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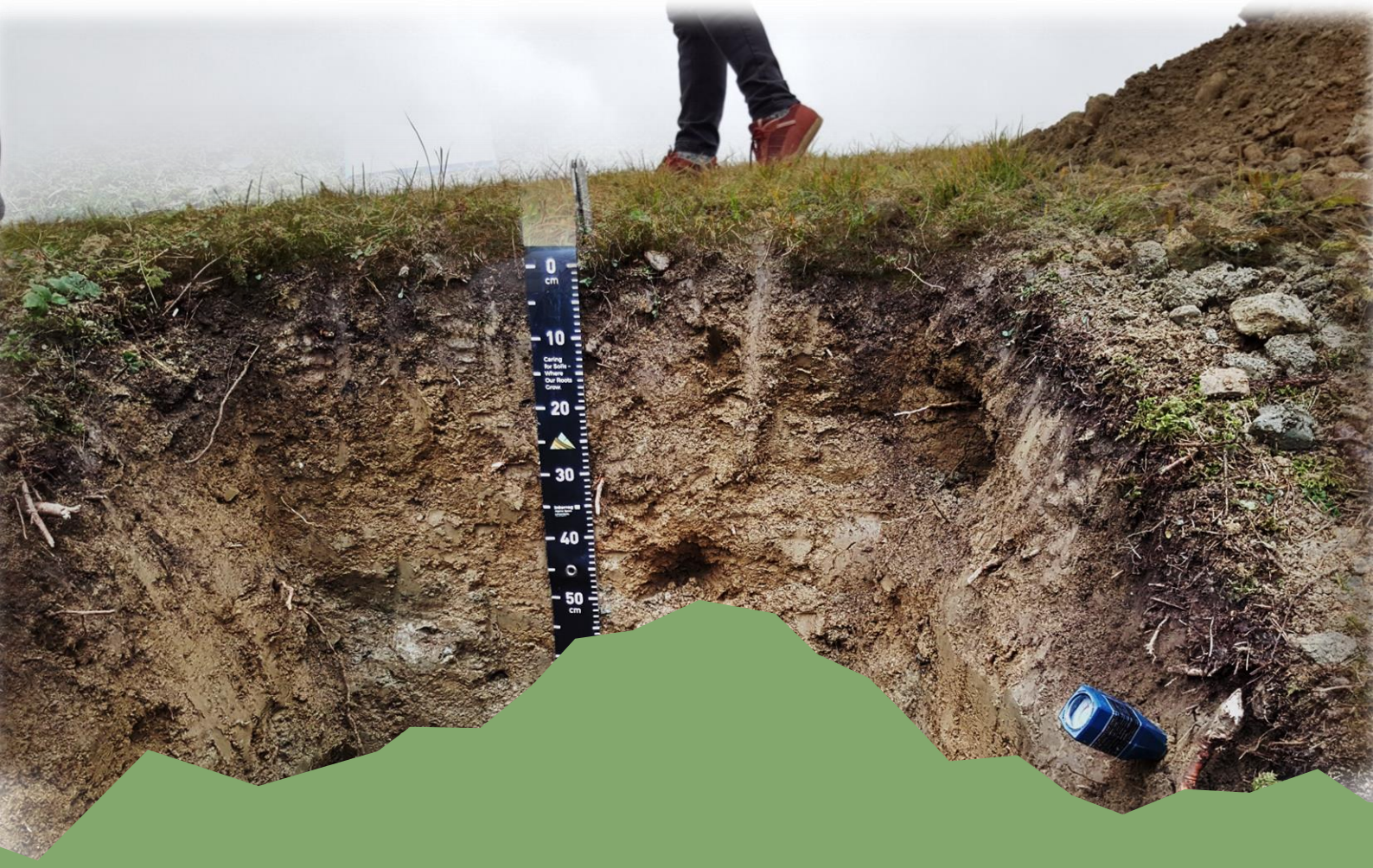
Soil Protection Working Group

Stock-taking summary of permanent soil monitoring areas in the perimeter of the Alpine Convention



This stock-taking summary of permanent soil monitoring areas in the perimeter of the Alpine Convention was approved by the Alpine Conference at its XVI meeting, held on 10 December 2020.

The stock-taking summary of permanent soil monitoring areas in the perimeter of the Alpine Convention was coordinated by the German Presidency of the Soil Protection Working Group and the Permanent Secretariat of the Alpine Convention and has been drafted based on material delivered by the members of the Soil Protection Working Group.

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Content

Annex to the stock-taking summary

Figures

Tables

1. Introduction

The task to facilitate the implementation of Articles 20 (establishment of harmonized databases) and 21 (establishment of permanent monitoring areas and coordination of environmental monitoring) of the Soil Conservation Protocol of the Alpine Convention was mandated to the newly established Soil Protection Working Group of the Alpine Convention in its first mandate (2019-2020). The Soil Conservation Protocol has been signed by all Contracting Parties of the Alpine Convention and it has been ratified by Austria, France, Germany, Italy, Liechtenstein, Monaco, Slovenia and the European Union, where it thus entered into force. The Articles 20 and 21 state:

> *"Article 20: Establishment of Harmonised Databases*
> *(1) The Contracting Parties agree to create comparable databases (soil parameters, sampling, analysis, evaluation) within the framework of the Alpine monitoring and information system, and to establish possibilities for data exchange.*
> *(2) The Contracting Parties shall reach agreement about soil-endangering substances which require priority treatment, and they shall strive for comparable evaluation parameters.*
> *(3) The Contracting Parties shall strive to establish representative records of the condition of Alpine soils taking into account the geological and hydrogeological situation, on the basis of identical evaluation systems and harmonised methods.*
>
> *Article 21: Establishment of Permanent Monitoring Areas and Coordination of Environmental Monitoring*
> *(1) The Contracting Parties undertake to establish permanent monitoring areas in the Alpine region and to integrate them in an Alpine-wide soil monitoring network.*
> *(2) The Contracting Parties agree to coordinate their national soil monitoring programmes with the environmental monitoring programmes for air, water, flora and fauna.*
> *(3) Within the framework of their monitoring programmes, the Contracting Parties shall establish soil sample databases according to comparable parameters."*

It was discussed by the Soil Protection Working Group of the Alpine Convention, that reaching data comparability between the Alpine States is a challenging task and can neither be accomplished easily nor quickly. Harmonization of soil data is a difficult issue, which has already been discussed for many years prior to the establishment of the Soil Protection Working Group of the Alpine Convention. It is already difficult, and not achieved in every State to have one standardized national soil monitoring system in place. Generally, soil monitoring is done in different systems in very heterogeneous ways.
In 1994 the subgroup on "*permanent soil monitoring sites*" of the joint working group on soil protection of the Arge Alp, Arge Alpen-Adria and Arge Donau had prepared a report in German language on permanent soil monitoring sites, including a recommendation to set up sites and monitor them in a coordinated way (Arge Alp, Arge Alpen-Adria and Arge Donau 1994). Sites in Tyrol, Salzburg, Switzerland as well as all agricultural and special monitoring sites in Bavaria are set up based on those common recommendations from 1994. However, the recommendations were considered, but have not been implemented in all regions and not been comprehensively coordinated.
Another good example of a joint approach for soil monitoring and creating harmonized data in the Alpine area is the Interreg Alpine Space project "*MonarPOP - Monitoring Network in the Alpine Region for Persistent and other Organic Pollutants*", which was undertaken 2005 – 2007

and continued until 2010 (Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008). The project underlined how working together internationally can be of significant added value regarding this issue, while a long-term approach would be necessary. Austria, Germany, Italy, Slovenia and Switzerland were involved in the project. In Austria, the project is currently continued from 2017 to 2020 under the title AustroPOPs.
Since also on the EU level the harmonization of national or regional soil data was not possible due to largely differing systems and data gaps, the LUCAS Soil survey coordinated by EUROSTAT and implemented by the JRC, was introduced in 2006. Thus, the Alpine EU member states - and in the survey of 2015 also Switzerland - are covered by the LUCAS Soil survey. Consequently, this European survey should be considered or even play a significant role regarding this topic.

To firstly start generating an overview of the currents state of soil monitoring in the perimeter of the Alpine Convention, the Group undertook a stock-taking of soil monitoring mechanisms and areas by collecting information about those instruments from the Alpine States by a first questionnaire.
On that basis, international monitoring instruments were identified for which soil in areas in the Alpine region are surveyed and for which thus comparable soil data is generated. Corresponding further information was collected from the Contracting Parties by a second questionnaire.
This stock-taking summary gives an overview of the delivered material and further discussions which took place during the mandate period. There is no claim for completeness of monitoring instruments and areas.
The document is followed by the original materials delivered by the Contracting Parties of the Alpine Convention that were prepared as answers for the two questionnaires as a separate annex.

2. Overview of national and regional monitoring instruments

As a starting point the Group agreed that the Contracting Parties prepare written overviews of their respective permanent monitoring instruments, which comprise locations inside the Alpine Convention perimeter. A questionnaire was developed by the Chair and circulated to the Working Group. It contained questions regarding

- the type of instrument,
- the monitoring mechanism,
- it's policy status,
- coverage in territory and land cover classes,
- the responsible administrations,
- topics addressed (soil threads, functions, parameter groups),
- site locations, as well as
- the availability of the generated data and
- in which international framework the sites are included if this applied.

Answers were delivered by Austria, France, Germany, Italy, Liechtenstein, Slovenia and Switzerland. The titles of the monitoring instruments are displayed in table 1, whereas the

compiled answers can be found as annex to this stock-taking summary. In total 46 answers to the first questionnaire were submitted of which 45 contain monitoring areas in the perimeter of the Alpine Convention. All Contracting Parties were asked at the 4th meeting of the Working Group to check, if a national or regional monitoring mechanisms is missing, which should be still included.

Name of instrument	In place since	Category space (I=Internat.), (N= National), (R= Regional), (L=Local)	Category QQ (A=qualitative), (B=quantitative), (O=other)
Austria			
LTER Zöbelboden	1992	I	A
Agricultural Soil Protection Program of Styria	1986	R	A
(Permanent) Soil Monitoring Salzburg	1996	R	A
(Permanent) Soil Monitoring Salzburg - Land Consumption	in pipeline	R	B
Soil Inventory Salzburg	1988	R	A
Permanent Soil Monitoring Program of Tyrol	1998	R	A
Soil Inventory Tyrol	1986	R	A
Forest Soil Monitoring ICP Forests Program Level I & II	1988	I/N	A
Land Use and Soil Consumption Monitoring Tyrol	in pipeline	R	B
Repeated Sampling of Soil Mapping Profile Locations, Lower Austria		R	A
Expandible Soil Database for Soil Physical Parameters (mainly: Lower Austria, Upper Austria, Styria)		R/N	A
Permanent Monitoring Sites in Lower Austria	1996	R	A
Hydrological Open-Air Laboratory Petzenkirchen, Lower Austria, 66ha catchment		R/N/I	A
Soil Inventory of Upper Austria	1990-93	R	A

Name of instrument	In place since	Category space (I=Internat.), (N= National), (R= Regional), (L=Local)	Category QQ (A=qualitative), (B=quantitative), (O=other)
Cooperative, Long-term Ecosystem Monitoring Across the Alps: Austrian Hohe Tauern National Park, South-Tyrol and the Swiss Central Alps, AT, IT, CH, LTER Sites in CH and IT	2017	I	A
France			
Spatiotemporal Observatory of Biodiversity and Ecosystem Functioning of Mountains' Socio-ecosystems	2016	R/N/I	A
French Soil Quality Monitoring Network	2000	N	A
Long-term Monitoring of the Forest Ecosystems - Air pollution impacts on soil/forests (ICP Forests Program)	1992	I	A
Germany			
Bavarian Soil Monitoring	1986	R	A
Italy			
Links4Soils - Outcomes for Aosta Valley - Soil Mapping (vulnerability assessment & erosion prevention)	in pipeline	R	O
Carbon Fluxes Observation	2008	L/I	A
Regulation (EC) No 1221/2009 – EMAS III, Environmental Management System (EMS) – Nature Park Mont Avic, Aosta Valley: Transhumance Monitoring of Cattle in the Mountain Pastures	2003	I	O
Soil Erosion in Sloping Vineyards	2014	R/I	O
Italian Land Use Inventory (IUTI)	1990	N	B
Lombardy Geological Monitoring Centre, Warning System for large Landslides	1987	R	B
Soil Quality Monitoring in Lombardy (focus on SOC)	2010	R	A
Soil and Cropping System Monitoring Established in Lombardy to implement the Nitrates Directive	2005	R	A

Name of instrument	In place since	Category space (I=Internat.), (N= National), (R= Regional), (L=Local)	Category QQ (A=qualitative), (B=quantitative), (O=other)
Italy (continued)			
Environmental Monitoring Project in Lombardy Region (Soil Project): Fact-finding Survey of the Quality and State of Health of Lombardy Soils	2015	R	A
Aosta Valley Landslide Monitoring System	1996	R	B
RERCOMF - Regional Network for Landslide Movement Control (Piemonte)	1994	R	B
Environmental Soil Quality Monitoring Network (Piemonte)	2005	R	A
Long-term Thermosensitive Species Monitoring in Periglacial Soil of Northern Piemonte: Monte Rosa, Valley Formazza	first tests since 2006	Sub-R	A
Permafrost Long-term Monitoring Network in Piedmont's Alps (started by ASP PermaNET 2008-11)	2009	R	A
Pedoclimatic Characterization and Production Performance of 4 Truffles of Tuber Magnatum (Piemonte)	2010	SR	O
ARPA-Veneto – Organic Compound Monitoring Scheme		R	A
ARPA-Veneto – Heavy Metals Monitoring Scheme	the 90th	R	A
ARPA-Veneto – Soil Biological Quality	2018	R	A
ARPA- Friuli Venezia Giulia – Organic and Inorganic Substances Monitoring Scheme	Started in 2016	R	A
ARPA Friuli Venezia Giulia – Soil Biological Quality	2018	R	A
Liechtenstein			
Soil Monitoring Network - Principality of Liechtenstein	1994	N	A
Slovenia			
NEC directive Monitoring of Negative Impacts of Air Pollution on Ecosystem	in pipeline	I	A

Name of instrument	In place since	Category space (I=Internat.), (N= National), (R= Regional), (L=Local)	Category QQ (A=qualitative), (B=quantitative), (O=other)
Slovenia (continued)			
ICP Forests Level II Intensive Monitoring of Forest Ecosystem	2003	I	A
ICP Forests Level I 16 x 16km Transnational Grid throughout Europe	1995	I	A
8 × 8 km Grid for Greenhouse Gas Sink Assessment: Land Use Change & Forestry - Spatial Planning for Reporting on LULUCF	2010	N	A
Switzerland			
Swiss National Soil Monitoring Network (NABO)	1985	N	A

Table 1: Overview of all submitted monitoring mechanisms on questionnaire permanent monitoring sites.

A high amount of monitoring sites in the Alpine States, which are not part of an international monitoring system, exist. However, the monitoring mechanisms, topics and delivered data are heterogeneously, which allows only few generalized statements. Thus, the answers on the first questionnaire have been summarized and the most comparable monitoring systems were compiled in order to generate a dataset which allows some general statements, such as regarding parameter groups which are monitored in all or most of the Alpine States.

2.1 Qualitative soil monitoring instruments

To allow some statements, which are more generalized, monitoring systems were selected, which are:

- already in place,
- examine qualitative soil aspects and
- cover a national-wide area or complete region.
- All international mechanisms, such as NEC, ICP Forests or LTER were excluded to avoid doubling. Those will be part of the next chapter.
- Also projects as well as monitoring of erosion and permafrost monitoring are not included in the following overview, since they were only delivered by one Contracting Party and thus no international comparison can be made.

The following analysis comprises 24 monitoring instruments, of which nine are from Austria, two from France, nine from Italy, one from Germany, Liechtenstein, Slovenia and Switzerland respectively. The main reason for the high number of instruments in Austria and Italy is the

Regional organisation of soil monitoring. This applies also for Germany, but only one German Federal State comprises a part of the Alpine Convention perimeter.
It must be considered that the intervals of monitoring the respective sites differ significantly between the monitoring systems. Furthermore, some instruments are inventories, which examine a soil site once or might have single repetitions. However, the choice of sites as well as the interval of resampling depends largely on the requirements, questions which should be answered and available resources.
Figure 1 gives an overview of the percentage of the instruments that examine certain parameter groups. It is obvious, that all qualitative soil monitoring schemes cover site characteristics. While soil chemistry and specifically soil carbon is also covered by a very high percentage of the surveys, soil biodiversity and climate parameters are included in a lower percentage of instruments. Main- and subcategories of parameter groups could be chosen in the questionnaire. The main category "*climate parameters*" had the subcategory "*soil temperature*" and the main category "*soil chemistry*" had the subcategories "*ph-value*", "*heavy metal concentrations*" and "*organic compounds*". In figure 1 subcategories are displayed with a lighter colour than the main categories.

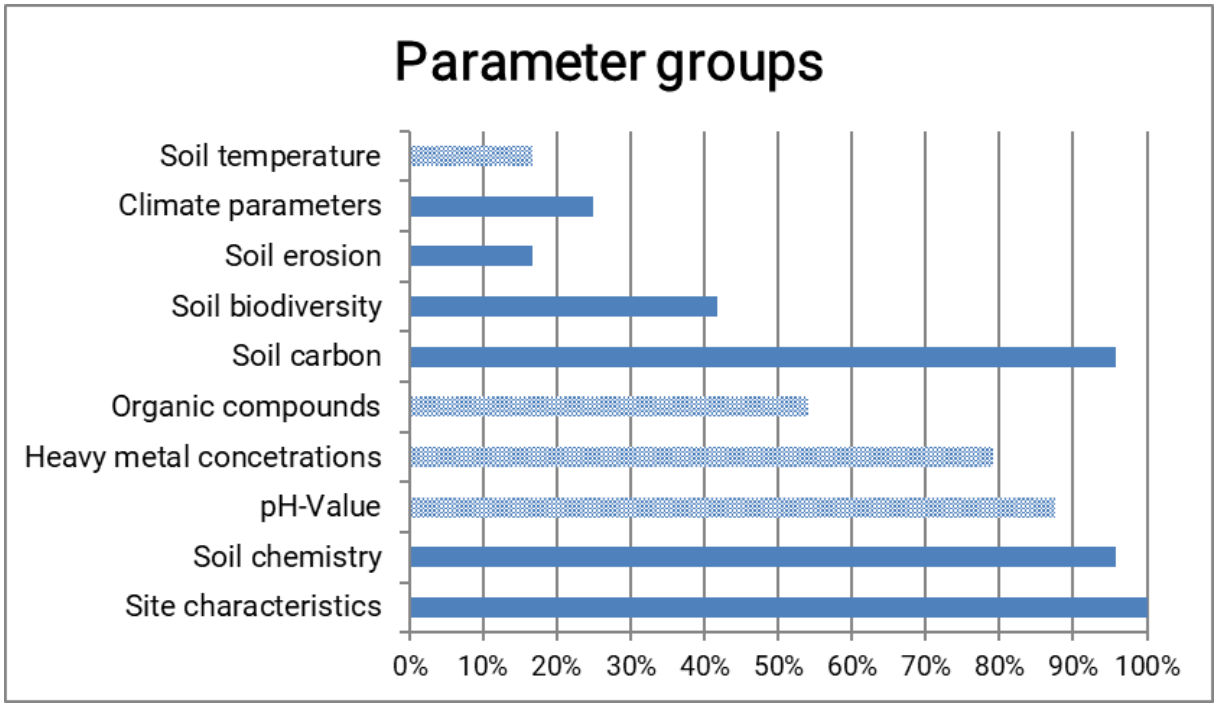

Figure 1: Percentage of parameter groups covered by selected monitoring mechanisms.

While figure 1 can give a good first insight, it must be considered, that the Alpine States are represented unequally, as the numbers of instruments per country differ (see above). Figure 2 displays this difference in showing the land cover classes addressed by the instruments firstly in total numbers and secondly per percentage of the respective Alpine State's instruments.

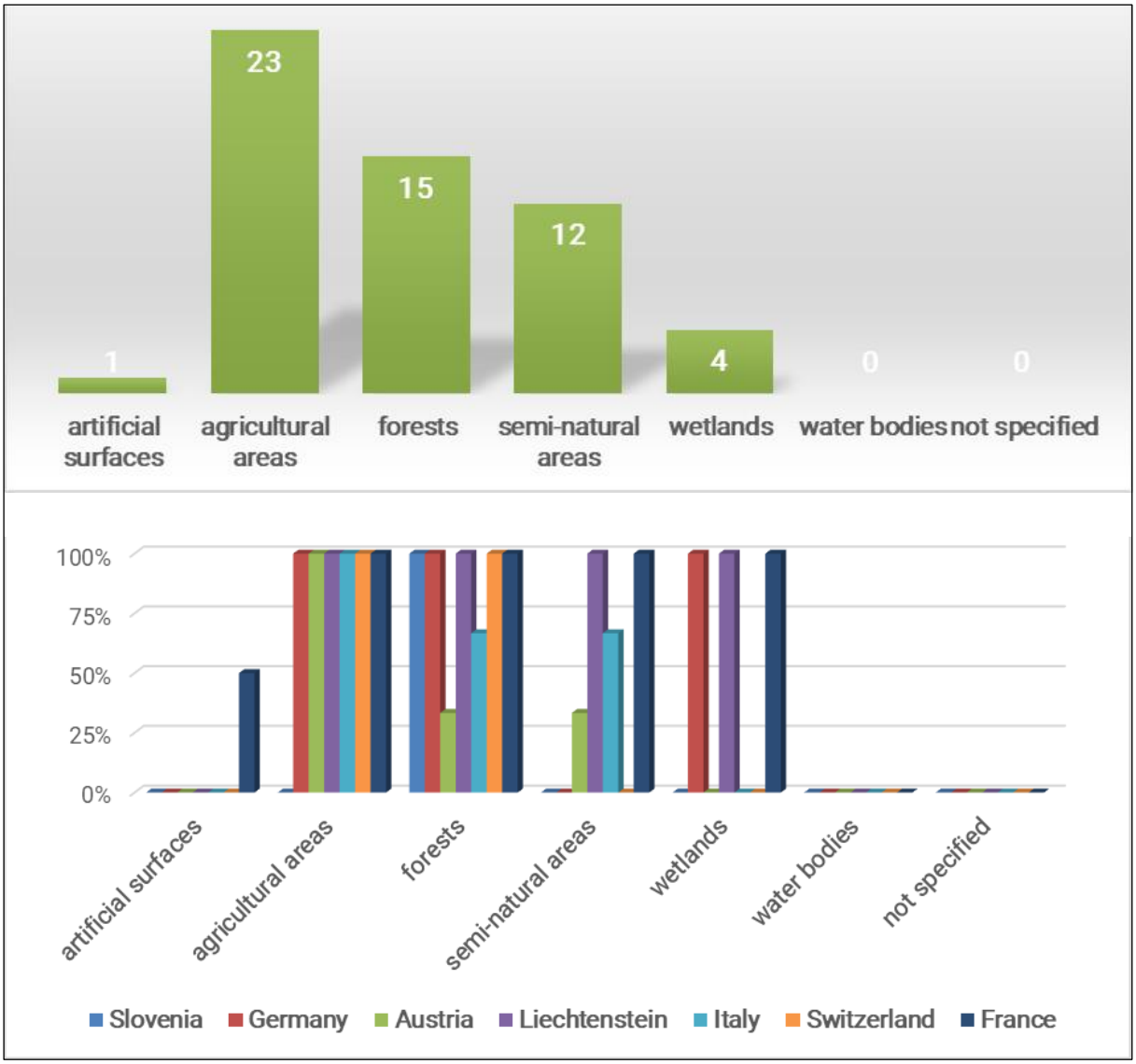

Figure 2: Land cover classes addressed by instrument in total numbers and in % of the State's instruments (Austria: 9, France: 2, Italy: 9, Germany: 1, Liechtenstein: 1, Slovenia: 1, Switzerland: 1).

Consequently, this more precise processing needed to be applied also for other key issues, such as,

- which parameter groups are examined (figure 3),
- which soil functions (figure 4) and
- which soil threads are addressed (figure 5)

in all or many Alpine States by national or regional-wide monitoring systems.

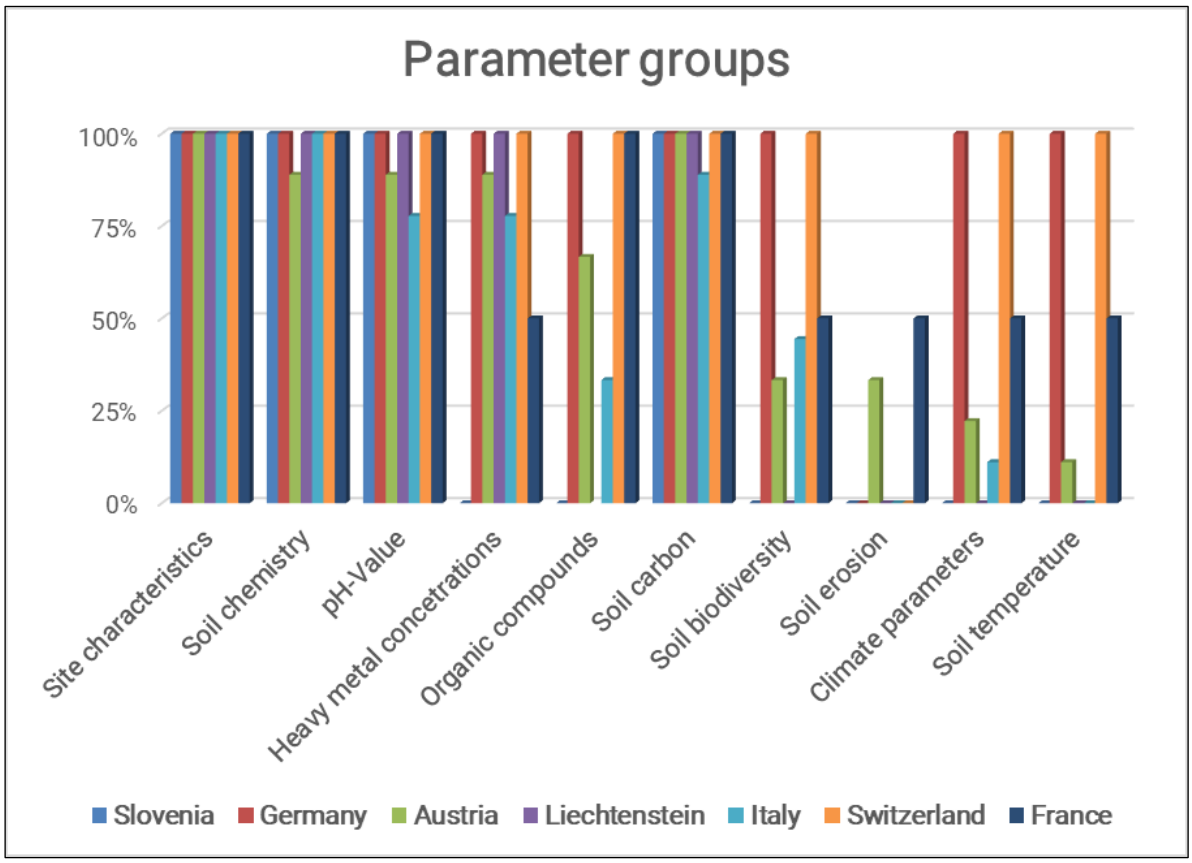

Figure 3: Parameter groups covered by instrument in % of the State's instruments (Austria: 9, France: 2, Italy: 9, Germany: 1, Liechtenstein: 1, Slovenia: 1, Switzerland: 1).

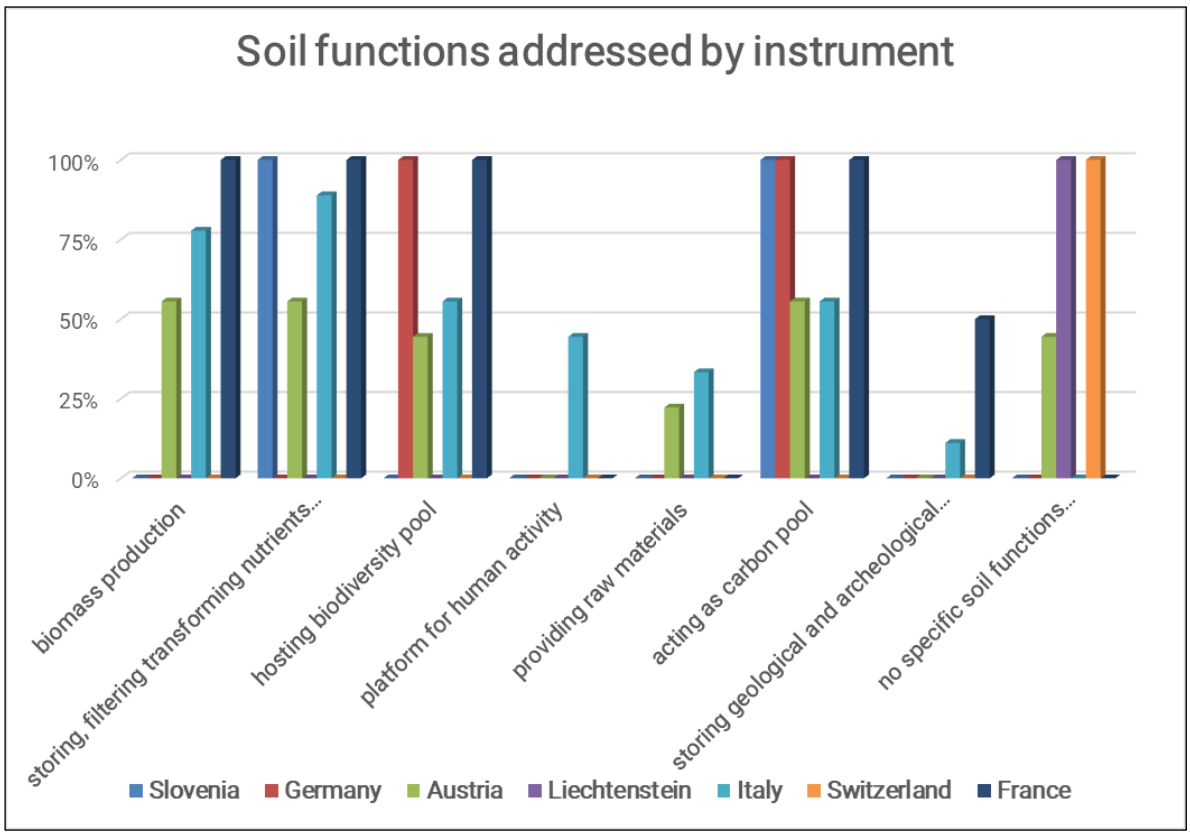

Figure 4: Soil functions addressed by instrument in % of the State's instruments (Austria: 9, France: 2, Italy: 9, Germany: 1, Liechtenstein: 1, Slovenia: 1, Switzerland: 1).

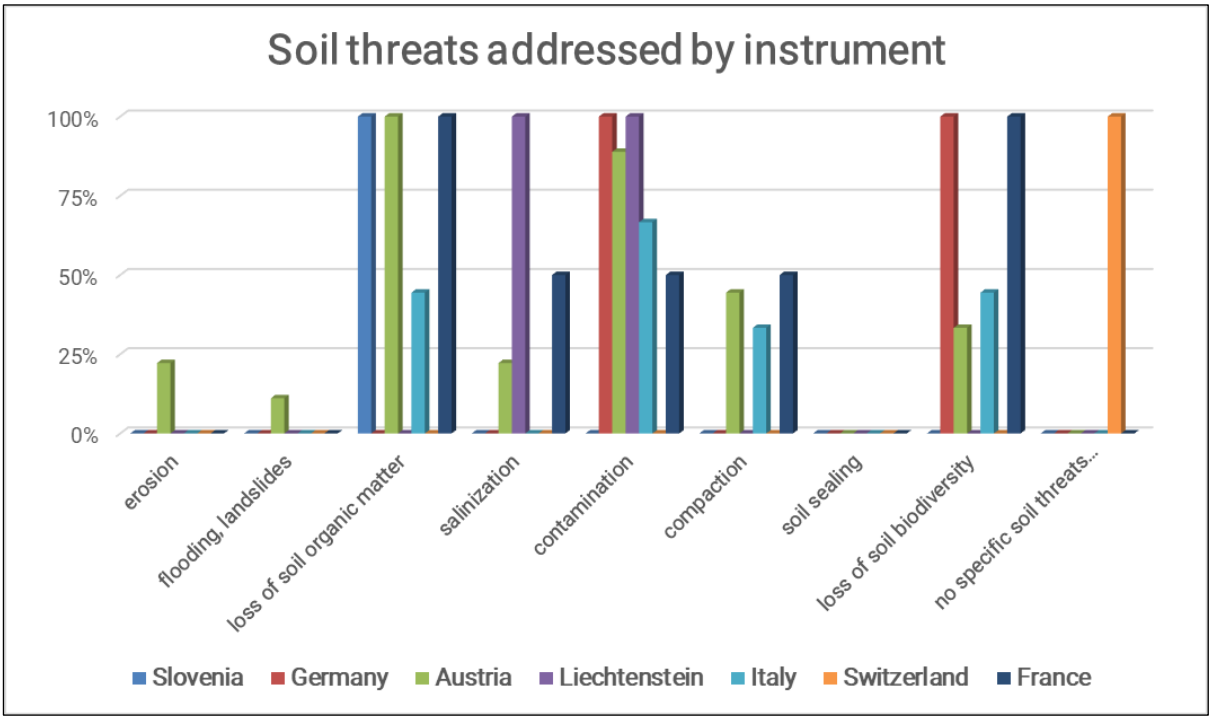

Figure 5: Soil threats addressed by instrument (Austria: 9, France: 2, Italy: 9, Germany: 1, Liechtenstein: 1, Slovenia: 1, Switzerland: 1).

2.2 An example per Alpine State

To give an insight into the monitoring instruments submitted in the first questionnaires, one example per Alpine State is briefly displayed here. The full questionnaires, comprising more details of all instruments can be found in the annex.

In Austria, the soil monitoring is organized on the regional level. Thus, an example is given here from Tyrol since the Region's area lays completely inside of the perimeter of the Alpine Convention.
The establishment of the Permanent Soil Monitoring Program of Tyrol serves the long-term monitoring of soil conditions and thus to a sustainable soil protection. It is planned for 70 years. Five sites, with each one plot under agricultural and silvicultural management, following different pollution scenarios and evenly distributed were set up. The soils are sampled and analysed every ten years to detect changing conditions and to allow taking measures for soil protection. The advantage is that targeted questions can be answered in a few informative and representative locations.
In addition to the permanent monitoring, a soil inventory has been done to assess the state of the soil condition, especially regarding heavy metal pollution. The investigations were based on the Austria-wide recommendation of the Austrian Soil Science Society. Monitoring points in a 4 x 4 km grid have been set. 658 sites were sampled between 1986 to 1987 and 107 sites resampled in 1993 (figure 6).

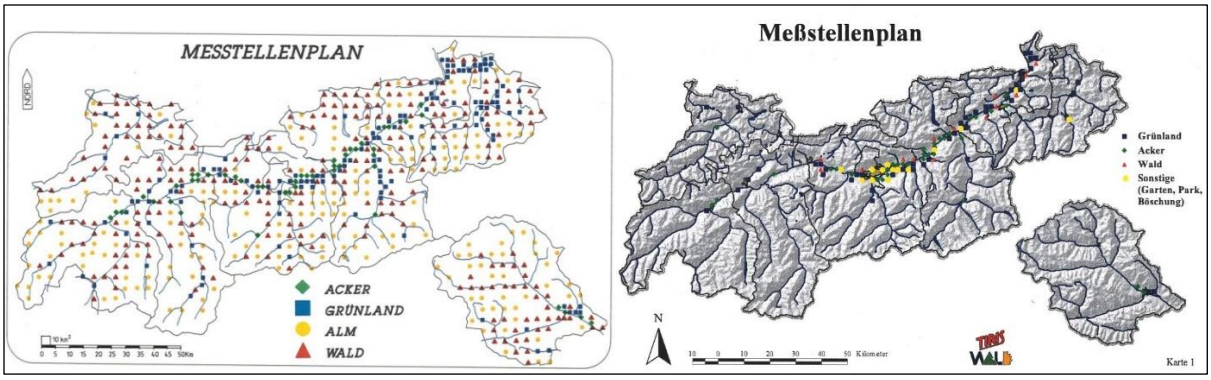

Figure 6: Plan of sampling sites of the Tyrol soil inventory, on the left: 1986-1987, on the right: 1993.

The French National Soil Quality Monitoring Network (RMQS) is a soil monitoring network based on a 16 x 16 km regular grid across the 550.000 km^2 of France. In continental France, it includes 2.173 monitoring sites, each located at the centre of a 16 x 16 km cell. For each, the soil profile, site environment, climatic factors, location, vegetation and land management have been described. Composite soil samples are collected up to 1 m depth, if possible. All samples are stored at INRA-Orleans in the European soil samples conservatory and data collected are available in the DONESOL database. The first campaign started in 2000 and ended in 2009 in continental France. The second campaign is ongoing. 158 sites are in the perimeter of the Alpine Convention (figure 7).

Next to the National Soil Monitoring, France has another system in place, which is especially relevant for the Alpine area: the Spatiotemporal observatory of biodiversity and ecosystem functioning of mountains' socio-ecosystems. It included 24 lines stretching over 600 to 1.200 meters of elevation. Each line contains ca. 6 plots.

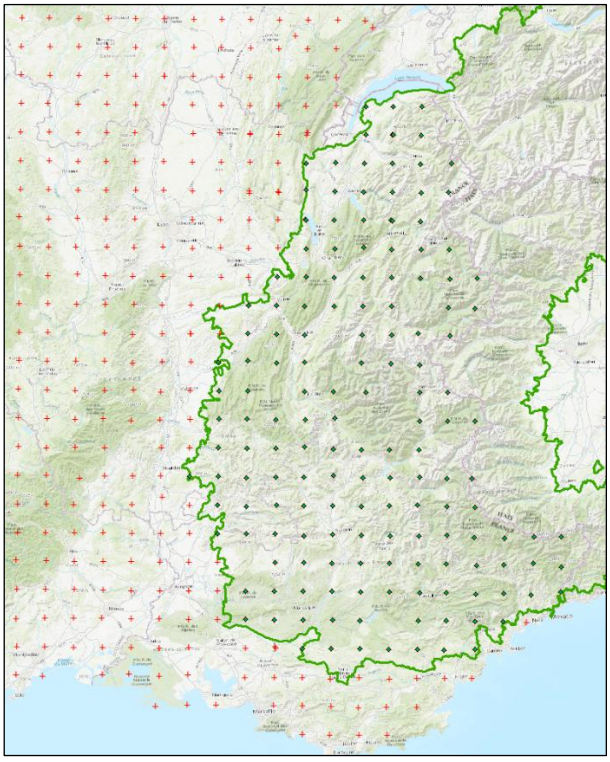
Figure 7: Locations in the Alpine Convention perimeter of the French National Soil Quality Monitoring Network.

Since 1986 the Bavarian Soil Monitoring assesses soil characteristic values at selected dates. This allows to compare the physical and chemical state of the soil and to detect trends of soil quality over extended periods of time. The Bavarian Environment Agency oversees protected areas and special sites; the agricultural areas are monitored by the Bavarian State Research Centre for Agriculture and the forest areas by the Bavarian State Institute of Forestry. The soil monitoring provides supportive data for political strategies and programs of the respective regional ministries, such as the Bavarian State Ministry of the Environment and Consumer Protection or the Bavarian State Ministry of Nutrition, Agriculture and Forestry. It comprises about 50 sites in perimeter in the land cover classes forest, agricultural areas and wetlands. The Bavarian soil monitoring is associated with the Bavarian Soil Protection Law and the Bavarian Soil Protection Program. The monitoring sites are displayed in figure 8.

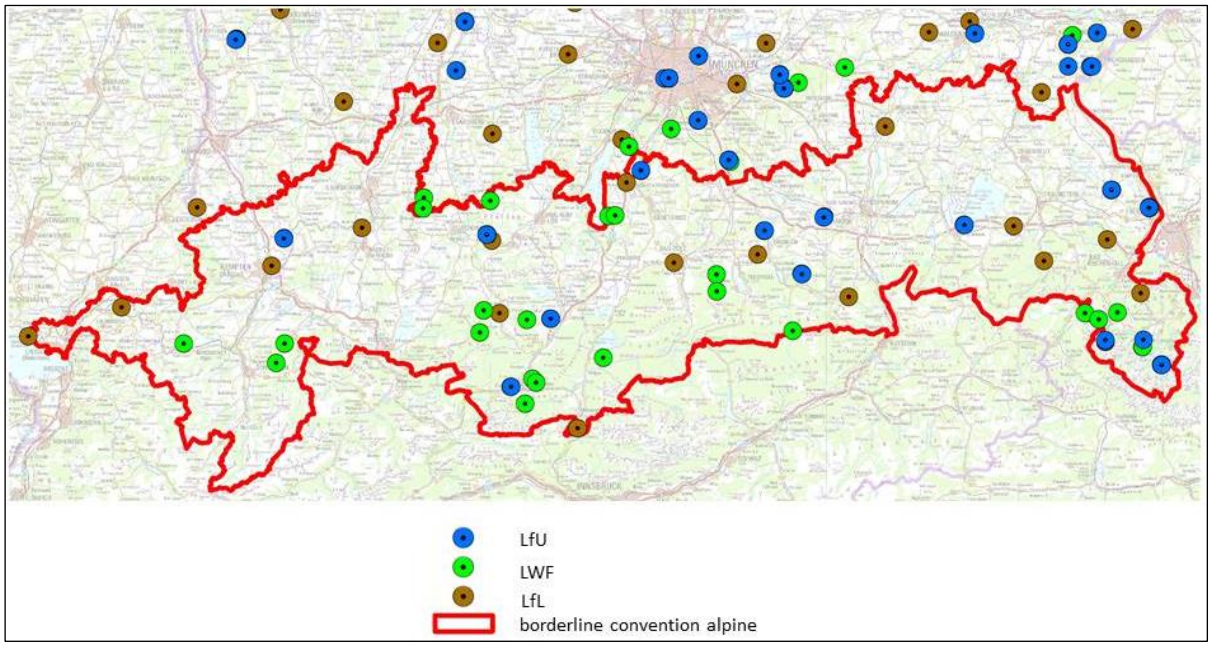

Figure 8: Bavarian Soil Monitoring. LfU = Bavarian Environment Agency, LWF = Bavarian State Institute of Forestry, LfL = Bavarian State Research Centre for Agriculture.

In Italy soil monitoring is organized on the regional level. Thus, many different monitoring programs and systems exist in Italy. Consequently, also for Italy one of the regional monitoring systems was chosen to present it here as an example.
The Environmental Soil Quality Monitoring Network of Piemonte is designed to provide homogeneous and validated data regarding the main contaminants. It is used as scientific reference support in activities related to the evaluation of soil quality and the application of the regulations concerning environmental contamination. The soil monitoring is carried out in monitoring stations distributed throughout the territory of the Region (figure 9), in correspondence with the vertices of a systematic network expanded with subsequent levels of depth. Soil sampling is carried out at fixed depths and for each sample taken, more than 70 contaminants are analysed, such as heavy metals, polycyclic aromatic hydrocarbons (PAHs) polychlorinated biphenyls (PCB), dioxins (PCDD) and furans (PCDF), for which limits are fixed by the Legislative Decree 152/06, in addition non-regulated heavy metals and rare earths.

Resampling is taking place at least every 10 years. The soils of 600 monitoring stations from the whole territory of Piemonte in the systematic grid have been sampled and analysed:

- 9 x 9 km grid: for the soils in the Alpine and hilly areas,
- 4,5 x 4,5 km grid: for the soils in the plain,
- 3 x 3 km or 1,5 x 1,5 km grid for areas characterized by problems related to widespread soil contamination.

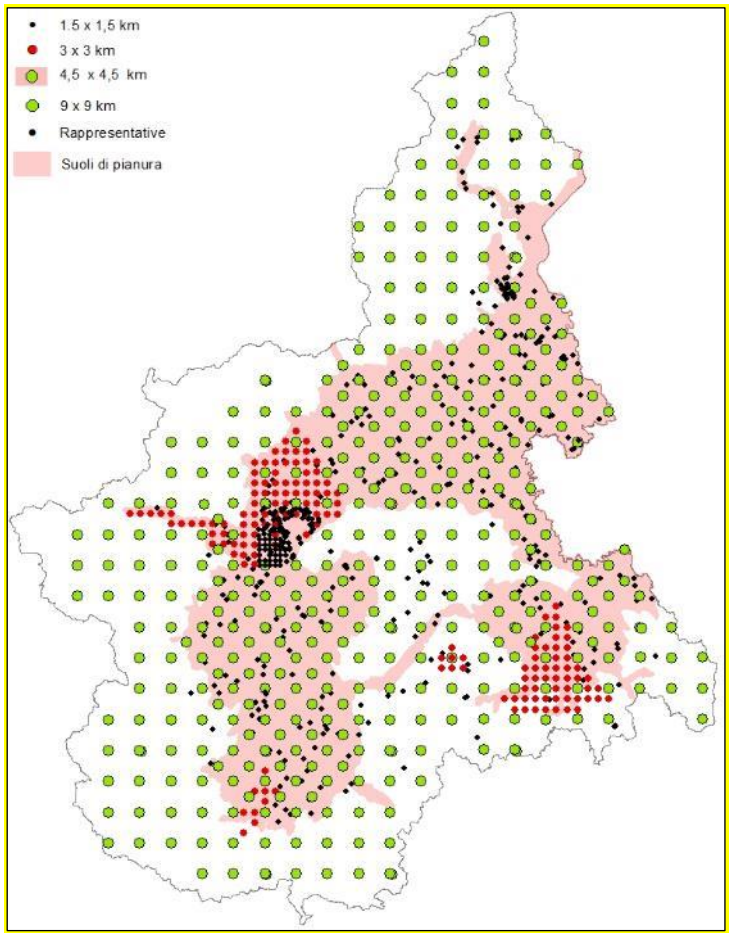

Figure 9: Locations of the stations of the Environmental Soil Quality Monitoring Network of Piemonte (data updated in December 2019).

The introduction of the Soil Monitoring Network of the Principality of Liechtenstein is based on the environment protection law. The task of the soil monitoring network is to record the contamination of soil pollutants as well as soil fertility in general. Repeated sampling of the same sites is intended to identify the longer-term development of pollutant loads. In the years 1994-1996 topsoil samples were collected at 37 locations, which are distributed over the whole nation in a grid of 2 x 2 km (figure 10). The sampled areas are currently used as forest, alpine pasture, grassland or arable land. Resampling took place at locations with critical loads of pollutants.

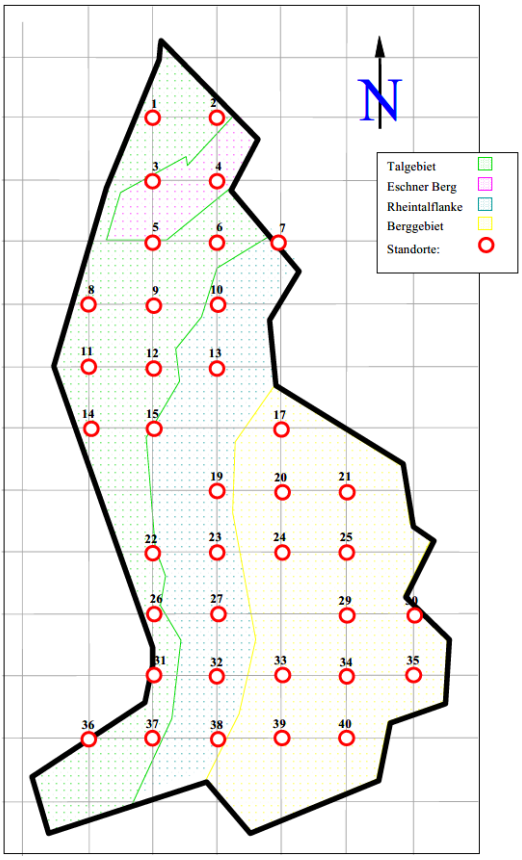

Figure 10: Soil monitoring grid of the Principality of Liechtenstein in 1995.

Slovenia has amongst other monitoring mechanisms for international instruments, the 8 x 8 km grid of plots in place. The main task of this instrument, on demand of the Ministry of the Environment and Spatial Planning, is carrying out activities related to greenhouse gas sink assessments needed for the regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (LULUCF). About 58 monitoring plots are located inside of the Alpine Convention perimeter as displayed in figure 11.
In addition, Slovenia is preparing the monitoring of negative impacts of air pollution on ecosystems for the NEC Directive.

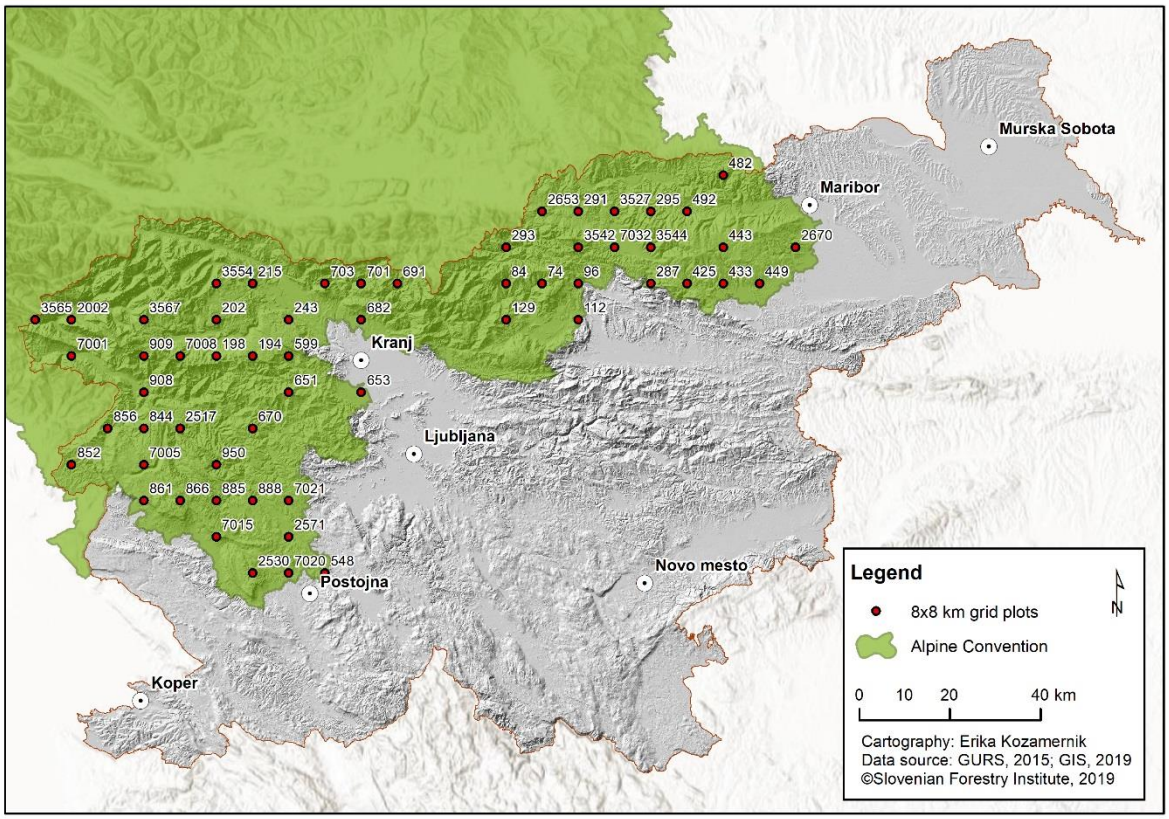

Figure 11: 8 x 8 km grid of plots in Slovenia for soil monitoring for LULUCF.

The Swiss National Soil Monitoring Network (NABO) records and documents the temporal development of the quality of Swiss soils based on chemical, physical and biological soil properties since 1985. The tasks also include early detection and forecasting of changes. For this purpose, a long-term monitoring system is operated, that monitors soils under their normal management. The monitoring network of around 110 sites spread across Switzerland is sampled regularly (figure 12). In addition, annually management and land use data are collected at selected sites. Also, NABO conducts supplementary studies on current issues. The selected NABO sites represent a combination of land use, soil type, geology, altitude and other site properties that are typical for Switzerland. Approximately two thirds are agricultural sites (arable land, permanent grassland, special crops) and one third is located in forests. Soil samples are collected at least every 5 years. Consequently, consistent time series over more than 30 years are available.

NABO carries out an additional indirect monitoring. Data on agricultural use will be collected for selected sites and material balances derived. Substance balancing helps to identify undesirable developments in the soil at an early stage and enables forecasts and scenarios to be drawn up. This modelling instrument serves as a precautionary tool in soil protection.

As a service, NABO offers consultation services for a diverse clientele with various needs. These services include developing recommendations for cantonal authorities, addressing specific soil-related questions of federal offices and offering technical advice to private clients. In addition, NABO regularly performs proficiency testing. These evaluations are commissioned by the federal government and conducted for interested laboratories to ensure data quality.

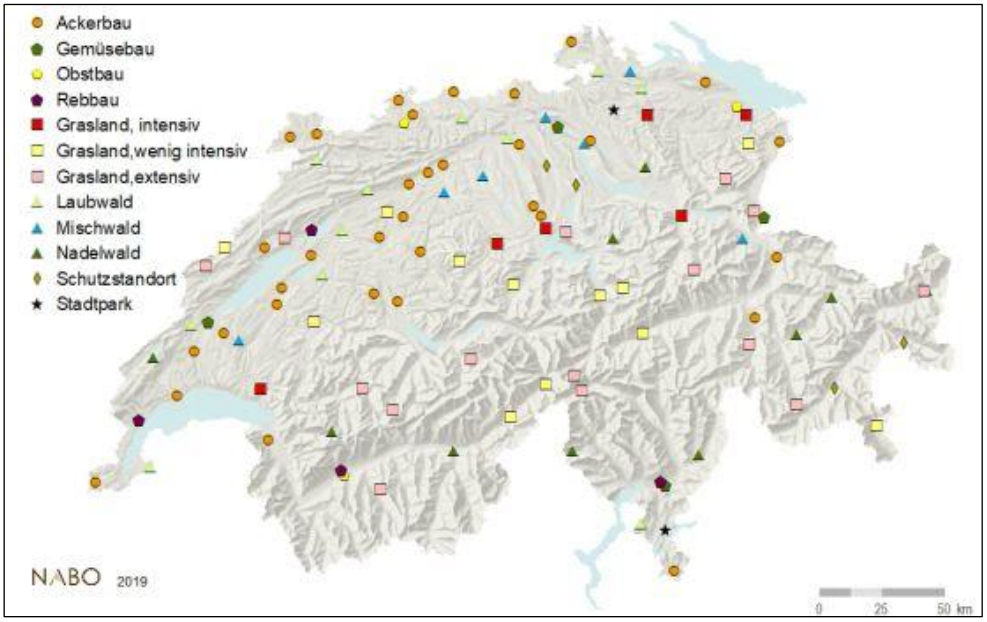

Figure 12: Swiss National Soil Monitoring Network (NABO), 2019. Source: Agroscope 2020.

3. Overview of sites for international monitoring instruments

As outlined above, harmonization of data generated by the largely differing monitoring systems in the Alpine States is hardly possible. Thus, it is important to take existing international monitoring systems into consideration, since in scope of those systems soil is already examined in an internationally comparable way. Consequently, the "*Questionnaire permanent monitoring sites for international monitoring mechanisms*", asking for soil monitoring sites in the perimeter of the Alpine Convention of previously identified international instruments - NEC directive, ICP Forests (Level I and II), LTER as well as LULUCF - was distributed and filled in by Austria, France, Germany, Italy, Liechtenstein, Slovenia and Switzerland.

The European soil monitoring LUCAS (Land Use/Cover Area frame statistical Survey) Soil, which also comprises locations inside the perimeter of the Alpine Convention is also an important instrument, which needs to be considered in this scope.

Sites, which are monitored for LULUCF (Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry) have also been demanded, but the answers underlined that this reporting mechanism can be disregarded for the purpose of this stock-taking, since there are no separate monitoring sites in some Alpine Countries and the reporting does not apply to Switzerland and Liechtenstein.

After presenting a summary at the 4th meeting of the Working Group the Contraction Parties have been asked for feedback regarding all open points. The Contracting Parties have been additionally asked to deliver, where possible, the coordinates and names of the sites, which are part of the monitoring for the NEC directive, ICP Forests (Level I and II) as well as LTER to avoid doubling and to prepare a correct overview. Since this was only partly possible in the short timeframe the displayed summary needs to be regarded as an initial overview, which should be updated in the future. Table 2 gives an overview on the current state of knowledge regarding the number of sites in the perimeter of the Alpine Convention, on which soil is monitored for the respective international instruments.

		Austria	France	Germany	Italy	Liechten-stein	Slovenia	Switzerland	AC perimeter	EU
LUCAS Soil survey	**Sites in survey 2015**	**363**	**183**	**54**	**290**	**x**	**61**	**58**	**1.009**	**over 250.000 sample points, 2015 also altitudes above 1.000 m**
	In place since	2009	2009	2009	2009		2009	once 2015	2009/2015	2009-2012, 2015, 2018 **next 2022, 2026**
ICP Forests Level II	**Sites**	**13** (5 core areas) (6 also part of LTER)	**9**	**2**	**10**	**x**	**3** 2 identic with NEC sites	**12**	**49 + x**	**around 500 plots**
	In place since	1988	1992	1991/1995	1995	x	2003			program launched in 1985
ICP Forests Level I	**Sites**	**114**	**47**	**8 x 8 km grid**	**15 x 18 km grid** (260 in Italy)	**x**	**14**	**12**	**187 + x**	**16 x 16 km grid**
	In place since	1987-1990 + 2006-2007	1988	1986 (next 2022-2024)	1995	x	1995			1986-1996 + 2004-2008
LTER	**Sites**	**30**	**25**	**1**	**16**	**x**	**4**	**12**	**88**	**25 national LTER networks**
	In place since	2001	2015	2004	2008	x	2003			LTER Europe since 2003
NEC directive	**Sites**	**15** (5 identic with ICP Forest) sites, 3 identic with LTER sites)	**6** (of 2 French national observatories. Air pollution monitoring plost should be added)	ICP and other preexisting monitoring sites used for monitoring	**4** (identic with ICP Level II sites)	**x**	**3**	***5***	**33 + x**	
	In place since	4-year interval for reporting data starting with 2019	To be implemented or reinforced over the period 2017-2021		sites identified since 2018	x	in preparation	*NABEL*		starting in 2019: 4-year interval for reporting data

Table 2: Overview of number of soil monitoring sites from international instruments in the perimeter of the Alpine Convention: current state of knowledge. The NEC Directive does not apply for Switzerland, but a comparable target is monitored by the Swiss National Air Pollution Monitoring Network (NABEL).

3.1 LUCAS Soil

The LUCAS (Land Use/Cover Area frame statistical Survey) Soil was developed in 2006 for the purpose of generating harmonized and thus comparable soil data for the EU (Joint Research Centre – European Soil Data Centre 2020), because the availability of soil data in the Member States and in their regions is very heterogeneously and the existing soil data is not comparable and thus cannot be harmonized. It is aimed at answering to policy needs of the EU and the Member States, such as regarding nature protection, climate change and agriculture. Soil data is becoming even more important in light of the EU Green Deal (Biodiversity Strategy, zero pollution, Farm2Fork Strategy, Circular Economy, climate law) and the Sustainable Development Goals. Eurostat coordinates the LUCAS Soil survey, while the implementation and development is done by the Joint Research Centre of the European Commission (JRC).
The soil surveys were continuously further developed in the extend of sample sites as well as in parameters covered, from the first survey in 2006 to the replications in 2009, 2012, 2015 and 2018. From now on the sampling interval will be extended to every four years. A core of sampling points always stays identical, while the majority of points change for each survey. For the Alpine area, the surveys from 2015 onwards are the most relevant once, since also sites on a higher elevation than 1.000 m over sea level were covered and additionally Switzerland was included. Figure 13 shows the locations inside of the perimeter of the Alpine Convention, which were sampled in scope of the LUCAS Soil survey 2015 including the sites in Switzerland.
Thus, this survey needs to be considered or even play a significant role regarding the issue of establishing a harmonized soil database for the Alpine region. Consequently, the soil monitoring sites in the perimeter of the Alpine Convention, which the survey comprises need to be included in this overview.

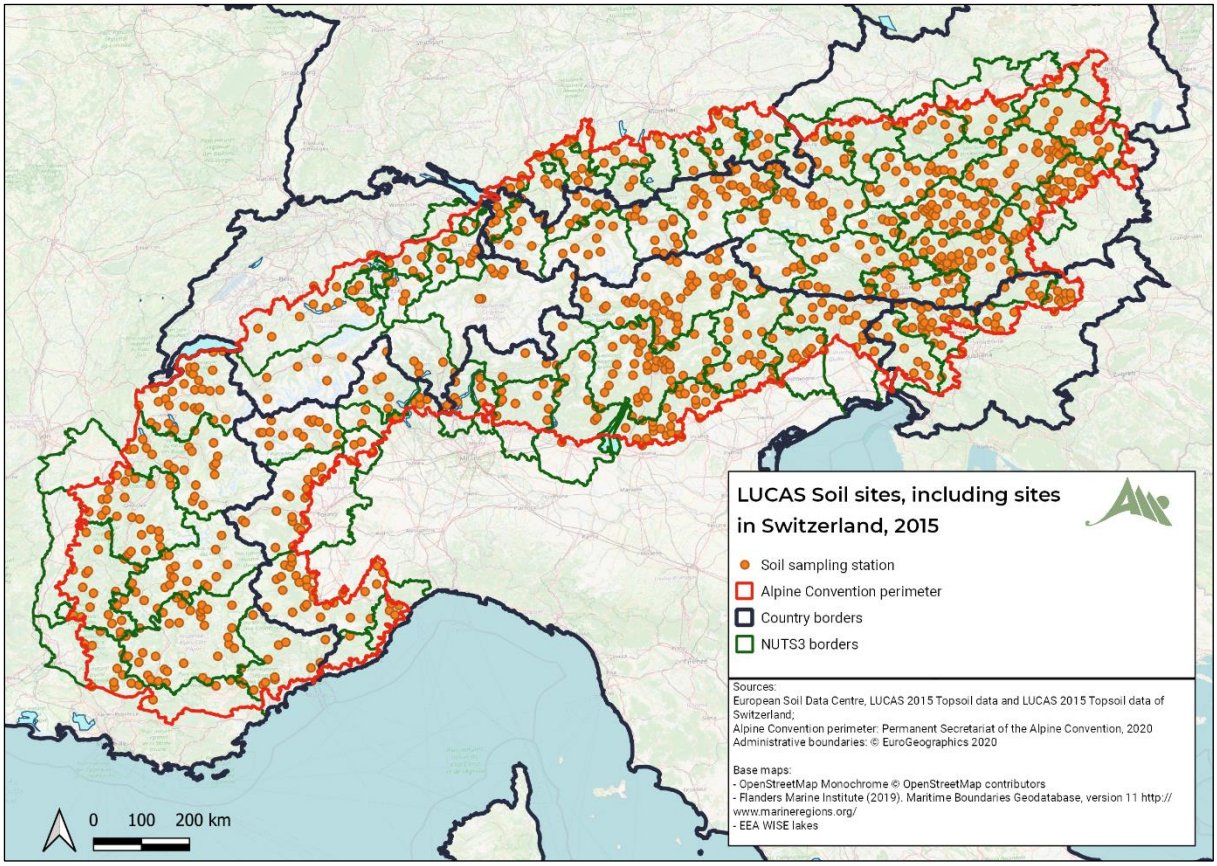

Figure 13: LUCAS Soil survey 2015 sampling sites and corresponding sampling sites in Switzerland 2015.

A cooperation with the JRC was started at the 4th meeting of the Soil Protection Working Group of the Alpine Convention. Currently the next LUCAS Soil survey is being prepared for the sampling phase from March to September 2022. While the first part of the surveys is always based on photointerpretation, the soil sampling is raised from 25.000 to 41.000 points. The samples will also be taken from deeper horizons (down to 30 cm). In addition, it is foreseen to expand on investigating soil biodiversity, sulphur, more cations and to research heavy metals again more extensively in the upcoming survey. While carbon content and organic soils were already a topic in the 2018 survey, a soil carbon indicator is currently further developed for reporting e.g. for the new CAP (EU Common Agricultural Policy). The Soil Protection Working Group of the Alpine Convention will prepare a proposal for the next survey for adjusting the locations in the Alpine region in order to record the state of the soils in the Alpine region in a representative way, taking into account the geological and hydrogeological situation, using the same evaluation bases and harmonised methods (Protocol on Soil Protection of the Alpine Convention Article 20 (3)).

3.2 ICP Forests

The ICP Forests Programme is the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests. In total 40 European countries as well as Canada and the United States of America are taking part in the ICP Forests Programme. Austria, Germany, France, Italy, Liechtenstein, Slovenia and Switzerland are participating.

ICP Forests was launched in 1985 under the Convention on Long-range Transboundary Air Pollution (Air Convention, formerly CLRTAP) of the United Nations Economic Commission for Europe (UNECE). A Task Force is the highest body of ICP Forests, and it represents all participating countries. National experts are organized in Expert Panels and Working Groups, which ensure the continuous development and harmonization of the monitoring methods and contribute to data evaluations. Different aspects are monitored, while samples for soil conditions are taken ca. every 10 years.

ICP Forests monitors forest condition in Europe on two monitoring intensity levels:

- The Level I monitoring is based on around 7.500 observation plots on a systematic transnational grid of 16 x 16 km throughout Europe and beyond to gain insight into the geographic and temporal variations in forest conditions. Figure 14 displays the spatial distribution of Level I plots in Europe in 2011classified by forest types. The network is subject of changes thus the distribution of plots (Level I and II) has slightly changed since then (Michel et. al 2018, 2019).
- The Level II intensive monitoring comprises around 500 plots in selected forest ecosystems with the aim of clarifying cause-effect relationships, to research the interaction between air pollution, climate change and forest ecosystems. At the current state of knowledge 39 plots are in the perimeter of the Alpine Convention.

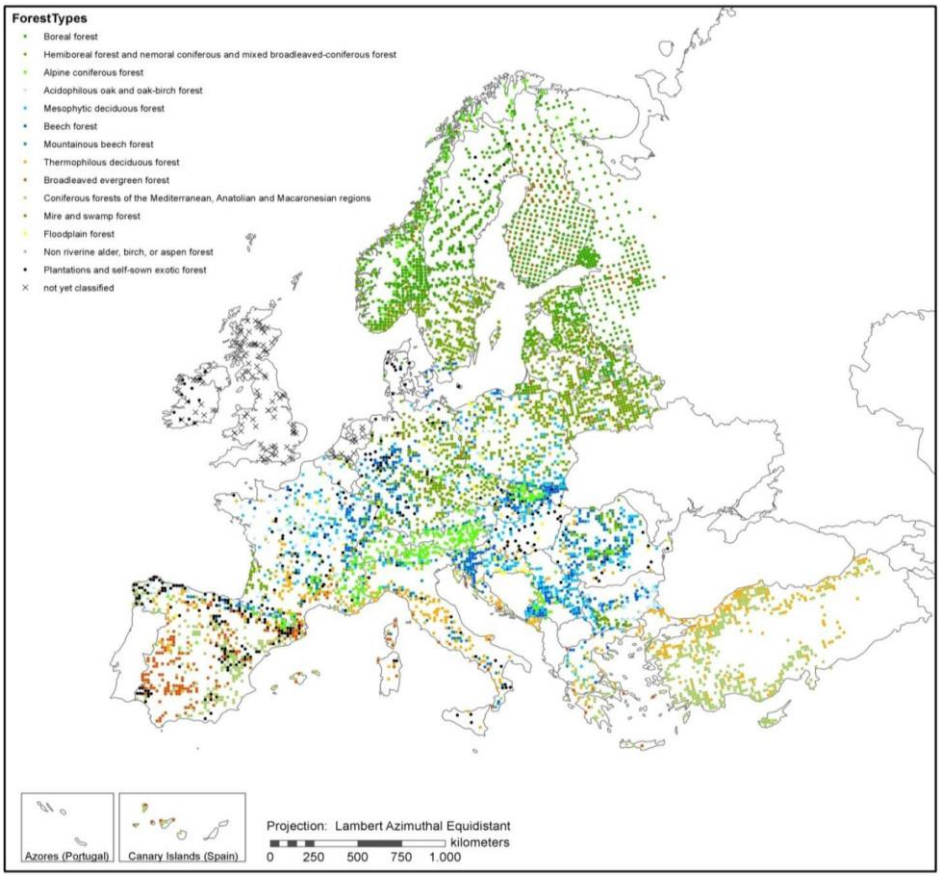

Figure 14: Spatial distribution of the ICP Forests Level I plots assessed in 2011, displayed according to respective forest types. Source: Lorenz et. al 2012.

3.3 LTER

Through research and long-term observation of representative sites around the globe, Long-Term Ecosystem Research (LTER) enhances our understanding of the structure and functions of ecosystems, which provide essential services to people (eLTER 2020). The LTER network was founded in 1980 by the United States National Science Foundation. eLTER was launched in Europe in 2003 as the umbrella network for Long-Term Ecosystem Research in Europe. Its members are national networks of LTER areas, which differ in their respective structures. Several permanent monitoring sites are located in mountain regions, where several biotic (e.g. plant phenology, plant composition, soil microbial biomass) and abiotic factors (e.g. air temperature, soil temperature, snow cover duration) are recorded. There are different classes of LTER sites:

- Master LTER sites,
- Regular LTER sites,
- Emerging LTER sites (new sites) and
- Extensive LTER sites.

At the current state of knowledge about 88 plots are in the perimeter of the Alpine Convention (see table 2). Figure 15 gives a general orientation of LTER sites in the perimeter. The locations are based on the information provided by the DEIMS-SDR (Dynamic Ecological Information Management System - Site and dataset registry). It displays only accredited LTER Europe sites, which differs slightly from LTER sites participating in the program, that were reported by the Contracting Parties.

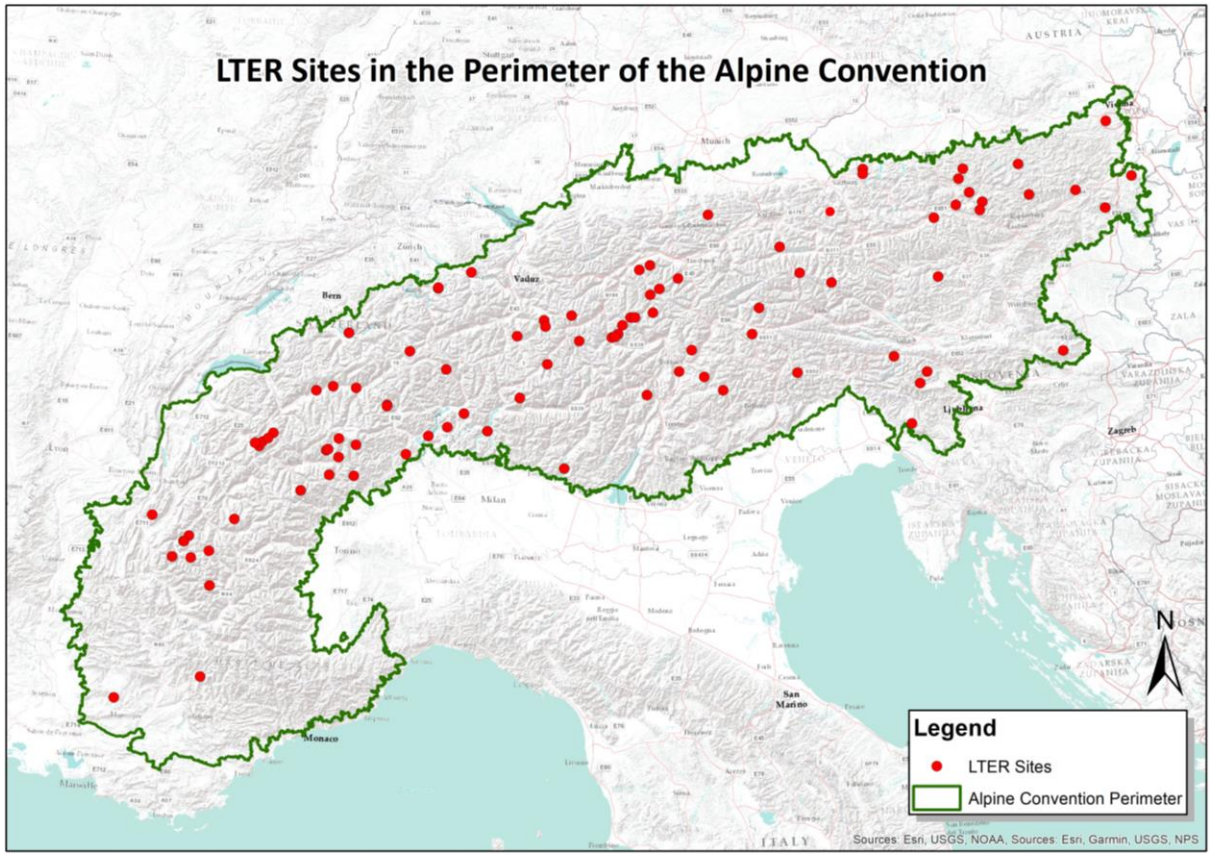

Figure 15: LTER sites in the perimeter of the Alpine Convention. Data source: DEIMS-SDR 2020.

The operators of the Austrian LTER sites, came together under the umbrella of "*LTER-Austria*". LTER in Austria provides an excellent link between environmental research and environmental monitoring, which is reflected in the reciprocal and highly synergistic utilization of the sites in both sectors. There are close connections to inter- and transdisciplinary sustainability research, to applied research, and to questions of sustainable regional development.

eLTER-France is organized in Workshop Zone Networks (RZA= Réseau des Zones Ateliers). The RZAs focus on functional units such as a river and its catchment area, landscapes - agricultural or urban - and biodiversity. They investigate ecosystems (marine, mountain, agricultural, fluvial, etc.). In the RZA observation, experimentation and analysis consider human practices in these environments and ecological functionalities such as ecosystem services. The RZAs are in direct contact with the stakeholders in the area, particularly regarding questions raised by managers, politicians and associations. Two LTER RZAs in France are part of the Alpine area: Zone Atelier Alpes and the research infrastructure OZCAR, both containing several sites. In addition, it is possible, that single sites of other RZA stretch into the Alpine perimeter.

The German LTER network "*LTER-D*" was founded in 2004. It comprises about 30 LTER areas. A LTER site in the perimeter of the Alpine Convention in the Berchtesgaden National Park.

LTER-Italy (ILTER) was founded in 1993, to meet the growing need for global communication and collaboration among long-term ecological researchers and to capture ecological phenomena in the context of global change. LTER-Italy is also one of the key nodes of the E-infrastructure for Biodiversity and Ecosystem Research LifeWatch (LifeWatch ERIC 2020).

LTER Slovenia is a network of eight institutions engaged in a long-term, site-based ecological and socioeconomic research since 2003. LTER Slovenia geographically covers a wide spectrum of monitoring sites, which are: two cave systems, 11 forest platforms, two lakes and one marine site. Depending on the physical characteristics of the LTER site, several ecological and biodiversity data are measured. Parameters are monitored in the air, water, soil, and vegetation. Four LTER areas are in the perimeter of the Alpine Convention.

In Switzerland, the identic sites are part in the LTER network as in the ICP Forests Program. It is covered by the Swiss national program "*Long-term Forest Ecosystem Research*" (LWF) which follows multiple objectives on 19 monitoring sites of which 12 are inside the perimeter of the Alpine Convention.

3.4 NEC

The NEC Directive (National Emission Ceilings Directive) entered into force on 31 December 2016. According to Article 9 of the NEC Directive, monitoring of impacts of air pollution on ecosystems must be ensured. The Clean Air Programme for Europe includes, in addition to its target for reduction of health impacts across the Union, a target for a reduction by 35 % of the ecosystem area subjected to eutrophication by 2030, compared with 2005. In order to have the data to assess this target, Member States must report monitoring data in a 4-year interval, starting with 2019.

The intention is to reinforce the ecosystem monitoring network to determine the state of terrestrial and freshwaters ecosystems in a long-term perspective with respect to the impacts of SOX, NOX, NH3, and ground level ozone and to enable prediction of changes. Thus, the objectives of the monitoring are to improve information on the impacts of air pollution, including the recovery time needed when the impacts are reduced, as well as to review critical loads and levels. The air pollution impacts of main interest for the ecosystem monitoring are acidification, eutrophication and ozone damage. While the impacts of other pollutants (e.g. metals) are also of concern, the first phase of monitoring focuses on these three issues.

In Italy "four sites sensitive to both acidification and nitrogen deposition where long-term data are collected (ICP Waters/LTER) were identified for water bodies monitoring, all of them located in the north alpine region, because this is considered a pristine area in Italy not affected by other anthropogenic sources of air pollution, where the contribution of transboundary air pollution can be distinguished from other pressures" (De Marco et al. 2019).

The NEC Directive does not apply for Switzerland. However, Switzerland has set a target similar to the targets of the NEC Directive. It aims at reducing the VOC (volatile organic compounds)-emissions by 30% until 2030, taking the year 2005 as the starting point. The Swiss National Air Pollution Monitoring Network (NABEL) is thus also listed in the table 2.

In Liechtenstein air quality and compliance with threshold values for human health and environmental protection is monitored in cooperation with the monitoring network of east Switzerland "*OSTLUFT*". Threshold emission values for human health and environmental protection and emission limits for energy production, industry, agriculture, traffic, combustion and power fuel, and domestic heating are defined in the national clean air act and further developed in the national air quality action plan.

4. Conclusions and further steps

The stock-taking of soil monitoring areas in the perimeter of the Alpine Convention as well as the stared discussions on data harmonization and the establishment of a cooperation with the JRC regarding the LUCAS Soil survey represent first steps in facilitating the implementation of Articles 20 (establishment of harmonized databases) and 21 (establishment of permanent monitoring areas and coordination of environmental monitoring) of the Soil Conservation Protocol of the Alpine Convention.
Further steps are necessary to build up on the started process. This applies especially to the continuation of the started cooperation regarding the European soil survey as well as the need to establish a medium- or long-term concept towards coordinated permanent soil monitoring areas and comparable soil databases for the Alpine area.
Furthermore, the assessment of soil functions of agricultural soils has been addressed and discussed by the Soil Protection Working Group at several meetings. The resulting soil function maps have proven to be a good and important tool for evidence based spatial planning decision, for enabling planers and decision makers to save the most valuable soils. Supporting Alpine regions in establishing such soil function maps and developing Alpine wide comparable soil function maps, would be important steps for soil protection in the Alps and a specific case of implementing article 20(1) of the Soil Conservation Protocol.

Sources and further information

Websites

Alpine Convention (Framework Convention):
https://www.alpconv.org/en/home/convention/framework-convention/

Protocols and declarations of the Alpine Convention:
https://www.alpconv.org/en/home/convention/protocols-declarations/

In scope of the Interreg Alpine Space project Links4Soils the **Alpine Soil Web GIS** has been established. It gives access to freely available regional, national and trans-border Alpine soil data collected within the Links4Soils project:
https://alpinesoils.eu/soil-info/

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ALPENKONVENTION
CONVENTION ALPINE
ALPSKA KONVENCIJA
CONVENZIONE DELLE ALPI