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Classification of the Soils in the Area of Achenkirch According to Chemical Parameters

By

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Summary

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The chemical soil parameters of the Achenkirch project area, which is located in the Limestone Alps, are evaluated and compared to those of the carbonate-influenced Austrian forest soils. Based on this comparison, the sample plots in the area of Achenkirch tend to have pH values and carbonate concentrations below average, but K concentrations above average. The content of organic substance, N, and P is above average, too, which allows the conclusion that the overall nutritional situation is relatively good as far as major nutritive elements are concerned. The supply with Cu is, however, insufficient. The Co, Cr and Ni concentrations are above average, and as the increased values of these three heavy metals always concern the entire soil profile, it is highly probable that geogenic reasons are responsible therefore. The increased Pb and Cd values, which appear to be above the Austrian average especially in the top soil, might indicate air pollution.

Introduction

To achieve a comprehensive description of an investigation area it is absolutely necessary that the soils of that area are characterized and that their chemical parameters are analyzed. For the Achenkirch project, both were carried out on selected sample plots. After the soils had been described in respect of their sites and classified into different types (rendzina- chromic cambisols on calcareous parent rock) by ENGLISCH 1992, the present study will now offer a classification of the soils of the Achenkirch project area among Austria's carbonate-influenced forest soils by chemical parameters.

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The results are meant as basic information for the interpretation of other investigations belonging to the large number of tests carried out in the framework of that project (HERMAN & SMIDT 1994); they also describe the "temporary" state of that area.

Methods

Sampling procedure and analysis

Sampling and analyzing were subject to the principles and methods used in conjunction with the Austrian Forest Soil Monitoring System (ENGLISCH & al. 1992). The following paragraphs therefore provide only a brief description of those methods.

The samples were taken in the field in 1992 and 1993. From the surface layer, at least 3 humus samples per plot were collected with a steel frame and put together to form a mixed sample. The samples from the mineral soil were collected separately for fixed depth layers, partly in proportion with volume, by means of a hollow auger, partly not. Where the samples were volume-proportional, it is now possible to determine the stock of particular elements per area unit. So ENGLISCH & al. 1992 studied the stock of nutrients and heavy metals of several sample plots from the area of Achenkirch; in the present study, concentrations are compared.

The depth layers for the mineral soil samples were fixed at 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, and 30-50 cm. The only deviation from the procedure of the Forest Soil Monitoring System was that the layer between 0 and 10 cm was subdivided into two layers, from 0-5 cm and from 5-10 cm, which permits a more precise delienation of critical pedological facts: In the top 10 cm the distribution gradient of the elements is steepest; that layer is also the one most densely rooted. As using a more detailed sampling method for that layer considerably improves the possibilities of interpretation, that differentiated sampling procedure which used on a large scale in the Achenkirch project area will from now on be obligatory in Austria.

For volume-proportional samples, 3 cuttings per plot were made with a hollow auger and then mixed; for non-volumetric samples 3 profile pits were opened and from all 4 faces sample material was taken and then combined to get a mixed sample.

For the analysis, the air-dry samples were sieved to a particle size of 2 mm. The following parameters were analyzed: pH, carbonate, C_{org}, N_{tot}; nutrients and pollutants from the acid extract: P, K, Ca, Mg, Fe, Mn, Cu, Zn, Co, Cr, Ni, Pb, Cd; exchangeable cations: K, Ca, Mg; and in a few acid horizons also Mn, Al, Fe, H.

Statistic evaluation

As regards the classification and evaluation of the results of the soil analyses, greater importance was attached to the collective project area of Achenkirch and its position within Austria's carbonate-influenced soils than to absolute values or individual analyses.

The collective of Austria's carbonate-influenced forest soils is defined by the data of the Forest Soil Monitoring System (n=178) from a statistical grid. From that collective of carbonate-influenced forest soils each parameter was subdivided into 10 classes including essentially the same number of values (10 percentile classes), using the method elaborated by MUTSCH 1994. With the help of such a classification, it is possible to identify the relative position of the values. For instance, the values measured in class 1 (= the class including the lowest 10 percent of the values) can be called extremely low, while those found in the percentile between 90 and 100 (= the highest 10 percent of the values) are extremely high. Such classifications were made separately for the individual depth layers.

To be able to classify the sample plots of the Achenkirch area within the all-Austrian carbonate-influenced collective of the Forest Soil Monitoring System, the medians of the individual parameters of, altogether, 24 Achenkirch sample plots were used, again separately for the different depth layers, and then allocated to the respective classes of the Austrian Forest Soil Monitoring System sample plot collective.

The geographic location of the sample plots can be seen from Fig. 1. Three of them are located in the Christlum area, the others are concentrated in the surroundings of the Schulterberg. Which sample plots were selected depended mostly on the demands and questions of other scientists involved in the project.

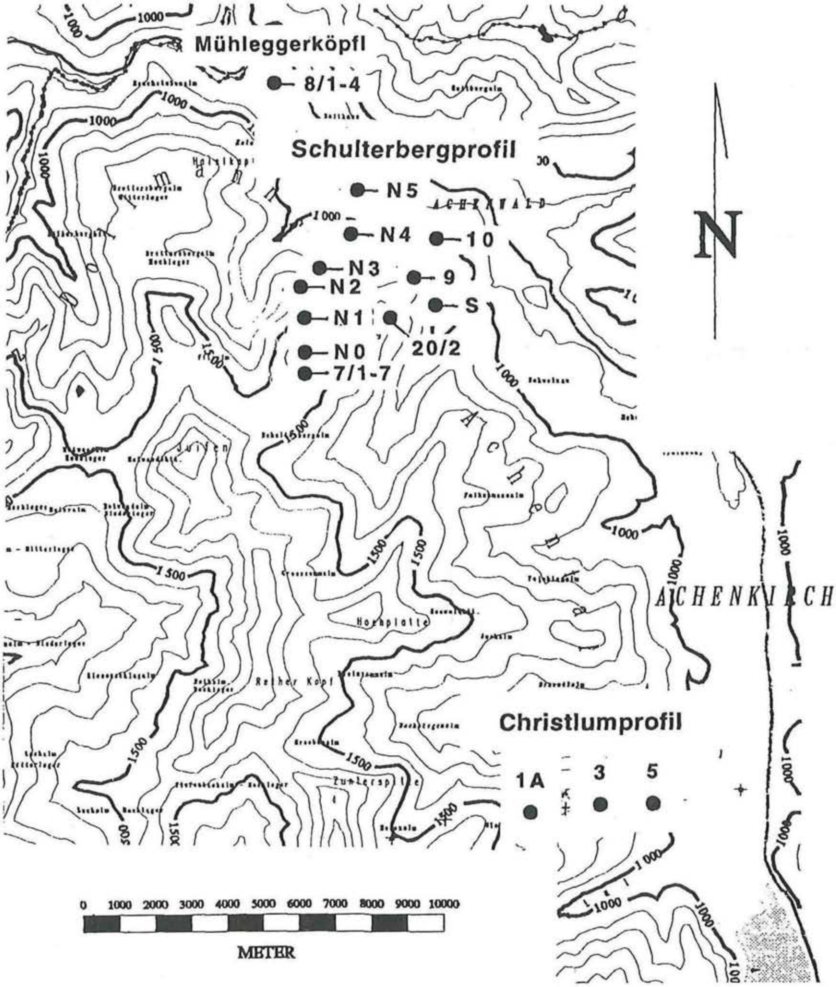

Fig. 1. Geographic location of the Achenkirch sample plots.

For the soil-chemical classification of the Achenkirch project area selected depth layers of the mineral soil were used. For the classification of the topsoil the results from the layers between 0 - 5 cm and 5 - 10 cm were used and compared to those from the layer between 0 and 10 cm of the Forest Soil Monitoring System, where the uppermost 10 cm had not been subdivided (see above). The present evaluation therefore enables us also to determine the gradient of the nutrient distribution of the top 10 cm. For the evaluation of the subsoil, the layer between 20 and 30 cm was chosen, as the shallowness of the Achenkirch soils did not allow a continuous sampling of the 30-50 cm layer.

Results

The medians of the individual parameters of the 24 sample plots shown in Figure 1 are given in Table 1, their relative positions compared to the carbonate-influenced sample plots of the Forest Soil Monitoring System in Figures 2 through 7.

Table 1. Medians of chemical soil parameters from the area of Achenkirch (n= 24) according to depth layers (CEC = cation exchange capacity)

					mg/g			
Depth layer	pH ($CaCl_2$)	Carb.	N_{tot}	C_{org}	P	K	Ca	Mg
0-5 cm	5,4	0	9,9	182	0,78	2,2	13,9	6,2
5-10 cm	6,1	0	6,5	127	0,60	1,9	21,2	6,6
20-30 cm	6,6	54	1,9	42	0,41	2,0	48,0	8,3

					µg/g			
Depth layer	Mn	Cu	Zn	Co	Cr	Ni	Pb	Cd
0-5 cm	542	13	117	14	34	31	110	1,47
5-10 cm	580	13	102	16	36	32	87	0,48
20-30 cm	529	12	68	19	37	41	46	0,73

		µmol IEq/g		
Depth layer	K	Ca	Mg	CEC
0-5 cm	3,9	399	43	485
5-10 cm	2,4	359	75	474
20-30 cm	1,3	160	27	198

General parameters and major nutrients

For certain parameters, the subdivision of the depth layer between 0 and 10 cm (0-5 cm and 5-10 cm) clearly shows the depth gradient of the top 10 cm of the soil. The pH value and the Ca concentration, which correlate with increasing depth of the soil, as well as the decreasing concentrations of organic substances (Corg) and, therefore, of N, P and K clearly show the dynamics of the top layer of the soil. Only for carbonate and Mg no such gradients were observed (Fig. 2).

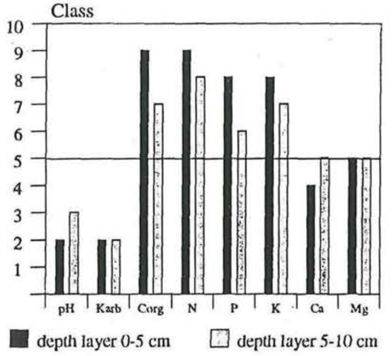

Fig. 2. Soils from Achenkirch compared to the all-Austrian situation: General parameters and major nutrients (0-10 cm).

Classification of the median values of the Achenkirch soils (depth layers: 0-5 cm and 5-10 cm; n=24) in the classes of the carbonate-influenced soils used by the Forest Soil Monitoring System (depth layer: 0-10 cm; the line at class 5 corresponds to the respective median of the Austrian total collective; n=172).

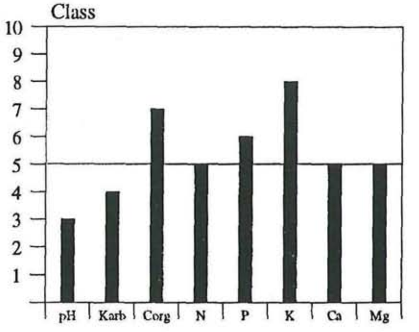

Fig. 3. Soils from Achenkirch compared to the all-Austrian situation: General parameters and major nutrients (20-30 cm).

Classification of the medians of the Achenkirch soils (depth layer: 20-30 cm; n=24) in the classes of the carbonate-influenced soils used by the Forest Soil Monitoring System (depth layer: 20-30 cm; the line at class 5 corresponds to the respective median of the Austrian total collective; n=150).

Compared to the carbonate-influenced sample plots of Austria's forests the pH values and the carbonate concentrations of the top layer are considerably lower for Achenkirch. On the other hand, the concentrations of Corg and of N, P, and K, which are closely connected with the amount of organic substance, were above average. The Mg concentrations corresponded to the average values of Austria's carbonate-influenced forest soils; the Ca concentrations were slightly below average.

For the layer between 20 and 30 cm (Fig. 3) about the same holds true as for the topsoil: The concentration of organic substances is comparably lower, but still above average; the N concentrations are only average any more, while the K content remains at a level markedly above average. The carbonate concentration is below average, although, compared to the all-Austrian data, it is higher than that of the topsoil. The pH values remained at a low level.

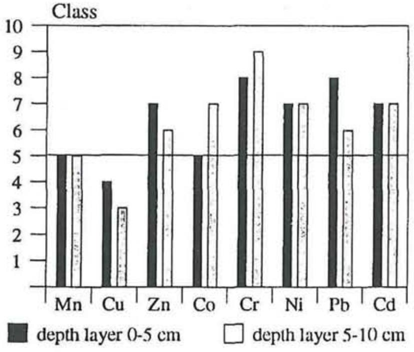

Fig. 4. Soils from Achenkirch compared to all-Austrian situation: Heavy metals (0-10 cm).

Classification of the medians of the Achenkirch soils (depth layers: 0-5 cm and 5-10 cm; n=24) in the classes of the carbonate-influenced soils used by the Forest Soil Monitoring System (depth layer: 0-10 cm; the line at class 5 corresponds to the respective median of the Austrian total collective; n=172).

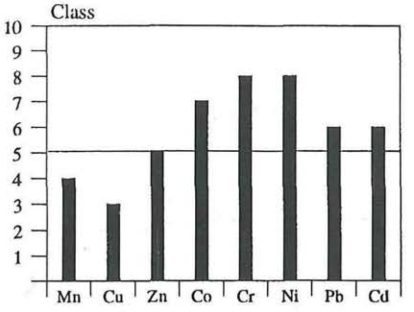

Fig. 5. Soils from Achenkirch compared to all-Austrian situation: Heavy metals (20-30 cm).

Classification of the medians of the Achenkirch soils (depth layer: 20-30 cm; n=24) in the classes of the carbonate-influenced soils of the Forest Soil Monitoring System (depth layer: 20-30 cm; the line at class 5 corresponds to the respective median of the Austrian total collective; n=150).

Heavy metals

Contrary to the major nutrients, the subdivision of the depth layer between 0 and 10 cm (0-5 cm and 5-10 cm) seemed to have but a minor influence on the values measured for the heavy metals: The Zn and Pb values decreased with the depth of the soil, while the Co and Cr values increased (Fig. 4). A remarkable aspect are the relatively low Cu concentrations observed in the area of Achenkirch. In combination with above-average Ni concentrations the extremely high Cr content implies geogenic accumulation, an assumption confirmed by the results from the layer between 20 and 30 cm (Fig. 5), which show that the Cr and Ni concentrations found in Achenkirch are clearly above the Austrian average, closely followed by Co. Petrochemically, those three elements frequently occur together. The Cu content is below average also in the subsoil. The concentrations of the essential heavy metals of Mn and Zn are average, compared to the all-Austrian values; those of the potentially toxic heavy metals of Pb and Cd are slightly above average.

Exchangeable cations

The all-Austrian comparison of the cation exchange capacity (CEC) and the individual exchangeable cations (K, Ca, Mg) (Fig. 6 and 7) offers interesting results. Altogether, it shows that the cation exchange capacity of the Achenkirch project area clearly decreases from topsoil (where it is slightly above average) to subsoil (low), which is due to the simultaneously decreasing content of organic substances (Fig. 2 and 3).

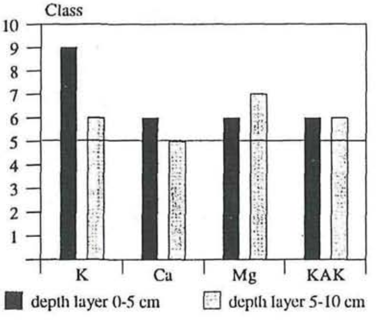

Fig. 6. Soils from Achenkirch compared to all-Austrian situation: Exchangeable cations (0-10 cm).

Classification of the medians of the Achenkirch soils (depth layers: 0-5 cm and 5-10 cm; n=24) in the classes of the carbonate-influenced soils used by the Forest Soil Monitoring System (depth layer: 0-10 cm; the line at class 5 corresponds to the respective median of the Austrian total collective; n=172).

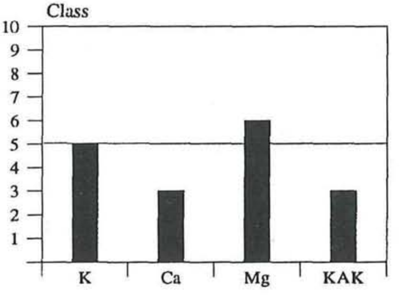

Fig. 7. Soils from Achenkirch compared to all-Austrian situation: Exchangeable cations (20-30 cm).

Classification of the medians of the Achenkirch soils (depth layer: 20-30 cm; n=24) in the classes of the carbonate-influenced soils of the Forest Soil Monitoring System (depth layer: 20-30 cm; the line at class 5 corresponds to the respective median of the Austrian total collective; n=150).

However, the dominance of the Ca-ion on carbonate-influenced soils (KILIAN 1992) seems to have been relativated in all depth layers studied: In the depth layer from 0-5 cm the K values are comparatively high. In the layer from 5-10 cm the values of Mg are by two classes higher than the Ca values; the value of K is by one class higher than the Ca values.

In the depth layer between 20 and 30 cm also the concentrations of exchangeable K and Mg were relatively higher than those of Ca were in investigation area. That Ca is nevertheless the predominant cation is proved by the fact that the relative positions of the CEC and the exchangeable Ca (both in class 3) and the relevant medians (Table 1) are identical. Considerably higher concentrations of K and Mg hardly ever influence the exchange capacity, but, in the concrete case, balance the K/Ca and Mg/Ca ratios in favor of K and Mg.

Discussion

As can be seen from Figures 2 through 7, the medians of the individual chemical parameters observed on the 24 sample plots of the Achenkirch investigation area are partly above, partly below, partly in accordance with the average of Austria's carbonate-influenced forest floors.

As no substantial acidification will occur on carbonate-influenced soils, the comparatively low pH values (5.4 on average in the layer fom 0-5 cm; 6.6 in those from 20-30 cm onward) allow a positive interpretation: Except for Mo and B that favours the availability of most nutrients and trace elements for the plants.

That pH values are low for carbonate-influenced soils, is correlated to the equally below-average carbonate content. Conditions for plants which are sensitive to carbonate-related chloroses are therefore better. That is not so much a consequence of the Ca-ion, but of the HCO_3-ion which is formed upon contact with water containing carbonic acid.

Compared to all-Austrian values, also the proportion of Ca to the other major nutrients, K and Mg, is favorable in the soils of the Achenkirch project area. While the available amounts of Ca and Mg are Austrian average, those of K are markedly higher (Figures 2 and 3). As regards the exchangeable cations, both the concentrations of K and Mg are comparatively higher than that of Ca (Fig. 6 and 7). As K and Ca have an antagonistic effect on the metabolism of plants, a relatively higher concentration of K is favorable for the development of the plants particularly on the Ca-dominated limy sites because very high Ca concentrations block the K takeup by plants (MINCHIN & BAKER 1973). From the nutritional point of view also the elevated content of Mg, which is due to the influence of dolomite, can be interpreted positively with regard to the physiological development of plants.

Absolutely, the decrease of the N concentrations from the topsoil to the subsoil is above average. While, compared to the all-Austrian values, the N concentrations are very high in the top 10 cm, namely between the 80 and the 90 percentile, the concentrations observed in the depth layer between 20 and 30 cm are only in the area of the 50 percentile (Fig. 2 and 3). That steep gradient and the very high concentrations found in the topsoil implies atmospheric N inputs. When evaluating N inputs it is important to take account of two contrary facts:

On the one hand, N shortages may be frequent in Central European forests, partly as a consequence of former landuses, partly site-related (GLATZEL 1991, HÜTTL 1991); such shortages can be compensated by N inputs. On the other hand, such inputs may, especially on heavily degraded sites, lead to nutrient imbalances, or, on certain others, cause a N eutrophication (HIPPELI & BRANSE 1992, KATZENSTEINER 1992).

All over Austria the results of the bioindicator grid of 1983 through 1990 showed in most cases a N deficiency of the needles and leaves (STEFAN 1994). The N content of foliar organs from the Northern Limestone Alps, measured between 1983 and 1992, varied between sufficient supply and shortage, with the N shortage increasing in warm/dry years (STEFAN & HERMAN 1995). Even if none of the test trees examined by STEFAN 1994 were exactly in the project area of Achenkirch, but only near it, we may assume that those test trees and their sites were subject to similarly severe N inputs, even if the needle analyses do not confirm such an interpretation.

An ecological evaluation of those inputs (N eutrophication and/or removal or reduction of a N shortage or causing imbalance of nutrient supply), based on the soil analyses, are not possible for the concrete test area, not even in conjunction with needle analyses. However, on a different site of the limestone Alps, LIU & al. 1993 clearly exclude negative impacts through long-distance transport of N inputs.

On certain sites, the Cu supply on limy substrate might become critical, because both compared to the all-Austrian values (Fig. 4 and 5) and absolutely (Table 1), Cu concentrations are rather low. However, Cu is present in most soils in the form of complex compounds; its solubility is therefore less heavily blocked by higher pH values than that of the other major heavy metals (HORAK 1977).

The relatively high concentrations of Co, Cr and Ni are presumably geogenic and without ecolocical relevance for the investigation area.

That the all-Austrian comparison shows slightly above-average concentrations of Pb and Cd may imply pollution stress. In that connection, the absolute values are not as important as the fact that the pollution is detectable (MUTSCH 1995).

Compared to Austria's other carbonate-influenced forest sites, the present soil-chemical results show that the investigation area of Achenkirch is mostly well-supplied with nutrients. However, soil chemistry considers but one aspect of plant nutrition. Especially carbonate soils considerably influence the development of plants also through their physical properties, as they are in most cases dryer and warmer than soils on silicate. The question of the "soil water" is therefore of importance and should be treated in greater detail in our future investigations.

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