Soil depth total</td> <td>cm</td> </tr> <tr> <td>Silt total</td> <td>%</td> <td>Soil depth to impermeable layer</td> <td>cm</td> </tr> <tr> <td>Sand total</td> <td>%</td> <td>Subsoil texture class</td> <td>class</td> </tr> <tr> <td>Texture class</td> <td>class</td> <td>Subsoil bulk density</td> <td>kg/dm³</td> </tr> <tr> <td>Acidity (pH or H2O or CaCl2)</td> <td>value</td> <td>Presence of compacted layer</td> <td>True/False</td> </tr> <tr> <td>Potassium (K) - plant available</td> <td>mg/100g</td> <td>Permeability rate</td> <td>cm/h</td> </tr> <tr> <td>Phosphorus (P) - plant available</td> <td>mg/100g</td> <td>Soil water retention capacity</td> <td>g/100g</td> </tr> <tr> <td>Nitrogen (N) total</td> <td>g/kg</td> <td>Coarse stone fragments gravimetric total</td> <td>g/100g</td> </tr> <tr> <td>Organic matter content (Corg)</td> <td>%</td> <td>Presence of industrial waste through soil profile</td> <td>%</td> </tr> <tr> <td>Total carbon (C)</td> <td>g/kg</td> <td>Presence of household & urban waste through soil</td> <td>%</td> </tr> <tr> <td>Calcium carbonate equivalent total</td> <td>g/kg</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Base saturation</td> <td>cmol(+)kg</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Cation exchange capacity (CEC)</td> <td>cmol(+)kg</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Electrical conductivity (EC)</td> <td>dS/m</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Structure</td> <td>class</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Bulk density (BD)</td> <td>kg/dm³</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Water retention gravimetric</td> <td>g/100g</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Coarse fragments gravimetric total</td> <td>g/100g</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Surface stoniness</td> <td>%</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Surface rockiness</td> <td>%</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Heavy metal concentration (Cd,Pb,Zn,Cu, Hg, Cr6+, and others)</td> <td>mg/kg</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Persistent organic concentration (PAHs,PCBs, HCH)</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> <tr> <td>Concentration of pesticide and pesticide residues</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> <tr> <td>Content/presence of of plastic, metals, mineral and organic</td> <td>%</td> <td></td> <td>#N/A</td> </tr> <tr> <td>Presence of urban waste (household, municipal)</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> <tr> <td>Presence of industrial waste</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> <tr> <td>Soil biota taxonomy richness</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> <tr> <td>Soil biota abundance and biomass of functional groups</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> <tr> <td>Soil biodiversity index (Shannon-Wiener, Simpsons)</td> <td><vary></td> <td></td> <td>#N/A</td> </tr> </tbody> </table>	Topsoil and subsoil data	Units	Soil body / Subsoil data	Units	Clay total	%	Soil depth total	cm	Silt total	%	Soil depth to impermeable layer	cm	Sand total	%	Subsoil texture class	class	Texture class	class	Subsoil bulk density	kg/dm ³	Acidity (pH or H2O or CaCl2)	value	Presence of compacted layer	True/False	Potassium (K) - plant available	mg/100g	Permeability rate	cm/h	Phosphorus (P) - plant available	mg/100g	Soil water retention capacity	g/100g	Nitrogen (N) total	g/kg	Coarse stone fragments gravimetric total	g/100g	Organic matter content (Corg)	%	Presence of industrial waste through soil profile	%	Total carbon (C)	g/kg	Presence of household & urban waste through soil	%	Calcium carbonate equivalent total	g/kg		#N/A	Base saturation	cmol(+)kg		#N/A	Cation exchange capacity (CEC)	cmol(+)kg		#N/A	Electrical conductivity (EC)	dS/m		#N/A	Structure	class		#N/A	Bulk density (BD)	kg/dm ³		#N/A	Water retention gravimetric	g/100g		#N/A	Coarse fragments gravimetric total	g/100g		#N/A	Surface stoniness	%		#N/A	Surface rockiness	%		#N/A	Heavy metal concentration (Cd,Pb,Zn,Cu, Hg, Cr6+, and others)	mg/kg		#N/A	Persistent organic concentration (PAHs,PCBs, HCH)	<vary>		#N/A	Concentration of pesticide and pesticide residues	<vary>		#N/A	Content/presence of of plastic, metals, mineral and organic	%		#N/A	Presence of urban waste (household, municipal)	<vary>		#N/A	Presence of industrial waste	<vary>		#N/A	Soil biota taxonomy richness	<vary>		#N/A	Soil biota abundance and biomass of functional groups	<vary>		#N/A	Soil biodiversity index (Shannon-Wiener, Simpsons)	<vary>		#N/A
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Soil biodiversity index (Shannon-Wiener, Simpsons)	<vary>		#N/A																																																																																																																							

Figure 4: The bottom part of the sheet: Soil management practices and measures, soil properties and soil data. (Example Agriculture)

4.1.2 The spreadsheet workflow

The workflow is carried out in two steps:

1. **Select a land use /sector** (open the appropriate sheet)

In the top-left corner of the sheet the list of relevant soil ecosystem services relevant for specific land use

Agriculture

SOIL ECOSYSTEM SERVICES relevant to

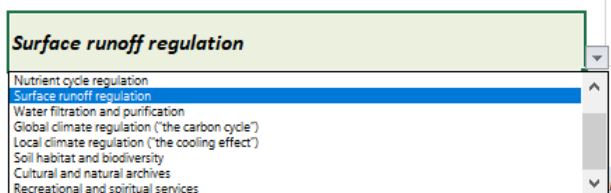
Agriculture

Agricultural biomass production

- Water retention
- Nutrient cycle regulation
- Surface runoff regulation
- Water filtration and purification
- Global climate regulation ("the carbon cycle")
- Local climate regulation ("the cooling effect")
- Soil habitat and biodiversity
- Cultural and natural archives
- Recreational and spiritual services

2. **Select the soil ecosystem service** (use pull-down menu under the SES list)

Selected soil ecosystem service:



Using embedded links and relations the sheet presents the sector-relevant information by highlighting the appropriate information (text in bold font on grey background):

- a) Soil management practices,
- b) Key soil properties to monitor, and
- c) List of required soil data to collect.

4.1.3.5 Sheet SES-Nature Disaster Prevention

Natural Disaster Prevention

SOIL ECOSYSTEM SERVICES relevant to

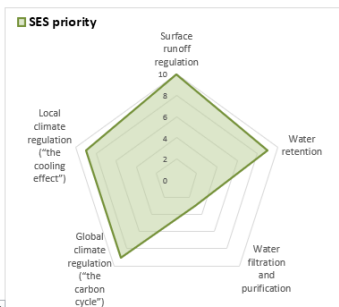
Natural Disaster Prevention

Surface runoff regulation

- Water retention
- Water filtration and purification
- Global climate regulation ("the carbon cycle")
- Local climate regulation ("the cooling effect")
- /
- /
- /
- /
- /

Selected soil ecosystem service:

Surface runoff regulation

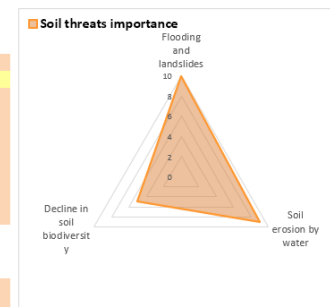


SOIL THREATS relevant to
Natural Disaster Prevention

- Flooding and landslides
- Soil erosion by water
- Decline in soil biodiversity
- /
- /
- /
- /
- /

Selected soil threat:

Soil erosion by water



KEY SOIL MANAGEMENT, PRACTICES & MEASURES

- Apply soil management practices:
- Utilize erosion prevention land management practices.
- Avoid/prevent clear-cutting. Apply terracing on slopes.
- Decreasing traffic on soils/use of heavy machinery. Contour

Relevant management practices

- Apply flood protection measures
- Utilize erosion prevention land management practices
- Apply land-sliding and soil creeping protective measures
- Avoid/prevent clear-cutting
- Apply terracing on slopes
- Decreasing traffic on soils/use of heavy machinery
- Contour farming, water and wind erosion prevention measures
- Prevent forest fires
- Remove waste and prevent soil contamination during forest-management
- Plan paths and trails to prevent/reduce soil erosion and compaction
- /
- /
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SOIL PROPERTIES TO MONITOR

- Monitor soil properties:
- Topsoil structure. Topsoil Corg content. Soil depth. Soil permeability.

Relevant soil properties

- Topsoil acidity
- Topsoil texture
- Topsoil structure
- Topsoil consistency
- Topsoil Corg content
- Topsoil biodiversity
- Topsoil nutrient status
- General soil fertility
- Topsoil buffering capacity
- Soil depth
- Soil permeability
- Soil water filtering capacity
- Soil water retention capacity
- Soil compaction status
- Topsoil water erodibility status
- Soil bearing capacity
- Topsoil stoniness
- Soil surface rockiness
- Topsoil pesticide residue contamination
- Topsoil heavy metal contamination
- Topsoil organic pollutants contamination
- Topsoil contamination status
- Industrial soil contamination
- Urban soil contamination
- Agricultural soil contamination
- Forest soil contamination
- General soil contamination status
- Soil biodiversity
- Topsoil salinity
- /

REQUIRED SOIL DATA

- Measure topsoil data:
- Silt total. Texture class. Nitrogen (N) total. Organic matter content (Corg). Total carbon (C). Structure. Coarse fragments gravimetric total.
- Evaluate soil body data:
- Soil depth total. Soil depth to impermeable layer. Permeability rate.

Topsoil and subsoil data		Units	Soil body / Subsoil data		Units
Clay total	%	%	Soil depth total	cm	cm
Silt total	%	%	Soil depth to impermeable layer	cm	cm
Sand total	%	%	Subsoil texture class	class	class
Texture class	class	class	Subsoil bulk density	kg/dm³	kg/dm³
Acidity (pH or H2O or CaCl2)	value	value	Presence of compacted layer	True/False	True/False
Potassium (K) - plant available	mg/100g	mg/100g	Permeability rate	cm/h	cm/h
Phosphorus (P) - plant available	mg/100g	mg/100g	Soil water retention capacity	g/100g	g/100g
Nitrogen (N) total	g/kg	g/kg	Coarse stone fragments gravimetric total	g/100g	g/100g
Organic matter content (Corg)	%	%	Presence of industrial waste through soil profile	%	%
Total carbon (C)	g/kg	g/kg	Presence of household & urban waste through soil	%	%
Calcium carbonate equivalent total	g/kg	g/kg			#N/A
Območje grafikona	mol(c)/kg	mol(c)/kg			#N/A
Cation exchange capacity (CEC)	mol(c)/kg	mol(c)/kg			#N/A
Electrical conductivity (EC)	ds/m	ds/m			#N/A
Structure	class	class			#N/A
Bulk density (BD)	kg/dm³	kg/dm³			#N/A
Water retention gravimetric	g/100g	g/100g			#N/A
Coarse fragments gravimetric total	g/100g	g/100g			#N/A
Surface stoniness	%	%			#N/A
Surface rockiness	%	%			#N/A
Heavy metal concentration (Cd,Pb,Zn,Cu,Hg, Cr6+, and others)	mg/kg	mg/kg			#N/A
Persistent organic concentration (PAHs,PCBs, HCH)	<vary>	<vary>			#N/A
Concentration of pesticide and pesticide residues	<vary>	<vary>			#N/A
Content/presence of of plastic, metals, mineral and organic	%	%			#N/A
Presence of urban waste (household, municipal)	<vary>	<vary>			#N/A
Presence of industrial waste	<vary>	<vary>			#N/A
Soil biota taxonomy richness	<vary>	<vary>			#N/A
Soil biota abundance and biomass of functional groups	<vary>	<vary>			#N/A
Soil biodiversity index (Shannon-Wiener, Simpsons)	<vary>	<vary>			#N/A
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Figure 9: Tool sheet that links soil ecosystem services and soil threats for NATURAL DISASTER PREVENTION.

5 Summary

The expert knowledge based concept of linking Alpine soil information, soil ecosystem services and ecosystem management is implemented in the MS Excel tool.

The links between the soil measured data, soil properties on one side are established to relevant soil ecosystem services and soil threats on the other side. At the same time, the sustainable soil management practices are linked to both; soil ecosystem services and threats as well as to soil properties and measured data.

The MS Excel tool enables user to quickly asses in which way the soil is important within a given sector/land use and get the information the expert are frequently asked:

- Which are relevant soil ecosystem services that have to be addressed within individual sector / sectoral land use?
- Which are management practices that help to protect/maintain, safeguard soil ecosystem services that are primary in the sector?
- Which soil properties important for providing selected soil ecosystem service?
- What kind of soil data should be collected to assess soil properties/soil quality relevant to the chosen soil ecosystem service?

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Imprint

What this is about

Soil is the basis of Alpine ecosystems; it is a fundamental natural resource especially in the vulnerable Alpine Region. Through the sustainable management and protection of soil, we enhance the sustainable management of the Alpine environment, considerably contribute to the performance and resilience of key ecosystem services, preserve biodiversity, and ensure the well-being of humans. Soil management and protection is provided for in the framework of the Soil Conservation Protocol of the Alpine Convention, which is aimed at safeguarding the multifunctional role of soil based on the concept of sustainable development.

About this book

This report presents the concept of linking ecosystem services, soil threats, soil information, to soil and ecosystem management, soil properties and soil data/measured parameters. An additional purpose of this report is to make the reader aware that soil provides an essential number of ecosystem services.

About the Links4Soils project

The Links4Soils project is focused on raising awareness of soils in the Alpine Region, reviewing the existing regional and national soil data, transferring knowledge and best management practices to policymakers, decision-makers, and other stakeholders, and promoting efficient soil protection strategies. Links4Soils aims to overcome existing gaps in soil-awareness, information, knowledge, and networking and to contribute to better implementation of the Alpine Convention Soil Protection Protocol.

Links4Soils project partners

Agricultural Institute of Slovenia, SI (project leader) • Office of the Tyrolean Provincial Government, AT • Autonomous Region of Aosta Valley, IT • Municipality of Kaufering, Department of Environment and Nature, DE • National Research Institute of Science and Technology for the Environment and Agriculture, Grenoble Regional Centre, Mountain Ecosystem Research Unit, FR • Slovenian Forest Service, SI • Institute of Geography, University of Innsbruck, AT • Climate Alliance Tirol, AT • University of Torino, Department of Agricultural, Forest and Food Sciences, IT

Acknowledgements

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WEB links

- Links4Soils, an Interreg III VB Alpine Space project: www.alpine-space.eu/projects/links4soils
- Alpine Soils: alpinesoils.eu/

Links4Soils project partners:



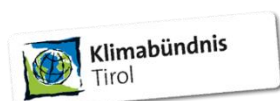
Agricultural Institute of Slovenia, SI (project leader)
Kmetijski inštitut Slovenije



Slovenian Forest Service, SI
Zavod za gozdove Slovenije



Office of the Tyrolean Provincial Government, AT
Amt der Tiroler Landesregierung



Climate Alliance Tirol, AT
Klimabündnis Tirol



Institute of Geography, University of Innsbruck, AT
Institut für Geographie, Universität Innsbruck



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Università degli Studi di Torino, Dipartimento di Scienze Agrarie, Forestali e Alimentari



Autonomous Region of Aosta Valley, IT
Regione autonoma Valle d'Aosta



National Research Institute of Science and Technology for the Environment and Agriculture, Grenoble Regional Centre, FR
Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture, Grenoble



Municipality of Kaufering, DE
Markt Kaufering