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Provincial soil-quality monitoring networks in the Netherlands as an instrument for environmental protection

E.R.V. Busink[1] & S. Postma[2]

[1] Corresponding author; Netherlands Institute of Applied Geoscience TNO, P.O. Box 80015, 3508 TA UTRECHT, the Netherlands; e-mail: R.Busink@nitg.tno.nl

[2] ARCADIS Heidemij Advies, P.O. Box 264, 6800 AG ARNHEM, the Netherlands; e-mail: S.Postma@arcadis.nl

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Abstract

Since 1991, several provinces in the Netherlands have put much effort in establishing soil-quality monitoring networks. The purpose of these networks is to provide insight in the trends in (geochemical) soil quality, on which new policies for environmental protection can be based, such as restrictions in certain landuse types and cleaner production processes. The soil quality networks are yet too young to serve this goal. Monitoring efforts are concentrated on micro- and macro-elements, particularly in the top layer of the soil (mainly heavy metals and PAH) as well as phreatic groundwater (mainly nitrates and phosphates) in the various regions of a province. The regional soil-quality monitoring networks focus explicitly on diffuse environmental pollution in the rural areas, which means that sample sites influenced by soil pollution caused by local sources are excluded. Regional differences in soil quality in the rural areas are primarily caused by chemical and physical differences in the natural soil composition and by differences in deposition loads (direct and indirect). Hydrological conditions can also exert a large influence, particularly for nitrate leaching. This leads to three major criteria which the network design is based upon: (1) soil type, (2) landuse (assumed to be representative for deposition), and (3) groundwater tables. Subregions are formed by combining these criteria. Subregions are considered to be more or less homogeneous at a regional scale with respect to the criteria named. Within each region, a pre-calculated number of sites, based on variability of present concentrations, have been sampled and the sample material has been analyzed. Descriptive statistical parameters could thus computed; they are the base for the geochemical soil mapping of the individual, homogeneous subregions.

A recent evaluation of all operational soil-quality monitoring networks shows that these networks are effective instruments to gain insight into the differences in quality of the soil and the phreatic groundwater between the various regions. The understanding of these differences and the processes that caused them provide the provincial authorities with valuable information for policy making and environmental management. The evaluation also reveals differences in network designs, mostly due to local differences in physical-chemical properties and political choices.

It can be concluded from the first results of the networks that the relative high loads of zinc and copper, caused by spreading manure on the farmlands in areas of intensive agricultural landuse, have led to notably higher concentrations of these elements in the top layer of the soil compared to more natural lands like forested areas. The fact that the intensive agricultural landuse is mainly situated on relatively highly permeable sandy soils results in high nitrate concentrations in the phreatic groundwater, up to concentrations far beyond EG drinking-water target levels. First monitoring results signalled several environmental problems of which most of the policy makers were already aware, but could not quantify. Delineation of the most vulnerable areas and/or areas with unacceptably high loads and quantification of concentrations of different elements enable regional governments to take appropriate measures.

The soil-quality monitoring networks will focus in the coming years on the effectiveness of the measures taken in the various areas. Efforts are being made to integrate the relatively new soil-quality monitoring networks and the longer existing groundwater-quality monitoring networks to achieve a better understanding of the (bio)geochemical cycling processes. Tuning the individual regional soil-quality monitoring networks of the various provinces will enable the provision of additional information about soil quality at a larger scale.

Keywords: environment, groundwater quality, heavy metals, monitoring, nitrate, soil quality

Introduction

Since 1991, several provinces in the Netherlands have put much effort into establishing soil quality monitoring networks. The purpose of these networks is to provide insight into the trends in (geochemical) soil quality, on which new policies for environmental protection can be based, such as restrictions in certain landuse types and cleaner production processes. The methods for the design of these networks were developed in the 'Provincial soil-quality monitoring networks' study (Kleijn & Leenaers, 1991). Until then, environmental monitoring in the Netherlands had concentrated on quality of air and deeper groundwater and did not include soil and phreatic groundwater. Subject of the 1991 study were the possible benefits of soil-quality monitoring networks for decision support in provincial environmental policy. The study also provided guidelines for designing the networks and is referred to as the 'Guideline for provincial soil-quality networks'. Based on this study, several provinces in the Netherlands have developed and established regional soil-quality monitoring networks in the past few years.

Eight out of the twelve Dutch provinces have currently operational networks, consisting of over 1,600 sampling sites (Fig. 1). Some provinces have successively monitored annually for 2-3 years now. The collection and processing of data as well as their interpretation, leading to a description of the actual geochemical soil quality, is a provincial responsibility. Provinces share experiences on a regular basis. They decided recently to evaluate the existing operational monitoring networks. The results of this evaluation showed these monitoring networks to be a solid base for regional geochemical mapping (scale 1:100,000- 250,000) of the top soil and phreatic groundwater in the rural areas of the provinces (Busink & Postma, 1998).

The present contribution first describes the methods for designing the soil-quality monitoring networks. Then, an overview is given of the present state of the soil-quality monitoring networks in the Netherlands, based on the evaluation study mentioned above. Finally, some of the most notable of the first results of the networks are presented. The focus is on concentrations of heavy metals in the top layer of the soil and concentrations of nitrate in the phreatic groundwater.

Fig. 1. Provinces in the Netherlands with and without an operational soil-quality monitoring network.

Results of the operational networks were reported individually. To make a comparison of data possible, the existing provincial databases were 'translated' to a main classification of homogeneous areas, on which statistical calculations were performed. As a consequence, results presented here are not necessarily similar to those reported for the individual soil-quality monitoring networks of the provinces. Data from five provinces have been reprocessed on a larger scale for the present contribution: not the regions within provincial boundaries, but larger regions in the Netherlands.

Network design

Objectives of the soil-quality monitoring networks

The main purpose of the regional soil-quality networks is to provide insight into the trends in geochemical soil quality, on which new provincial policies, such as restrictions in certain landuse types and cleaner production processes, can be based. The objectives of the soil-quality monitoring networks are defined as:

- to determine the trends in soil quality in a province in relation to the physical/geochemical geographic characteristics (soil type and geohydrology) and landuse (assumed to be representative for deposition);
- to monitor soil quality in areas of special interest, such as nature reserves, in order to recognize unwanted developments, and to take appropriate action.

The soil-quality networks are yet too young to serve these goals to full extent. At this stage, most efforts are put into data collection and optimizing the design of the networks. The regional soil-quality monitoring networks are explicitly developed for monitoring diffuse pollution in the rural areas; urbanized areas are not the subject of study. This also means that sampling sites influenced by local sources are excluded. In agricultural areas, the load of heavy metals, nitrate and phosphate is mainly due to the spreading of manure upon the fields (direct load). In natural areas, the loads is mainly due to deposition from the atmosphere (indirect load). The monitoring networks are concentrated on three environmental subjects:

- concentrations of heavy metals and polycyclic aromatic hydrocarbons (PAH's) in the top layer of the soil in all the regions of a province;
- monitoring concentrations of nutrients (mainly nitrates and phosphates) in phreatic groundwater, often in combination with monitoring phosphate concentrations in the unsaturated zone of the soil; this is mostly concentrated in the most vulnerable and/or most affected areas in a province;
- monitoring the process of acidification by analyzing (among others) the NH_4/K and Al/Ca ratios in soil moisture from forested areas on sandy soils (most vulnerable areas).

Some provinces have made adaptations to this standard. For example, by adding measurements like heavy metals in the phreatic groundwater, heavy metals and the C/N ratio in the litter and P complete with Fe and Al in the soil. Other adaptations are made by leaving some measurements out, such as measurements in soil moisture. The reasons for different choices are based on specific physical/chemical geographic characteristics, or on differences in policies and decisions of the provinces. For example, specific measurements can, due to costs, be difficult or even impossible to realise if the phreatic groundwater is more than 20 m below surface.

Network design methods

Differences in concentrations at a regional scale are caused by differences in the natural physical and chemical soil composition and by differences in deposition (indirect and direct loads). Also groundwater levels can have a considerable influence, particularly for nitrate leaching. The network design aims to delineate areas that are considered homogeneous at the regional scale for these three criteria. This homogeneity is assumed to be represented by soil type, groundwater tables and deposition of the relevant elements. Deposition is assumed to be represented by landuse.

The mapping of homogeneous areas is performed by combining and overlaying digital soil/groundwater table maps (scale 1:50,000) and landuse maps (scale 1:100,000) within the Geographical Information System (GIS). The soil and landuse maps were simplified to some extent for the purpose. First, each occurrence of a combination was taken into account. Next, choices were made to include homogeneous areas into the network. Homogeneous areas that are too small were not considered as representative for a province, unless they represent a very rare or otherwise valuable landuse type. The decision to take a homogeneous area into the network was based on technical as well as political criteria. Homogeneous areas sometimes consist of large contiguous areas, but can also consist of small areas scattered over the province.

Each concentration of an element for a sample taken within a specific combination of soil type and landuse contributes to the final statistical description of soil quality of that specific homogeneous area. When all soil samples have been analyzed and results are available, the classification of homogeneous areas is tested with basic statistical methods. This leads for each of the monitoring networks to a revised classification of homogeneous areas. The final network design is based on an upscaling of the classification to a regional scale, resulting in fewer but larger homogeneous areas, in which monitoring will take place in the years to come. Depending on the physical/chemical geographic complexity of a region and the variability found in the concentrations, the total number of remaining combinations of soil type and land use for a province varies between 5 and 20 homogeneous areas, being representative of an average of 80% of the total rural area.

Site sampling

Farming activities and strategies in the agricultural areas of the Netherlands differ from land parcel to land parcel. To exclude local variation in concentrations caused by these differences, a typical sampling site is a parcel – or a part of a parcel – with a size of approx. 10,000 m^2. Local variations in concentrations within a parcel were accounted for by analyzing a composite sample of forty subsamples for the top soil, and out of five subsamples for phreatic groundwater. The number of forty subsamples is based on an evaluation of the variability of heavy-metal concentrations at a local scale (Edelman, 1984; De Kwaadsteniet, 1987). The amount of five subsamples for phreatic groundwater is a compromise between levelling local variations and financial limitations.

The choice of sampling sites was such that an equal spatial distribution was obtained over the total homogeneous area. Sampling-site selection was controlled by criteria. For example, the influence of local and diffuse sources of pollution other than those that are the subject of monitoring was to be avoided as much as possible. This means that, for example, sampling sites in forests bordering an agricultural field, sites close to ditches and field entrances, and sites below electrical transmission cables were avoided. Priority was given to locations in the middle of larger contiguous areas of the same landuse types.

Sampling at a regional scale

Within each homogeneous area, a pre-calculated number of sites was sampled and the sample material analyzed. Sampling density was based on the variability of concentrations of the elements being monitored. Larger coefficients of variation resulted in a larger fraction of the total number of samples being taken in the particular homogeneous area. The general aim was to be able to present results for each distinguishable homogeneous area with the same reliability. This resulted, for example, for heavy metals in more intensive sampling of areas with sandy soils compared to areas with clayey soils, because variability in concentrations is on average lower in the latter.

The exact number of sampling sites was based on general assumptions on expected variations, while no data were present before the first sampling round. On the other hand, the number of samples was restricted by budget. After the first data had become available, calculations were made to estimate the number of sampling sites required for each homogeneous area more accurately. Calculations were made for certain prediction intervals, using a statistical method referred to as 'best technical means'. The guideline for soil quality networks (Kleijn & Leenaers, 1991) stresses that the design of a network cannot be based only on statistical methods. Network design is also based on best practical means, implying that not all the theoretically best choices can be met, because of practical and financial limitations. An example is the compromise of five subsamples for phreatic groundwater characterization.

Monitoring frequencies

Time-series analysis can provide a statistical base for decisions on monitoring frequencies (Davis, 1986). The soil-quality monitoring networks in the Netherlands were established so recently, however, that at best results for three monitoring periods are available. Up till now, results are restricted to just one or two monitoring periods for most of the regions. Monitoring frequencies are currently based on a rough theoretical system analysis.

The high variability in concentrations and fast system response, as with nitrate concentrations in phreatic groundwater, gives sufficient reason for intensive monitoring, i.e., samples are taken each year. Because of the low variability in concentrations and slow system response of heavy metals in the top soil, this topic is monitored less frequently, i.e. once every 10-15 years. The limiting factors for sampling frequency and sample density is the budget available from the provincial governments.

Geochemical analysis

All provinces used commercial laboratories for the geochemical analysis. These laboratories have been certified by STERLAB. In a laboratory, all the material of composite samples (soil: one sample is about 200 g; groundwater: one sample is roughly 100 ml) was mixed to certify a homogeneous sample. A small subsample from the homogenized sample was taken for analysis. The methods comply with the NEN-ISO regulations available at the time of analysis. Over time, some methods have improved, resulting in lower detection limits. The detection limits used in the present study are not the actual detection limits, but the reporting limits, which are higher than the actual detection limits.

In the soil samples, the general parameters – dry weight, organic matter and clay content (particles smaller than 2 μm) – were measured. All parameters are expressed as mass % or mg/kg of dry weight. Organic matter was determined as loss on ignition. The clay content was determined by standard sieving / pipette method (column test) during 48 hours.

Both organic matter and clay content are important parameters in interpreting the data in the light of Dutch legislation for soil quality. Because both parameters play an important role in the binding capacity of a soil for contaminations such as heavy metals, they are used for determining the critical levels for soil quality (according to Dutch law). This provides a critical level specified for each type of soil and also provides a method for comparing different types of soils in terms of level of contamination.

For the analysis of heavy metals, the soil samples were digested with Aqua Regia. Heavy metals were analyzed by inductively coupled plasma – atomic emission spectrometry (ICP-AES). For mercury, the atomic absorption spectrometry (AAS) cold-vapour technique was used. Samples of the groundwater remained unfiltered. Nitrate en ortho-phosphate were analyzed using an ion chromatographic technique.

Comparison of the individual provincial soil-quality monitoring networks

Similarities and differences

Except for one (Limburg), all the seven remaining operational soil-quality monitoring networks are monitoring heavy metals throughout whole provinces at low frequencies. Nitrate leaching is commonly monitored on a yearly basis and concentrated in very sensitive areas and/or areas of high loads. These are, in general, the sandy soils with deep groundwater tables (on average > 1.5-7 m below surface) that are also intensively used for agriculture. In the present context, this involves the stock raising industry (pigs) in combination with the cultivation of maize, used as food for cattle. Maize is popular, because of the insensitiveness of this crop to high nitrate loads caused by spreading surplus volumes of manure over the farmlands.

Although the methods used for the classification of homogeneous areas are basically the same for each province, differences in the procedure do occur. This is a result of the specific physical/chemical geographic characteristics of the various regions, and of the chosen degree of spatial detail in the various areas. The provinces of Gelderland, Utrecht, Drenthe and Noord-Brabant contain large forested areas, whereas the cultivation of bulbs is very specific for the provinces of Zuid-Holland and Noord-Holland, the latter not having a soil-quality monitoring network operational yet. Orchards (fruit) are quite specific to the provinces of Utrecht, Gelderland and Limburg. In general, a landuse type not common in a province does not occur in the individual networks. Differences in spatial resolution used for the homogeneous areas can be illustrated by the choices of the provinces of Utrecht, Zuid-Holland and Noord-Brabant, which classify main soil types like sand, peat, clay (divided in river and marine sediments), whereas the province of Friesland classifies on the basis of subtypes of soil.

Although the monitoring networks support primarily provincial policies, the evaluation study gave rise to the wish to realize an added value, available when individual network designs will be tuned (Busink & Postma, 1998). This will enable the provinces in the future to cooperate and share experiences to a greater extent, and will improve the possibilities of data comparison. As stated in the introduction, the existing provincial databases have been 'translated' for the present contribution to a national-scale classification of homogeneous areas based on soil type and landuse, on which statistical calculations are performed. The main classification used here is presented in Table 1, together with the number of samples available.

Soils and landuse in the various provinces

The soils in the Netherlands are, at the national scale, classified into five categories (Stichting voor Bodemkartering, 1981):

1. marine clay: mainly in the western and northern part of the Netherlands, roughly a zone of 20 km along the coast (provinces of Zeeland, Zuid-Holland, Noord-Holland, Friesland, Groningen and Noord-Brabant);
2. river clay: sedimented by, and along, the main rivers, Rhine, Meuse, Waal and IJssel (provinces of Utrecht, Noord-Brabant, Limburg, Gelderland, Overijssel and Friesland);
3. sandy soils: in the eastern, central and southern part of the Netherlands (deposited by wind during glacial periods) and a small zone of dune landscapes directly along the coast (all provinces);

Table 1. The homogeneous areas in the various provinces 'translated' to a national-scale classification, and the number of samples taken.

homogeneous area		number of samples per province[1]						
code	*description*	*Noord-Brabant*[a,b]	*Friesland*[a]	*Groningen*[a]	*Utrecht*[a,b]	*Drenthe*[c]	*Zuid-Holland*[b]	*Gelderland*[c]
AM	agriculture (extensive) on marine sediments (clay)	40		44			10	
AR	agriculture (extensive) on river sediments (clay)				6			20
AS	gricultural (extensive) on sandy soils			29		47	8	
AP	agricultural on peaty soils	31				16		
BS	bulbs on sandy soils						20	
FS	forest on sandy soil	98	39	6	7	21		30
FP	forest on peaty soil	6						
GR	grazing land/pastures on river sediments (clay)	23			12			
GP	grazing land/pastures on peaty soil		175		14	17	45	
GS	grazing land/pastures on sandy soil	46	99	12	8	49		50
GM	grazing land/pastures on marine sediments (clay)		145	28			10	
GRS	greenhouses (agricultural) on sandy soils						20	
GRM	greenhouses (agricultural) on marine sediments (clay)						5	
IS	intensive agriculture on sandy soil	197			9			50
IR	intensive agriculture on river sediments (clay)	15						
MS	moorland/heath on sandy soil	15				7		
MP	moorland/heath on peaty soil	11						
NS	nature on sandy soil			6			10	
NR	nature on river sediments (clay)		31					
NM	nature on marine sediments (clay)		8	12				
NP	nature on peaty soils			13		9	42	
OR	orchard (fruit) on river sediments (clay)				12			
	TOTAL	482	497	150	68	166	170	150

[1] The number of samples depends on the purpose of monitoring and is based here on the number of sample locations for heavy metals.
[a] Database used in the present contribution for analysis on heavy metals.
[b] Database used in the present contribution for analysis on nitrate and phosphate.
[c] Database not used in the present contribution.

4. peaty soils: occurring in the transition zones between elevated sandy soils and river or marine clays in the northern part of the Netherlands, and also occurring in (vertical as well as horizontal) alternation with the marine clays in the western part of the Netherlands (provinces of Zuid-Holland, Noord-Holland, Utrecht, Noord-Brabant, Drenthe, Overijssel, Gelderland, Friesland and Groningen);
5. loamy soils: the majority are found in the southern part of the province of Limburg.

Landuse in the rural areas is strongly related to soil types but historical regional differences are still reflected by current landuse. The majority of the marine and river clay and peaty soils are in use as grazing land for cattle. Marine clays in the south-western (Zeeland) and northern part of the Netherlands (Friesland and Groningen) are used as agricultural lands for the cultivation of crops like potatoes and vegetables. The more sandy river clays deposited along the rivers are typically used for (fruit) orchards. The small zone of sandy dune landscape along the coast is mainly a nature conservation area; a smaller inland part is intensively used for the cultivation of bulbs. The main areas of sandy soils in the southern, central and eastern parts are used intensively for agriculture, e.g., cattle breeding, particularly pigs. Furthermore, most forested areas are found on these soils.

In general, groundwater tables in the clayey and peaty soils are high, averaging between 0.1 and 1.5 m below surface, whereas groundwater tables in sandy soils are deeper, averaging between 1.5 and 10 m below surface. In some smaller parts of the elevated sandy soils, the groundwater tables can be much deeper: up to 25 m below surface.

First results of the monitoring networks

Results for heavy metals and pH

In all the operational networks, influences of agricultural landuse on soil quality are clearly visible. Concentrations of zinc and copper – elements that are a constituent of cattle food deposited on the farmlands by spreading manure – are notable higher on agricultural land compared to, for example, forested areas, as shown in Figures 2 and 3. In all the four individual provinces used for this example, median zinc concentrations in forested areas on sandy soils do not exceed 20 mg/kg, whereas the median zinc concentrations in the three agricultural areas on sandy soils vary between 24 mg/kg and 45 mg/kg (Fig. 2). The highest median concentrations are found in the provinces of Utrecht and Brabant, where agricultural landuse on sandy soils is fairly intensive (Busink & Hoogerwerf, 1994; Postma & Busink, 1997). The same pattern is found for copper. Median concentrations do not exceed 5 mg/kg in forested areas on sandy soils. Median copper concentrations in the three agricultural areas on sandy soils vary between 10 and 16 mg/kg (Fig. 3).

The difference between agricultural landuse and natural landuse is also reflected well by pH levels, as shown in Figure 4. In the four areas with natural landuse (moorland/heath and forest on sandy soils and peat), the median pH levels in the top layer of the soil vary between 2.9 (moorland/heath on peat) and 3.1. The median pH levels on agricultural land are higher. On both sandy soils and clay (river sediments), pH levels vary between 5.0 and 6.2. Calcareous material is added to the soil in agricultural landuse, which is reflected by the results. The influence of calcareous material of natural origin is reflected by a higher median pH-level of 7.1 in the area of agricultural land on marine clay (Fig. 4).

In contrast with the above, elements that are not, or

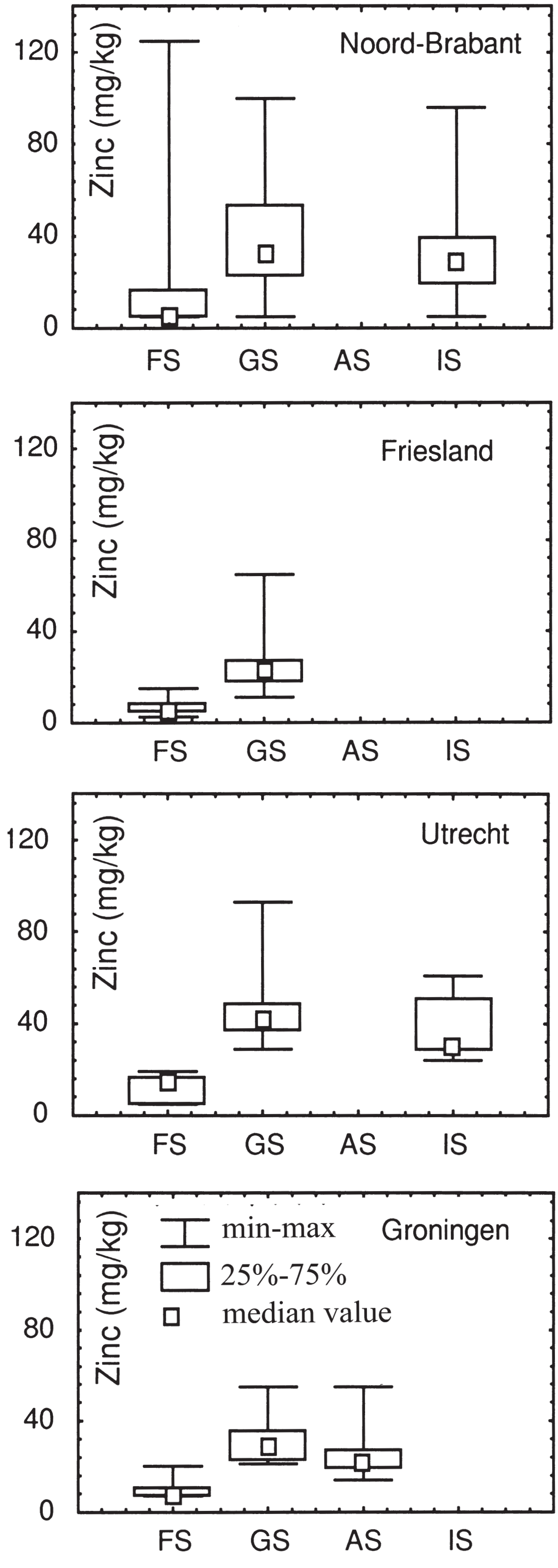

Fig. 2. Zinc concentrations (mg/kg) in the top layer of sandy soils in four individual provinces, differentiated by landuse (see Table 1 for codes).

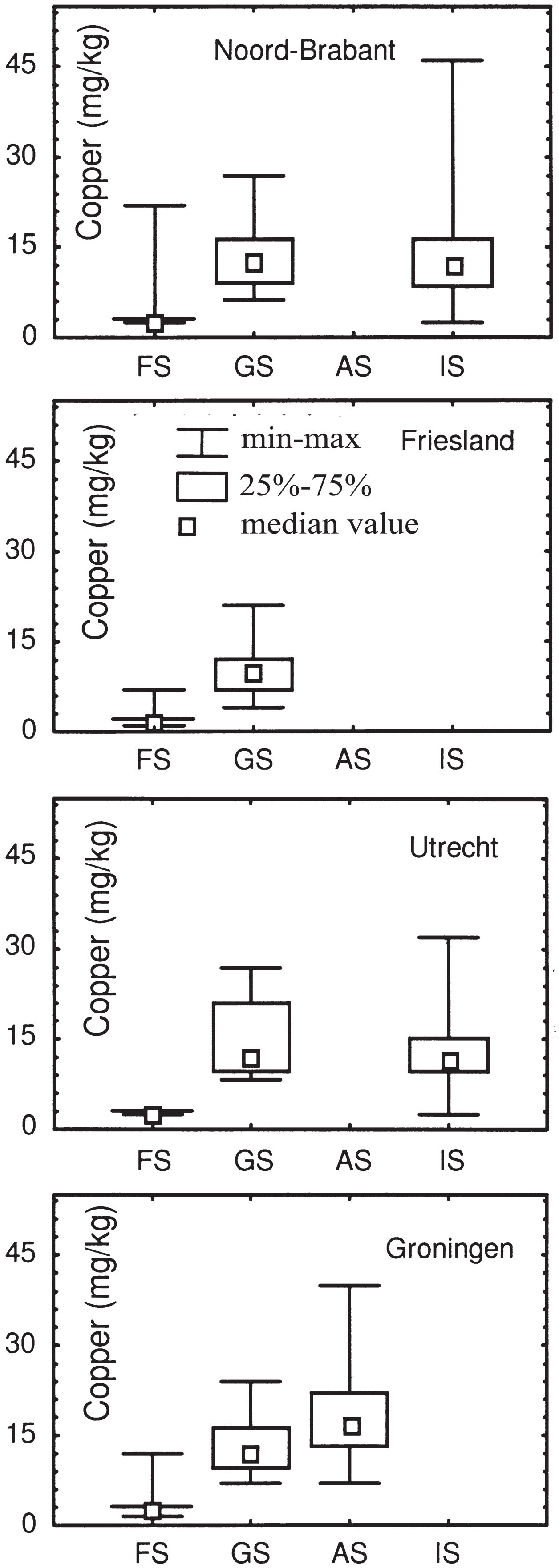

Fig. 3. Copper concentrations (mg/kg) in the top layer of sandy soils in four individual provinces, differentiated by landuse (see Table 1 for codes).

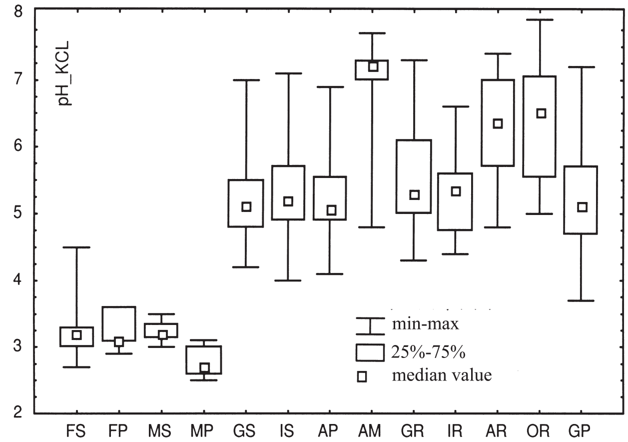

Fig. 4. pH levels in the top layer of the soil (0-10 cm) in several homogeneous areas (see Table 1 for codes, joint data of four provinces).

only slightly, related to agricultural landuse – such as lead, nickel, and chromium – show no or only little differentiation on landuse within the same homogeneous area. These concentrations can possibly be considered as typical background concentrations for the top layer of the soil, independent of landuse (Edelman, 1984; Lexmond & Edelman, 1992).

Chemical similarities between characteristics and behaviour of the various heavy metals lead to strong correlations between some of the elements. This also depends on the properties of the various soil types, such as organic-matter content and magnitude of the silty fractions. For the total dataset of the four provinces used in the examples above (a total of around 1600 samples), the correlation coefficient for copper and zinc is 0.69; for nickel and chromium it is

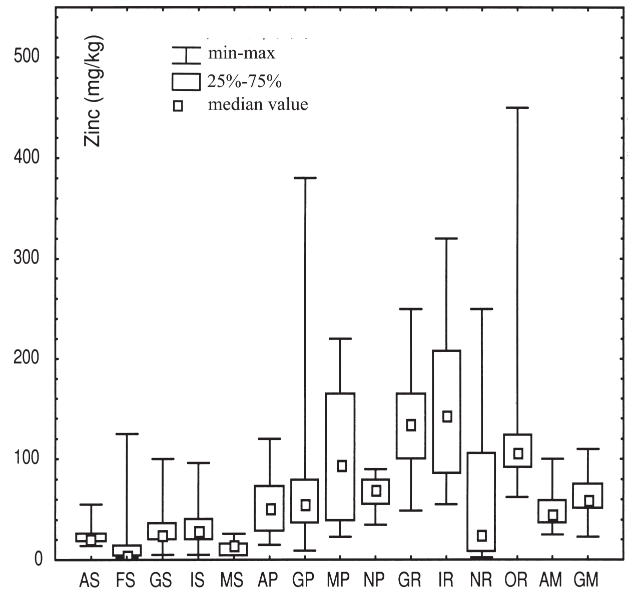

Fig. 5. Zinc concentrations (mg/kg) in the top layer of the soil (0-10 cm) in several homogeneous areas (see Table 1 for codes; joint data of 4 provinces).

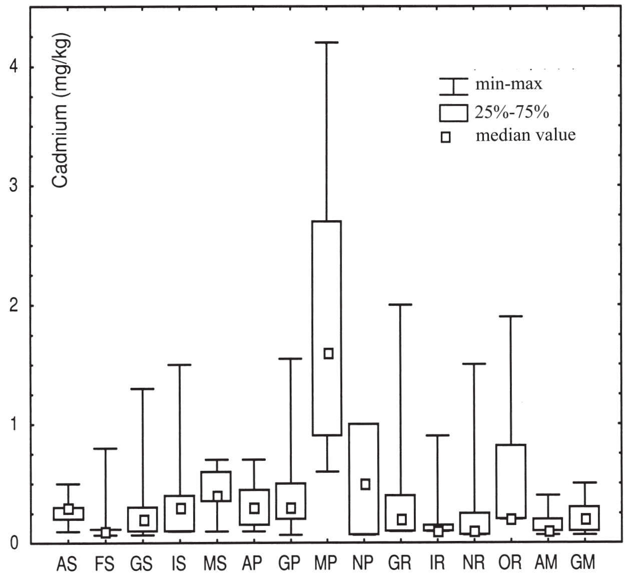

Fig. 6. Cadmium concentrations (mg/kg) in the top layer of the soil (0-10 cm) in several homogeneous areas (see Table 1 for codes; joint data of 4 provinces). The very high values for MP relate to metallurgical industrial activities (see text).

0.92. Comparable correlations were found in other studies (Lexmond & Edelman, 1992).

The available database shows some notable differences between the various homogeneous areas. As an example, results for zinc and cadmium are presented. It is obvious from Figure 5 that sandy soils have the lowest concentrations of zinc in their top layer compared to the areas with peat and clay rich soils. The range of zinc concentrations for all the homogeneous areas is far greater than in the example that was given in Figure 2 for sandy soils. As for sandy soils, Figure 5 shows that, within each single soil type, homogeneous areas with natural landuse show less variation in concentration. Moreover, maximum concentrations are lower, representing less human influence (less deposition), leading to smaller variability of the concentrations found. A very distinctive exception is moorland on peat (MP). Median zinc concentrations, and especially median cadmium concentrations, as well as maxima found for these elements are quite high (see Figs. 5 and 6). This is the result of a very specific situation: the homogeneous moorland/heath area on peat is only included in the network of the province of Noord-Brabant. The south-east of this province contains a known (historic) source of cadmium and zinc pollution in the form of metallurgical industrial activities; it has affected the soil quality (Gertzen et al., 1984; LISEC, 1985; Van Drecht et al., 1996). Heavy metals have been spread by air and occur in a vast area. The specified homogeneous area lies mainly in the southeast of the province and in the middle of the region influenced by this large-scale pollution source.

Results for nitrate and phosphate

Monitoring nitrate and phosphate leaching to groundwater is different from monitoring heavy metals in the top layer of the soil. In contrast to heavy-metal concentrations in the top soil, nitrate and phosphate concentrations in the upper metre of the phreatic groundwater change rapidly. Even within seasons, concentrations change because they dependend heavily on weather conditions as well as on the volume

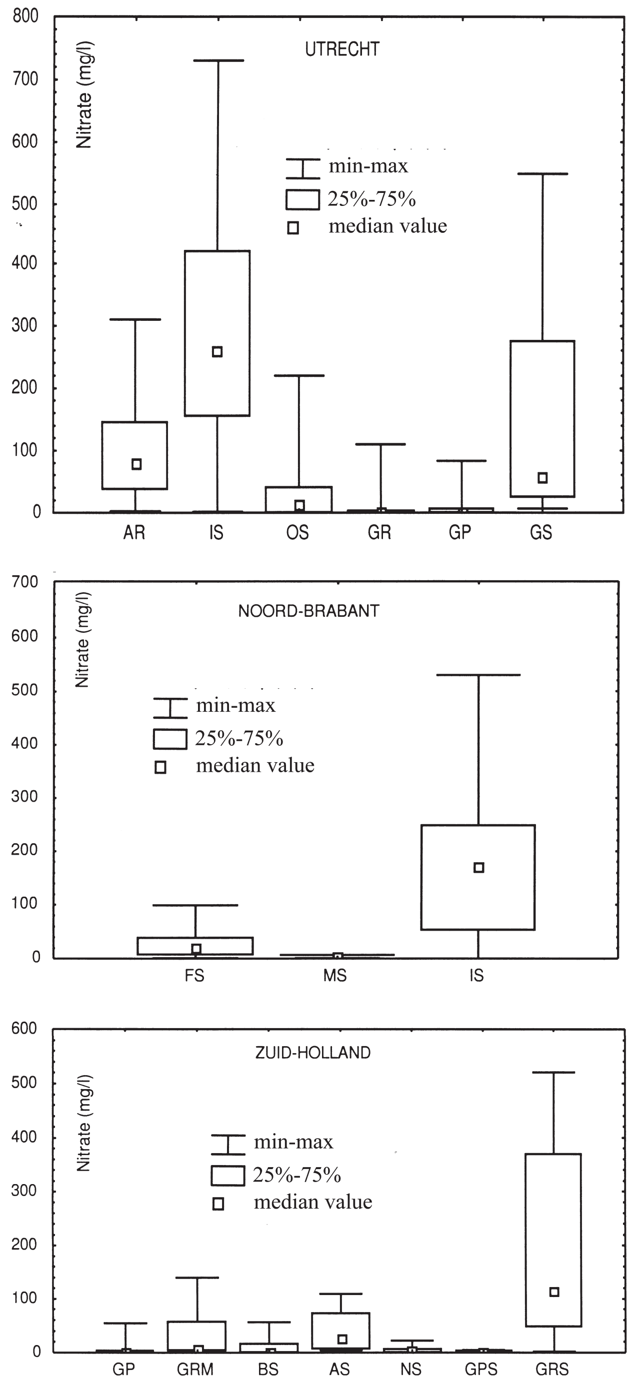

Fig. 7. Nitrate concentrations (mg/l) in the upper metre of phreatic groundwater in several homogeneous areas in the provinces of Utrecht, Noord-Brabant and Zuid-Holland (see Table 1 for codes).

and spreading time of manure on the farmlands. At this stage, a choice is made for most of the operational monitoring networks to sample once a year, at the end of the growing season (November/ December). Because of the larger variabilities in concentrations, most of the provinces are concentrating their (financially limited) efforts to the most vulnerable areas and to the areas with highest deposition.

The differences found for heavy-metal concentrations are also found for nitrate and phosphate concentrations, but in a more extreme fashion. Areas with intensive agriculture in combination with sandy soils with deep groundwater tables (> 1-2 m below surface) show median nitrate concentrations varying from 110 mg/l in the province of Zuid-Holland, and 170 mg/l in the province of Noord-Brabant, up to 260 mg/l in the province of Utrecht, as shown in Figure 7 (note: these concentrations are not directly comparable with each other because the samples have been collected in different years). The EG drinking-water maximum concentration is 50 mg/l. In the provinces of Utrecht and Noord-Brabant, the nitrate concentrations are caused by the high loads of manure; in the province of Zuid-Holland, the high nitrate concentrations are caused by the high loads of (chemical) fertilizer used in the area of greenhouses on sandy soils (Brombacher & Busink, 1996).

Since the first year of monitoring, the provinces of Utrecht and Zuid-Holland have sampled sandy soils as well as peaty soils and clays. Although landuse has a relation to soil type and cannot be handled totally independently, it can be deduced that these soils provide a good buffer for nitrate leaching. Median concentrations are low: sometimes at the level of detection limits. The province of Noord-Brabant, which is only monitoring nitrate leaching on sandy soils, sampled nitrate concentrations in the second year of monitoring in the upper metre of phreatic groundwater, in forested areas as an addition to areas of intensive agricultural use. The main reason is that, with these samples, a reference level can be established for areas that are not influenced by human activity. The differences are large: no concentrations above the detection limit are found in moorland/heath on peat, whereas the median nitrate concentration in forested areas is 20 mg/l, which is below the EG drinking-water target level. The maximum concentration found in this area is just above 50 mg/l. This is nearly the same as the minimum concentration found in the areas of intensive agriculture. In this homogeneous area of Noord-Brabant, median nitrate concentrations are 170 mg/l, with a maximum at 300 mg/l (Busink, 1998).

A final proof of human influence is shown in Figure 8, where ortho-phosphate concentrations in the province of Zuid-Holland are plotted. In bulb cultivation, which is typically concentrated on the sandy soils just behind the coastal dunes, median phosphate concentrations are on average four times higher than in other areas. This reflects the specific use of chemical fertilizers with high phosphate contents.

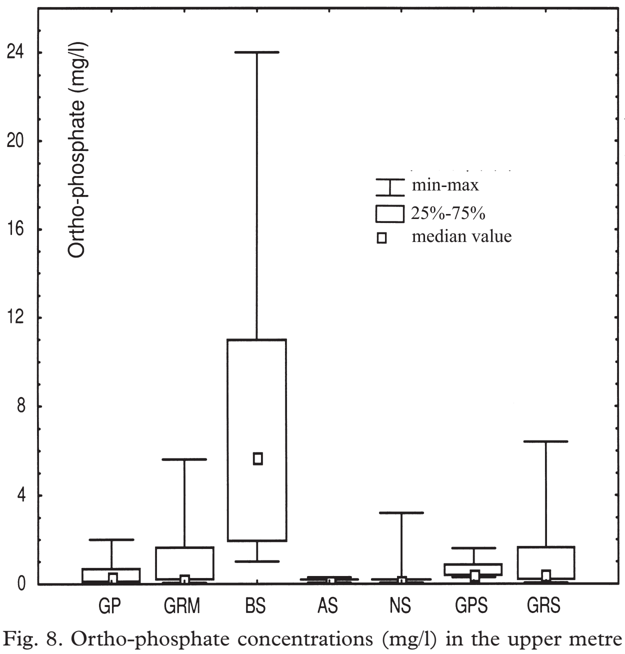

Fig. 8. Ortho-phosphate concentrations (mg/l) in the upper metre of phreatic groundwater in several homogeneous areas in the province Zuid-Holland (see Table 1 for codes).

Conclusions

An evaluation of the first results of the recently developed and implemented soil-quality monitoring networks in the Netherlands show that these provide a good basis for mapping the regional geochemical soil quality. The networks provide insight into the actual quality, and the differences in soil quality between various regions, represented by homogeneous areas. Homogeneous areas are defined by physical/mechanical geographical properties (soil type and groundwater tables) and deposition (mainly represented by landuse).

It can be concluded from the first results of the monitoring-network data that the relative high loads of zinc and copper caused by spreading manure on the farmlands in areas of intensive agricultural landuse, have led to notably higher concentrations of these elements in the top layer of the soil compared to more natural lands like forested areas. The same patterns, but more extremely, are found for nitrate concentrations in the upper metre of the phreatic groundwater. The fact that intensive agricultural landuse is mainly situated on relatively highly permeable sandy soils, results in high nitrate concentrations in the phreatic groundwater, up to concentrations far beyond EG drinking-water target levels.

Although trends in soil quality cannot be distinguished yet by the established networks after only just one or two sampling periods, the first results have already achieved an important function in bringing to the notice of regional governments certain areas subject to different potential environmental problems. The first results signalled several environmental problems, most of which the policy makers were already aware of, but could not quantify. Delineation of the most vulnerable areas, and of areas with unacceptably high loads, and the quantification of concentrations of different elements enable regional government to take appropriate measures.

The technical objective of the monitoring networks is no other than providing information about trends in soil quality, including phreatic groundwater. The information provided by the networks can, however, also be used in many other fields of environmental interest. This usage will only grow, as temporal trends can be analyzed with statistical methods when repeated sampling will have taken place and when enough sampling data will have been accumulated.

Although the monitoring networks primarily support provincial policies, the evaluation study shows that added value can be realized if individual provincial network designs be fine-tuned. This will enable the provinces to cooperate and further share experiences in the future, and will improve the possibilities for data comparison.

Because of the (very) slow system response regarding heavy-metal concentrations in the top layer of the soils, future sampling efforts will have the character of a more periodical inventory of soil quality than real monitoring. For leaching of nitrate, however, monitoring will take place each year. The problem in analyzing for temporal trends is the relatively large variability in nitrate concentrations, which can hinder a good understanding of the problem. Effort will be taken in the near future to support the results of the periodical monitoring field sampling with detailed studies of short-term variability in nitrate concentrations related to weather conditions and other important factors. The longer-term (up to 15 years) groundwater-monitoring networks in the Netherlands, in which deeper groundwater is monitored on a yearly basis, will be one of the more valuable information sources to get a better understanding of processes in the field. The next step will be a further, eventually fully, integration of the soil and groundwater monitoring networks in the Netherlands.

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