Soil Survey and Soil Data in Austria

Winfried E.H. Blum[1]
Michael Englisch[2]
Alexandra Freudenschuß[4]
Peter Nelhiebel[3]
Hannes Pock[2]
Wilhelm Schneider[3]
Sigrid Schwarz[4]
Josef Wagner[5]
Michael Wandl[2]

[1] Institut für Bodenforschung, Universität für Bodenkultur, Gregor-Mendelstraße 33, A-1180 Wien, AUSTRIA
[2] Institut für Forstökologie, Bundesamt und Forschungszentrum für Wald, Seckendorff-Gudent-Weg 8, A-1131 Wien, AUSTRIA
[3] Institut für Bodengesundheit und Pflanzenernährung, Österreichische Agentur für Gesundheit und Ernährungssicherheit, Spargelfeldstraße 191, A-1226 Wien, AUSTRIA
[4] Abteilung Terrestrische Ökologie, Umweltbundesamt GmbH, Spittelauer Lände 5, A-1090 Wien, AUSTRIA
[5] Abteilung IV/8 - Bodenschätzung und landwirtschaftliche Einheitsbewertung, Bundesministerium für Finanzen, Himmelpfortgasse 4-8, A-1015 Wien, AUSTRIA

Introduction

There are three principal systems of soil survey in Austria: on forested land the Forest Soil Survey, on agricultural land, the Soil Taxation Survey and the Soil Management Survey. In addition, there is an Environmental Soil Survey, a Soil Monitoring System and a Soil Information System (BORIS). Each of these is described below.

Forest Soil Survey

Forest Site Mapping

Major efforts to map forest sites started in the late 1950s and early 1960s, carried out mainly by the University of Agricultural Sciences in Vienna, the administration of the government-owned forests (Österreichische Bundesforste) and the Federal Office and Research Centre for Forest (BFW).

Today, the main emphasis is concentrated on site classification, with site mapping limited to local projects. These local projects are carried out by various organisations of governmental and private forest administration. BFW acts as service unit for harmonisation, quality control and training.

Methods and Output

Forest site mapping in Austria uses the ‘combined method’ developed in Baden-Württemberg (Kirschner and Schlenker 1955) with some minor variations. The method takes into account climate, soil (geology) and vegetation characteristics in site classification. The goal of mapping is to delineate ecologically-based site units that are locally valid and fit into a hierarchical framework (groups of sites, growth districts, altitudinal zones and growth regions).

Vegetation type, growth data, and soil characteristics, supplemented by chemical analyses (pH value, C_{org}, N_{tot}, nutrients, CEC, base saturation), are identified on plots selected to be representative of the entire range of the sites in the area to be mapped. The plots, which may be arranged in a grid, a transect covering important gradients or distributed randomly in pre-stratified areas, are used to define the site units of the proposed mapping area. Based on these investigations the site units are classified and from this classification is developed the key for mapping the units. Mapping of soil indicators is carried out using a 1m soil auger (1-4 samples per hectare).

Recently a working group of all involved organisations has completed a guide for forest site mapping in Austria, considering new developments and modern techniques e.g. GIS, use of databases, IR-aerial pictures and multivariate statistical analysis (Englisch and Kilian, 1998). Currently, a database (‘METAMAP’) containing meta-information on methods, area mapped, data availability etc. is being set up. Up to now, about 400,000ha, i.e. approximately 10% of forest land has been mapped, predominantly at scales of 1:10,000 and 1:25,000.

Mapping has been focussed on state-owned forest land (mainly the federal provinces of Salzburg, Upper Austria (southern part) and Styria, the floodplain forests of the Danube, the Vienna Woods and North-Eastern Styria. Additionally, the BFW has carried out site classifications in most of the 21 forest growth regions in order to provide a basis for local mapping projects.

Application of results

Forest site maps have been instrumental in the selection of tree species and are thus part of the forest management. In addition, they serve in understanding ecological changes (e.g. to identify changes of the water regime of sites after construction of power stations), as a basis for local forest amelioration and can be used for scientific purposes (e.g. selection of trial plots).

Recently, site classification and mapping has been used for environmental planning, as a basis for the assessment of biodiversity, for nature conservation, and for wildlife management, amongst other uses.

Forest Soil Monitoring

In Austria, there are two schemes for forest soil monitoring. In the late 1980s the *Forest Soil Monitoring System* (FSMS) was started by the BFW as part of the *Forest Damage Monitoring System* in order to obtain information on the causes and effects of forest die-back. The FSMS consists of 514 plots arranged in a grid of 8.7km x 8.7km. At each plot, growth measurements and vegetation relevés, site and soil description, chemical analyses of soil and foliar samples are carried out and crown defoliation class is assessed.

Soil and site descriptions and soil analyses (pH-value, C_{org}, N_{tot}, nutrients (‘total’ contents in aqua regia, cations in $BaCl_2$-solution), carbonate content, CEC, base saturation, heavy metals, texture analysis) were carried out between 1987 and 1990. Soil samples, including soil organic (ectorganic) horizons, were taken at predefined soil depths (0-10cm, 10-20cm, 20-30cm, 30-50cm). About 140 plots are included in the European-wide level I ECE/ICP forest soil monitoring network. Repetition of soil sampling is planned.

Additional forest soil monitoring networks were established in several Federal Provinces (Länder), including Lower Austria, Salzburg, Tyrol and Vorarlberg. All plots of the *FSMS* and of the regional networks were included in the combined report on soil conditions in the countries of ARGE Alp and ARGE Alpen-Adria (Huber and Englisch 1997).
The main results of these projects indicate moderate regional forest soil acidification, wide-spread heavy metal pollution (Pb, Cd), which peaks at the northern fringe of the Alps and varies with increasing altitude, and accumulation of nitrogen.

Another 20 plots are part of the level II /ECE/ICP intensive soil monitoring network, which was established in 1994. Intensive soil sampling (5 samples as a mixed sample of 8 subsamples in the upper soil horizon, 4 samples as a mixed sample from 4 subsamples in the lower soil horizon) is carried out in soil organic (ectorganic) horizons and mineral soil horizons at predefined depth intervals of 0-5cm, 5-10cm, 10-20cm, 20-40cm, 40-80cm. The same methods of soil analyses as in level I are used. The aim of the intensive monitoring is to assess soil changes with time.

Forest Soil Database

The largest forest soil database (GEA) in Austria is managed by BFW. It includes descriptions of about 5,000 forest soil profiles and about 26,000 analyses of individual soil horizons (standard suite of analysis: compare FSMS). It is planned to enlarge this database to become a general forest-site information system.

Applications of Forest Soil Data

Forest soil data are principally used for site mapping, for the protection of forest soils and forest ecosystems (mainly in relation to heavy metal pollution, acidification, nitrogen input), ground water protection and environmental planning, for forest amelioration and fertilisation, and for scientific purposes.

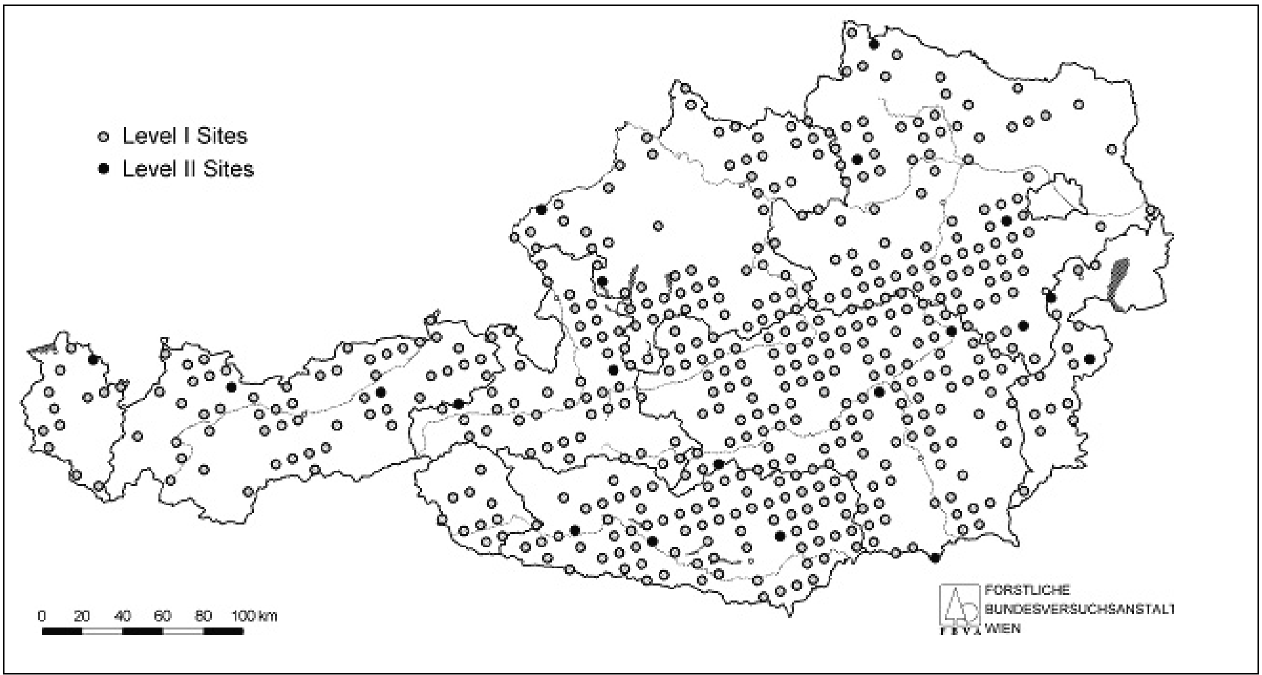

Figure 1: Forest Soil Monitoring System

Outlook

Recently introduced methods for intensive soil monitoring mainly focus on soil biological parameters. The most widely applied microbial parameters are microbial biomass (measured as substrate induced respiration) (Beck *et al.*, 1996) and nitrogen mineralisation potential (Kandeler, 1996). These have been used in soil surveys in Upper Austria and in monitoring programmes (e.g. Salzburg) as indicators of soil fertility. These methods can reveal local soil pollution (Tscherko and Kandeler, 1997).

Soil fauna can also be used as an indicator of soil quality. Earthworms (*lumbricidae*), potworms (*enchytraeidae*), and springtails (*collembola*) have proved to be successful indicators in the intensive monitoring programmes. Because of the constant development of new biological methods and increasing experience in this field, it can be expected that, in the future, these methods will be used increasingly as an obligatory part of intensive soil monitoring programmes.

Agricultural Soil Survey

Soil Taxation Survey

Since 1947 the taxation of agricultural land has been carried out by the financial administration in co-operation with the Federal Surveying Office. The first taxation, mainly based on the German Soil Taxation Act of 1934, was completed in 1973. The Austrian Soil Taxation Act of 1970 provided a new legal basis, regulating the continuity and updating of soil taxation data as well as their integration into the Austrian cadastre.

The main task of the soil assessment is to maintain up-to-date data on agricultural properties. Since 1974 the data have been updated through revision and reassessment to take into account changes in important environmental factors.

Methods and Output

Field methods are used to estimate the quality and natural productivity of soils for taxation purposes. Soil is described to a depth of 1 metre at intervals of 40 metres in general across the agricultural land using a soil auger. Parent material, texture, organic matter, horizons and structure are investigated. Units with comparable conditions of soil, relief, water regime and climate are defined and included in the Cadastre Map. Such maps are at a scale of 1:2,000 or 1:2,880 (scale of the old cadastre).

For comparison purposes, a system of values between 1 and 100 is used to assess soil conditions, relief, climate and water regime. The best possible value is 100, attributed to the soil with the highest yield potential. In typical Austrian regions, 432 standard sites guarantee a harmonised assessment. There is a close relationship between a given soil taxation and these standard sites.

The results of the soil assessment are documented in the Soil Taxation Register, the 'Schätzungsbuch', and in soil taxation maps. These data exist for every parcel of agricultural land in Austria. For each parcel the value mentioned above is multiplied by the size of the parcel and this new value forms the basis for agricultural taxation.

Soil assessment data exist in analogue form for approximately 2.7 million hectares of agricultural land, corresponding to 32% of the total area of Austria.

Application of Results

As the soil taxation data have been investigated with a high degree of continuity and comparability for decades and are characterised by very precise geometric positioning, they can be combined with other data of the Cadastre for every parcel. Therefore, soil assessment data are not only used for taxation of agricultural property. They also include basic ecological information about soils and are used for various purposes, including:

1. Soil reform;
2. Compensation;
3. Land use planning;
4. Use of sewage sludge;
5. Proceedings of the Water Act;
6. Measures within the Austrian Programme for the Promotion of Environmentally Friendly and Extensive Agriculture that Protects Natural Habitats (ÖPUL);
7. Basis for site adapted soil management;
8. Scientific projects.

Outlook

Currently about 20% of the soil taxation data are available in digital form. The continuation of the digitisation in co-operation with the Federal Surveying Office is planned.

Soil Management Survey

The origins of agricultural soil mapping - a cartographic representation of soil conditions at a scale as large as possible - go back to the 19th century. One of the oldest 'agro-geological'soil maps was drawn in 1858, in the Austro-Hungarian Empire, at a scale of 1:500,000 (Szabolcs, 1997). In Austria, soil mapping has been carried out since the 1920s. Experimental soil mapping was carried out after the Second World War. Since 1958, systematic mapping has been conducted by the Federal Institute of Soil Survey and Soil Management. At that time it was decided to survey agricultural land only, and involved the collection of field data and production of maps.

By 1969, 20% of the arable land in Austria had been surveyed at a scale of 1:2,880 (Cadastre scale) and maps produced at a scale of 1:5,000. Since 1970 the survey has been made at a scale of 1:10,000 and published at a scale of 1:25,000, to accelerate the procedure. The latter scale is exact enough to meet several needs and related questions.

Methods and Results

Soil mapping, which includes an assessment of geological, geomorphological and climatic conditions, is carried out from an agricultural and pedological point of view. The sampling density varies with soil heterogeneity but on average one bore per hectare is made. This approach is used to identify Soil Units, which are defined as areas with the same soil type and similar site characteristics.

For each Soil Unit at least one profile is described (to approximately 120cm depth) and samples of the individual horizons are subjected to laboratory analysis, including texture (percentage of clay, silt and sand), organic matter, carbonate, pH-value, electric conductivity, exchangeable cations, nutrients and heavy metals. Until 1995, the 1:25,000 soil maps, as well as the supporting explanatory texts, were produced by offset printing. A digitised soil databank is currently being established. Maps of some 144 mapping regions (mostly judicial districts), representing an area of approximately 22,000km^2 or 63% of agricultural land have been published.

Manuscript soil maps (1:25,000 scale) exist for another 10% of agricultural land. In total, about 98% of the agricultural land has been surveyed and the results are available to interested persons or institutions. Since 2002, the soil survey group has been part of the Austrian Federal Office and Research Centre for Forests, whereas the analytical staff belongs to the Austrian Agency for Health and Food Safety.

The composition of the digital soil map consists essentially of the results of the Austrian Soil Survey, i.e. all information of printed soil maps including the information of printed manuals. Furthermore soil analysis data as well as the extensive data of the soil quality network programme will be integrated in the database. Additional data, like digital topographic maps, digital terrain-models, aerial photographs, satellite images and various other external data enlarge the application area of the digital soil-information system (Figure 2).

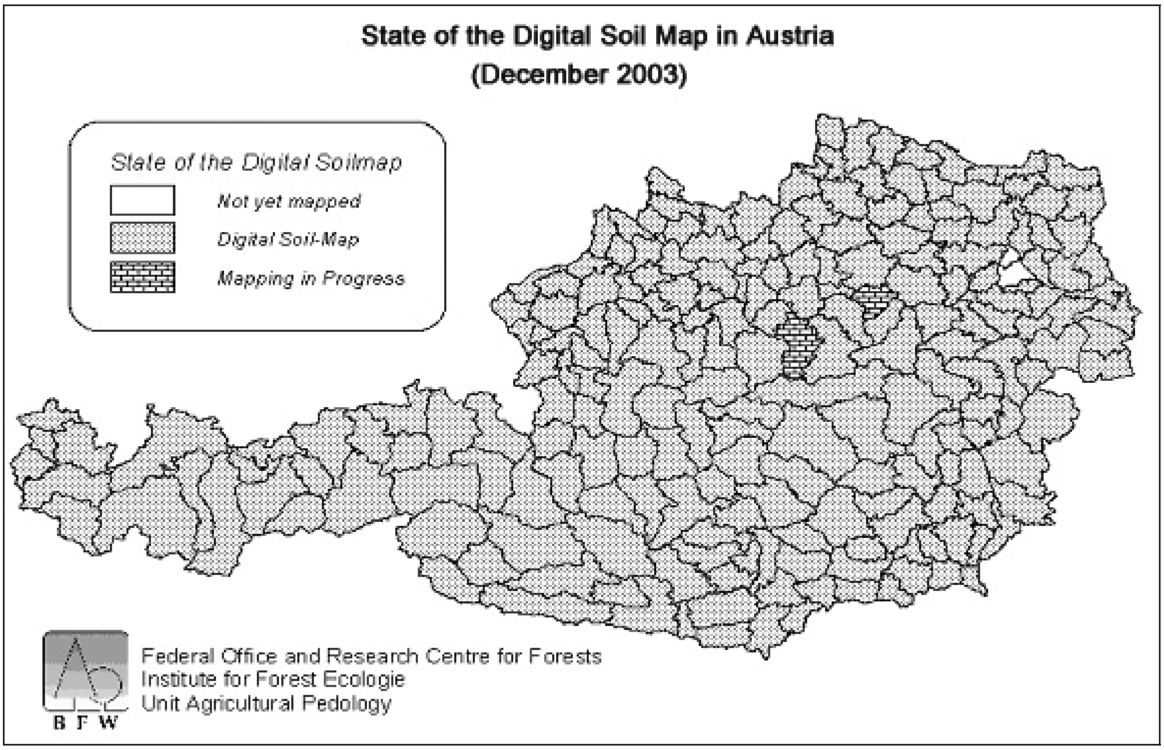

Figure 2: State of Soil Management Survey

Application of Results

Examples of the practical applications of the 1:25,000 scale soil maps include:

1. Sustainable fertilisation and cultivation practice of soil in an environmentally friendly way;
2. Selection of experimental sites;
3. Modelling (e.g. Crop suitability);
4. Regional, Provincial and Integrated Land Use Planning and River Basin Management;
5. Evaluation of the preservation of ecologically sensible sites;
6. Survey of the Potential of Natural Habitats;
7. Use in research projects.

Based on the 1:25,000 soil map, a number of special maps have been generated, concerning:

1. Water regimes;
2. Sensitivity to erosion;
3. Possible use of sewage sludge;
4. Sensitivity to nitrate leaching.

These special soil maps allow early detection of negative impacts on soil, such as wind erosion, water erosion, decline of soil structure, and contamination and drought, enabling relevant measures to be taken.

Outlook

Thirty hectares of agricultural land are lost to non-agricultural purposes every day. This is likely to lead to a greater pressure on soils suitable for agriculture in the future, especially if the planned extensification of crop production takes place. By this time a well-organised digital soil information system will be indispensable. Areal and point data for Austrian soils are essential to protect and conserve the soil and to sustain soil fertility.

Environmental Soil Survey

The decision to establish an intensive environmental soil survey programme was taken by provincial governments, which have the main responsibility for soil management and soil protection of agricultural land. In 1986, Vorarlberg, the most western province of Austria, started an environmental soil survey although, at the time, no special guidelines were available.

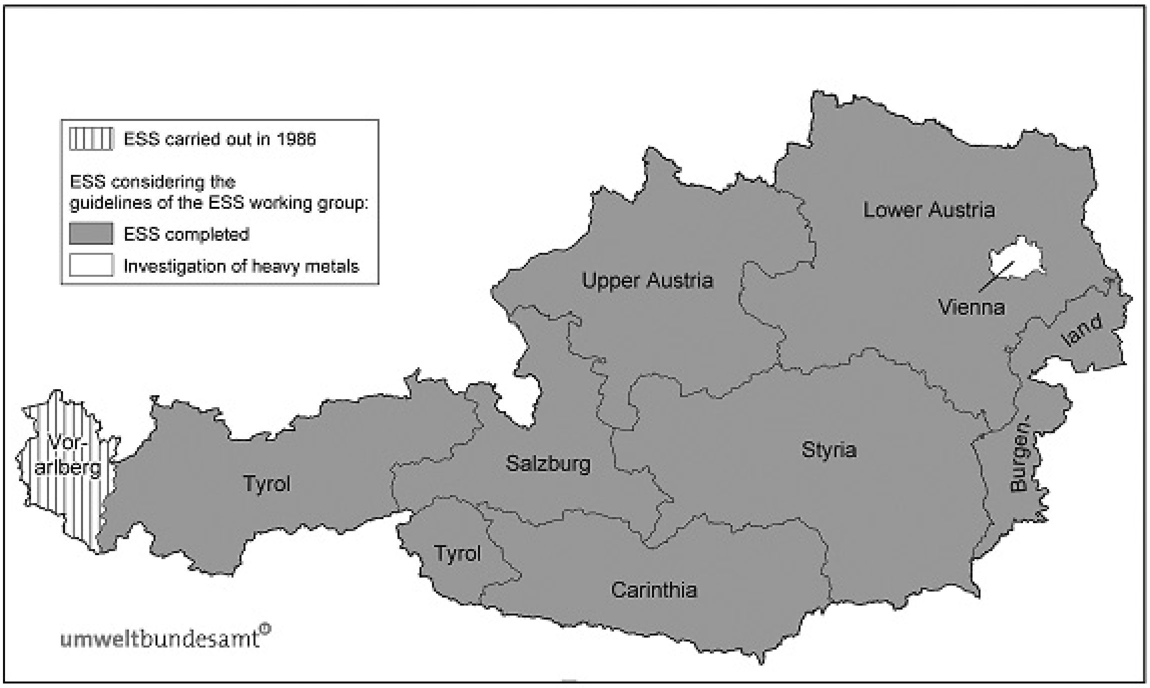

Figure 3: State of Environmental Soil Surveys in Austria

A recommendation for carrying out an environmental soil survey was prepared by the working group 'Environmental Soil Survey' of the ASSS (Austrian Society of Soil Science) (Blum *et al.*, 1989) to create a basis for comparable soil data all over Austria. According to this guideline the investigations of all the other Federal Provinces (between 1989 and 1998) are to a large extent comparable in soil sampling design and analytical methods (Figure 3).

Methods and Output

The sites are situated in a basic grid of about 4km x 4km. In some regions the grid was narrowed to 2.75km x 2.75km. For the Forest Soil Monitoring System (FSMS) a grid of 8.7km x 8.7km was used. Each sampling site is marked and coded.

Sites and soil profiles are described and composite soil samples are taken at predetermined depths (mixed from several parallel samples) using a soil auger. The number of subsamples in each composite sample varied between the Environmental Soil Surveys in the different Federal Provinces. Soil analyses include pH, carbonate concentration, nutrients, heavy metals, humus content, particle size distribution. Special programmes also included organic pollutants, biological and physical soil parameters.

In Table 1 the number of investigated sites according to land use is given. Most of the sites of the environmental soil surveys are situated on agricultural land.

In Tyrol a replicate sampling was made in 1996, eight years after the first investigation. 107 of the original 658 sites were investigated in the second sampling. In Vienna - the capital of Austria - a special programme focusing only on heavy metals was launched in 1992. Since then replications have been carried out at regular intervals (1994, 1997, 2000, 2003). The last investigation includes also analysis of some organic compounds (PAH).

The Forest Soil Monitoring System (FSMS) of the Federal Office and Research Centre for Forest (BFW) is included in Table 1, although the FSMS is a Federal nationwide investigation (*cf.* Forest Soil Monitoring Section above).

An evaluation of all the data (of more than 5,000 sites), investigated with comparable methods, is currently in progress at the Federal Environment Agency in order to derive soil background values according to different land use and the geological conditions for Austria.

Furthermore an overview of the state of agriculturally used land in Tyrol (153 sites), Salzburg (197 sites), Lower Austria (1,449 sites), Upper Austria (453 sites), Burgenland (174 sites) and part of Styria (84 sites) has been made by the Federal Office and Research Centre of Agriculture in 1997 (Danneberg *et al.*, 1997), based on the upper 20cm of arable and grassland soils, with data from approximately 2,500 sites.

Table 1: Number of Environmental Soil Survey (ESS) sites in Austria according to land use (1998).

Land use	Tyrol	(Tyrol [1])	S	UA	LA	St	Vbg[+]	B	Car	Vie [2]	FSMS	TOTAL
forest	263	(15)	177		90	17	150				514	1,211
agricult. land	47	(33)	14	439*	1,151	193	40	164	140			2,188
grassland	139	(59)		441*	298	256	243	10	250			1,637
extensively used			137									137
intensively used			134									134
alpine pasture	209					61			91			361
others						21	2			286		309
total	658	(107)	462	880	1,539	548	435	174	481	286	514	5,977

[1] ....replicate sampling

*[2] ....regular investigations of heavy metals (1992, 1994, 1997, 2000, 2003 additionally some organic compounds): *agricultural and horticultural land*

*** ....grassland incl.alpine pastures, pastures and others*

+..........As the ESS in Vorarlberg was completed in 1986 before the ESS-guidelines (Blum et al.,1989) were published, the data cannot be compared to the other ESS, due to different methodology.

S Salzburg, UA Upper Austria, LA Lower Austria, St Styria, Vbg Vorarlberg, B Burgenland, Car Carinthia, Vie Vienna, FSMS Forest Soil Monitoring System

Bundesamt und Forschungszentrum für Landwirtschaft (1996), Amt der Kärntner Landesregierung (1999), Bundesanstalt für Bodenwirtschaft (1994), Bundesanstalt für Agrarbiologie (1993), Amt der Salzburger Landesregierung (1993), Amt der Steiermärkischen Landesregierung (1991-1996), Amt der Tiroler Landesregierung (1988, 1996), Husz (1986), MA 22 (1993, 1995, 1998, 2000), FBVA (1992)

Acidification and pH Value

Acidification is a minor problem on agricultural land compared with land under forest, since acidic inputs are smaller. Moreover, they are neutralised by regular fertilisation and by liming. Problems occur only in extensively used areas.

Alkaline sites, with a pH value of more than 7.2, occupy more than 40% of the areas in the east of the country, in Lower Austria and in Burgenland, whereas the percentage in Tyrol, Salzburg and Upper Austria is less than 4%. Strongly acidic sites with a pH-value below 4.5 are found in Styria (14%), Tyrol (35%) and Salzburg (38%).

Low cation exchange capacity, which indicates sensitivity to acidification, occurs in soils on siliceous parent materials (e.g. granites) in the Wald- and Mühlviertel area, Semmering, Wechsel, Central Alps and the foothills of the Alps.

Organic Matter Depletion

The content of organic matter is determined by the amount of organic litter produced by plants and by the intensity of turnover processes. This is why the humus content in grassland is higher than in crop land and therefore is higher in the cool and humid west of Austria than in the warm and dry east.

For example, in Salzburg 40% of the soils have more than 8% organic matter in the topsoil whereas in Lower Austria about 40% have less than 2%. In the areas used for agriculture in the east of Austria the organic matter content may have diminished by 0.5%, probably due to an intensification of soil tillage and former straw burning or a dilution of organic matter caused by increasing the plough depth.

Heavy Metal Contamination

In general, contamination with heavy metals is not very extensive. The standard values ÖNORM L 1075 (Austrian standard L 1075) for most heavy metals are only exceeded in less than 3% of the sites. Arsenic, lead and cadmium pollution occurs in more than 3% of the sites.

Arsenic contents are especially high in some regions of Salzburg, Styria and Lower Austria. This may be due to geogenic or anthropogenic sources.

The standard value for lead (100 mg/kg) is exceeded in Tyrol at 9.2% of the investigated sites, and in Salzburg at 3.6% of the sites. This could be due to local emissions, impacts of mining or long range transport of pollutants. The latter is seen as accounting for contamination north of the main alpine ridge. Due to high transit traffic, the valley of the Inn river is the most polluted region in Tyrol. Furthermore, local lead emissions (e.g. metal processing) result in point pollution.

High cadmium contents can partly be explained by long-range pollution and subsequent deposition on exposed slopes. On the other hand, the Northern Calcareous Alps seem to have a naturally elevated content of cadmium.

Application of Results

Some Federal Provinces (e.g. Styria, the Tyrol) have taken measures at those sites where the content of heavy metals exceeded the threshold values. More detailed investigations have been carried out, including analyses of plants. In heavily polluted areas a risk assessment programme has been carried out which is used to derive land use recommendations.

As mentioned above, the question of widespread higher contents of arsenic will be answered by detailed studies.

Outlook

One of the Federal Provinces, Styria, is carrying out a replicate Environmental Soil Survey, which forms a transition to an extensive form of Soil Monitoring. Furthermore a replication of the FSMS is planned.

Soil Monitoring

The Environmental Soil Survey, with approximately 6,000 sites, provides information about the variability of soils all over Austria. A repeat of these surveys was originally planned in order to monitor the changes with time. However, the results of replicate sampling in Tyrol showed that the sampling design at each site was not precise enough to distinguish between changes over time and the variability within the sampling site.

Another reason for changing the plan of carrying out environmental soil surveys at regular time intervals is the great expense. Therefore, for technical and financial reasons and with regard to previous results, fewer but intensively investigated soil monitoring areas are being established. A methodological handbook has been prepared by the Institute of Soil Science at the University of Agricultural Sciences, Vienna, on behalf of the Federal Environment Agency and in co-operation with the Austrian Soil Science Society (Blum *et al.*, 1996).

Appropriate nationwide co-ordination of the sites will result in a reduction of costs for the benefit of the individual provinces. There will be a representative distribution of sites according to characteristic landscape units of Austria (soil landscapes, main agricultural production areas, silvicultural growth areas, etc.), different exposures to pollution (background, close to emission sources, etc.) and types of use (forest, cropland, grassland, etc.).

The Institute of Soil Science has elaborated a proposal for possible sites, which is presented in Figure 4 (Blum *et al.*, 1996). Full points in the Figure refer to already established soil monitoring areas. These are found mainly in Salzburg, which was the first province to set up soil monitoring areas (Juritsch, 1994). Further Soil Monitoring Sites are established in Tyrol and Vorarlberg (Figure 4), others are planned in Upper and Lower Austria in the near future. In Upper Austria, the Federal Environment Agency is running a long-term ecosystem monitoring site (UN-ECE Integrated Monitoring) in the Reichraminger Hintergebirge.

As part of the ECE/ICP-Forest Programme, the Federal Office and Research Centre for Forest, Vienna has established 20 forest monitoring areas (see Forest Soil Monitoring Section above). Further sites identified in Figure 4 are non-obligatory proposals. It is expected that between four and ten areas, will be established in each province.

Following the establishment of the soil monitoring sites, the data collected will provide information on changes in soil properties as well as on the state of soil pollution. Optimum selection of areas and standardised methods of investigation will allow relevant policy statements to be made on environmental impacts on certain regions and the whole of Austria (UMWELTBUNDESAMT, 1998 and 2002).

The subject 'soil monitoring' is already being considered by the ARGE Alpen-Adria working group in Bavaria and in Switzerland (Blum *et al.*, 1994). The directives of ARGE Alpen-Adria, which are also binding for Austria, provide a framework, which has been enlarged to contain additional parameters to those in the above mentioned Austrian methodological handbook and more precise investigation methods.

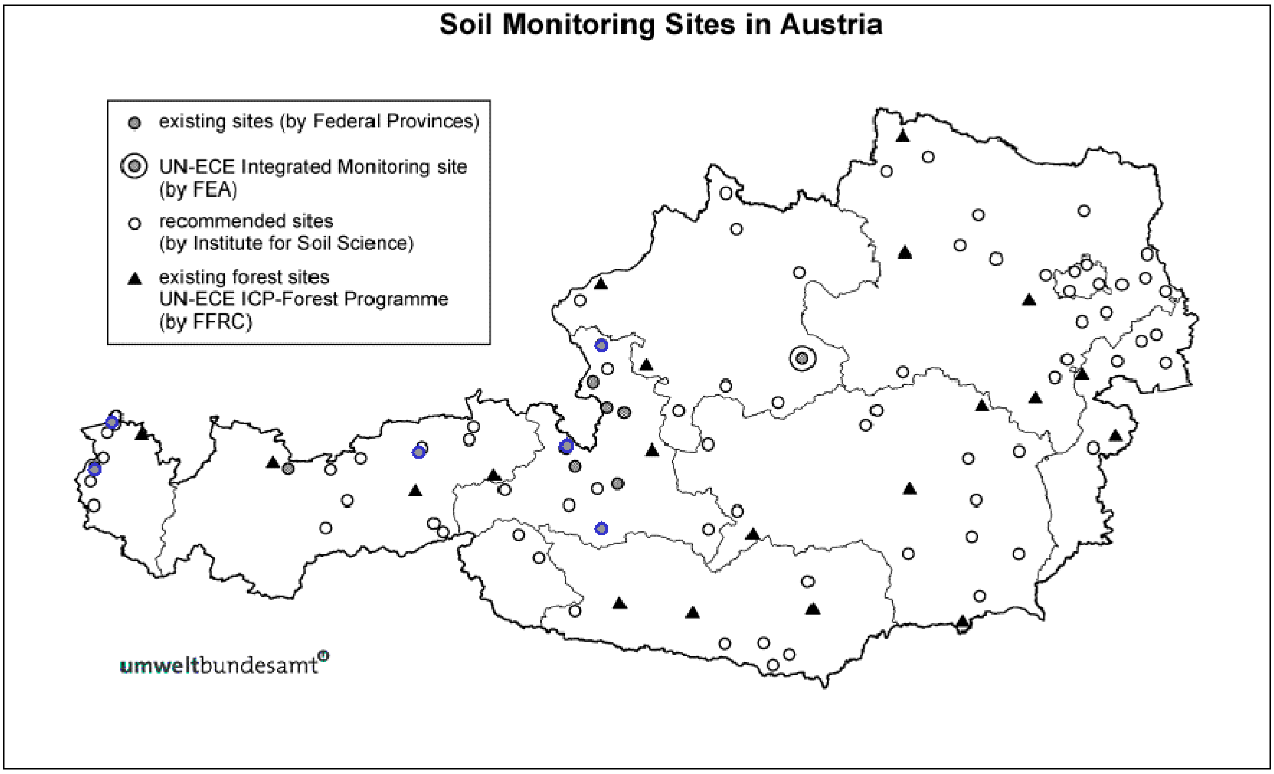

Figure 4: Soil Monitoring Sites in Austria

Soil Information System (BORIS)

A Soil Information System is necessary for effective soil conservation nationwide and for ensuring accessible information on general soil conditions, contamination and the sensitivity of soils to detrimental impacts. Detrimental effects on soils can be assessed more easily by means of a nationally standardised recording of spatial and point data in a Soil Information System. This provides the basis for an evaluation and projection system needed for effective soil protection.

Compared to many other European countries, Austria possesses comprehensive soil data. Yet, these data are structured heterogeneously, as they have been collected by different institutions with varying objectives. At the Federal Environment Agency, a pilot project (µBORIS) for the implementation of a national Soil Information System was carried out in order to test the possibility of realising a joint soil information system. In the city of Linz and its surroundings, data records from different investigations were linked (point data, spatial data/maps). Experience with the pilot project has clearly demonstrated that a combined evaluation of the selected data sets is possible (Schwarz *et al.*, 1994; Schicho-Schreier 1994).

In future, an integrated Soil Information System consisting of a combination of soil maps, the real estate database, soil data from Environmental Soil Survey sites and from Soil Monitoring sites will be a cornerstone for soil use and management.

Methods and Output

Since 1992 the Federal Environment Agency has been developing the Soil Information System, BORIS. The main tasks that have been fulfilled are the:

1. Preparation of a handbook, the 'Data Key Soil Science' (DKSS-Datenschlüssel Bodenkunde), to make data records form different investigations comparable. It was developed by the Federal Environment Agency and has been approved by the Austrian Soil Science Society (ASSS) (Schwarz *et al.*, 1999);
2. Development of a complex data model (Schreier *et al.*, 2001);
3. Transformation of the existing datasets according to the DKSS and the data model;
4. Implementation of access to the database via internet (BORIS EXPERT and BORIS INFO) for different user groups;
5. Establishment of the BORIS User Committee;
6. Annual meetings of the data owners;
7. Development of a model for data quality assurance (Tulipan *et al.*, 2001);
8. Implementation of an Internet based assessment tool (Freudenschuss *et al.*, 2002).

The Data Model offers special possibilities, e.g.:

1. It is an open system including approximately 600 different parameters (measurement information, site or soil description), which are described with all possible characteristics in the DKSS. Additional soil information can be added whenever necessary using new parameters.
2. Every single measurement is linked to a variety of information (the owner of the data, the analytical method used, etc.).
3. Information about sampling design, conditions of sample transport, handling and treatment of samples, etc. is available.
4. If replicate sampling or parallel sampling has taken place, this is documented for each sample.
5. The combination of soil description in terms of natural soil horizons and analytical data according to predetermined soil depths is easily possible.

Currently, the database holds a soil map of Austria (scale 1:750,000) and more than 1.5 million records from over 10,000 sites. These are data from all Environmental Soil Surveys of the Austrian provinces, the Forest Soil Monitoring Survey and data from more than 30 other special investigations e.g. in Brixlegg, Linz, Arnoldstein, Köflach-Voitsberg as well as from the Austrian-wide caesium investigation.

Building this extensive database was made possible by the constructive co-operation of the above mentioned Federal Provinces and the responsible institutions. Extensive work was necessary to prepare the individual data sets for the implementation into the database (checks of quality and correctness, translation according to DKSS).

Table 2 and Figure 5 give an overview of the all sites integrated in BORIS (December 2003).

Since 2001 BORIS provides access to soil information via Internet http://www.umweltbundesamt.at/umwelt/boden/boris/.

BORIS INFO is open to the public and allows detailed data queries about site and soil description as well as meta data about measurements for each site. Internet users can also get an overview of all the available information and provided data sets and links to data owners and literature references.

BORIS EXPERT is a complex instrument for data selection, assessment and evaluation and allows access to all data sets, also the analytical values. This expert tool is only accessible for a selected circle of institutions; primarily those institutions are concerned which have already provided relevant data for BORIS. Data access is restricted by passwords and data use is formally regulated by the BORIS User Committee.

An example for an Austrian-wide evaluation of soil contamination with caesium-137 is given in Figure 6. Austria was one of the countries most strongly affected by the Chernobyl fallout. The average contamination level in Austria amounts to 21 kBq $^{137}Cs/m^2$ (=21,000 Becquerel Caesium-137 per square metre). The map was drawn up by the Austrian Federal Environment Agency (FEA) and the Austrian Ministry of Health. It presents all the measured data for caesium-137 (Cs-137) in soils that are available. More than 2,000 results were used for producing the map. Approximately 200 of them were located in neighbouring countries close to the Austrian border (UMWELTBUNDESAMT, 1996). The Cs-137 data are available on the Internet.

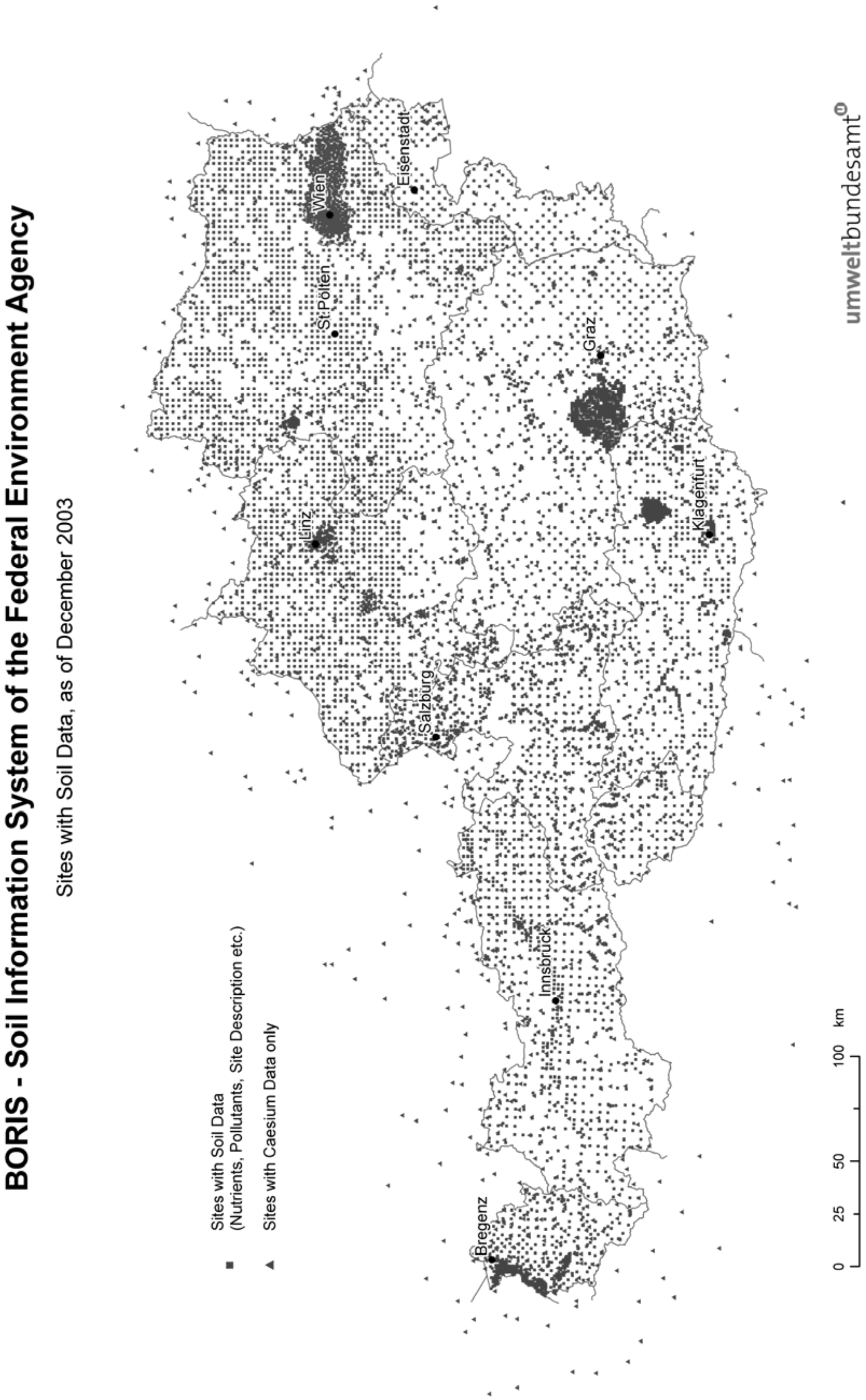
BORIS - Soil Information System of the Federal Environment Agency
Sites with Soil Data, as of December 2003
Sites with Soil Data
(Nutrients, Pollutants, Site Description etc.)
Sites with Caesium Data only
Wien
Eisenstadt
St.Pölten
Linz
Salzburg
Graz
Klagenfurt
Innsbruck
Bregenz
0
25
50
100 km
umweltbundesamt

Figure 5:

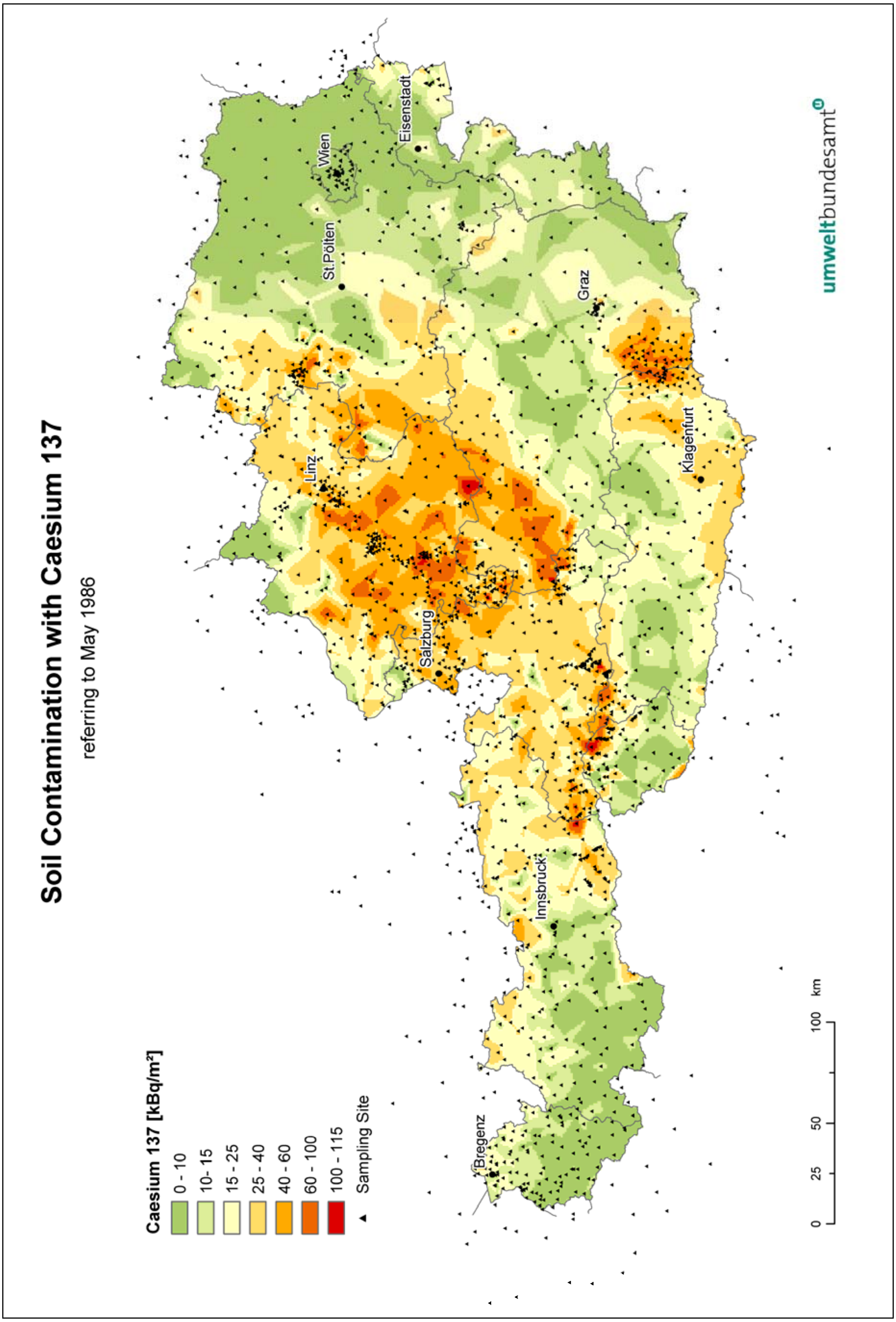
Soil Contamination with Caesium 137
referring to May 1986
Caesium 137 [kBq/m²]
0 - 10
10 - 15
15 - 25
25 - 40
40 - 60
60 - 100
100 - 115
Sampling Site
Wien
Eisenstadt
St.Pölten
Graz
Linz
Klagenfurt
Salzburg
Innsbruck
Bregenz
umweltbundesamt
0
25
50
100
km

Figure 6:

Table 2: Number of sites in the Soil Information System, BORIS (December 2003).

Provinces	Bgl	Car	LA	UA	S	St	Tyrol	Vbg	Vie	Abroad: near Austrian border	Total
ESS *	174	481	1,449	880	462	636	658	435	287		5,462
Caesium Data	53	164	519	387	291	249	319	119	39	233	2,373
Other investigat		498	449	188	150	360	63	4	42		1,754
FSMS**	16	75	97	69	44	134	66	13			514
Total:	243	1,218	2,514	1,524	947	1,379	1,106	571	368	233	10,103

* ESS (Environmental Soil Surveys). These datasets were provided by the Federal Provinces of Burgenland, Upper Austria, Lower Austria, Salzburg, Styria, Tyrol, Vorarlberg and Vienna (Municipal Department 22)

**FSMS (Forest Site Monitoring System) of the Federal Office and Research Centre for Forest (BFW).

Application of the Results

The comprehensive soil data of BORIS will be combined with soil maps (at different scales) and data sets of related subjects such as land cover, geology, water, cadastre, etc. These data provide a basis for:

1. A classification of soil data with comparable characteristics site or soil description, methods, sampling design, etc.);
2. Nationwide evaluations of soil data (pollutants, heavy metals, erosion);
3. Development and adaptation of standard values;
4. Combined evaluation with CORINE land cover data, Austrian Surface and Groundwater Monitoring System;
5. Soil assessment in communal and regional planning processes;
6. Decision-making with regard to land use planning;
7. Environment Impact Statements and Environment Impact Assessments;
8. Decisions on the spreading of sewage sludge and other organic waste;
9. Service to provincial authorities and data owners concerning data quality assurance and data documentation as well as the provision of an internet based expert tool for data selection and evaluation (BORIS EXPERT);
10. Aggregated data for international reports and projects;
11. Further international agreements and protocols for the reduction of trans-boundary pollutants and other inputs;
12. Translation of Austrian soil types into international classification schemes (FAO-System, WRB);
12. Scientific projects (e.g. basis for the development of pedo-transfer rules and pedo-transfer functions (e.g. with Artificial Neural Networks));
13. Finally BORIS can provide information for local, Provincial and Federal authorities, for the public and for the scientific community. The data transfer depends on the prior agreement of the data owners.

Outlook

The BORIS soil information system provides comparable data sets and IT-tools for data management, selection and evaluation. This facilitates the treatment of a great number of different soil protection aspects as well as nationwide statements. Further steps will be to combine the point related data of BORIS with spatial soil information.

The efforts towards the enlargement and intensification of the nationwide soil information system will be continued as well as the collaboration with European soil information networks, such as European Soil Bureau.

General Outlook

Soil survey and the collection of soil data in Austria are now well developed to the extent that the use of soil data for specific purposes or their link with other environmental data through GIS or other geo-statistical tools can be facilitated.

The BORIS database is a way to raise public interest in soils, to assess the status of Austrian soils and to promote the use of these data for the future development of sustainable land use.

The potential changes of soil conditions can be assessed more easily when further monitoring stations are installed.

All the above mentioned soil information can also be used in the co-operation with other European countries and European institutes. Co-operation has already begun and will develop further to harmonise the use and availability of soil information in Europe.

References

Amt der Kärntner Landesregierung (Eds.). (1999). Bodenzustandsinventur Kärnten, Klagenfurt.

Amt der Niederösterreichischen Landesregierung (Eds.).(1994).Niederösterreichische Bodenzustandsinventur. Amt der Niederösterreichischen Landesregierung, Bundesanstalt für Bodenwirtschaft. Wien.

Amt der Salzburger Landesregierung. (Eds.).1993. Salzburger Bodenzustandsinventur, Salzburg.

Amt der Steiermärkischen Landesregierung. (1991-1996). Steiermärkischer Bodenschutzbericht, Graz.

Amt der Tiroler Landesregierung (Eds.). (1988). Bericht über den Zustand der Tiroler Böden, Innsbruck.

Amt der Tiroler Landesregierung (Eds.). (1996). Bericht über den Zustand der Tiroler Böden, Wiederholungsbeprobung, Innsbruck.

Beck, T., Öhlinger, R. and Baumgarten, A. (1996). Substrate-induced respiration. In: Methods in Soil Biology. Schinner F., Öhlinger R., Kandeler E. and Margesin R. (Eds.). Springer Verlag, Berlin, 64-68.

Blum, W.E.H., Spiegel, H. and Wenzel, W.W. (1989). Bodenzustandsinventur-Konzeption, Durchführung und Bewertung; Arbeitsgruppe Bodenzustandsinventur der Österreichischen Bodenkundlichen Gesellschaft, Wien.

Blum, W.E.H., Brandsetter, A., Jochwer, F., Riedler, Ch. and Wenzel, W.W. (1994). Bodendauerbeobachtung - Vergleich von Konzepten zur Bodendauerbeobachtung auf nationaler und internationaler Ebene, BE-018, Umweltbundesamt Wien.

Blum, W.E.H., Brandsetter, A., Riedler, Ch. and Wenzel, W.W. (1996). Bodendauerbeobachtung-Empfehlung für eine einheitliche Vorgangsweise in Österreich, Umweltbundesamt Wien.

Bundesamt für Agrarbiologie (1993). Oberösterreichischer Bodenkataster, Bodenzustandsinventur., Linz.

Bundesamt und Forschungszentrumfür Landwirtschaft (1996). Burgenländische Bodenzustandsinventur. Amt der Burgenländischen Landesregierung,. Eisenstadt.

Danneberg, O.H., Aichberger, K., Puchwein, G. and Wandl, M. (1997). Bodenchemismus. In: Blum, W. E. H., Klaghofer, E., Köchl, A. and Ruckenbauer, P. (Eds). Bodenschutz in Österreich. Bodenzustand - Entwicklungstendenzen - Schutzmaßnahmen. Studie im Auftrag des BMLF; Bundesamt und Forschungszentrum für Landwirtschaft, Wien.

Englisch, M and Kilian, W. (Eds.). (1998). Anleitung zur forstlichen Standortskartierung in Österreich. FBVA-Berichte 104, Wien.

FBVA (Eds.). (1992). Österreichische Waldbodenzustandsinventur. Mitteilungen der Forstlichen Bundesversuchanstalt, Wien.

Freudenschuß A., Tulipan M., Huber S., Ackerl, W.and Schwarz S. (2002). Interactive Evaluation Module for Soil Quality Data- An Application within the Austrian Soil Information System BORIS. In: Proceedings of the 16th Conference ‚Informatics for Environmental Protection‘ Sept. 25-27, 2002 Vienna, Austria.

Huber, S and Englisch, M. (1997). Bericht über den Zustand der Waldböden im Bereich der Länder der ARGE Alp und ARGE Alpen-Adria. Arge Alp, ARGE Alpen Adria und FBVA, München- Wien 190pp.

Husz, G. (1986). Lebensraum Vorarlberg, Grundlagenarbeiten zu Natur und Umwelt. Band 2, Bodenzustandserhebung Vorarlberg 1986. Amt der Vorarlberger Landesregierung, 1986. Bregenz.

Juritsch, G. (1994). Einrichtung von Bodendauerbeobachtungsflächen im Bundesland Salzburg. Amt der Salzburger Landesregierung, Salzburg.

Kandeler, E. (1996). N-Mineralization under waterlogged conditions. In: Methods in Soil Biology. Schinner F., Öhlinger R., Kandeler E. and Margesin R. (Eds). Springer Verlag, Berlin, 141-143.

Kirschner, K. G. and Schlenker, G. (1955). *Vorwort*. Mitt. Verein Forstl. Standortskartierung 1:1.

MA 22. (Eds) (1993). Untersuchung des Wiener Bodens auf Blei und Cadmium. Magistrat der Stadt Wien, Magistratabteilung 22 - Umweltschutz, Wien.

MA 22 (Eds.). (1995). Flächendeckende Schwermetalluntersuchung des Wiener Bodens an 257 Stellen, 1994. Magistrat der Stadt Wien, Magistratsabteilung 22 - Umweltschutz, Wien.

MA 22 (Eds.). (1998). Wiener Bodenbericht 1997 - Untersuchung des Wiener Bodens auf Schwermetalle. Magistrat der Stadt Wien, Magistratsabteilung 22 - Umweltschutz, Wien

MA 22 (Eds.). (2000). Wiener Bodenbericht 2000 - Untersuchung des Wiener Bodens auf Schwermetalle. Magistrat der Stadt Wien, Magistratsabteilung 22 - Umweltschutz, Wien

ÖNORM L 1075 (1990). Anorganische Schadelemente in landwirtschaftlich und gärtnerisch genutzten Böden. Ausgewählte Richtwerte.

Schicho-Schreier, I. (1994). Pilotprojekt (Micro-BORIS) zu einem Bodeninformationssystem in Österreich. In: Alef, K.; Blum, W.; Schwarz, S.; Riss, A.; Fiedler, H. & Hutzinger, O. (Hrsg.): Eco-informa-94; Band 6: Bodenkontamination, Bodensanierung, Boden-informationssysteme. 447-456.

Schreier, I.; Schwarz, S.; Tulipan, M. and Miksits, H. (2001). Entwicklung von Datenmodell und Schnittstelle des Bodeninformationssystems BORIS. Mitt. d. dt. Bodenkundl. Ges., 96, 773-774.

Schwarz, S., Dvorak, A., Riss, A. and Falkner, Th. 1994. Einrichtung eines Bodeninformationssystems in Österreich. In: Alef, K., Blum, W., Schwarz, S., Riss, A., Fiedler, H. and Hutzinger, O. (Hrsg.): ECO-INFORMA-94; Band 6: Bodenkontamination, Bodensanierung, Bodeninformationssysteme. 429-446.

Schwarz, S.; Huber, S.; Tulipan, M.; Dvorak, A. and Arzl, N. (1999). Datenschlüssel Bodenkunde - Empfehlung zur einheitlichen Datenerfassung in Österreich. Umweltbundesamt Wien, Monographien Band 113, 152 S.

Schwarz, S.; Freudenschuss, S.; Huber, S.; Riss A.; Schreier, I.; Tulipan, M. and Weber, M. (2001): Das österreichweite Bodeninformationssystem BORIS - Aufbau und Auswertungen. Mitt. d. dt. Bodenkundl. Ges., 96, 777-778.

Szabolcs, I. (1997). The 1st International Conference of Agrogeology, April 14-24, 1909, Budapest, Hungary. In: Yaalon, D.H. & S. Berkovitz, (Eds.). (1997): History of Soil Science, Advances in Geoecology 29, 67-78, Catena Verl. Reiskirchen.

Tscherko, D. and Kandeler, E. (1997). Ecotoxicological effects of fluorine deposits on microbial biomass and enzyme activity in grassland. European Journal of Soil Science 48, 329-335.

Tulipan, M.; Schreier, I. and Schwarz, S. (2001). Datenqualitätsmanagement im Bodeninformationssystem BORIS - Ein Bericht aus der Praxis. Mitt. d. dt. Bodenkundl. Ges., 96, 783-784.

UMWELTBUNDESAMT (1996). Cäsiumbelastung der Böden Österreichs, 2. erweiterte Auflage, Monographien Band 60, Umweltbundesamt, Wien.

UMWELTBUNDESAMT (1998). State of the Environment in Austria - An Overview. Federal Environment Agency, Vienna 1998.

UMWELTBUNDESAMT (2002). State of the Environment in Austria - An Overview. Federal Environment Agency, Vienna 2002.