Soil Quality
Monitoring Programs:

A Literature Review

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ABSTRACT

The soil resource is a vital component of our environment and the monitoring of soil properties is essential to achieving sustainable land use. The AESA Soil Quality Benchmark Program measures soil parameters on a yearly basis to identify changes in soil quality due to management influences and in the process gathers important data to use in model validation. This literature review provides a basis of comparison for the AESA Soil Quality Benchmark Program to other soil monitoring systems, in order to evaluate the state and effectiveness of the AESA program.

This review is a compilation of 52 environmental/soil monitoring programs from around the world. An emphasis was placed on finding programs currently operating or those operational within the last two decades, which repeatedly monitor the soil resource in some capacity, without imposing agronomic treatments. Programs were researched using computerized database searches, bibliographic references and through use of the Internet. The soil related information is summarized into tables, which contain extensive information describing each monitoring program, including management, program lifespan, ecosystem monitored, variables monitored, sampling sites, soil sampling interval, data uses and trends and parameters measured. The discussion includes analysis of the information tables and serves as a summary of the various approaches to repeated monitoring of environmental and soil components. A comparison of the AESA Soil Quality Benchmark Program to the other programs was carried out.

1.0 BACKGROUND

The importance of the soil resource is simply summarized by the Chinese saying “The soil is the mother of all things” (21). Soil is the foundation of life as it has many functions such as providing a medium for plant growth, regulation of water supply, recycling of wastes, providing a habitat for organisms and supporting human infrastructure. These functions are essential to support and sustain crop, range and woodland production as well as to maintain other resources such as water, air and wildlife habitat.

Soil quality is the ability of a soil to function within its surroundings for its given purpose. The use of indicators is essential to measure how well a soil is performing its functions. Soil indicators are measurable physical, chemical and biological properties, processes and characteristics that influence the capacity of a soil to function. Indicators should:

- correlate well with ecosystem processes
- integrate soil physical, chemical and biological properties and processes
- be relatively easy to use under field conditions
- be sensitive to variations in management and climate
- be components of existing soil data bases if possible

A minimum dataset of indicators was proposed by Doran and Parkin in 1994 (Table 1). These indicators represent the minimum variables that should be measured in order to assess soil quality.

Table 1. Proposed minimum data set of physical, chemical and biological indicators for soil quality determination*

	Indicators	
Physical	**Chemical**	**Biological**
Texture	Soil organic matter	Microbial biomass C and N
Topsoil and rooting depth	pH	Potentially mineralizable N
Infiltration	Electrical conductivity	Soil Respiration
Bulk density	Extractable N, P and K	
Water holding capacity		

* Source: Doran and Parkin, 1994.

Degradation issues such as erosion, loss of organic matter, compaction and contamination, all which affect soil functions, are common around the world and will continue to grow as the need for food and fiber increases. Maintaining soil productivity while ensuring environmental health is an ongoing issue which requires soil quality to be defined and evaluated.

Monitoring of the soil is essential to assess the sustainability of the soil resource in response to human induced pressures such as land use and soil contamination (8). Monitoring is defined as the repeated inventory of an item to determine trend and status (29). One method of monitoring soils is benchmark sampling. The basic principle of benchmark sampling is to sample at the same location each year. Benchmark sites are representative of larger areas and are usually about a quarter acre (0.1 ha) in size (44). Sampling with this method is less expensive and time consuming than traditional grid sampling and is more consistent because it assumes the benchmark area is less variable than the larger area which it represents (58).

In 1997, the AESA (Alberta Environmentally Sustainable Agriculture) Soil Quality Program was established to determine the state of soil quality across Alberta and to determine the risk of change in soil quality with various management practices (15). The AESA Soil Quality Program realized that soil quality models (i.e. crop growth models and soil degradation models) would need to be employed because of limited resources, a large diverse farming area of 233, 839 km^2 in Alberta, and the time required to observe measured changes in soil parameters. Consequently, a need for a monitoring network of sites to provide data to test and validate these models was identified.

The AESA Soil Quality Monitoring Program established soil quality benchmark monitoring sites in 1998. Forty-three sites, located in 42 ecodistricts within the agricultural areas of Alberta (Figure 1), were established with the following objectives in mind (14):

- provide a dataset to test and validate simulation models
- provide baseline soil information
- evaluate landform effects on soil quality
- monitor changes in soil quality over time on a field landscape basis

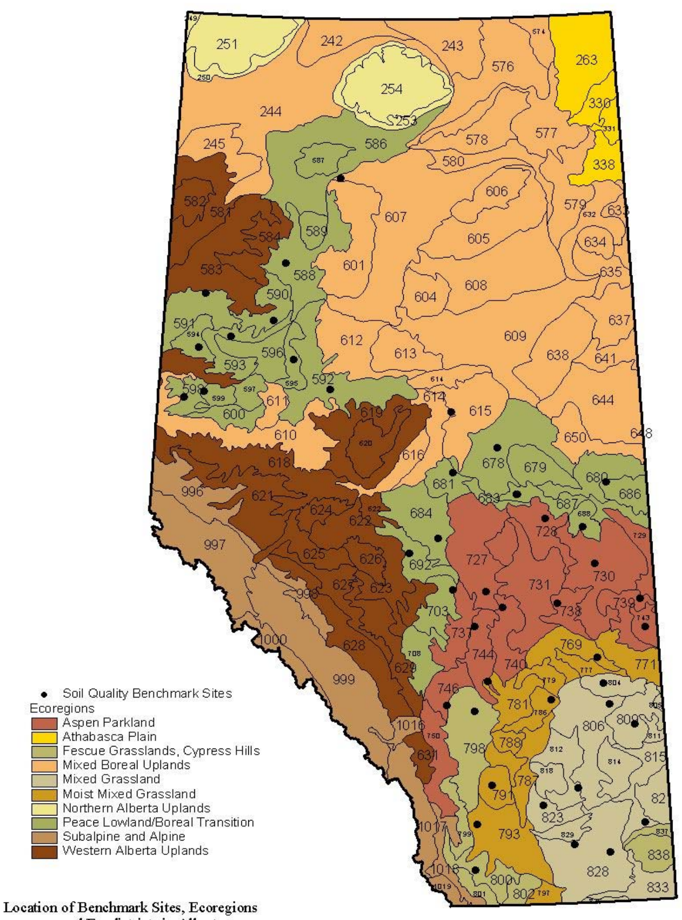

Figure 1. Location of benchmark sites in Alberta

Benchmark sites were chosen to represent the soil-landscape patterns and agronomic practices central to each ecodistrict. Sampling points are located at three landform positions at each site (upper, mid and lower slope positions). Annually, biomass samples are taken at harvest time and soil samples are collected in the fall, after harvest (15).

The year 2002 marked the fifth anniversary of the AESA Soil Quality Benchmark Program. This was considered an appropriate time to summarize the data collected to date and to review the program as a whole. This literature review contributes to the program review process.

2.0 OBJECTIVES

The primary objective of this literature review is to examine international literature for the existence of soil monitoring programs or environmental monitoring systems, which include the monitoring of soil parameters. The second objective is to compare these programs with the AESA Soil Quality Benchmark Program in order to determine if the monitoring protocol could be altered in any way to increase the value of the data that is being collected.

3.0 METHODS

3.1 Criteria

Criteria were developed to help focus the literature search. The decision was made not to include long-term research plots (i.e. agronomic plots where agronomic treatments are imposed). In addition, monitoring programs had to meet the following criteria:

- include monitoring of soil parameters
- have been re-sampled since establishment or re-sampling planned for the future
- be currently operational or operational within the last 15-20 years
- based in areas comparable to Alberta in climate or land use

3.2 Search Tools

The primary search method used for this review was the Internet. Search engines most often used included Google, MSN Search, AltaVista, Excite and Ixquick metasearch. In most cases, mention of a monitoring program was encountered and then the Internet was used to find more in-depth information about the program by visiting the URLs of the Departments of Environment, Agriculture or Forestry of the participating country. Additional references were found by searching bibliographies or references lists from books, journal articles and reports. All Internet searches were performed between September 2001 to June 2003 and concentrated on English language resources, which resulted in the exclusion of some programs.

Bibliographic databases were used by the Neil Crawford Provincial Centre library staff to perform searches for this project. The primary databases searched include:

- Agricola
- Agris International
- BIOSIS
- CAB
- Conference Papers Index
- EiCompendex
- Elsevier Biobase
- Environmental Bibliography

- Embase
- Enviroline
- Life Sciences Collection
- PAIS
- Pascal
- Scisearch

These databases were searched for documents in the English language, which limited the results, as many of the international monitoring programs were documented in languages other than English. As a result, approximately 10 percent of the references included in this literature review were found using computerized database searches.

The library staff assisted in the acquisition of literature from various libraries and organizations around the world in the form of journal articles, conference proceedings, reports and books.

3.3 Search Terms

A variety of search terms were used to find documentation. Variations and combinations of these terms were used to search the Internet:

- soil quality
- soil health
- soil monitoring
- soil quality monitoring
- soil quality indicators
- soil quality assessment
- soil quality evaluation
- soil benchmark
- soil quality index
- environmental monitoring
- ecological benchmarking
- baselines

In most cases, basic terms such as “soil”, “soil quality” and “soil monitoring” were the most successful in searching for information on the Internet. There were very few references to the term “benchmark” which is the term used by the AESA Soil Quality Benchmark Program to describe monitoring the same site in representative areas during subsequent years.

When searching the bibliographic databases, the terms used in Internet searches were too broad and yielded thousands of results in some cases. Therefore, combinations of the monitoring program titles, managing organization and country(ies) of origin were used.

4.0 RESULTS AND DISCUSSION

The literature search yielded 52 environmental monitoring programs that met the search criteria. The term “program” is used to describe both entire programs and separate parts of a monitoring program. The search revealed environmental monitoring programs which did not include the repeated monitoring of any soil properties. Others had not resampled any soil properties since the program was established. An example of this is the National Resources Inventory (NRI) in the

United States of America. This program monitors over 800,000 sample points across the entire nation but does not monitor soil on a regular basis (53). Many long-term monitoring programs, which imposed agronomic treatments were also found. For example, in Alberta alone, there are six long-term, small plot, sustainable cropping systems studies which 1) determine crop productivity and soil quality effects in accordance with established research protocols and 2) determine the capacity of Alberta agroecosystems to sequester atmospheric carbon. Although programs of this type are valuable in identifying profitable and sustainable agricultural systems and may provide supplemental information for monitoring programs, they impose agronomic treatments and therefore do not meet the criteria set out for this literature review.

A majority of the references are "grey" or unpublished literature found on web pages and in institutional reports. This poses a problem because the documents referenced may become unavailable or outdated in a short time frame. Dramstad et al. (2002) also experienced difficulties finding documentation because a large portion of information about certain monitoring programs is located in non-English language institutional reports. An analysis of the literature cited finds that 35% are web pages or electronic citations, 20% are conference proceedings, 16% are reports, 11% are refereed journal articles, while the remainder are from magazine articles, books, emails, dissertations and poster presentations.

Programs that met the criteria were researched further and the program details were summarized (Tables 2 and 3). The information collected in Table 2 includes:

- country or organization responsible for the monitoring program
- program title
- program management
- program lifespan
- objectives or purpose of monitoring
- type of ecosystem and components measured
- spatial variability of sampling points
- sampling interval and methods
- program costs
- data dissemination
- data trends

In many instances, a complete program description was not available. Blank cells in Table 2, with the exception of the "End Date" column, indicate no information was provided in the reviewed documentation or the category was not applicable. The "End Date" column includes text only if the program was terminated, otherwise the program is assumed to be operational. The programs were grouped into continents or networks, organized by alphabetical order and were then given numbers (column labeled "Prog No."). The numbers facilitate referencing the programs in the document and in displaying the information in tables. Bibliographic references appear as numbers in the "References" column of the table and are recorded in ProCite version 5 for Windows (ISI ResearchSoft, Philadelphia, Pennsylvania, USA) The numbers correspond to the same number listed in section 6.0, the "Literature Cited" section of this document.

Selected parameters measured by each program are included in Table 3. The ten parameters are:

- soil test analysis
- chemical
- physical
- biological
- biochemical
- micronutrients
- pollutants
- management information
- site description
- climatic data

Some programs measured other parameters related to air, water and biota, which were not the focal point of this review and were excluded. A "yes" in the table indicates the parameter was measured or is pertinent. Blank cells in the table, indicate no information was provided in the reviewed documentation or the category was not applicable.

Additional program details are provided in section 7.0, the "Appendix" of this document.

Table 2. Monitoring program descriptions – Part 1

Prog. No.	Country/ Org.	Program Title	Management / Funding	Start Date	End Date	Purpose
NORTH AMERICA						
1	Alberta	AESA Soil Quality Benchmark Program	Alberta Environmentally Sustainable Agriculture Program-Alberta Agriculture, Food and Rural Development	1998		- provide baseline soil information, evaluate landscape effects on soil quality, provide data for modeling and monitor changes in soil quality over time
2	Alberta	Long-Term Soil and Vegetation Plots Established in the Oil Sands Region	Syncrude Canada/ Suncor Energy/ Albian Sands/ Cumulative Environmental Management Association	2000		- initial purpose was to determine forestry success and meet equivalent productivity with reclaimed sites - now more focus on the importance of biodiversity and the value of understory
3	Canada	Soil Quality Benchmark Sites	Agriculture and Agri-Food Canada	1992		- assess soil quality change, provide validation for models, provide well documented sites for future integrated research programs and evaluate sustainability
4	United States of America	Forest Health Monitoring Program (1990-1999) / Forest Inventory and Analysis Program (1999-present)	USDA Forest Service / Environmental Protection Agency / USDA Bureau of Land Management / USDA Natural Resource Conservation Service	1990		- determine the status, changes and trends in indicators of forest health on an annual basis - identify important forest health and sustainability issues, select appropriate data and develop approaches to address the issues
EUROPE						
5	Albania	Map of Soils of Albania	Soil Science Institute of Tirana			
6	Austria	Forest Soil Monitoring System	Federal Forest Research Centre	1987		- originated as part of the Forest Damage Monitoring System to research causes and effects of forest diebacks
7	Bulgaria	Background Monitoring	Bulgarian Executive Environmental Agency			- background monitoring of atmosphere, precipitation, surface water, soil and vegetation
8	Bulgaria	National Environment Monitoring System	Bulgarian Executive Environmental Agency			
9	Czech Republic	Basal Soil Monitoring Scheme	Ministry of Agriculture / Ministry of Environment	1992/ 1993		- characterize the status of soils, observe changes in soil as a result of human activity, test new analytical methods and develop new strategies/standards of soil protection and prevention
10	Denmark	Heavy Metal Monitoring Programme	Danish Environmental Protection Agency	1993		- statistically safe detection of a 2% increase in the mean concentration of heavy metals in soils

Prog. No.	Country/ Org.	Program Title	Management / Funding	Start Date	End Date	Purpose
11	England and Wales	National Soil Inventory	National Soil Resources Institute	1978-1983/ 1994-1996		- provide information on the range of concentrations of pollutants, nutrients, soil organic matter and pH in soils of England and Wales
12	England and Wales	Annual Representative Soil Sampling Scheme	Ministry of Agriculture, Fisheries and Food / Agricultural Development and Advisory Service	1969		- provides an estimate of the status of agricultural soils in relation to changes in agricultural practices
13	Finland	National Forest Inventory	Finnish Forest Research Institute	1921		- to produce objective and up to date information on forest resources, forest health conditions and their development for national and regional decision making
14	Finland	Soil Quality Monitoring Program		1992		
15	France	Soil Quality Observatory	Ministry of Environment / Ministry of Agriculture / French Environmental Institute / National Institute of Agronomic Research	1986		- assess the present situation of soils, monitor their changes and identify the causes to improve on and implement a soil preservation policy - provide data for modeling and increase soil quality awareness
16	France	RENECOFOR	National Forest Office	1992		- help detect long-term changes is a wide variety of ecosystems and determine the cause of those changes
17	Germany	Permanent Soil Monitoring Sites		1986		- to investigate how soils change due to anthropogenic involvement
18	Germany	Air Measuring Network	Federal Environmental Agency			- registration of extensive emission loads caused by air pollutions, including depositions - determine influence of air pollution on soil quality
19	Great Britain	Country-side Survey		1978/ 1984/ 1990/ 1998		- estimate extent and characterize habitats, derive sustainable development indicators and provide data and databases
20	Hungary	Information and Monitoring System of Soil Conservation (TIM) - National Basic Monitoring System	Ministry of Agriculture / Plant Protection and Soil Conservation Service	1992		- to provide information for scientifically based planning and implementation of sustainable land use and rational soil management

Prog. No.	Country/ Org.	Program Title	Management / Funding	Start Date	End Date	Purpose
21	Hungary	Information and Monitoring System of Soil Conservation (TIM) - Forestry Observation Points	Ministry of Agriculture / Plant Protection and Soil Conservation Service	1992		- to provide information for scientifically based planning and implementation of sustainable land use and rational soil management
22	Hungary	Information and Monitoring System of Soil Conservation (TIM) - Special Areas Monitoring	Ministry of Agriculture / Plant Protection and Soil Conservation Service	1992		- to provide information for scientifically based planning and implementation of sustainable land use and rational soil management
23	Hungary	Soil Fertility Monitoring System		1978	1986	- monitor changes in soil parameters and make recommendations on nutrient supply to farmers
24	Hungary	Microelement Survey		1987	1990	
25	Latvia	National Agricultural Land Monitoring Programme	State Land Service	1992	2000/ 2001	- supervise process and trends of soil quality changes, gather information, make interpretations and report regularly to the public and decision makers - long-term observations of anthropogenic impacts on agricultural land
26	Lithuania	National Environmental Monitoring Programme - Field Soil Monitoring	Agrochemical Research Centre of the Lithuanian Institute of Agriculture / Joint Research Centre of the Ministry of the Environment	1993		Soil monitoring component: to analyze and explain the development of qualitative and quantitative processes, to forecast and control anticipated processes and to identify the means for prevention of loss of soil stability
27	Lithuania	National Environmental Monitoring Programme - Forest Soil Monitoring	Lithuanian Forestry Institute	1992		Soil monitoring component: to analyze and explain the development of qualitative and quantitative processes, to forecast and control anticipated processes and to identify the means for prevention of loss of soil stability
28	Lithuania	National Environmental Monitoring Programme - Integrated Monitoring of Agricultural Ecosystems	Lithuanian Water Management Institute / Institute of Ecology / Agrochemical Research Centre of Lithuanian Agricultural Institute / Institute of Botany / Institute of Geography			- to determine, assess and forecast the status of ecosystems subjected to intense agricultural activities and its changes in time with consideration of the type of farming practices
29	Netherlands	National Soil Quality Monitoring Network	National Institute of Public Health and Environmental Protection (RIVM)	1993		- establish changes in soil quality over time in soil and upper groundwater - determine actual quality of soil and upper groundwater with a focus on the rural environment
30	Netherlands	Regional Soil Quality Monitoring Networks	individual provinces of the Netherlands	1991		- provide insight into geo-chemical soil quality trends on which to base new provincial policies

Prog. No.	Country/ Org.	Program Title	Management / Funding	Start Date	End Date	Purpose
31	Netherlands	Soil Quality and Shallow Ground Water Monitoring	National Institute of Public Health and Environmental Protection (RIVM)	1992		- assess the vulnerability of agricultural soils and ground-water to pollutants such as manure and artificial fertilizers
32	Norway	Agricultural Environmental Monitoring Program	Ministry of Agriculture / Ministry of Environment	1992		- to relate losses of plant nutrients to catchment characteristics and changes in agricultural practices
33	Poland	National Program of Environment Monitoring	Ministry of Agriculture and Food Economy	1994		- to perform a detailed evaluation of existing resources in order to identify areas of high risk to the food chain
34	Poland	Arable Soils Monitoring Program	Ministry of the Environment	1995	1998	
35	Poland	Programme for Forest Monitoring		1989		- to monitor environmental threats to the forest ecosystem such as atmospheric pollution
36	Republic of Estonia	Estonian Environmental Monitoring Program - Agricultural Landscape Monitoring	Estonian Environment Information Centre	1996		- monitor long-term and large-scale changes in environment, identify problems which need countermeasures and future research - to define changes in land use and assess the anthropogenic impact on ecological status of soil
37	Romania	National Integrated Soil Monitoring System	Research Institute for Soil Science and Agrochemistry	1992		- to identify problem areas, causes of problems and possible remedial actions
38	Slovakia	Slovak Environment Monitoring	Ministry for the Environment / Ministry of Landhusbandry	1993		- reflect the environmental situation and apply measures for environmental improvement
39	Slovakia	Slovak Environment Monitoring - Soil Monitoring System- Humus	Soil Science and Conservation Research Institute	1993		- to monitor soil contamination and soil properties
40	Sweden	National Swedish Environmental Monitoring Programme - Integrated Monitoring	Swedish Environmental Protection Agency	1981		- regular and permanent recording of environmental conditions and long-term changes in background regions - to track the flux of pollutants in and between various media
41	Sweden	National Swedish Environmental Monitoring Programme - National Survey of Forest Soils and Vegetation	Department of Forest Resource Management and Geomatics / Swedish University of Agricultural Sciences	1983		- describe the state of and changes in forest resources of Sweden

Prog. No.	Country/ Org.	Program Title	Management / Funding	Start Date	End Date	Purpose
42	Sweden	National Swedish Environmental Monitoring Programme - Agricultural Land Programme Area	Department of Soil Sciences- Swedish University of Agricultural Sciences			- quantify variations in time and space regarding concentrations and transported amounts of nutrients and pesticides in surface and groundwater whose catchment areas are dominated by agriculture
43	Switzerland	Swiss Soil Monitoring Network	Swiss Agency for the Environment, Forests and Landscape / Swiss Federal Office for Agriculture / Swiss Federal Research Station for Agroecology and Agriculture	1985		- scientific validation and evaluation of the success of environmental policy measures aiming long-term conservation of soil fertility
NEW ZEALAND						
44	New Zealand	Implementing soil quality indicators for land - "500 Soils Project"	Ministry for the Environment Sustainable Management Fund / Landcare Research	1998	2001	- to determine the effects of land use on soil quality and integrate the data from regions into a national overview
ICP						
45	United Nations Economic Commission for Europe	UN-ECE ICP Integrated Monitoring of Air Pollution Effects on Ecosystems	UN/ECE Working Group on Effects/ Sweden / ICP IM Programme Centre	1993		- long-term international ecosystem monitoring program to predict the state of and possible medium to long-term changes in natural ecosystems caused by trans-boundary air pollutants
46	United Nations Economic Commission for Europe	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests - ICP Forests Level 1	UN/ECE Working Group on Effects / Task Force of ICP Forests / Programme Coordinating Centre	1986		- monitor the effects of anthropogenic and natural stress factors on the condition and development of forest ecosystems in Europe - contribute to a better understanding of cause-effect relationships in forest ecosystem functioning
47	United Nations Economic Commission for Europe	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests - ICP Forests Level 2	Forest Intensive Monitoring Coordinating Institute	1994		- monitor the effects of anthropogenic and natural stress factors on the condition and development of forest ecosystems in Europe - contribute to a better understanding of cause-effect relationships in forest ecosystem functioning
Networks						
48	United Kingdom	Environmental Change Network	Natural Environment Research Council	1994		- detection, interpretation and forecasting of environmental changes resulting from natural and anthropogenic causes
49	International	Terrestrial Ecosystem Monitoring Sites	Global Terrestrial Observing System	1995		- database on terrestrial ecosystem monitoring sites which registers sites and networks carrying out long-term terrestrial monitoring

Prog. No.	Country/ Org.	Program Title	Management / Funding	Start Date	End Date	Purpose
50	International	International Long-Term Ecological Research Network	Global Terrestrial Observing System	1993		- promote and encourage long-term ecological research, exchange of data, produce comparable results and facilitate development of other programs
51	Pan-European	Networking of Long-term Integrated Monitoring in Terrestrial Systems - NoLIMITS	European Network for Research in Global Change	future		- facilitate and co-ordinate the exchange and integration of environmental data between other monitoring networks, further scientific research and implement sustainable development policy
52	Europe	proposed European Soil Monitoring Network (EuroSoilNet)	European Commission Directorate General Joint Research Centre	future		- provide policy relevant information on the major threats to soil in Europe in a harmonized and coherent way

Table 2. Monitoring program descriptions – Part 2

Prog. No.	Components Measured				Site Type				Soil Type
	Soil	Air	Water	Biota	Agricultural	Forested	Natural	Other	
NORTH AMERICA									
1	yes			yes	yes				agricultural soils across Alberta
2	yes			yes		yes		reclaimed	
3	yes			yes	yes				agricultural soils across Canada
4	yes	yes	yes	yes		yes			
EUROPE									
5	yes				yes				
6	yes			yes		yes			
7	yes	yes	yes	yes					light brown, high mountainous, sand-clay
8	yes	yes	yes	yes				pollution areas	
9	yes			yes	yes			protected areas	
10	yes				yes			sewage sludge areas	
11	yes				yes	yes	yes	open lands	
12	yes				yes				
13	yes			yes		yes			
14	yes				yes				
15	yes				yes	yes	yes		
16	yes	yes	yes	yes		yes			
17	yes				yes	yes		municipal	
18	yes	yes							
19	yes		yes	yes	yes			open lands	
20	yes		yes		yes				
21	yes		yes			yes			
22	yes		yes					threatened	
23	yes			yes	yes				
24	yes				yes				
25	yes			yes	yes				20 soil types
26	yes				yes				15 soil regions

Prog. No.	Components Measured: Soil	Air	Water	Biota	Site Type: Agricultural	Forested	Natural	Other	Soil Type
27	yes					yes			
28	yes		yes	yes	yes				
29	yes		yes		yes	yes			10 land types
30	yes		yes		yes	yes	yes	greenhse/bulb/orchard	peaty/ sandy/ marine clay/ river sediments
31	yes		yes		yes				pre-Holocene and Holocene deposits
32	yes		yes		yes				
33	yes	yes	yes	yes	yes	yes			
34	yes				yes				
35	yes	yes	yes	yes		yes			
36	yes			yes	yes				
37	yes				yes	yes			
38	yes	yes	yes	yes	yes	yes		highland areas	
39	yes				yes		yes		
40	yes	yes	yes	yes	yes	yes	yes		
41	yes			yes		yes			
42	yes				yes				28 different soil types
43	yes				yes	yes		urban parks	
NEW ZEALAND									
44	yes				yes	yes	yes	yes	
ICP									
45	yes	yes	yes	yes			yes		
46	yes			yes		yes			
47	yes	yes		yes		yes			
NETWORKS									
48	yes	yes	yes	yes	yes	yes	yes	freshwater, upland	
49	yes	yes	yes	yes	yes	yes	yes	yes	
50	yes	yes	yes	yes	yes	yes	yes	yes	
51									
52	yes				yes				

Table 2. Monitoring program descriptions – Part 3

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
NORTH AMERICA								
1	42 sites 126 sample points	landform transect sampling (upper, mid, lower slope) site <0.65 km^2	annual	0-15 cm 15-30 cm	$154,000 (Cdn) establishment cost $25,000 per year (Cdn)	- data used internally for modeling, trend determination and to monitor land use management		14,15,16
2	74 (additional 1 reclaimed site per 100 ha established each yr)	10 m * 40 m plot on upland sites	- reclaimed-5 years - natural-10 years	- principle horizons to 100 cm - composite of 10 subsamples	$5000 (Cdn) per plot to startup	- database used by companies and researchers to guide future reclamation practices		51
3	23 sites 60-100 sample points	25 m * 25 m grid or 5-8 transects per 5-10 ha site (upper, mid, lower slope)	1-10 years	- loose sample of Ap horizon - loose sample of sub-surface horizons	$2.4 million (Cdn) from 1990-1993			140,141,142,143
4	4000	27 km * 27 km grid -4 subplots each 7.32 m in radius	5 years	litter samples 0-10 cm 10-20 cm in mineral soil and forest floor		- stored by a central database - data reported to States annually and complete report every 5 years	-erosion not an issue - pine health decreases with low organic matter - low pH increases birch/beech/maple dieback	12,57,82,99,108, 129,130
EUROPE								
5			- chemical-5 years - physical-10 years			- stored by the Soil Science Institute - used for erosion control and tillage/fertilization systems		85

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
6	514	8.7 km * 8.7 km grid	no scheme	0-30 cm at 10 cm increments and 30-50 cm			-moderate soil acidification, widespread heavy metal pollution, accumulation of nitrogen	10,35,144
7	3		annual	0-5 cm 5-20 cm			-heavy metal concentrations are lower than background standards	49,66
8	303	nation wide						20,49,65
9	240 plots; 200 agr and 40 protected areas	1000 m^2 plot	6 years	-four samples from each genetic horizon			- Cr, Cd Cu, Hg,Pb, Zn contamination	8,19, 27,89,90,145
10	393	country-wide gridnet 50 m^2 plot	10 years	0-25 cm			- heavy metals in arable soils and natural areas don't constitute a serious ecological risk	2,22
11	5692 original samples taken - 904 resampled	5 km * 5 km grid samples taken at 4 m intervals in 400 m^2 plot	15 years	0-15 cm (25 cores per site)		- stored in LandIS database	- decrease in organic carbon and copper, increase in available P, K	35,64,78,96,122,126, 131
12	180 farms/year 900 sampling sites		5 years				- mean pH, P and K in grasslands has decreased - average OM has remained constant	35,96,126
13	3000 permanent plots 7000 temporary plots	country-wide	variable		800,000 Euros/year (field work)	- used in forest management planning, policy decisions and forest inventory planning		26,132
14	150		5 years					25,35

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
15	11 sites 52 sampling points per site	sites approx. 1 ha each in size - country-wide	5 years	- plough layer in agr. soils -pedogenic horizons in forest soils		- data base managed by ORACLE - soil descriptions stored in DONESOL data base		8,11,35,45,59,60
16	102	2 ha plots	10 years	0-10 cm 10-20 cm 20-40 cm	1990-1995 28.5 million Francs	- stored by Coordination Centre for the Technical Research Dept of the National Forest Office		11,45,77,121
17	794	across 16 provinces	periodic				- most important soil changes occur in the organic layers and those changes can be expected within 5-10 years	35,46,91
18	17							35,46
19	276 sample squares, 5 soil samples per square	1 km^2 plots	6-8 years	bulk topsoil sample			- increase in pH -abnormal heavy metal concentrations	4,5,9,35,54,63,123, 124,125
20	865		1-6 years					36,37,138,139
21	183		1-6 years					36,37,138,139
22	189		1-6 years					36,138,139
23	7142 over 5 million ha	12 ha site	3 years	0-30 cm 30-60 cm			- soil acidification had increased 6% and calcareous soils decreased 3%	76,138,139
24	6000 over 5 million ha		3 years	0-30 cm 30-60 cm 60-90 cm				138,139
25	202 points		1-6 years		funded by State Land Service	- stored by State Land Service, reported in annual report	- acidification is increasing	43,118

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
26	75 plots - pesticides and heavy metals 600 - other parameters	400 m^2 fixed plots for heavy metals and pesticides 3-3.5 ha site for other parameters - each site is 200 ha in size	5 years	humic layer 0-20 cm 20-40 cm 40-60 cm	40,000 lita in 2000	- reported annually - detect and track changes in soil indicators, heavy metals and pesticides - assess soil sensitivity to anthropogenic loads and possible impact of contamination on human health	- content of lead is below background levels in most soils - heavy metal accumulations only in humic layer	42,52,61,62,67
27	235	4 km * 4 km plot - distributed 8 km *8 km apart	2-3 years for soil parameters 5 years for heavy metals and pollution	0-5 cm 5-10 cm 10-20 cm 20-40 cm 40-80 cm		- reported annually - identify forest damage, assess background heavy metal concentrations, pathways of accumulation and impact on forests	- least amounts of trace metals found in podzolic and marshy soils - most soils are not heavily contaminated with trace metals	42,52,67,135,136
28	1	13.65 km^2 watershed	2-5 years		5000 lita in 2000	- data reported once per year by the Lithuanian Water Management Institute		42,52,67,94
29	100 (35- 40 yearly)	400 m^2 site	annual	0-10 cm 30-50 cm		- stored by RIVM	- accumulation of heavy metals in arable and cattle farms	30,31,32,33,35,73, 74,137
30	1683 samples	based on size of homogenous area 10,000 m^2 site	10-15 years	topsoil			- agricultural areas have higher concentrations of zinc and copper and have higher pH levels	13,35,73,74,137
31			5 years			- stored by RIVM		74,137

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
32		15 catchments <10 km^2 site					- processes are primarily driven by weather events leading to largely variable seasonal and annual nutrient loss rates	22,80,133,134
33	227 (45,000 samples)	100 m^2 plot	5 years 10 years in forests	0-20 cm or 0-10 cm in (grasslands)			- natural content of heavy metals and sulphate	107,109,116,117
34	151 samples	218 000 km^2		0-20 cm			- PAH levels low	55,107
35	1461	1 plot per 60 km^2	4 years			- published in full in Environmental Monitoring Library	- decreasing concentrations of SO_2 and NO_2 in air pollutants	17,18
36	20-22 areas		4-5 years		6,788,000 Estonian crowns in 1994	- data is stored in a meta-database	- lowest biodiversity on lands abandoned less than 4 years ago	81,87,88,92,93
37	942; 670 agr. and 272 forested	16 km^2 grid 400 m^2 plot at each node point	4 years					23,72,86,120
38	650; 312 agr. and 338 forested	314 m^2 site	5 years	0-10 cm 20-30 cm 35-45 cm 10-30 cm in agric soils		- stored in Information System of Monitoring - results reported in State of the Environment Report	- 98.6% of soils are not contaminated - trace elements are not high	47,48,68,69,70,71, 97,98,100
39	300		5 years				- highest organic matter found in mountain soils such as rendzina and podzols	3,47

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
40	4 sites 1 or 2 plots per watershed	50 m * 50 m plot / watershed 1 km^2 watershed	2-10 years	0-5 cm 5-10 cm 10-20 cm 20-30 cm 30-60 cm	109 million SEK for entire program	- data hosts have been established to store and distribute quality assured environmental data	- soils predominantly podzols	7,111,114
41	23,500	circular plots (7-10 m radius)	10 years	- samples taken up to 1m deep	10 814 thousand SEK in 2001	-data stored in the SK-BAS database - annual publication		8,110,111,112,113
42	40 sites	2-15 km^2 site		0-20 cm 40-60 cm	6580 thousand SEK in 2001			110,111
43	107; 74 agr., 31 forested and 2 urban p arks	100 m^2	5 years	0-20 cm, 4 composite samples from 25 sample locations in a square grid pattern		- data is included in the NABO- database	- after five years, 87 of 100 sites showed a change in one measured pollutant - the main inorganic pollutants are a consequence of anthropogenic contamination	115
NEW ZEALAND								
44	511	10 regions 40 m transect with five 25 m^2 plots at 1 m spacings 20 cores per plot	anticipated to be 5-10 years	0-10 cm 0-7.5 cm for BD and macro porosity		- data used for State of Environment reporting	- soil quality is within acceptable levels - structural degradation on half of arable cropping and market garden sites	56,79,101,102,103, 104,105,106

Prog. No.	No. of Sampling Points	Spatial Variability Sampling Pts	Sampling Interval of Soil	Sampling Method	Project Costs	Data	Data Trends	References
ICP								
45	70 sites	40 m * 40 m plot 10-1000 ha sites	5 years	0-5 cm 5-10 cm 10-20 cm 20-40 cm 40-80 cm		- data submitted to National Focal Point and then to Programme Centre		8,40,83,127
46	6000 (5300 soil)	16 km * 16 km grid	10 years	0-10 cm 10-20 cm				8,38,39,84,128
47	860	0.25 ha plot surrounded by 10 m buffer zone	10 years	0-10 cm 10-20 cm 20-40 cm 40-80 cm		- stored at the Forest Intensive Monitoring Coordinating Institute	- depositions of nitrogen, acidity and heavy metals exceed critical loads over a large portion of plots	8,38,39,84,128
NETWORKS								
48	12 terrestrial sites 37 freshwater sites	9 ha site - soil sampled on 1 ha on 50 m and 25 m grids	5 years / 20 years	0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm and by horizons for first 30 cm	50,000 British pounds/year/site			6,8,24,34,119,126
49	1700 sites	120 countries						28
50		25 countries						41
51								50,95
52		16 km * 16 km grid	possibly 5, 10 -20 years					35,75

Table 3. Soil, site and management parameters measured by monitoring programs[1]

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
NORTH AMERICA										
1	N, P, K, S, NH_4	pH, EC, $CaCO_3$, TOC, Total N, CEC (at site establishment)	Db, PSA (at site establishment), soil water characteristics in 2003	hot KCl-NH_4	LFC, LFN	B, Cl, Co, Cu, Fe, Mg, Mn, Mo, Ni, Se, Si, V, Zn (once in 2003)	2,4-D sorption (once) Ag, Al, As, Ba, Be, Bi, Cd, Cr, Li, Pb, Sb, Sn, Sr, Ti, Tl (once in 2003)	yes	yes	yes
2	N, P, K, S, Ca, Mg	pH, EC, CEC, $CaCO_3$	Db, PSA			trace metals	trace metals, hydrocarbons		yes	
3	P, K	pH, EC, CEC, $CaCO_3$, TOC, Total N, Total K, Total Na, Total Mg, Total Ca	Db, hydraulic conductivity, soil moisture, PSA, aggregate stability, ^{137}Cs	mesofauna		Co, Cu, Fe, Ni, Zn	Al, Cr, Li, Pb	yes	yes	yes
4	P, S	pH, CEC, Total inorganic C, Total C, TOC, Total N, $CaCO_3$	Db, soil moisture, PSA, aggregate stability, penetration resistance			Mn, Ni, Cu, Zn	Ba, Cd, Pb, Sr		yes	
EUROPE										
5		pH, hydrolytic acidity, CEC, $CaCO_3$, Total N, Total P, P fractions, soil greenhouse analysis, sorptive capacity	Db, porosity, soil water characteristics, PSA, aggregate stability	Nmin	organic humus, humus fractions	Cu, Fe, Mn, Zn	Ba			
6	yes	pH, CEC, $CaCO_3$, TOC, Total N	PSA				As, Cd, Pb		yes	
7		pH, EC				Co, Cu, Ni, Zn	Cd, Pb			yes
8	SO_4					Cu, Zn	As, Cd, Pb			

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
9	P, K, Ca, Mg	pH, exchangeable acidity, CEC, TOC, Total P, Total K, Total Ca, Total Mg	Db, specific gravity, porosity, FC, PSA	Nmin, micro-biological, enzyme activity, mesofauna		B, Co, Cu, Fe, Mn, Mo, Ni, V, Zn	As, Be, Cd, Cr, Hg, Pb, Tl, pesticides, PCB, radionuclides	yes		
10						Cu, Ni, Zn	As, Cd, Cr, Hg, Pb			
11	P, K, Mg	pH, TOC, Total Na, Total Ca, Total P, Total K,	PSA, soil water characteristics			Co, Cu, Fe, Mg, Mn, Mo, Ni, Se, V, Zn	Al, Ar, Ba, Cd, Cr, F, Hg, Pb, Sr	yes	yes	
12	P, K, Mg	pH, TOC						yes		
13										
14	yes					yes	yes			
15	PO_4, Ca, Mg, K	pH, TOC, Total N, CEC, $CaCO_3$	PSA, Db	Nmin, Cmin, mesofauna, micro-biological, enzyme activity	LFC, LFN	Co, Cu, Ni, Zn	Cd, Cr, Pb radionuclides	yes	yes	
16	yes	TOC, Total N						yes	yes	yes
17	Ca, K, Mg, Na	pH		yes	humus	Zn	Al, Cd, Pb, Sb, Tl	yes		
18							heavy metals, hydrocarbons			
19		pH, TOC		micro-biological, macrofauna, enzyme activity		Cu, Ni, V, Zn	Cd, Pb, PCB, hydrocarbons, pesticides		yes	

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
20	N, P, K, S, Ca, Mg, NO_2	pH, EC, CEC, TOC, Total N, $CaCO_3$	hydraulic conductivity, soil water characteristics, PSA	micro-biological, respiration	humus content	B, Cl, Cu, Co, Fe, Mn, Mo, Ni, Se, Zn	Al, As, Cd, Cr, Hg, Pb, organic micropollutants, pesticides, radionuclides		yes	
21	N, P, K, S, Ca, Mg, NO_2	pH, EC, CEC, TOC, Total N, $CaCO_3$	hydraulic conductivity, soil water characteristics, PSA	micro-biological, respiration	humus content	B, Cl, Cu, Co, Fe, Mn, Mo, Ni, Se, Zn	Al, As, Cd, Cr, Hg, Pb, organic micropollutants, pesticides, radionuclides		yes	
22	N, P, K, S, Ca, Mg, NO_2	pH, EC, CEC, TOC, Total N, $CaCO_3$	hydraulic conductivity, soil water characteristics, PSA	micro-biological, respiration	humus content	B, Cl, Cu, Co, Fe, Mn, Mo, Ni, Se, Zn	Al, As, Cd, Cr, Hg, Pb, organic micropollutants, pesticides, radionuclides		yes	
23	N, P, K, S, Ca, Mg	pH, EC, $CaCO_3$, TOC, Total N	soil water characteristic			Cu, Mn, Zn		yes	yes	yes
24		Total P, Total K, Total S, Total Na, Total Mg, Total Ca				B, Co, Cu, Fe, Mn, Mo, Ni, Se, Zn	Al, Cd, Cr, Hg, Pb			
25	N, P, K	pH, TOC	Db, porosity, WP, WHC	mesofauna		Cu, Ni, Mn, Zn	Cd, Cr, Pb, pesticides, radionuclides	yes		
26	P, K, Ca, Mg	pH, EC, TOC, Total S			organic humus, sulfur content of humus fractions	Cu, Fe, Ni, Zn	Cd, Cr, Pb, pesticides			

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
27	Na, S	pH, CEC, exchangeable acidity, TOC, $CaCO_3$, Total C, Total N, Total P, Total K, Total Mg, Total Ca			humus fractions	Cu, Fe, Ni, Mn, Zn	Al, Cd, Cr, Pb			
28	NH_4, NO_3, SO_4, K, Ca, Mg, Na	pH, EC, CEC, TOC, Total N, Total C, Total P, exchangeable acidity, Total S, sorptive capacity	Db, PSA	Nmin, enzyme activity	litter/cellulose decomposition	Cl, Cu, Fe, Mn, Ni, Zn	Al, Cd, Cr, Pb, pesticides, radionuclides	yes	yes	
29	PO_4, NH_4, NO_3, SO_4	pH, EC, TOC, Total K				Cu, Cl, Mg, Zn	Cd, Pb, PAH, hydrocarbons, pesticides			
30	NH_4, NO_3, PO_4, K, Ca	pH, TOC	PSA			Cu, Fe, Ni, Zn	Al, Cr, Pb, PAH, hydrocarbons			
31	NO_3, P						Cd, pesticides			
32	yes	yes	yes			yes	pesticides	yes	yes	
33	PO_4, K, S, Ca, Mg, Na	pH, CEC, $CaCO_3$, Total C, Total N, TOC, sorptive capacity	Db, PSA		humus fractions	B, Cu, Mn, Ni, Se, V, Zn	Al, As, Be, Cd, Cr, F, Hg, Pb	yes	yes	
34		pH, TOC	PSA				PAH			
35	P, K, SO_4, Ca, Mg, Na, NH_3, NH_4, NO_3					Cl, Cu, Fe, Mn, Zn	Al, Cd, Pb			
36	P, K	TOC, Total N	soil moisture	mesofauna, micro-biological						
37		yes	yes				organochlorine pesticides		yes	

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
38	P, K, Mg, Ca	pH, EC, CEC, TOC, Total N, Total P, Total K, Total Mg, Total C, KCl	Db, porosity, infiltration rate, PSA		organic humus, humus fractions, oxidizable C	Co, Cu, Ni, Se, Zn	Al, As, Cd, Cr, F, Hg, Pb, organic pollutants, radionuclides, halogenated compounds, PAH			
39		TOC, Total N			humus fractions					
40	PO_4, K, Ca, Mg, Na, NH_4, NO_3	pH, CEC, Total C, Total N, Total P, Total S, exchangeable acidity				Cl, Cu, Fe, Mn, Zn	Al, Cd, Hg, Pb			
41		pH, CEC, Total C, Total N	PSA		litter/cellulose decomposition	yes	yes	yes	yes	
42	yes	yes			humus	yes	heavy metals, organochlorine pesticides			
43	P, Ca	pH, CEC, aluminum oxide	Db, PSA		humus fractions	Co, Cu, Fe, Ni, Zn	Cd, Cr, F, Hg, Pb, halogenated compounds, PAH			
NEW ZEALAND										
44	P	pH, CEC, Total C, Total N	Db, porosity, soil water characteristics, PSA, aggregate stability	Nmin, respiration, microbial biomass		Fe			yes	

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
ICP										
45	K, Ca, Mg, Na	pH, CEC, TOC, Total N, Total P, Total S	Db, PSA	Nmin, enzyme activity, respiration	litter/cellulose decomposition	Cu, Fe, Mn, Mo, Ni, Zn	Al, As, Cd, Cr, Hg, Pb			
46	Na	pH, CEC, $CaCO_3$, TOC, Total N, Total P, Total K, Total Mg, Total Ca				Cu, Fe, Mn, Ni,, Zn	Al, Cd, Cr, Pb		yes	
47	P, K, S, Ca, Mg, Na	pH, EC, CEC, TOC, $CaCO_3$, Total N, Total K, Total Na, Total Ca, Total Mg				Cu, Fe, Mn, Ni, Zn	Al, Cd, Cr, Hg, Pb		yes	
NETWORKS										
48	N, P, NH_4-N, S	pH, CEC, exchangeable acidity, $CaCO_3$, TOC, Total inorganic carbon, Total N, Total P, Total S	Db, PSA, soil water characteristics	micro-biological		Co, Cu, Fe, Mo, Ni, Zn	Al, As, Cd, Cr, Hg, Pb	yes	yes	yes
49	P	pH, CEC, TOC, $CaCO_3$, Total, N, Total C, Total P, exchangeable acidity	Db, PSA, infiltration, soil water characteristics	macrofauna, microfauna, microflora, respiration		B, Cl, Co, Cu, Fe, Mn, Mo, Ni, Zn	Cd, Cr, Hg, Pb		yes	
50										
51										

Prog No.	Soil Test Analysis (Fertility)	Soil Chemical Properties	Soil Physical Properties	Soil Biological	Soil Biochemical	Micro-nutrients	Pollutants	Mgt	Site Description	Climate Data
52	N, P, K, S, Mg	pH, EC, CEC, Total C, Total N, Total P	Db, hydraulic conductivity, infiltration rate, PSA, soil water characteristics, aggregate stability, shrinkage/ swelling tests, plastic/liquid limit	Nmin, Cmin, micro-biological, enzyme activity, respiration	humus fractions, particulate organic matter	Cu, Mo, Mn, Ni, Se, V, Zn	Al, As, Cd, Cr, F, Hg, Pb, pesticides, radionuclides, surfactants, halogenated compounds, PAH, PCB	yes	yes	

[1]**NOTES:**

SOIL TEST ANALYSIS (fertility): can include measurements of N, P, K, S, Ca, Mg, Na, NH_4, NH_3, NO_2, NO_3, PO_4, SO_4

SOIL CHEMICAL: can include TOC, Total inorganic carbon, soil greenhouse analysis, sorptive capacity, pH, EC, $CaCO_3$, CEC, base saturation, acid and base cations, soluble cations, exchangeable cations, exchangeable acidity, hydrolytic acidity, sodicity, Total N, Total P, Total K, Total S, Total Mg, Total Ca, Total Na, SAR

SOIL PHYSICAL: can include Db, compaction, penetration resistance, total porosity, macroporosity, infiltration rate, shrinkage/swelling tests, plastic/liquid limits, saturated and near-saturated hydraulic conductivity, aggregate stability, texture, PSA, specific gravity and soil water characteristics

SOIL BIOLOGICAL: can include Nmin, Cmin, respiration, microbiology, microfauna, mesofauna, macrofauna, microflora, microbial biomass activity, enzyme activity and earthworms

SOIL BIOCHEMICAL: can include measurements of LFC, LFN, organic humus, humus fractions, litter/cellulose decomposition, oxidizable C, particulate organic matter

MICRONUTRIENTS: can include measurements such as B, Cl, Co, Cu, Fe, Mg, Mn, Mo, Ni, Se, Si, V, Zn

POLLUTANTS: can include measurements of Ag, Al, As, Ba, Be, Bi, Cd, Cr, F, Hg, Li, Pb, Sb, Sn, Sr, Ti, Tl, PCBs, PAH, halogenated compounds, surfactants, tricyclic aromatic hydrocarbons, organochlorine pesticides, herbicide residues, chlororganic insecticides, radionuclides

MANAGEMENT: can include land use history, site history, crop residues, cultivation, vegetation composition, plant yield, plant quality, manure application, manure storage, fertilization

SITE DESCRIPTION: can include morphology, soil profile description, soil type, soil series, soil classification, mass of forest litter, type/depth of humus horizon, landscape attributes, slope, aspect, relief, soil parent material, erosion/deposition, weathering, mineralogy/rock type, hydrological conditions, phases/stages of soil development

Soil Water Characteristics: can include water holding capacity, field water capacity, total available water, readily available water, soil moisture, hygroscopic moisture content, soil water release, soil moisture retention, wilting point, saturation point
FC: field capacity; the content of water, on a mass or volume basis, remaining in a soil 2 or 3 days after having been wetted with water and after free drainage is negligible
WP: wilting point; the percentage by weight of water remaining in the soil when the plant wilts permanently
WHC: water holding capacity
pH: the degree of acidity or alkalinity of a soil, expressed as a measure of free hydrogen ion activity in the soil on a scale from 1-14
EC: electrical conductivity or a measure of soluble salt content of soil
CEC: cation exchange capacity; the total amount of exchangeable cations that a soil can adsorb. It is sometimes called "total exchange capacity", "base exchange capacity" or "cation adsorption capacity"
TOC: total organic carbon, includes measures of organic matter
Db: bulk density; the mass of dry soil per unit bulk volume; includes measures of compaction and resistance
PSA: particle size analysis; determination of the various amounts of the different soil separates in a soil sample, usually by sedimentation, sieving, micrometry, or combinations of these methods
LFC: light fraction carbon, amount of carbon in the proportion of soil which is less than 2.0 g cm^{-3}
LFN: light fraction nitrogen, amount of nitrogen in the proportion of soil which is less than 2.0 g cm^{-3}
Nmin: mineralizable nitrogen
Cmin: mineralizable carbon
PCB: polychlorinated biphenyls
PAH: polycyclic aromatic hydrocarbons

4.1 Countries/Organizations
The 52 monitoring programs reviewed are distributed across the world with the majority (80%) being situated in Europe (Figure 2). Thirty-nine programs originate in 21 different European countries. Since 80% of the programs originate in Europe, it appears that soil monitoring may be more of a priority in Europe than in other areas of the world or perhaps information regarding environmental monitoring in Europe may be more accessible to the public. Sixteen of the 21 European countries are also member states of the European Union and perhaps environmental monitoring is mandatory as part of membership. Arrouays et al (1998) noted that European soil monitoring networks result primarily because of soil acidification and the effects of air pollution. These issues seem to be addressed more in the northern and eastern European countries than over the rest of the continent. Three United Nations programs and five international/European networks were also found. Networks provide a setting for the collection and sharing of information.

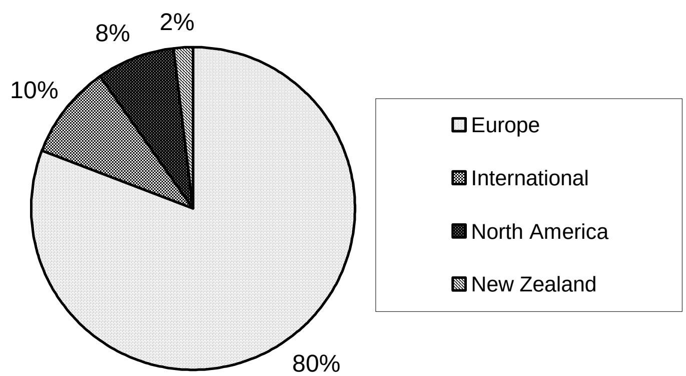

Figure 2. Distribution of monitoring programs by location

4.2 Management
A majority of monitoring programs are conducted at the national level and are managed by governmental organizations. For example, nine programs are managed by Departments of Agriculture, four by Departments of Forestry and 12 by Departments of Environment. Government controlled institutes and universities manage 11 programs, while eight are managed by non-governmental organizations and private industry. The remaining eight programs are managed at the provincial level or the managing party was not stated in the literature. The AESA Soil Quality Benchmark Program is operated at the provincial level within the Alberta Department of Agriculture, Food and Rural Development.

4.3 Objectives/Purpose
The range of program purposes or objectives includes determining the state/trends in soil, forests or ecosystems due to human involvement, developing approaches to address the issues, data storage and exchange of information, to solely identifying risks to the food chain and researching the cause and effect of forest dieback. Monitoring schemes differ in their primary objectives

because of differences in environmental concerns. Although not stated as the key objective, the strongest single reason for soil monitoring may ultimately be the crucial role the soil plays in food production and the potential risk of contamination of the food chain (90). The objective of the AESA Soil Quality Benchmark Program is to determine the effect of different management practices on soil quality and to collect data for validation of modeling exercises. Twenty-seven programs have the purpose of determining the status and trends of soil, which is similar to the AESA Soil Quality Benchmark Program. Eighteen programs, including the AESA program, make reference to using the data they collect for modeling purposes.

4.4 Establishment Period

Program establishment has spanned several decades ranging from the 1920's to plans for the future (Figure 3). The earliest monitoring program began in Finland in 1921, while two monitoring systems in Table 2, the Networking of Long-term Integrated Monitoring of Terrestrial Systems (program number 51) and the European Soil Monitoring Network (program number 52), will become operational in Europe in the future. The literature indicates that only five programs have officially been terminated. The majority of the programs were initiated in the late 1980's and early 1990's. This probably corresponds to increasing environmental consciousness and concern about issues regarding land use sustainability. The late appearance of soil monitoring systems and perhaps the complete absence of soil monitoring in many environmental monitoring programs may be due to the lack of awareness of the functions soil performs or its slow reaction to contamination (74), which makes it easy to ignore. The AESA Soil Quality Benchmark Program has monitored soil quality annually for the last five years and is planning to continue for at least five to ten more years.

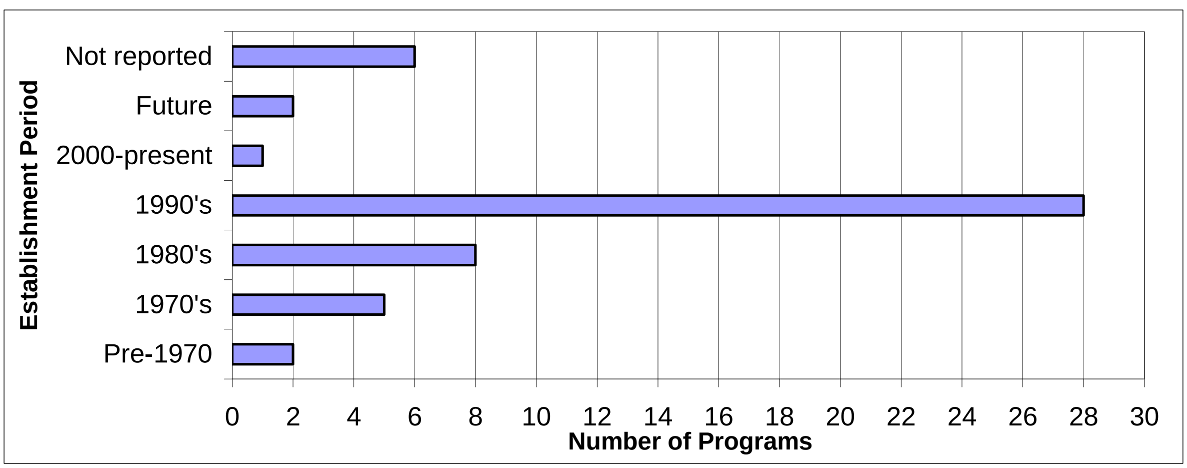

Figure 3. Distribution of monitoring program establishment period

4.5 Components Monitored

The programs were grouped according to the ecosystem components that each measures (Figure 4). Twelve programs follow an integrated approach by measuring a combination of four ecosystem components (soil, biota, air and water). Eleven programs measure only soil and biota (plant and/or animal), similar to the AESA Soil Quality Benchmark Program. Seventeen of the 52 programs have soil as the only focus of their monitoring efforts.

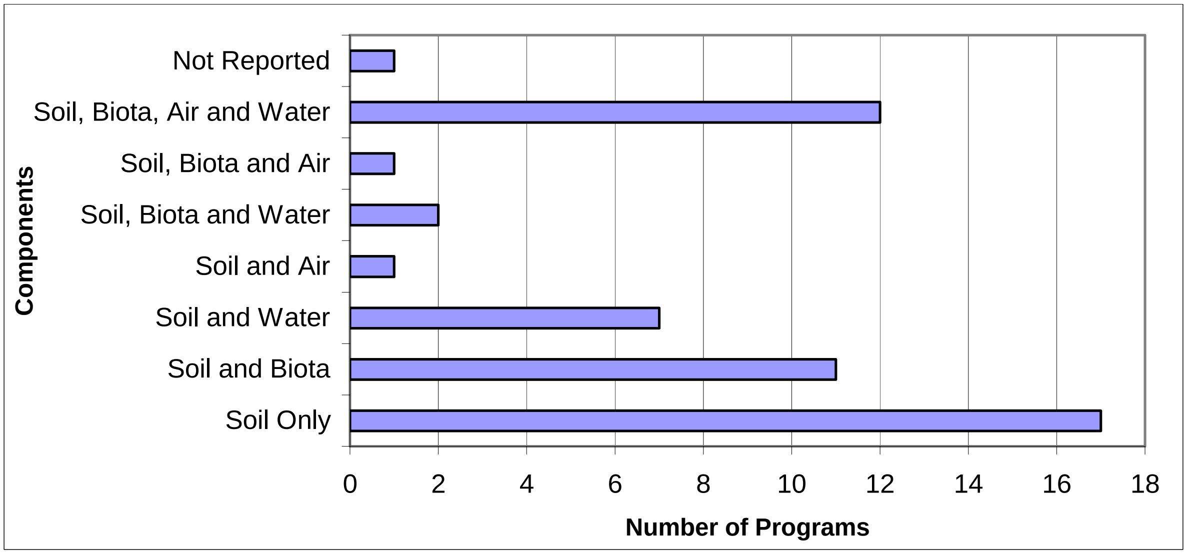

Figure 4. Distribution of monitoring programs by ecosystem components measured

4.6 Ecosystems Monitored

The programs were grouped according to the type(s) of ecosystems that they monitored (Figure 5). Land used by agriculture is the focal point of most of the monitoring programs as seventeen solely monitor variables on agricultural land. The AESA Soil Quality Benchmark Program only measures parameters in the agricultural ecosystems of Alberta. Ten of 52 programs focus on forested ecosystems, while two programs incorporate the monitoring of agricultural, forested, and natural areas and six others programs monitor agricultural, forested, natural and other ecosystems. Referring to sections 4.5 and 4.6, only four monitoring programs are similar to the AESA Soil Quality Benchmark Program and exclusively measure soil and biota on agricultural land. These programs are 3, 23, 25, and 36 (Table 2).

4.7 Soil Sampling Interval

Distribution of the sampling interval for the soil component is reported (Figure 6). Sampling intervals range from one to 20 years depending on the parameter measured. Within a program, an interval such as “1-6” means that some soil attributes are measured annually while others are measured every six years. A five-year interval is the most commonly used sampling scheme. The AESA Soil Quality Benchmark Program measures most soil attributes on an annual basis, which may be too frequent as changes in soil status may be difficult to determine using sampling intervals less than five years (126).

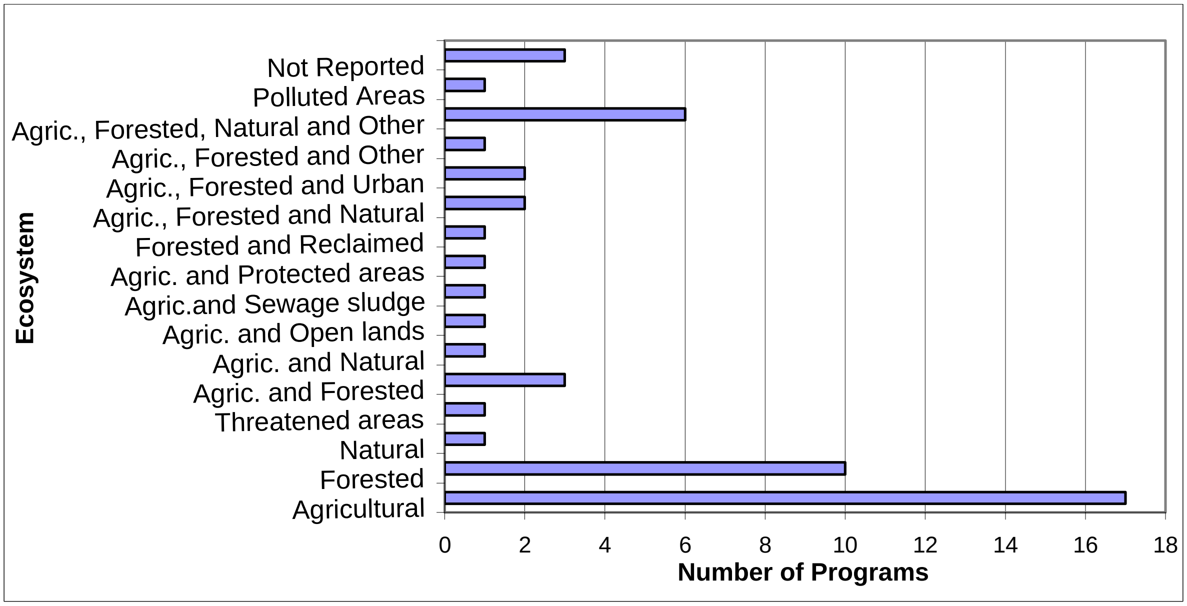

Figure 5. Distribution of ecosystem type(s) monitored

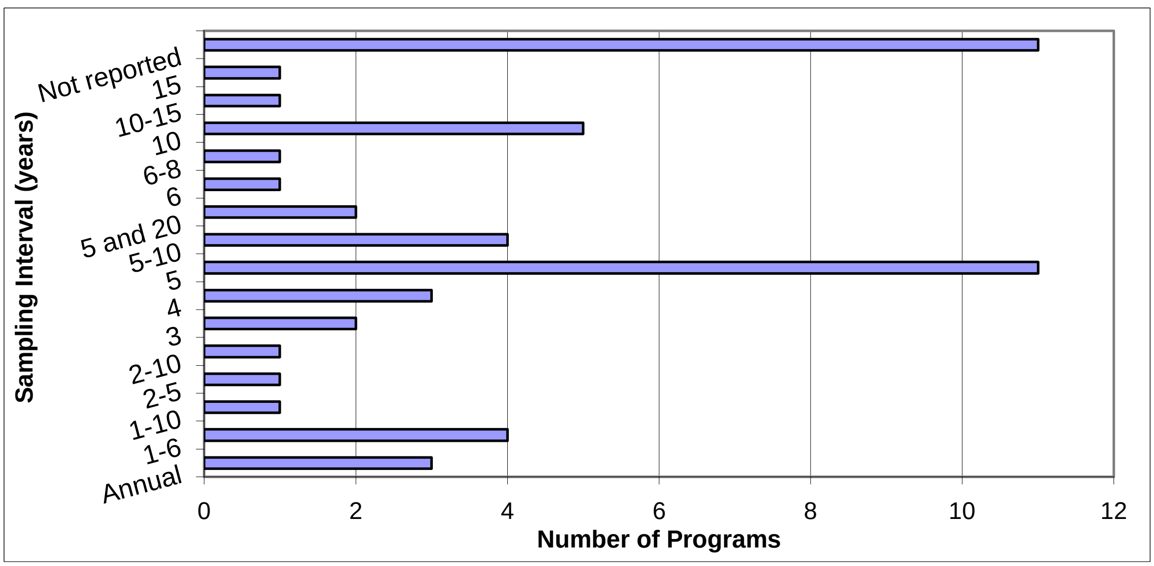

Figure 6. Distribution of interval (in years) between soil sampling events

4.8 Sampling Spatial Variability

Monitoring programs use various approaches to sampling (Table 2). Spatial variability across a landscape can occur due to differences in natural soil forming factors, topsoil depth, fertility, landform and management. The AESA Soil Quality Benchmark Program and the Canadian Soil Quality Benchmark Site Program (program number 3) stratify their sample points by ecodistrict and topography. Both programs measure soil properties at various slope positions along a catena and chose sample sites based on areas of relatively homogeneous biophysical and climatic conditions. Landform based measurement ensures that variability caused by differences in moisture, temperature, vegetation and other soil factors are captured during sampling. A grid-sampling scheme, which covers an entire site or region at regular intervals is used by programs 3, 4, 6, 10, 11, 27, 35, 37, 46 and 52. Grid based sampling is the easiest way to ensure coverage of large areas and enables unbiased estimates. Others chose specific sampling points based in a watershed/catchment area or simply areas representative of land use, management or soil type within a region or across the entire country.

4.9 Parameters

The parameters measured by each program are reflective of its given objectives or purpose. Each program could measure a total of ten selected soil, site and management parameters. The parameter classes selected for analysis in Table 3 are:

- soil test analysis
- chemical
- physical
- biological
- biochemical
- micronutrients
- pollutants
- management information
- site description
- climatic data

The ability of a soil to function is determined by interactions between various physical, chemical and biological soil attributes. These parameters make up a minimum dataset of parameters needed to monitor overall changes in soil quality.

Programs were grouped according to the number of the parameters mentioned above that each measures. A majority measure fewer than six parameters, five measure nine of ten parameters, while five programs including the AESA Soil Quality Benchmark Program, regularly measure eight of ten parameters (Figure 7). Each parameter is discussed below in more detail.

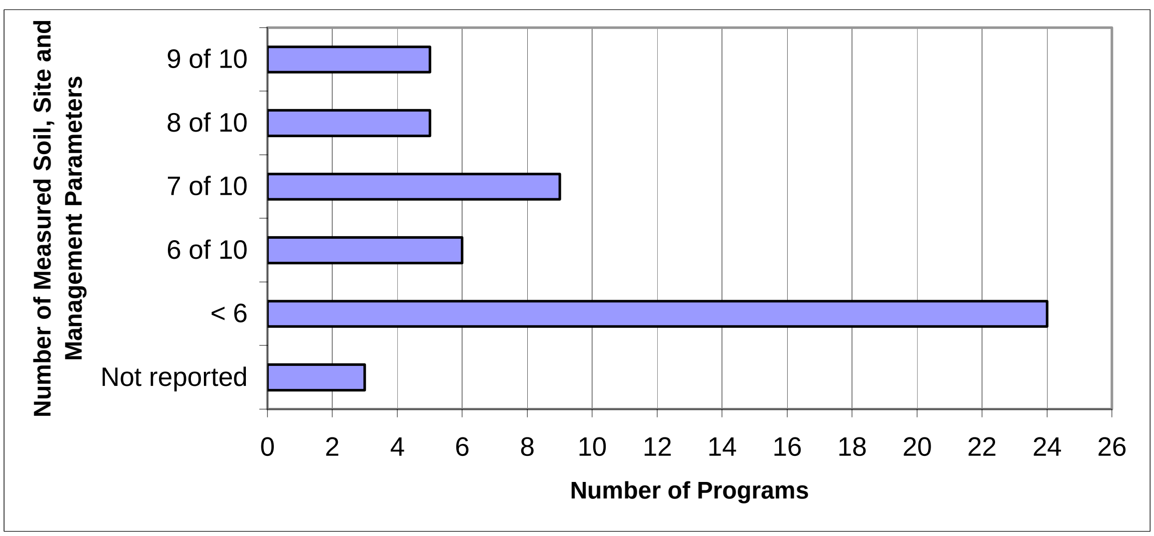

Figure 7. Distribution of the number of soil, site and management parameters measured

4.9.1 Fertility

Selected soil attributes which contribute to the fertility of a soil are measured by 39 of 52 programs (Table 3). Soil test analysis are used to indicate nutrient availability in a soil, which helps explain plant growth and yield patterns. The measurement of fertility can include N, P, K, S, Ca, Mg, Na, NH_4, NH_3, NO_3, PO_4, and SO_4 The AESA Soil Quality Benchmark Program uses soil test analysis for calculation of nutrient balances and for modeling exercises.

4.9.2 Chemical

Chemical soil attributes are measured by 43 of 52 programs (Table 3). Many chemical measurements are dynamic and change under human induced pressures. Their measurement is necessary to understand soil function and the effects of use and management on the soil resource.

4.9.3 Physical

Physical attributes are also essential to understand how well soils are functioning. Twenty-nine programs include the monitoring of physical soil attributes in their protocols (Table 3). The AESA Soil Quality Monitoring Program uses measurements of bulk density, particle size and moisture as indicators of physical soil parameters. Five of 52 programs include the measurement of aggregate stability.

4.9.4 Biological

The inclusion of biological attributes in soil quality assessment is continually evolving and many attributes are being evaluated for use as soil quality indicators. Soil biological attributes are measured by 18 programs (Table 3). Of those 18 programs, seven measure nitrogen mineralization. Currently, the only biological indicator measured by the AESA Soil Quality Benchmark Program is potentially mineralizable nitrogen. Other programs also include mineralizable carbon, mesofauna, microfauna and soil enzyme activity as biological measurements.

4.9.5 Biochemical

Eighteen programs measure soil biochemical attributes (Table 3.) Measurements include humus, light fraction organic matter and decomposition. The AESA program measures light fraction (LF) organic matter and light fraction carbon (LFC) and nitrogen (LFN). Light fraction organic matter is enriched with carbon and nitrogen and is an indicator of changes in the biologically active portion of organic matter.

4.9.6 Micronutrients

Monitoring for micronutrients occurs in 40 of 52 programs (Table 3). Micronutrients necessary for plant growth include boron, chlorine, cobalt, copper, iron, magnesium, molybdenum, nickel, selenium, silicon, vanadium and zinc. In 2002, the AESA Soil Quality Benchmark Program looked at micronutrient content in agricultural soils across Alberta for the first time. Annual analysis does not currently occur but a future need may arise as industry and food production systems further impact the environment.

4.9.7 Pollutants

Pollutants are measured in 43 of 52 programs (Table 3). The pollutant category can include measurements of heavy metals, pesticides, radionuclides and hydrocarbons. Heavy metals may include silver, aluminum, arsenic, barium, beryllium, bismuth, cadmium, chromium, lithium, lead, antimony, tin, strontium, titanium, thallium, fluorine, and mercury. These elements can become pollutants if their concentrations reach levels high enough to cause contamination. Pollutant monitoring is primarily concentrated in Europe which may be due to high population densities and a history of intense industrialization throughout the continent . Pollutant buildup in the environment has large economic consequences and heavy metal buildup may be irreversible in a human lifetime (119). The AESA Soil Quality Benchmark Program performed a one time analysis of heavy metals in 2002 and also collaborated with the University of Manitoba to measure 2, 4-D sorption values (ratio of 2, 4-D sorbed to the soil relative to the amount in solution) in agricultural soils of Alberta. Other pesticides have not been monitored or determined and further heavy metal monitoring is not currently planned.

4.9.8 Management

Land management information such as crop rotation, crop yield, tillage and fertilization is collected by 16 programs (Table 3). This information is important to explain productivity, nutrient cycling and changes in soil properties. The AESA Soil Quality Benchmark Program collects this type of information on an annual basis by interviewing the land managers and harvesting plant samples from each site.

4.9.9 Site Description

Site descriptions and soil characterization such as landscape and soil type are useful to interpret soil analysis data as they help explain changes in soil quality and are important inputs of any modeling program. This information is collected by 24 programs (Table 3). The AESA Soil Quality Benchmark Program collected site information and characterized the soil when the sampling sites were initially selected.

4.9.10 Climatic Data

Climatic data is documented by six of the 52 programs (Table 3). Climatic data is important to interpret soil data because temperature and moisture have a large influence on numerous soil processes such as microbial activity, mineralization, and various physical characteristics. Climate also drives many soil models. The AESA Soil Quality Benchmark Program collects precipitation on site with manual rain gauges and uses climatic data collected at Environment Canada weather stations across Alberta to interpret soil data from the benchmark sites.

4.10 Trends

After monitoring has been conducted for a period of time, trends in changes of soil properties can be determined. Many programs produce reports which include the state of the soil resource at one point in time and do not describe changes in soil properties between monitoring periods.

4.11 Comparison of Parameters Measured

The parameters measured by the AESA Soil Quality Benchmark Program and those that are not included in the sampling protocol but are measured by other programs are given in Table 4. A blank cell indicates that the AESA program is currently measuring all parameters being measured by others in the particular category.

Table 4. Comparison of parameters measured by AESA Soil Quality Benchmark Program to other monitoring programs

Parameters Measured By AESA Soil Quality Benchmark Program	Parameters Measured By Other Programs Not Included in the AESA Soil Quality Benchmark Program
Soil Test Analysis (Fertility)	
NO_3, PO_4, K, SO_4, NH_4	Ca, Mg, Na, NO_2, NH_3
Soil Chemical	
pH, EC, $CaCO_3$, TOC, Total N, SAR if EC>4, CEC (at site establishment)	Total P, Total K, Total S, Total Na, Total Mg, Total Ca, Total C, Total inorganic C, K fractions, P fractions, soil greenhouse analysis, sorptive capacity, hydrolytic acidity, exchangeable acidity, base saturation, acid/base cations, soluble cations, exchangeable cations, sodicity
Soil Physical	
Db, PSA (at site establishment), wilting point (once), field capacity (once)	aggregate stability, total porosity, macroporosity, compaction, penetration resistance, saturated hydraulic conductivity, near-saturated hydraulic conductivity, specific gravity, water holding capacity, total available water, hygroscopic moisture, soil water release, saturation point, infiltration rate, shrinkage/swelling tests, plastic/liquid limit
Soil Biological	
Nmin potential	Nmin, Cmin, mesofauna, macrofauna, microfauna, microflora, respiration, microbiology, enzyme activity, microbial biomass activity, earthworm concentrations
Soil Biochemical	
LFC, LFN	organic humus, humus fractions, particulate organic matter, litter/cellulose decomposition, oxidizable C
Pollutants	
pesticide (2,4-D) sorption values (once), Ag, Al, As, Ba, Be, Bi, Cd, Cr, Li, Pb, Sb, Sn, Sr, Ti, Tl (all sampled once)	organochlorine pesticides, hydrocarbons, radionuclides, PCB, halogenated compounds, PAH, surfactants, F, Hg
Micronutrients	
B, Cl, Co, Cu, Fe, Mg, Mn, Mo, Ni, Se, Si, V, Zn (all sampled once)	
Management	
land use history, plant yield, plant quality, manure applications, fertilizer applications, pesticides/herbicides, cultivation activity, crop type, cropping rotations	
Site Description	
legal land descriptions, air photos, profile descriptions, soil classification, site characterization, topsoil depth, parent material, horizon descriptions, slope position, aspect, erosion, moisture regime, drainage, stoniness	
Climate Data	
annual precipitation	

5.0 SUMMARY

The AESA Soil Quality Benchmark Program was designed to provide data for modeling exercises, provide baseline soil information, evaluate landform effects on soil quality and to monitor changes in soil quality over time. The fifth year of monitoring agricultural soil quality in Alberta has been completed and this literature review of international soil monitoring programs is part of the program evaluation process. The review, conducted between September 2001 and June 2003, provides a basis of comparison for the AESA program to determine if the monitoring protocol could be altered to increase the value of the data currently being collected.

The monitoring programs described in this review include the monitoring of soil properties, which have been resampled or were intended to be resampled. The programs are currently operational or were operational during the last 15 to 20 years and are situated in areas comparable to Alberta in climate or land use. Although long term agronomic plot studies and one time surveys were not included in the review, they may provide supplemental information to monitoring programs.

The 52 monitoring programs illustrate the variability of the soil resource across the globe and the wide range of issues that stem from the utilization of soil. Each program is unique, having different objectives, which are created to address specific concerns relating to sustainable land use, human health and policy development.

A majority of the monitoring programs originate in Europe, which may indicate that the sustainability of the soil resource is more of a priority there than in other parts of the world, or perhaps information about monitoring programs in Europe is more accessible to the public than for example, in North America. Most of the programs are managed and/or funded at the Federal government level, which may explain why most began in the 1990s and are still operational. The 1990's marked the beginning of widespread environmental consciousness where the public demanded environmental accountability from all levels of government.

The number of ecosystem types and components monitored by each program varies mainly because of the environmental concerns in the particular country or region. Some programs measure only one ecosystem or one component within that ecosystem, but many are part of a larger environmental monitoring program which integrates all four ecosystem types (agricultural, forested, natural and others) and the four components within those ecosystems (soil, biota, water and air). Even those with a narrow focus, concentrating on one ecosystem or component, contribute by increasing the knowledge about the sustainable use of environmental systems and should be considered as an asset.

There are various sampling methods applied by the monitoring programs. Spatial variability of sampling points ranges from grid based to benchmark sampling. The monitoring interval is also quite variable between programs. A five-year sampling interval is the most commonly used method.

The soil parameters measured by each program relate back to the objectives of the program. The parameters are chosen for their ability to provide the necessary information to meet the objectives. The networks described in this literature review are designed to integrate many monitoring projects or programs and decrease data compatibility problems by encouraging the use of similar monitoring protocols and measurement of the same soil parameters.

Parameters such as land management, climatic and site description information are approached in different manners. Some programs focus only on the changes in soil parameters, while others acknowledge the valuable role climate, topography, soil classification and land use have in determining soil quality.

The AESA Soil Quality Benchmark Program is unique in North America. The data collected from these benchmark sites is valuable as it encompasses a wide range of variables such as climate, soil type, and land management. The benchmarks are stratified by ecodistrict (characterized by relatively homogeneous biophysical and climatic conditions) and landform. Temporal and spatial variability is addressed by annual sampling of several parameters and through the use of a landform sampling strategy.

To date, the AESA program has examined data from individual soil parameters such as organic matter and micronutrients/heavy metals from the standpoint of landscape, management and soil/climatic influences. One time sampling of micronutrient/heavy metal and pesticide contents has resulted in collaboration with other research institutions to answer other environmental questions related to agricultural soil sustainability such as nitrogen mineralization, pesticide accumulation and phosphorus adsorption.

Upon comparing the AESA Soil Quality Benchmark Program to other soil monitoring programs around the world, it is clear that the AESA program has identified the importance of soil quality. The AESA Soil Quality Benchmark Program regularly measures eight of ten parameters. Areas concentrated on include fertility, chemical properties, physical properties, management and climate information, many of which are included in the minimum dataset of indicators proposed by Doran and Parkin in 1994. The indicators proposed by Doran and Parkin that are not being addressed include rooting depth, infiltration and respiration. Measurement of these indicators could provide a more comprehensive evaluation of agricultural soil quality across Alberta. Soil quality is currently being monitored on an annual basis and the AESA program needs to assess when significant differences in results can be determined which may influence future refinements in the sampling interval.

Monitoring is an essential component of environmental management. It provides us with information in order to make educated decisions about how we manage our resources. Regardless of the magnitude and focus of each monitoring program, they all strive to increase the understanding of how human involvement and environmental interaction impacts soil quality, ultimately leading to more sustainable use of the soil resource. The AESA Soil Quality Benchmark Program helps document the complexity of soil and management practices across the agricultural areas in Alberta, provides a cost effective cross validation dataset for model verification and ultimately improves the public's understanding of soil quality issues in Alberta (16).

You are invited to visit the AESA Soil Quality Monitoring Program website at: http://www.agric.gov.ab.ca/sustain/aesasoilqm.html

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7.0 APPENDIX

1. Alberta: AESA Soil Quality Benchmark Program
Objectives

- provide baseline soil information
- evaluate landscape effects on soil quality
- provide a dataset to test and validate simulation models
- monitor changes in soil quality over time on a field landscape basis

Site Selection
Sites were to be distributed across the agricultural areas of Alberta and stratified according to major land use and landscape patterns. They were to occur only on cultivated land and were to be representative of soil-landscape patterns and land-use of the ecodistrict that each occurs in. The sites also need long-term security and cooperation from the land manager. The sites were not to be situated on headlands, pipeline right-of-ways, water courses, field corners or areas of weed infestations.

Soil Sampling Methods
Each sampling site consists of an upper, mid and lower slope transect. Each sampling position is recorded using high quality, real-time DGPS and is relocated each year using GPS. When each site was initially developed, profile descriptions and site characteristics were completed for each landform position to ensure that the site was representative of the ecodistrict in which it is located. At the time of the field inspection and description, topsoil depth, pedon descriptions and landscape descriptions were also taken. Soil samples of each principle horizon were collected and analyzed for particle size analysis, CEC, pH, EC, SAR (when pH>4.0), calcium carbonate, available NH_4, NO_3-N, P, K, SO4-S, total nitrogen and organic carbon. Bulk density samples were taken from 3 cm to 15 cm in the topsoil and 20 cm to 50 cm in the subsoil.

Soil samples are collected annually from each site. Samples are collected after harvest but before cultivation or fertilization and soil freeze-up. Five to ten soil cores are taken from 0-15 cm and 15-30 cm at each landform position and are bulked to provide one sample. The samples are collected using either a STAR SS soil sampler or Dutch auger. Samples are kept cool and are then air-dried and ground to pass a 2 mm diameter sieve. The soils are then analyzed for fertility, pH in water and $CaCl_2$, EC, SAR (if EC>4), mineralizable N and light fraction C. Excess soil is archived for future use. Bulk density samples are also taken from the 0-15 cm depth.

Monitoring Components
The program also collects information about weather conditions and annual land management practices, in addition to collecting and analyzing annual plant yield samples from each landform position.

Data Uses
Data is compiled in a database and has been shared with collaborating institutions to determine phosphorus sorption, verify a nitrogen mineralization model and to determine pesticide accumulations.

Data Trends
Monitoring has revealed significant differences in organic carbon between agricultural ecoregions, depending on soil horizon and slope position. Differences in nutrient levels were also found based on soil properties, slope position and agricultural ecoregion.

Data Dissemination
Annually, results are distributed to the land manager of each site. Fact sheets on results from analysis of organic matter and micronutrients have also been prepared for distribution.

2. Alberta: Long –Term Soil and Vegetation Plots Established in the Oil Sands Region
No additional information is available.

3. Canada: Soil Quality Benchmark Sites

Objectives

- provide baseline dataset for assessing soil quality change and yields of representative farming systems
- provide a way of testing and validating predictive models of soil degradation and evaluating sustainability of current and proposed agricultural land management
- provide a network of well-documented sites at which integrated multidisciplinary research programs can be developed
- provide means of evaluating agricultural sustainability of current production systems in major agricultural regions of Canada

Site Selection

Sampling sites were selected based on the following seven criteria, with priority given to the first three:

1. represent a major soil or climatic region and /or ecological region
2. represent a typical physiographic region (landscape) or broad textural grouping of soils
3. represent a major or potentially major farming system within a region
4. complement provincial priorities or opportunities
5. provide the potential of revaluation of the impact of a susceptible degradation process
6. occupy approximately five to ten hectares of land or a small watershed
7. be located on cultivated agricultural land and as part of an actual farming system

Soil Sampling Methods

On simple slopes, a grid design is used. This is a 25 m by 25 m grid and 80 to 100 points are contained within each grid. A transect design is used on hummocky to undulating terrain. Five or more transects placed perpendicular to the contour of the landscape are used. The transects stretch from the crest to the base of the hill and are spaced 10 m apart from each other. Sixty sample points are contained within the transect sampling design.

At each sample point, a loose sample of the Ap horizon is taken, while a loose sample of the subsurface horizons are taken randomly in the grid design and at 25 percent of the points at each different slope position using the transect design.

4. United States of America: Forest Health Monitoring Program / Forest Inventory and Analysis

Purpose

The Forest Health Monitoring Program was initially part of the Environmental Monitoring and Assessment Program (EMAP). It was designed to provide a basic understanding of conditions of forests through annual assessment and to address environmental concerns related to the impacts of air pollution, acid rain, global climate change and land management practices on forest ecosystem health. The program had four main components:

- detection-monitoring: permanent plot grid system and aerial and ground surveys
- evaluation monitoring
- intensive site ecosystem monitoring
- research on monitoring techniques

In 1999, the Forest Health Monitoring Program and the Forest Inventory and Analysis program were integrated in response to further information needs. The Forest Inventory and Analysis program is now mandated to provide annual state inventories, provide 5 year reports of forest health for the entire nation and each individual state, and provide national standards and definitions.

The purpose of the soil quality indicator is to provide baseline information about the status of forest soils so that changes in quality can be monitored over time.

Monitoring Component

The program monitors many ecosystem components including: biological diversity, productive capacity, ecosystem health and vitality, water resources, global carbon cycles and lastly, soil resources, which is divided into 3 separate categories. The three categories are soil erosion (% bare soil, forest floor thickness, slope and soil texture), soil compaction and soil chemistry (organic matter, nutrients and heavy metals).

Soil Sampling Methods
During the first visit to a plot, soil is collected from a point labeled "1" on transects which run at tangents to the annual subplots (58.9 ft radius). Each subsequent sampling takes place at 10 ft intervals on opposite sides of point "1" along the transects. The sampling plots are distributed on the basis of one plot per 158,00 acres of forested land in 27 states. The intent is to have the program implemented in all 50 states by 2003.

Samples are collected from the forest floor (litter and O horizon) and also from the mineral soil in 0-10 cm and 10-20 cm increments. A total of five samples (3 forest floor, 2 mineral soil) are collected from each plot. Collection takes place during the months of June to September.

5. Albania: Map of Soils of Albania
Country Description
Albania is a country of almost 29,000 km^2. Hills and mountains cover 80% of this area.

Soil Issues
Erosion is a problem due to deforestation for use as arable land and securing wood for heating purposes. The need to produce the nation's entire food supply without importing raw materials has forced agricultural production into areas not suitable for cultivation.

Soil Sampling
In 1993, it was hoped to also include the following in the suite of analyses performed on the samples: hydraulic conductivity, pF, exchangeable Al, H, pH (CaCl2), EC, CEC, BS and matrix color.

Data Uses
The soil data has enabled the elaboration of drainage and irrigation projects, the determination of tillage and fertilization systems and erosion control. The information may serve monitoring relative to environmental protection although the pollution of soils and ground waters was still minor in 1993.

6. Austria: Forest Soil Monitoring System
Monitoring Components
The monitoring system measures tree growth, vegetation, crown damage, site descriptions, soil descriptions and chemical analysis of soil and foliar material.

Soil Sampling Methods
The site descriptions and soil analysis were carried out between 1987 and 1990. The soil samples were taken from 0-10 cm, 10-20 cm, 20-30 cm and 30-50 cm intervals. No repetition of soil sampling was planned before 2003.

Data Trends
The main results from the first sampling indicate moderate regional forest acidification, widespread heavy metal pollution, particularly lead and cadmium and the accumulation of nitrogen.

7. Bulgaria: Background Monitoring
Country Description
Arable land comprises 61 percent of the land area of Bulgaria. Thirty-three percent of the total land area is hilly or mountainous.

Soil Issues
The main areas of concern are heavy metal pollution, acidification, salinization, dehumidification, soil compaction, water logging and water and wind erosion.

Monitoring Components
Background monitoring involves monitoring many ecosystem components. Measured on a hourly basis are: ozone concentrations, relative humidity, air temperature, precipitation, sun radiation, and wind speed and direction. Sulphur and nitrogen dioxide are measured daily. Weekly measurements include dust, lead aerosols and the physical and chemical analysis of precipitation. Soil samples are collected annually, while phytomonitors are taken at the beginning and end of the growing season.

Soil Description
The soils at the background monitoring station in Rojen are high mountainous, light brown in color and are a sandy clay mix. They generally have good aeration, are slightly acidic and rich in humus.

8. Bulgaria: National Environment Monitoring System
Site Selection
The sample sites are organized by pollution source. Ninety-two sites are in industrial pollution areas, 80 sites are in areas affected by agricultural chemicals, 52 sites are situated in areas of irrigation and 79 sites are in zones polluted by automobiles.

9. Czech Republic: Basal Soil Monitoring Scheme
Objectives
- provide information on the main soil types and how their characteristics change with time
- assess the influence of anthropogenic activity on the soil resource
- provide information on strategic research
- act as a source of information for framing of legislation in the fields of soil protection and environmental impact assessment

Site Selection
Agricultural plots were selected for: soil type, proportion of land use type (arable pastures, vineyards, orchards, hop gardens), level of environmental contamination, even distribution of plots across counties, and the probability of agreement with the landowner.

Protected area plots were selected based on: the desire to cover all of the large scale protected areas in the Czech Republic, to cover all soil types, to reflect the aerial distribution of soil types in each individual monitoring area and to locate the plots in areas of least disturbance, mainly nature reserves.

Soil Sampling Methods
Each plot is divided into four equal subplots. Ten samples are taken from each genetic horizon in the subplots. Those samples are bulked to provide a 1 kg sample from each subplot, which equates to four samples from each genetic horizon over the whole plot. Soil cores are taken in triplicate for physical measurements. Soils are kept in a condition as close to field conditions as possible for measurement of biological parameters. The samples are air dried and ground to pass a 2 mm screen. Quality of analysis is assured by having various Institutes perform analysis of a reference soil that is provided by the Basal Soil Monitoring Scheme.

Monitoring Components
Atmospheric deposition is also monitored on 69 agricultural soil plots and 31 protected area plots.

10. Denmark: Heavy Metal Monitoring Programme
Country Description
Denmark is one of the smallest nations in Europe. As a result, it is densely populated and has well developed industrial and agricultural sectors. Agricultural activities use 62 percent of the land area and only four percent is used for municipal and industrial purposes.

Soil Issues
The largest environmental concern is food safety.

Site Selection
The sample sites were situated where detailed information on soil, land use and agricultural practices was available.

Monitoring Components
The program also monitors 20 agricultural fields with a known history of sewage sludge application.

Soil Sampling Methods
Each soil sample collected consists of a 2 kg sample composed of 17 subsamples. The subsamples are taken in a regular pattern within a 50 m^2 sample plot. A 3 cm cylindrical drill is used to obtain a sample to a 25 cm depth after removal of the organic layer. The soil is homogenized and sieved to 2 mm before analysis.

Data Trends
Two major trends have been found from the monitoring. The lowest concentration of heavy metals has been found in sandy soils and the use of phosphate fertilizers has increased the concentration of cadmium in arable soils. The low annual input of heavy metals in Denmark has prompted a 10 year waiting period before the sampling is repeated.

11. England and Wales: National Soil Inventory
The last re-sampling of the soils in England and Wales took place on arable and ley-arable soils in 1994.

Soil Sampling Methods
Soils are sampled by taking 25 soil cores to a depth of 15 cm These are taken at 4 m intervals within a 20 m by 20 m square plot centered on the 5 km by 5 km grid. The soil cores are bulked, air-dried and sieved to 2 mm prior to analysis.

Data Trends
The data collected to date indicates a decrease in organic matter and copper while indicating an increase in P and K in arable soils. The largest of the declines in organic matter are in grasslands ploughed up for arable use and on cultivated peaty or organic soils. No overall pattern of soil quality change can be detected but may indicate an actual change in chemistry or a change in agricultural practice over time.

12. England and Wales: Annual Representative Soil Sampling Scheme
This program, which began in 1969, measures 180 agricultural fields each year. The fields rotate each year, with one-third of the fields being sampled after a ten year interval, one-third being sampled after five years and one-third of the fields being sampled for the first time. Sampling at each site is discontinued after it has been in the sampling scheme for ten years.

13. Finland: National Forest Inventory
Country Description
Approximately eight percent of the total land area is used for cultivation.

Soil Issues
Finnish soils are thin with sandy till parent material. As a result, common soil phenomena are water surpluses, leaching and transport of substances into lower soil layers. Most of the soil degradation issues are confined to diffuse air pollution, in particular acidifying S and N deposition. Acidification by natural and anthropogenic processes is widespread, while salinization and wind erosion of arable land is not common. Climate changes, extensive forestry and regionally centralized agriculture have had the greatest impact on soil quality.

Program History
The National Forest Inventory has been performed for more than seventy years. The first inventory took place between 1921 and 1924. The ninth and most recent inventory was completed from 1996-2000.

Objectives
The traditional role has been to provide unbiased, reliable and large area forest resource information from the entire country. The information has been used in large area forest management planning, forest policy decisions and in strategic planning of forest inventories.

Funding
The annual budget for 1997 was about 1.5 million ECU of which 0.6 million ECU was used for field measurements.

Personnel
The inventory team is composed of 1 project leader, 16 researchers, 6 crew leaders, 3 field data operators, 4 secretaries, 4 associates, 10 temporary crew leaders and 30 field assistants.

14. Finland: Soil Quality Monitoring Program
No additional information is available.

15. France: Soil Quality Observatory
Country Description
The land area of France is divided into 56 percent arable, 28 percent wooded and 8 percent natural areas.

Soil Issues
Land is being swallowed up for development purposes and is putting more pressure on soil quality.

Program Management
The Observatory is one component of the DINIOS organization, which is the National Inventory of Soil Observation. It is governed by the Ministry of the Environment, Ministry of Agriculture, French Environmental Institute and the National Institute of Agronomic Research.

Site Selection
The observatory is a network of sites approximately 1 ha wide which are distributed throughout France. They were chosen based on four criteria: soil type, land use, type and intensity of presumed changes in soil quality and the human context and land status. In 1999, eleven sites were operational and the goal of the program is to have 100 operational monitoring sites.

Monitoring Components
In 1993, it was planned to include the monitoring of biological properties, the assessment of pesticide effects, soil physical degradation, erosion and crop quality.

16. France: RENECOFOR
This is a long-term forest ecosystem monitoring system which is part of the Forest Health Network, a network of 863 plots in 34 European countries.

Site Description
Each sampling plot is two hectares in size and has one-half hectare fenced off in the middle.

Monitoring Components
This monitoring system evaluates many ecosystem components. Weather has been monitored weekly since 1992, through the use of automatic weather stations in 27 plots. Atmospheric deposition in open fields and under tree canopy is monitored in 27 plots and plant inventory is monitored on each plot by using 8 transects, each 100 m^2 in size. The program also measures foliar analysis on an annual basis and dendrometric inventories.

Soil Sampling Methods
Soil profile descriptions are made from two profiles per sampling plot. Soil samples are taken from 25 mini-trenches dug on each side of the one-half hectare paddock. Samples are obtained from three intervals: 0-10 cm, 10-20 cm, and 20-40 cm depths. Soil fertility is monitored every 10 years through intensive sampling of each plot. Soil solution is measured in 17 plots.

Funding
The monitoring system is funded by the European Union, French National Forest Office, Ministry of Agriculture and Fisheries, and the National Agency for Environment and Energy.

Personnel
The program is directed by the network coordination center which employees four staff members. Sampling is done by 188 monitors, 11 graduates and 17 diploma holding members. The laboratory analysis is contracted out.

17. Germany: Permanent Soil Monitoring Plots

Soil monitoring is aimed at the registration of long-term changes due to pollution and soil damage caused by erosion, compaction and other changes of physical properties. Monitoring is meant to obtain reliable information on the effects of environmental influence over longer periods. To obtain this reliable information, it is necessary to investigate representative areas according to specific criteria.

Objectives

The focus of this monitoring program is on the chemical status of soil and input and output estimates.

Data Trends

The data has shown that most changes occur in the organic layers of the soil. Two plots indicated increasing pH values and also had a decreasing content of humus. Al, Ca, K, Mg and Na increased significantly in the organic layer and topsoils in most plots.

18. Germany: Air Measuring Network

Objectives

The aim of this network is to investigate the current state and long-term changes of soil quality and the influence of air pollution on soil.

19. Great Britain: Country-Side Survey

Purpose

The aims of the survey across Great Britain include:

- estimate the extent and distribution of widespread habitats in Great Britain
- characterize widespread habitats in terms of land cover and botanical composition
- derive indicators of sustainable development for the wider countryside
- provide accessible databases containing information on the state of the British countryside
- provide ground reference data for the calibration and validation of "Land Cover Map 2000"

History

The survey has previously been carried out in 1978, 1984, 1990 and most recently 1998.

Monitoring Component

The survey measures ecosystem components other than soil. Vegetation is monitored on 16,718 plots, 405 freshwater biota samples are taken from 500 m stretches of water, bird populations, freshwater features, linear features, buildings, land use, and land cover are also monitored.

Soil Sampling Methods

A bulked topsoil sample is taken from five randomly selected squares within each one km^2 area. The sample squares are stratified by climate, topography and other stable attributes. More than 60 field surveyors working in teams of two to collect samples during the months of June to mid August.

Of the 1067 organic matter samples taken in 1998, 744 were from the same areas sampled during the 1978 survey. One thousand and seventy-one samples were taken for pH analysis of which 769 were from the same area as the 1978 survey.

Data Trends

The data indicate that there has been an increase in pH across Great Britain since 1978. Soil organic matter has increased slightly or has had no change over the last 20 years. A non-normal distribution of all heavy metal concentrations has also been noticed.

20, 21 and 22. Hungary: Information and Monitoring System of Soil Conservation (TIM)

Country Description

Agriculture is the main land use in Hungary. Eighty percent of the land area is cultivated while forests cover only 18 percent. Based on fertility, 90 percent of the total land area is suitable for agricultural use.

Soil Issues
Some of the factors affecting soil degradation in Hungary include soil acidification, erosion, salinization, marsh formation, desertification, soil infertility and toxicity.

Site Selection
TIM has three monitoring components: national basic monitoring system (program no. 20), forestry observation points (program no. 21), and special areas monitoring (program no. 22). The sites cover the entire country regardless of land use or ownership. The special areas component monitors “threatened areas” which refer to sensitive areas such as ameliorated soils, drinking water supply areas, watersheds of important water bodies, protected areas, pollution hotspots, military fields, surface mining areas and waste water disposal areas.

Monitoring Component
Along with the soil component, groundwater is also sampled and chemical composition is determined annually. The analyses include pH, electrical conductivity, CO^3, HCO^3, Cl, SO^4, NO^3, PO^4, Ca, Mg, Na, K, micronutrients and micropollutants.

Soil Sampling Methods
The sites are sampled from September 15 to October 5 each year.

23. Hungary: Soil Fertility Monitoring System
No additional information is available.

24. Hungary: Microelement Survey
No additional information is available.

25. Latvia: National Agricultural Land Monitoring Programme
Soil Issues
The major type of soil degradation is erosion due to the fact that the soils are sandy and landforms are mainly hilly moraines. Sixty-three percent of agricultural land has the potential for low pH values, while soil compaction and organic matter decline are also a concern.

Objective
The aim of the program is to make long term observations regarding anthropogenic impacts on agricultural land.

Program Design
This program has three levels of monitoring. Level 1 monitors soil at 12 research stations covering 20 soil types and texture groups. Level 2 is carried out on family farms which are representative of farming systems, soil and climatic conditions. The third level applies land use monitoring within 512 municipalities. It involves the observation of how land owners follow state and municipality rules and regulations regarding land use and conservation.

Data Trends
The program organizers have found that the producers don’t properly fill out the agronomic data forms each year because they have no incentive to do so. It has also been difficult to compare the results from monitoring level 3 because there is no consistency in who performs the monitoring of land user activities at each location.

Funding
Agricultural soil monitoring has not received much support in Latvia due to the declining importance of agriculture in the Latvian economy. Meanwhile, the importance of environmental protection is increasing due to the European Union accession process.

26. Lithuania: National Environmental Monitoring Programme – Field Soil Monitoring
Country Description
Agricultural land covers 3.5 million hectares of Lithuania.

Objectives

- to register the positive and negative changes of soil cover and individual characteristics through a certain time
- to identify the regions and individual plots of agricultural land that are to reach negative nutrient balances due to poor management practices
- to establish the impact of various chemical means on the properties of soil
- to control the changes in soil acidity especially in areas where extensive mineral fertilization had been applied and in formerly acid but frequently limed lands
- to track the accumulation trends of pesticides and heavy metals

Soil Sampling Methods

Heavy metals and pesticides are sampled in 20 m by 20 m fixed plots. The accumulation of organic carbon humus and sulphur are analyzed from the humic layer of those fixed plots. The other soil parameters measured are taken from the cultivated layer of 3 to 3.5 ha plots.

Data Uses

The data collected illustrates the level of accumulation of the main agrochemical soil indicators, heavy metals and pesticides in the soil. There is national interest in the regularities of heavy metal distribution and changes over time, the detection of correlation between individual indicators and compilation of heavy metal distribution maps for the agricultural areas of Lithuania.

This program also provides information on the sensitivity of soil to anthropogenic loads, its migrational qualities and natural clean-up capacity and ultimately the possible impact of soil contamination on human health.

Funding

The main funding source for the National Environmental Monitoring Programme is the state budget. The soil monitoring budget for 1999 was 98,000 in Lithuanian currency, while the total ecosystem monitoring budget was 310,000 in Lithuanian currency. The funds are used for sampling, analysis of samples, calibration of testing equipment, systemization of collected data, and the assessment and preparation of reports and publications.

27. Lithuania: National Environmental Monitoring Programme – Forest Soil Monitoring

Objectives

- to track the amounts of heavy metals and biogenic substances in forest soil
- to register the positive and negative changes of soil cover and individual characteristics through a certain time
- to establish the relationship between the qualitative and quantitative changes in forest soils and air pollution

Soil Sampling Methods

Fieldwork for this monitoring program is carried out during the months of August and September.

A number of plots (74) from this portion of the National Environmental Monitoring Programme are used as part of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests.

Data Uses

Data collected is used for the identification of forest damage, to assess the background levels of heavy metal contamination, identify the pathways of heavy metal accumulation and migration, and assess the impact they have on forest ecosystems.

28. Lithuania: National Environmental Monitoring Programme- Integrated Monitoring of Agricultural Ecosystems

Objectives

- determine the balance of nutrients, accumulate data for hydrological, hydrochemical and biological models of agricultural ecosystems
- establish biological impact of changes in observed parameters on the agricultural ecosystem by combining observations of nutrient circulation with soil, vegetation and wildlife monitoring within the same basin

- assess the impact of agricultural activities on ecosystems by comparing the status of ecosystem components with that of relatively natural ecosystems to forecast the changes in ecosystem components

Soil Sampling Methods
Soil is sampled every two to three years, while heavy metals, pesticides and herbicides are sampled for every five years.

Data Uses
The data collected from this program is used for the establishment of nutrient balances and other environmental problems, such as the assessment of nutrient use by humans, the assessment of the impact of agricultural activities on the ecosystem and to forecast the changes in agroecosystem components.

29. Netherlands: National Soil Quality Monitoring Network
Country Description
The Netherlands has a land area of only 37,000 km^2. It is heavily industrialized, intensely cultivated and densely populated with over 400 people per square kilometer. As a result, anthropogenic management affects most land. The parent material is predominantly aeolian, fluvial and marine sediments and the topography is mostly flat.

Soil Issues
Approximately 64 percent of the land base is utilized by agriculture. Due to this fact, soil quality is a major concern. The focus of soil monitoring is on chemical pollution because salinization, erosion and other physical/chemical processes aren't a large concern in the Netherlands.

Objectives
A primary objective is to determine the actual quality and temporal trends of soil in the Netherlands and to gain insight into the relationship between deposition and transport to groundwater and its use in transport models. The main aim of the monitoring network is to relate the type of agricultural activity to eutrophication of the soil and determine which measures would be the best to reduce eutrophication and leaching of nitrates.

Site Selection
The network monitors both agricultural and forested sites. All sites chosen are on areas of known pollution loading. The agricultural sites range from dairy cattle farms in sandy regions, intensively managed cattle farms with high phosphate production, cattle farms on peaty soils and river clays to arable farms on sandy soils and sea clay. The cattle farm intensity is divided into intensive and extensive. The forested sites are deciduous, pine and mixed stands on sandy soil. Each sampling site has an area of approximately 400 m^2.

Soil Sampling Methods
The soil is sampled at two depths: 0-10 cm and 30-50 cm. Forty subsamples are taken at each depth and combined to create four composite samples from each site.

Data Trends
Monitoring has indicated that the heavy metal content of topsoils in both arable and cattle farms is below the target value. The heavy metal values in the second sampling depth are slightly lower than topsoil values. The target values for polycyclic aromatic hydrocarbons, organochlorine pesticides and atrazine were exceeded in both arable and cattle farming operations. An accumulation of heavy metals has been determined to continue in both farming practices.

30. Netherlands: Regional (Provincial) Soil Quality Monitoring Networks
Objectives
- to determine the trends in provincial soil quality in relation to the physical/geochemical characteristics (soil type and geohydrology) and land use
- to monitor soil quality in areas of special interest, such as nature reserves in order to recognize unwanted developments and take appropriate action

Site Selection
Sample sites were selected based on homogenous areas, represented by soil type, ground water tables and deposition of relevant elements. The representative areas could represent one contiguous area or small areas scattered all over the province. Sites were selected in agricultural and forested areas and other vulnerable or affected zones. The sample site size selected was approximately 10,000 m^2.

Monitoring Components
The networks are explicitly developed to monitor diffuse pollution in rural areas, namely contaminant spread, eutrophication and acidification. Contaminant spread (heavy metals and PAH) are monitored in the topsoil of all regions in a province. Eutrophication, in vulnerable or affected areas, is monitored through annual phreatic groundwater analysis in combination with phosphate monitoring in the unsaturated zone of the soil. Acidification is monitored by analyzing the ammonia/potassium ratio and aluminum/calcium ratio in the soil moisture from forested areas on sandy soil.

Soil Sampling Methods
Over 1600 samples are obtained for analysis from across 7 provinces in the Netherlands. Sampling density is determined by the variability of concentrations of the elements being monitored in each province. Forty subsamples of topsoil are taken and combined to create four subsamples.

Data Trends
The data collected suggest that the influence of agricultural land use on soil quality is clearly visible. Zinc and copper are notably higher on agricultural land than in forested soils, while pH is higher in agricultural soil than in natural areas. High loads of zinc and copper result from spreading manure on farmlands. Elements not related to agriculture such as nickel, lead and chromium show little differentiation between land use on the same homogenous area sampled. Soil type also contributes to differences in zinc concentrations, as sandy soils had lower concentrations than did clay or peat rich soils.

31. Netherlands: Soil Quality and Shallow Ground Water Monitoring
No additional information is available.

32. Norway: Agricultural Environmental Monitoring Programme
Country Description
Norway is a rural and mountainous country with only three percent of its total land area being arable. The Norwegian system has acknowledged the need for information beyond that collected by the agricultural census. This is because of the growing awareness of the multiple roles of the agricultural industry. Ecosystem monitoring programs have been the result. The Agriculture Ministry is focusing its efforts on "quality" for all Norwegian food production, assuring high yielding, contamination free products, produced in an environmentally sustainable way.

Soil Issues
Arable land area is being consumed by urbanization, therefore soil health is becoming a priority. Air and soil contamination by agriculture are a minor concern in Norway. While soil degradation by heavy metals is increasing, the most significant agricultural environmental issue is surface water pollution resulting from soil erosion and increased loss of nutrients due to high stocking rates.

Objectives
- to give the public administration the basis for implementing a cost effective environmental policy
- to document the result of environmental efforts within agriculture as compared to the Ministerial Convention of the North Sea
- to inform the agricultural sector about the environmental impact of agricultural practices and the result of environmental efforts

The program registers and reports on the extent of erosion and nutrient losses from different agricultural systems under various agro-climatic conditions. The information is related to farming practices, natural resources and climatic conditions.

Site Selection
The program monitors small agricultural catchments representing major cropping systems under varying soil and climatic conditions.

Monitoring Component
In addition to monitoring soil parameters, the program also measures water discharge. In 1995-1996, the program included the monitoring of pesticides and heavy metals.

33. Poland: National Program of Environmental Monitoring
Soil Issues
There are two major causes of soil degradation in Poland. The first being soil acidification from industrial emissions of gases and dusts and the second is soil erosion. Thirty-nine percent of soil is threatened by water erosion and 28 percent has the potential to be eroded by wind.

Site Selection
The earth surface monitoring component includes 227 sites established on mineral and organic soils. The sample sites are located on arable land (210 sites), grasslands (40 sites) and forested areas (50 sites). Forty percent of the sites are positioned in heavily polluted zones, 40 percent in low pollution zones and the remaining sites are in medium intensity pollution areas. The sites are situated across the entire country and include all major soil units.

Monitoring Components
The Environmental Monitoring Program includes the monitoring of seven ecosystem components. These include air pollution, surface ground water, underground water, earth surface (soil and plant monitoring), forest monitoring, radioactivity and finally, food and health.

Soil Sampling Methods
At each sample site, the soil profile is exposed to 150 cm. A morphological description of each profile is made and four samples are collected from each genetic horizon or from the arable layer. For arable and forested sites, samples are taken from the 0-20 cm depth within a 100 m^2 area. The protocol for the grassland sites calls for a 0-10 cm sampling depth. The sampling is replicated every five years, with a ten year interval for the forested sites.

34. Poland: Arable Soils Monitoring Program
Site Selection
The sampling sites are located in a variety of areas, from high industrialization to rural land use areas.

35. Poland: Programme for Forest Monitoring
Site Selection
The permanent observation plots are located in Scots pine, spruce, fir, oak, beech and birch forest stands. A portion of the plots are part of the UN-ECE Forest Monitoring Program.

Monitoring Components
The Forest Monitoring Programme examines damage to stands, chemism of trees assimilatory apparatus, health of pine seeds, pollutant deposition, entomological monitoring and phytopathological monitoring.

36. Republic of Estonia: Estonian Environmental Monitoring Program – Agricultural Landscape Monitoring Sub-programme
Country Description
Thirty percent of the land area of Estonia is used for agriculture and 44 percent is covered by forests. Before independence, the country was heavily industrialized with 1/5 of the population employed in the agricultural industry. The major environmental problems at the time were atmospheric and water pollution resulting from emissions, mining and fertilization. By 1998, the agricultural labour force had been decreased to six percent. With the decrease in agricultural production also came a decrease in the use of pesticides and fertilizers. With a slight

improvement in the environmental situation, the new issue became land abandonment.

Objectives

- follow up and evaluate the environmental effects of land and agricultural reforms
- define changes in land use structure in the different types of agricultural landscapes (intensive, extensive and marginal land use)
- to study changes in land cover types, especially fallow land and semi-natural areas
- to explain the connection between landscape structure indicators and the characteristics of ecological status of the agricultural landscapes

The main reason to monitor the landscapes of Estonia is to provide a comprehensive and adequate overview of the consequences of agricultural and land reforms and the influence of a decrease in pesticide and fertilizer use on soil organisms.

Site Selection

Sites are selected on the following criteria:

- distribution according to Estonian landscape regions
- must be distributed across the country
- situated in intensive, extensive and marginal land use areas
- additional data is available from the site
- have a good relation to other environmental monitoring sites

Soil Sampling Methods

Earthworms are collected from a 0.1 m^3 block of soil collected during September and October when the earthworms are at their greatest density, activity and lowest variability.

Soil Parameters

There is a large focus on soil biological parameters. In particular, the diversity of earthworms and microorganisms, the maximum dominance in earthworm communities, hydrolytic acidity of soil microorganisms, the number of colony forming microorganisms per gram of dry soil, plate counts of heterotrophic aerobic bacteria and the functional diversity of soil microbes.

37. Romania: National Integrated Soil Monitoring System

Country Description

Half of the land area of Romania is used for agricultural production. Sixty-seven percent is cultivated annually while only 37 percent of the agricultural land is deemed suitable and efficient for agriculture.

Soil Issues

Erosion is the largest problem facing arable land in Romania. Other soil degradation issues include acidification, water logging, salinization, compaction, pesticide and heavy metal pollution and low humus content. Soil quality degradation is mostly due to industrial emissions and animal waste.

System Design

The monitoring system is organized into two subsystems (agricultural and forest soils) and into three detailed levels. Level 1 plots are designed to identify problem areas and are located in a 16 km^2 grid. Level 2 is designed to identify the cause of the problems and Level 3 identifies the possible remedial actions.

38. Slovakia: Environmental Monitoring System

Country Description

In the year 2000, half of the land area of Slovakia was used by the agricultural industry. Forests covered 41 percent of the remaining area.

Soil Issues

Anthropogenic activity has intensified the effects of pollution over the past decades. This has threatened and destroyed many sensitive biological ecosystem components and has negatively impacted human health.

Objectives
Slovakia has attempted to gather objective and comparable ecological information through the Environment Monitoring System. It will contribute to more effective decision-making, environmental improvement and the preservation of sustainable growth.

The aim of the soil portion of the monitoring system is to monitor soil contamination and soil properties which are important to soil fertility and other environmental functions. The essential activity of soil monitoring is to monitor changes in the most important soil properties and monitor their stability.

Site Selection
Agricultural, forested and highland areas are monitored, while urbanized areas are avoided.
Twenty-one key sites are monitored yearly in addition to 19,257 agricultural plots which are part of a survey to measure the total area of soil contamination.

Monitoring Components
The Environmental Monitoring System monitors various ecosystem components including: air, water, soil, biota, forests, geological factors, radiation, waste, settlement, land use, allochtonous substances in foodstuffs and fodder, population load, meteorology and climatology.

Soil Sampling Methods
Forest soils are sampled from 0-10 cm, 20-30 cm, 35-45 cm and the soil parent material. Agricultural soils are only sampled from 10-30 cm and one to five subsamples are mixed together to form the sample from each plot.

Data Trends
Observations were made based on the 2000 sampling period. Only 1.4 percent of the monitored soil is contaminated and 0.4 percent is heavily contaminated. The heavily contaminated soil was located mainly in mountainous areas with the occurrence of geochemical anomalies. No changes were found in heavy metal content since the 1993 sampling. Heavy metal values don't exceed the limits of natural spatial heterogeneity and the content of agricultural lands is significantly below the valid sanitary limits. The content of polycyclic aromatic carbohydrates (PAU) in agricultural soils is below background limits. A significant amount of agricultural soils (457,000 ha) are potentially endangered by compaction while 191,000 ha are already compacted. Water erosion presents a problem, while wind erosion isn't a concern; the lowest intensity of erosion is under permanent grasslands.

39. Slovakia: Soil Monitoring System
Data Trends
Results have shown that the lowest amount of soil organic carbon was found in luvisols, planosols and regosols. A medium content of humus was detected in chernozems and phaeozems.

40. Sweden: National Swedish Environmental Monitoring Programme- Integrated Monitoring
Objectives
- describe the state of the environment
- assess the possible threats to the environment
- provide a basis for analysis of the national and international environmental impact of various pollution sources
- provide the basis for actions
- follow up measures that have already been implemented

Environmental monitoring activities are to focus on following national environmental quality objectives, provide state of the environment information and trace the effects of situations, which are of significance for ecologically sustainable development. Sweden has monitoring on both a national and regional basis, which is designed to meet the needs of society to carry out effective, measure oriented environmental protection work.

Site Selection
Sites were selected based on the following criteria:

- area not affected by local environmental disturbances or direct human influence
- vegetation in the drainage area should have reached the late stage of succession
- geographical and geological factors characterizing the drainage areas should be representative of those in the surrounding watershed
- sites should not be located in brooks or lakes in order to increase the range of environmental factors accessible for monitoring

The watersheds selected for the program were located in National parks or nature reserves to increase the protection of the site

By 1987, most of the sites became part of the UN-ECE Integrated Monitoring Programme. In 1993, the 15 remaining sites were reduced to 4, with 3 of those being new sites.

Monitoring Components
There are ten individual ecosystems monitored by the Swedish Environmental Monitoring Programme. These are: air, coast and sea, fresh water, wetlands, toxic substances coordination, mountain areas, forest, agricultural land, health related environmental monitoring and landscape.

Budget
The total budget in 2001 was 109 million SEK. Of that total, 73.5 million was allocated for national monitoring, 17.9 million for regional monitoring and 1.5 million for international monitoring.

Within the Swedish Environmental Protection Agency there is an environmental monitoring council consisting of 10 members and a chairperson. This council decides on the focus of national environmental monitoring and allocates funds to national and regional monitoring activities.

41. Sweden: National Swedish Environmental Monitoring Programme - National Survey of Forest Soils and Vegetation
This survey is part of the National Swedish Environmental Monitoring Programme – Forest Programme area. The survey began in 1983 and the second re-sampling period was between 1993 and 2002, with one tenth of the sites being sampled each year.

Monitoring Components
The vegetation-monitoring component focuses on timber production but also monitors vegetation understory and includes an inventory of pendulous lichens and algal growth on spruce needles.

Sampling Design
The survey uses circular plots seven to 10 m in radius which are arranged in a square tract having sides from 300 to 1800 m long. The tracts are systematically distributed across the entire country and the size of the tract varies between different parts of the country.

Personnel
The survey employs 50 field workers during the period of May to October. Field crews consist of two to three people, one whom is trained in the collection of data for the National Survey of Forest Soils and Vegetation. When sampling is complete, approximately 20 employees are responsible for preparatory work, finishing work and presentation of the collected data.

Information Dissemination
Some of the collected data is presented in an annual publication called Skogsdata. A new system called Markinfo is being developed which will be a system for presenting the results from this survey.

42. Sweden: National Swedish Environmental Monitoring Programme – Agricultural Land Programme Area

Objective

The aim of the survey of agricultural land is to quantify concentrations of transported nutrients and pesticides in surface and groundwater whose catchment areas are dominated by agriculture.

43. Switzerland: Swiss Soil Monitoring Network

Soil Issues

The soil in Switzerland is slowly being degraded. A large contributor is anthropogenic soil contamination stemming from industry. Permanent monitoring of soil contamination is therefore necessary for political decision making to prevent further degradation.

Objectives

The mandate of the Swiss Soil Monitoring Network is to collect data on contamination in space and time and to evaluate it in relation to monitoring the success of soil conservation measures.

Site Selection

The sites were chosen to reflect typical vegetation, land use, land management, air quality and soil conditions.

Soil Sampling Methods

Samples are taken using a steel gauge auger with an inside diameter of 3 cm. In the sampling of 2000, soil physical and biological parameters were added to the list of properties measured.

44. New Zealand: 500 Soils Project

Country Description

Two-thirds of the land area of New Zealand is hilly or mountainous terrain. The rock is geologically young and is easily eroded.

Soil Issues

Most of the soils in New Zealand are thin and of low nutrient status in their natural state. Generally, they are in good biological and physical condition and are suitable for native vegetation adapted to low nutrient conditions.

Soil quality issues include structural decline, nutrient issues, soil organic matter depletion, biological activity concerns and soil acidification.

Objectives

The project provided a national baseline of soil data, which environmental staff can now use to measure soil quality trends in the future.

Site Selection

In total, 511 sites under various land uses such as indigenous forest, plantation forest, tussock, pasture, scrub, horticulture/crop and urban areas were measured for soil quality parameters. The sites selected for the project represented the prominent land uses in each region of the country.

Soil Sampling Methods

A transect method was used to sample soil at each site. At 2 m intervals along a 50 m transect, soil cores of 2.5 cm diameter were taken to a depth of 10 cm. This resulted in 25 samples, which were bulked prior to chemical and biochemical analysis.

Three undisturbed samples were taken from each plot, along the transect at 15, 30 and 45 m positions. These were collected by pressing 75 cm^3 steel liners into the topsoil. Sub samples of the resulting cores were used for particle size analysis, bulk density measurement and moisture release. Samples for aggregate stability determination were taken from the same positions as the cores. A 1000 cm^3 block of soil was cut away and bagged for analysis. The samples were then stored at 5 °C.

45. United Nations Economic Commission for Europe (UN-ECE): International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP-IM)
Integrated monitoring of ecosystems involves measuring physical, chemical and biological properties of various ecosystem compartments at the same location over time.

Program History
This was a pilot program from 1989 to 1991 and became a permanent monitoring program in 1993. It is part of the effects monitoring strategy under the Long-Range Transboundary Air Pollution Convention of the UN-ECE. The international ICP-IM Programme Centre is located in the Finnish Environment Institute. The program center collects, stores, processes and analyses the data and is responsible for the cooperation among the ICP's and other related programs. Each "national focal point" or national agency overseeing the data collection, is responsible for the quality of data reported to the ICP-IM Programme Centre.

Program Participants
Presently, there are 20 countries participating in the program. The countries are: Austria, Belarus, Canada, Czech Republic, Denmark, Estonia, Finland, Germany, Iceland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Russian Federation, Spain, Sweden, and the United Kingdom.

Objectives
The main objective of the program is to observe and predict the state of and possible medium and long-term changes in natural ecosystems caused by transboundary air pollution. Other objectives include:
- to monitor the biological, physical and chemical status of ecosystems over time to explain changes
- to develop and validate models simulating ecosystem response
- to carry out bio-monitoring to assess the effects of pollutants and climate change. Emphasis is placed on the fluxes and effects on ecosystems of acidifying sulphur and nitrogen compounds and also ozone and heavy metals

The main aim of the program is to establish a consistent time series for environmental variables rather than establishing representative surveys across the UN-ECE region.

These objectives are met by:
- monitoring both biogeochemical trends and biological responses in small (10 -1000 ha) and clearly defined areas
- seeking to separate noise of natural variation, including succession from the signal of anthropogenic disturbance, by monitoring natural and semi-natural ecosystems
- developing and applying tools for regional assessment and prediction of long-term effects

Site Selection
The ICP-IM sites are located in catchments/plots within natural or semi-natural areas. The ideal site is between ten and 1000 ha in size and has no ongoing management activities. It should be typical of the region and the closest significant pollution source should be 50 km away.

Components Monitored
Various ecosystem components are monitored within this program. These sub-programs include:
- inventory of birds and small rodents: 3-5 years
- inventory of plants: 5-20 years
- climate: daily
- meteorology
- air chemistry: daily/weekly
- precipitation chemistry: weekly/monthly
- moss chemistry: 5 years
- throughfall: weekly/monthly
- stemflow: weekly/monthly
- soil chemistry: 5 years
- soil water chemistry: monthly
- ground water chemistry: 2-6 months

- lake water chemistry: 2-6 months
- runoff water chemistry: daily/weekly/monthly
- foliage chemistry: 1 year
- litterfall chemistry: 1 year
- microbial decomposition and soil respiration: 1 year
- forest damage: 1 year
- vegetation subprograms: 1-5 years
- hydrobiology of streams and lakes: 6 months
- trunk epiphytes: 1-5 years
- aerial green algae: 1-5 years
- forest stand inventory: 5 years
- plant cover inventory: 5 years

Soil Sampling Methods
The sampling procedure at each plot should be systematic, cover the whole soil plot and include an adequate number of subsamples to give sufficient precision so changes over time can be detected. A manual describing the protocols for each parameter is applied throughout the program and was revised in 1999. The following soil chemistry sub-program protocols are outlined in the manual. In order to minimize soil disturbance, a soil auger is used to take the samples. A set of undisturbed soil samples used for bulk density determination are taken from a soil pit dug outside of the plot. The humus layer is sampled separately and only includes the Of and Oh organic layers and not the green and Ol material. The mineral soil is sampled from fixed depths of 0-5 cm, 5-10 cm, 10-20 cm, 20-40 cm and 40-80 cm. Peat soil samples are sampled from 0-5 cm, 5-20 cm and 20-40 cm depths. The sub samples taken from a plot are mixed into one composite sample. They are kept at 4°C in dark conditions until they are pretreated by drying at 40°C and then sieved through a 2 mm mesh. The soil component is sampled every five years during the months of August and September.

46 AND 47. UN-ECE International Cooperative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests): Level I and II
Program History
The program was established by the United Nations Economic Commission for Europe (UN-ECE) under its Convention on Long-range Transboundary Air Pollution (CLRTAP).

Participants
There are 38 countries participating including: Albania, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Canada, Austria, Belarus, Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Ukraine, United Kingdom, Cyprus, Liechtenstein, Luxembourg, Republic of Moldova, Russian Federation, Switzerland, Turkey and Yugoslavia.

Objectives
- provide periodic overview on the spatial and temporal variation in forest condition, in relation to anthropogenic and rural stress factors on a European and national, large scale systematic network
- contribute to a better understanding of the relationships between the condition of forest ecosystems and anthropogenic and natural stress factors, through intensive monitoring on a number of selected permanent observation plots spread over Europe
- provide a deeper insight into interactions between various forest ecosystem components
- provide policy makers and general public with relevant information

Program Structure
ICP Forests is divided into two levels. The first level monitors forest condition on a representative, systematic grid net throughout Europe. Level II involves intensive ecosystem monitoring on permanent plots.

Monitoring Components

Level I

Level I involves large-scale forest condition monitoring. Crown condition is monitored annually, while foliar condition and soil chemistry have only been monitored once since the program inception.

Level II

Level II is an intensive monitoring scheme in which more than 860 permanent plots are used to investigate key factors and processes at the ecosystem scale. Ecosystem components measured include: crown condition (annually), soil (10 years), soil solution (continuous), foliage (2 years), deposition (continuous), ambient air quality (continuous), meteorology (continuous), forest growth (5 years), ground vegetation (5 years), phenology (many times per year) and remote sensing (initial).

Soil Sampling Methods

Soil sampling is completed in the same manner for both levels of the program. Before sampling begins, the litter layer of the sample site is removed and the O horizon is sampled separately from the mineral horizons. The samples are taken either by fixed depth or from each genetic horizon. When the horizon method is used, one composite sample is taken per horizon. Macroscopic roots and stony material (>2 mm) in size must be removed. The sample is dried at temperatures lower than 40 °C and is ground immediately before analysis.

48. United Kingdom: Environmental Change Network (ECN)

The ECN gathers information about the pressures on and responses to environmental change in physical, chemical and biological systems. The soil monitoring component of the network has the main objective to characterize and quantify physical, chemical and mineralogical properties of soils and identify and quantify any changes.

Objectives

- provide a network of sites from which to obtain comparable long-term datasets
- integrate and analyze the data in order to define possible environmental change and improve the understanding of such change
- use the data for modeling and prediction of future change
- provide a range of sites with good instrumentation and reliable information for research purposes

Site Distribution

The ECN has sites located across the United Kingdom. There are 7 sites situated in England, 3 sites in Scotland, and 1 site in each of Wales and Northern Ireland.

Monitoring Components

Along with soil sampling, the network also monitors vegetation, vertebrates (birds, bats and rabbits), invertebrates (moths, butterflies, spittle bugs, beetles), surface water, atmospheric chemistry and precipitation chemistry.

Soil Sampling Methods

Each sample site in the ECN is 8 ha in area. Within each site, the central 1 ha is used for soil sampling. The sampling is done on two grid sizes, 50 m and 25 m within the 1 ha area. Within the 25 m grid, the actual sampling is performed in 6 of the blocks; four samples taken from the edges and two from the center. Different blocks within the grid are sampled for the five and 20 year sampling periods and each block is sampled only once.

Soil samples are taken by horizon and fixed depth. One set of samples is obtained from 0-5 cm, 5-10 cm, 10-20 cm, and 20-30 cm, totaling 16 samples, which are then bulked. A second set of samples are taken from each horizon up to a 30 cm depth, for a total of 16 samples which are bulked to form one sample. Samples are kept at 4-6 °C and in the dark prior to processing. The samples are then air dried and sieved to 2 mm and once the analyses are performed, each sample is archived.

49. Terrestrial Ecosystem Monitoring Sites (TEMS)

TEMS is a database, which registers terrestrial sites, and relevant networks that carry out long-term terrestrial monitoring and research. Currently the network measures 114 variables and includes sites from approximately 120 countries.

Purpose
The purposes for development of TEMS are:

- to develop modeling, assessment and research programs
- to assess the gaps in geographic coverage of key variables
- to link ground and satellite observations
- to evaluate the quality of data and measurement methods
- to identify terrestrial sites that need upgrading

Site Criteria
There are several criteria that sites must meet to be included in the TEMS database. First, the sites must be relevant to one of the five key priorities set out by the Global Terrestrial Observation Sites. These five criteria are:

- changes in land quality
- availability of fresh water resources
- loss of biodiversity
- climate change
- impacts of pollution and toxicity

Secondly, the sites must be actively gathering data, demonstrate international interest in collaboration and lastly, have a reasonable history of observation and security of long-term funding.

50. International Long-Term Ecological Research Network (ILTER)
ILTER is an international network of long-term ecological research programs. As of January, 2003, 25 countries had established formal, national, long-term ecological research programs.
Member countries include: Australia, Brazil, Canada, China, China-Taipei, Costa Rica, Columbia, Czech Republic, France, Hungary, Israel, Korea, Mexico, Mongolia, Namibia, Poland, Slovakia, South Africa, Switzerland, Ukraine, United Kingdom, United States, Uruguay, Venezuela and Zambia.

51. Pan-European: Networking of Long-Term Integrated Monitoring in Terrestrial Ecosystems (NOLIMITS)
No additional information is available.

52. Europe: Proposed European Soil monitoring Network (EUROSoilNet)
Soil Issues
The major soil issues concerning Europe are climate change, pollution, urban development, desertification, erosion, salinization and acidification.

The proposed European soil monitoring network will be based on a nested sampling design with three levels:
<u>Level 1</u>
Level 1 is based on a 16 km by 16 km grid system. It will target decline in organic matter, diffuse soil contamination and loss of soil biodiversity. It will be managed by the member states who will have a degree of flexibility to meet their national interests and international commitments with respect to soil monitoring.

<u>Level 2</u>
These will be benchmark sites selected from the Level 1 sites. The national institutions overseeing Level 1 and the European coordinating organization will select these. Soil sampling will be performed by the member states while the soil analyses and sample archiving will be performed at the central European level.

Level 2 sites will gather information on soil physical degradation such as compaction, soil structure, aggregate stability, slaking, infiltration, soil salinization and local soil contamination. Monitoring at these benchmark sites will include all parameters monitored at Level 1 sites and additional parameters, which indicate physical degradation, salinization and soil contamination. Soil pollution parameters monitored will specifically include monitoring of nonyl-phenol and nonylphenol-ethoxylates, which are nonionic surfactants commonly found in sewage sludge and linear alkylbenzene sulfonates which is an anionic surfactant. A measure of microbial activity will include respiration rate monitoring.

Level 3
These will be specialized sites, which monitor for soil erosion, urban and rural soil sealing and hydrogeological risks. The sites monitoring soil erosion and hydrogeological risks will be situated in small catchments representative of climatic and landscape conditions, jointly selected by the two organization levels.

EuroSoilNet will impose mandatory use of GPS, aerial photography and site specific reference points to ensure accurate repeated sampling. The network will also allow existing National soil monitoring systems to be fully integrated and reporting will be done at the lowest possible level (municipal) in order to ensure a strong involvement by local communities which may result in a strong local commitment to soil protection.