Technisches Büro & Chemisches Labor
BODEN
Technisches Büro Unterfrauner GmbH
Umseerstraße 39, A-3040 Neulengbach
+43 676 364 10 30
office@bodenoekologie.com
www.bodenoekologie.com

Client:
Agricultural Business
Farm John Smith
123455 Flower Hill
Germany

Farm/Business:
Agricultural Business
Farm John Smith
123455 Flower Hill
Germany

Initial Sampling „Ecological Basic Characterization" Report BD 9473

Sample:	Antenne
Soil Sampler:	John Smith
Date of Sampling:	17.08.2022
Sampling Depth:	0 to 16 cm
Crop/Yield:	Grainmaize 12 t/ha
Elevation:	280 m a.s.l.
Climate:	Ø Precipitation: 500 mm
Coordinates (WGS84):	--

Laboratory:	Laboratory TB Unterfrauner GmbH
Laboratory-Nr:	563
Sample received:	30.08.2022

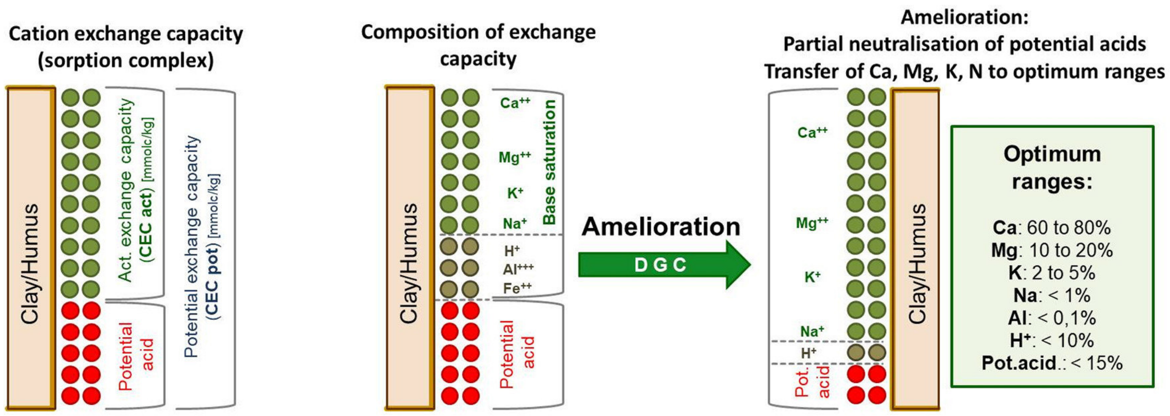
Neulengbach, 21.09.2022

SOIL PROPERTIES   Sample BD 9473

Technisches Büro & Chemisches Labor **BODEN**

Field name: Antenne

BASIC CHARACTERISTICS	Depth 0 - 16 cm		Gravel content vol.-%: 0				Sampling date 17.08.2022
Parameter	**Value**	**very low**	**low**	**favour.**	**high**	**very high**	**Assessment**
Soil texture (KH)	38						light soil
pH value H2O [-log H+]	6,9						slightly acidic
pH value KCl [-log H+]	5,4						moderately acidic
Lime content CaCO3 [%]	0,0						not detectable
Dissolved substances [eL, mS/cm]	0,3						low
Org.matter [%] = Corg * 1,724	3,0						favourable
C/N ratio of organic matter	12,2						subsequent delivery of N from org. mat
C/P ratio of organic matter	133,6						P fixation
C/S ratio of organic matter	98						subsequent delivery of S from org. mat
Stability of organic matter	1						transformation processes at equilibriu
Aggregate stability	4						very high risk of erosion
CATION EXCHANGE CAPACITY (CEC); Total potential = CEC potential; actually used potential = CEC actual							
CEC potential [mmolc/kg]	114						pot moderate sorption
CEC actual [mmolc/kg]	50						act weak sorption
CEC act in % CEC pot	44						very low
Base saturation in % CEC pot	44						risk of acidification
Elements related to **CEC pot**: Ca in % CECpot	29,5						very low
Mg in % CECpot	11,8						low
K in % CECpot	1,4						very low
Na in % CECpot	0,7						favourable
Al in % CECpot	0,0						favourable
NH4N in % CECpot	0,4						favourable
Fe in % CECpot	0,0						favourable
Mn in % CECpot	0,0						favourable
H in % CECpot	0,4						actual acid low
Pot.acid in % CECpot	55,8						very high
Elements related to **CEC act**: Ca in % CECact	66,8						favourable
Mg in % CECact	26,8						very high
K in % CECact	3,1						favourable
Na in % CECact	1,6						very high
Al in % CECact	0,0						favourable
H in % CECact	0,8						actual acid low



AMELIORATION in kg/ha – Measures for improvement / preservation of soil fertility

	Dolomite* (mit 40% MgCO3)	**Gypsum*** (CaSO4 * 2 H2O)	**Lime*** (CaCO3)	**Magnesium** (Mg)	**Potassium** (K)
min.	850 kg/ha	420 kg/ha	4220 kg/ha		260 kg/ha
org.	**humus formation**	green manure, catch crops			

*** Calculation refers to high quality, finely ground products!**

PLANT NUTRITION Sample BD 9473

Technisches Büro & Chemisches Labor BODEN

Field name: Antenne **Crop:** Grain maize **Yield:** 12,0 t/ha

PLANT-AVAILABLE ELEMENTS at date of sampling: 17.08.2022								Depth 0 - 16 cm
Nutrient [kg/ha]	**Value**	very low	low	favour.	high	very high	Diff. [1]	**Assessment**
Calcium (Ca)	1490							sufficient
Magnesium (Mg)	365							sufficient
Potassium (K)	135						90	deficiency
Phosphorus (P)	5						40	serious deficiency
Nitrogen (N)	15,5						210	serious deficiency
Sulphate (SO4)	13,9						80	serious deficiency
Iron (Fe)	2,6						0,90	sufficient
Manganese (Mn)	2,34							extreme surplus
Copper (Cu)	0,24							sufficient
Zinc (Zn)	1,96							surplus
Molybdenum (Mo)	0,02						0,05	deficiency
Boron (B)	0,16						0,29	serious deficiency
Silicon (Si)	21,6							sufficient
Cobalt (Co)	0,002						0,010	serious deficiency

ORGANICALLY BOUND NUTRIENTS [kg/ha] and potential for mineralisation [kg/ha and year]					
Nutrient	**Total organically bound**	**Assessment**	**Potential for mineralisation**		
org. Carbon (C org)	42750	intermediate crops	342	to	641
org Nitrogen (N org)	3520	high reserves	28	to	53
org. Phosphorus (P org)	320	low reserves	3	to	5
org. Sulfur (S org)	435	high reserves	3	to	7

POTENTIAL TOXIC SUBSTANCES in soil solution	
Aluminium (Al)	risk of contamination
As, Ni, Cr, Pb, Cd	no abnormalities

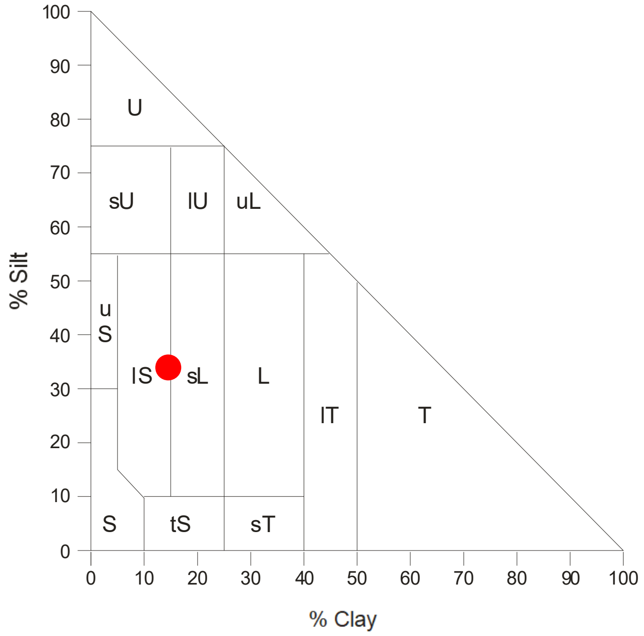
FRACTIONS: water-soluble, exchangeable, reserve

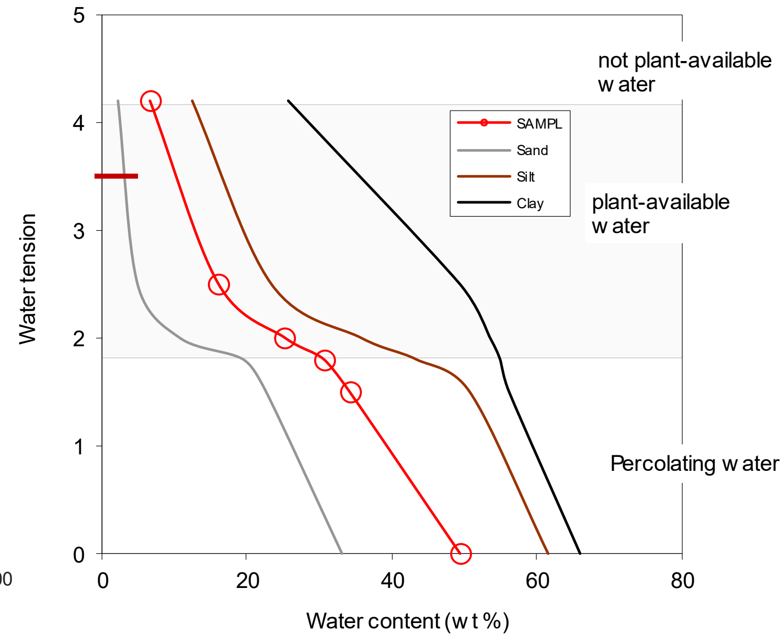
Soil solution [mg/l]		Exchangeable [kg/ha]		Reserve [kg/ha]	
Calcium (Ca)	26,85	Calcium (Ca)	1469	Calcium (Ca)	1800
Magnesium (Mg)	11,54	Magnesium (Mg)	357	Magnesium (Mg)	500
Potassium (K)	5,13	Potassium (K)	133	Potassium (K)	200
Sodium (Na)	10,14	Sodium (Na)	39	Sodium (Na)	
Ammonium nitrogen (NH4-N)	1,68	Ammonium nitrogen (NH4-N)	13	Nitrogen total (N tot)	3535
Nitrate nirogen (NO3-N)	1,07				
Phosphorus (P)	0,91	Phosphorus (P)	4	Phosphorus min. (P min)	800
				Phosphorus total (P tot)	1625
Sulphate (SO4)	14,91			Sulphur total (S tot)	440
Chloride (Cl)	29,12				
Aluminium (Al)	4,20	Aluminium (Al)	0,00	Aluminium (Al)	5100
Iron (Fe)	3,06	Iron (Fe)	0,00	Iron (Fe)	6600
Manganese (Mn)	0,09	Manganese (Mn)	2,26	Manganese (Mn)	430
Boron (B)	0,02	Boron (B)	0,14	Boron (B)	0
Zinc (Zn)	0,02	Zinc (Zn)	1,95	Zinc (Zn)	20
Copper (Cu)	0,02	Copper (Cu)	0,22	Copper (Cu)	15
Molybdenum (Mo)	0,00	Molybdenum (Mo)	0,02	Molybdenum (Mo)	0
Silicon (Si)	11,83	Silicon (Si)	11,69	Silicon (Si)	1570
Cobalt (Co)	0,00	Cobalt((Co)	0,00	Cobalt (Co)	5

MOBILISATION:	**Phosphorus**
SUPPLY:	**Potassium, Nitrogen, Sulphur, Molybdenum, Boron, Cobalt**

[1] **Difference in plant requirements during the entire vegetation period at the time of sampling**

SOIL PHYSICAL DEDUCTIONS SNR.: BD 9473





Austrian texture triangle OENorm L 1050

Water tension and water content

Source:Stefan Diringer (2010): Gibt es in der Bodenphysik Möglichkeiten Einzelparameter durch einen einzelnen Summenparameter zu charakterisieren? Wissenschaftliche Diplomarbeit. Institut für Geographie und Regionalforschung, Universität Wien

Detailed picture of soil sample

Explanations and deductions of recommendations and amelioration measures

Basic properties (see information sheet "Soil Properties")

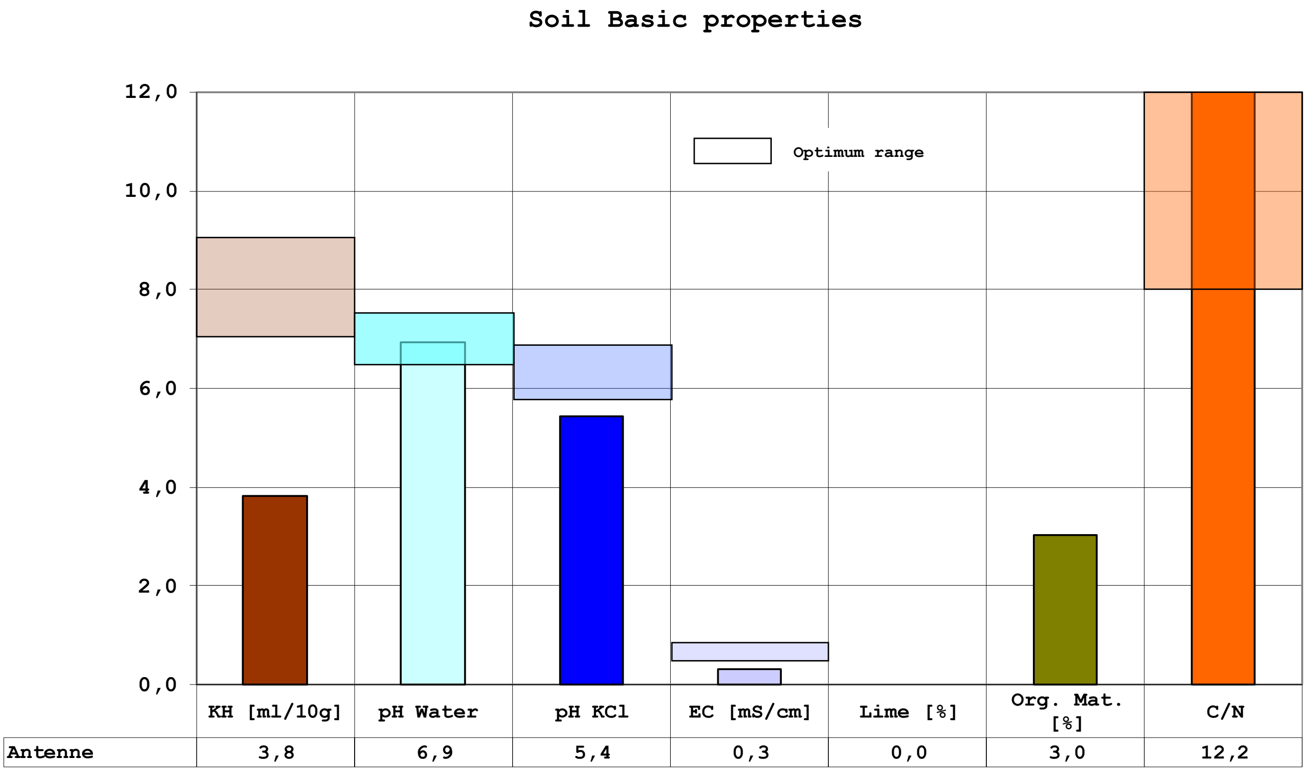


Figure: Soil basic properties

Soil texture/Water balance

The **loamy/sandy** soil texture results in a **light** soil. At full water saturation, the soil can retain ~ **3.8 ml** of water per 10 g, this amount is approximately equivalent to a ***water quantity*** of **400 m^3/ha** at a depth of 16 cm. At full water saturation in winter/spring, this is not sufficient to bridge short dry periods (e.g., early summer drought) unscathed. From the point of view of the water supply, the mentioned amounts of precipitation (~500 mm) must be distributed favourably over the vegetation period to assume attractive yields.

➔ The **water storage capacity** in the soil can be improved through humus formation and optimal usage of the accessible soil volume by roots and soil life. The water storage capacity can also be increased by adding certain soil additives.

The **pF curve** on the sheet for "Soil Physical Deductions" shows at which water contents in percentage (wt.%) which water tension (pF) prevails. Below pF 1.8, the water is weakly bound (percolating water) and not plant-available. The range of plant-available water is found from pF 1.8 to 4.2 (= usable field capacity). Above pF 4.2, the water in the soil is already bound so strongly that the forces exhibited by most crops are no longer sufficient to absorb the water from the soil and the plants wither ("wilting point"). The energetic "cracking point" is at pF 3.5. From this water tension onwards, the plant needs more energy to extract water from the soil than can be bound by photosynthesis. If there is a possibility of irrigation, it should be started at the latest at a of pF value of 3.5 (marked in red in the diagram).

In order to determine the current state of the water tension, it is sufficient to take a representative soil sample. This soil sample is weighed in a moist and dry state, the difference in weight corresponds to the water content (gravimetrical determination of water content). With relative reference (water content in %) the water tension can be determined directly via the pF curve of the figure.

Aggregate stability

Stable aggregates are the prerequisite for adequate ***soil infiltration performance*** and ensure that precipitation water is drained and stored from near-surface soil layers to deeper areas. Earthworm tubes and roots support the rapid drainage of water. Rapid drainage and re-aeration of the coarse pores promote the biological processes in the soil. The aggregate stability significantly affects the vulnerability of a soil to ***silting/crusting*** and ***soil erosion***. Stable aggregates reduce the risk of destroying the bridges between the soil particles due to impacting raindrops, tillage and passage. ***Standing biomass*** (crops, catch crops, green manure) and ***mulch*** additionally protect the soil from the destructive impact energy of raindrops.

The ***aggregate stability*** of the examined sample is ***poor***; when mixing and shaking the sample with distilled water, the protruding liquid was ***very clouded***. The turbidity is due to the fact that fine particles go into suspension (mainly clay and fine silt particles). This can lead to ***silting/crusting*** and ***reduced infiltration*** of the soil and thus cause problems in the water and air balance. The disturbed gas exchange also has a negative effect on biological activity and nutrient uptake. The ***risk of erosion*** is currently ***very high***.

➔ **Water management** should be optimised, and the risk of erosion reduced by strengthening soil aggregate stability. The promotion of balanced soil life and root growth (biological engineering/revegetation) and the regular supply of calcium and magnesium (acting as bridges between clay particles) are of particular importance. These erosion control measures should be carried out regularly.

pH-Wert

The pH of a soil can be measured in ***aqueous solution*** (***pH_{Water}***) and in ***neutral salt solution*** (***pH_{KCl}***).
The ***pH_{Water}*** corresponds to the pH value of a soil pore filled with rainwater and describes the ***environmental conditions*** for ***microorganisms*** and ***nutrient species***. The optimum range of the pH_{Water} is between *6.5 and 7.8*. This is the range in which the greatest biodiversity of the microbiological community (including mycorrhiza) is found. In the present sample, the **pH_{Water}** is at a **slightly acidic 6.9**.

The ***pH_{KCl}*** allows the statement of which ***buffer system*** the soil can be assigned to. The optimum value range of pH_{KCl} is between *5.9 and 6.9*.
In the present sample, the **pH_{KCl}** is at a **moderately acidic 5.4**. The current buffer system is located at the transition area between the exchanger buffer to the silicate buffer. From pH values (KCl) of < 5.9, clay minerals begin to disintegrate; their components (e.g. Al, Fe, Si) increasingly dissolve into the soil solution and can be leached. On the one hand, this leads to the loss of important exchange surfaces and, on the other hand, to further acidification of the soil (e.g., through Al hydroxides). To increase/preserve soil fertility, the acid buffering capacity should be strengthened (target pH_{KCl}: 5.9-6.9).

➔ In order to **prevent** further **acidification** and soil degradation, acid components should be neutralised in a targeted manner. Mixtures of different carbonatic products should be used, which are individually tailored to the soil parameters (see amelioration section on the overview sheet "Soil Properties").

Soil solution (dissolved substances)

The soil solution is the ***most important medium*** for ***plant nutrition***, as the roots can only absorb dissolved substances. The soil solution should have an "ideal composition" of the individual nutrients since the selectivity of the plant uptake for certain nutrients only works optimally from an "ideal solution".

The ***salinity*** of the soil solution (= sum of all dissolved ions), measured by the **electrical conductivity (eC),** is **0.3 mS/cm** in the present soil and thus **beneath the favourable range** for the vegetation period (*target: 0.5 to 0.8 mS/cm*). At the end of the vegetation period or during the dormancy period, the eC should be *<0.5 mS/cm*, otherwise there is a risk of leaching.

The following elements are responsible for electrical conductivity in the soil solution (see water-soluble fraction in the overview sheet “Plant Nutrition”):

Table 1: Composition of the soil solution, Concentrations in mg/l

Nutrient	Antenne
Ca	27,0
Mg	12,0
K	5,0
Na	10,0
NH_4-N	1,7
NO_3-N	1,0
P	0,91
SO_4	15,0
Cl	29,0
Al	4,20
Fe	3,06
Mn	0,09
B	0,02
Zn	0,02
Cu	0,02
Si	11,83

The ratios of calcium **(Ca)** to potassium **(K)** and magnesium **(Mg)** are favourable (Target: Concentration of Ca >> K > Mg >> Na).
The phosphorus (**P**) concentration is **above** the optimum range (*Target*: *0.2 to 0.8 mg/l*). The **trace element provision** is **good.**
The water-soluble content of iron (**Fe**) is **increased** (*target: < 0.5 mg/l*), a higher concentration can negatively affect the availability of other nutrients.

The water-soluble proportions of aluminium (**Al**) are **significantly elevated** (*target: <0.001 mg/l*), a contamination of adjacent systems (e. g. groundwater bodies) and of the harvest cannot be excluded. Al in the soil solution can severely affect the absorption of phosphorus (**P**), calcium (**Ca**) and magnesium (**Mg**) and therefore be the cause of visible deficiency symptoms for P, Ca and Mg. As Al is also toxic to roots, there is a risk of yield losses.

The concentration of chloride (**Cl**) is **elevated**. Cl enters the soil via the application of animal excreta (manure, slurry, dung) and mineral fertilisers (e.g. KCl, $MgCl_2$, …).

The site can be described as **currently weak** in terms of **sorption**; **leaching** of elements from the soil solution is to be expected during precipitation events.

➔ **Dissolved aluminium** indicates the decay of valuable clay particles and thus the loss of soil fertility. Through the targeted neutralisation of acids the pH value is gradually increased, further degradation is inhibited, and regenerative processes are initiated (see amelioration section on the overview sheet “Soil Properties”).
➔ In soils with **weak sorption**, easily soluble substances should only be applied in exceptional cases and the amount should be adapted to the current development stage of the plant stand.

Organic matter

The **amount** of **organic matter** is **favourable** considering the textural class of this soil and should be preserved. The **C/N** ratio of **12.2** is favourable (*target: 8 to 14 to 1*), as is the **C/P** ratio of **133.6** (*target: 40 to 100 to 1*), the **C/S** ratio is within the optimum range at **98** (*target: < 130 to 1*).
Under favourable weather conditions (temperature, humidity), the following amounts of nitrogen (**N: 28 to 53 kg/ha**), phosphorus (**P: 3 to 5 kg/ha**) and sulphur (**S: 5 to 7 kg/ha**) can be mineralised by microbiological processes during the vegetation period. The mineralised nutrients can be absorbed by the plants and make an important contribution to their nutrition.

According to the information provided on the assignment form, the straw is left on the field after harvesting. This promotes the formation of permanent humus and subsequently enhances soil fertility.

➔ To foster the **formation of permanent humus,** crop residues should remain on the field after harvesting (important: ***straw decomposition***!), as well as the regular application of green manure, the cultivation of catch crops, and the promotion of biological activity (optimisation of air-water balance, pH value) are recommended.

Cation exchange capacity (see overview sheet "Soil Properties")

Organic matter and clay particles in the soil have charged surfaces and can thus attach nutrients in an exchangeable manner (= plant-available) and protect them against leaching.
The total potential of a soil to store nutrients in exchangeable form is referred to as "**Potential Cation Exchange Capacity**" (CEC potential). The cation exchange capacity describes a characteristic parameter for each soil. For example, it can be deduced which quantities of supplied nutrients (e. g. from mineral/organic fertilizers) can be stored in the soil at maximum.
In addition to the "Potential Exchange Capacity", the current degree of utilization ("**Current Exchange Capacity**" or CEC actual), as well as the ratios of the accumulated nutrients to each other (**Ca : Mg : K**) are of essential importance for the assessment of soil fertility and plant nutrition.

Potential Cation Exchange Capacity (CEC potential): Site potential

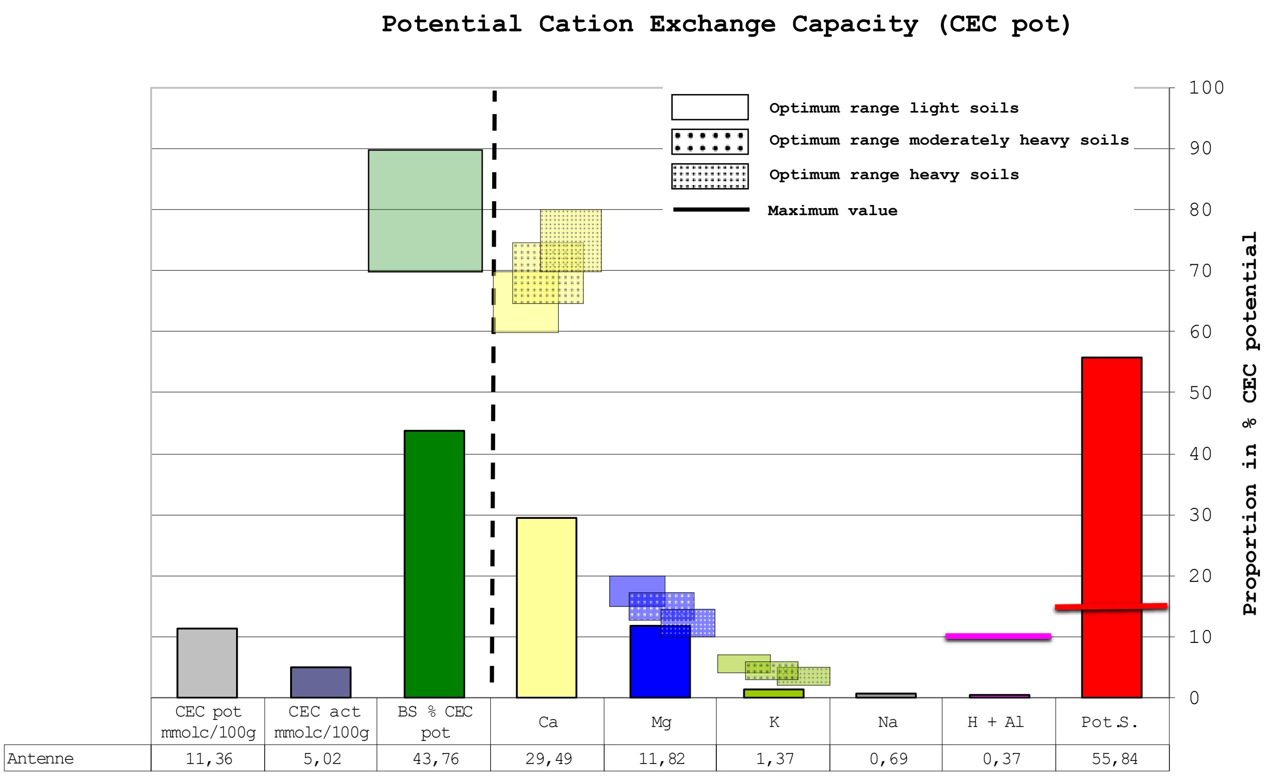


Figure: **Composition of potential cation exchange capacity (CEC pot)**

For the examined soil (see figure above), the potential capacity of the exchanger (**CEC pot**) is **11.4 mmolc/100g**. The exchange capacity is attributable to the amount of organic matter and to the presence of clay minerals, oxides and hydroxides. The actual exchange capacity (**CEC act**) is **5 mmolc/100g**. The soil can currently be described as **currently weak** in terms of **sorption**.

The ***base saturation*** (**BS**), the percentage of the sum of calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) on the sorption complex (CEC pot), is at **44%** and therefore **significantly below** the **optimum range** (*target: 70 to 90%*). The ability to buffer further acidic inputs is very poorly pronounced. There is an immediate risk of **further acidification** within a short period of time and that **soil fertility** will **collapse permanently**.

Soil fertility is determined by the complex interaction of mineralogical, physical, chemical and biological factors. These include, for example, the content and proportions of plant-available nutrients, soil acidity (= pH value), soil permeability and storage capacity for water and air, humus content and biological activity. These factors form the basis for optimising the yield in a sustainable and environmentally friendly way, taking into account climatic conditions and management options.

The potential soil fertility is not being fully utilized in the examined soil at current stage. The amount of potential acid (**pot.S**.) on the exchanger is **very high (56%)**, the substance ratios are not within the optimum range, the proportions of Ca and Mg are very low or low (see figure above or overview table "Soil Properties").

In the course of **exchange processes**, nutrients (e.g., Ca, Mg, K) are displaced from the exchanger by acids, and the acids become attached to the exchanger in return. The process of nutrient mobilisation, however, is of essential importance to crop nutrition during the vegetation period. To maintain these processes, it is necessary that ***portions*** of the ***attached acids*** are being ***neutralised*** at regular intervals. Exceeding a certain amount of acid on the exchanger means that the acids become increasingly attached and no longer take part in the exchange reactions (= "***potential acid***", see red bar in figure above).
This ***blockage of sorption sites*** reduces the actual exchange capacity. At the same time, the proportions of Ca, Mg and K are reduced and the difference to the optimum ranges is increasing (yellow / blue / green bar in figure).

Current exchange capacity (CEC actual): ACTUAL status

Due to the ***blockage*** of sorption sites of the exchanger surfaces by the potential acid (***pot.S***.), Ca, Mg and K can only become ***attached*** to the part ***that is still active***. To evaluate the current status, the active part must therefore be used as a reference value (CEC act). This corresponds to the conditions that the plant roots and microorganisms encounter at the current (actual) stage.

The ratio between the substances is an essential key factor in assessing soil fertility (plant nutrition, biology, aggregate stability, air / water ratios).

The following table shows the distribution of substances at the exchanger, in which optimal conditions prevail (Target). The “target” state is contrasted with the current situation on the exchanger of the analysed soil sample. The optimum ranges of values depend on various basic parameters.

Table 2: Optimum ranges compared to actual measured proportions on the exchanger in %

	Ca	Mg	K	Na	(H+Al)
TARGET	**60-70**	**13-18**	**2-5,5**	**< 1**	**< 10**
Antenne	66,8	26,8	3,1	1,6	0,8

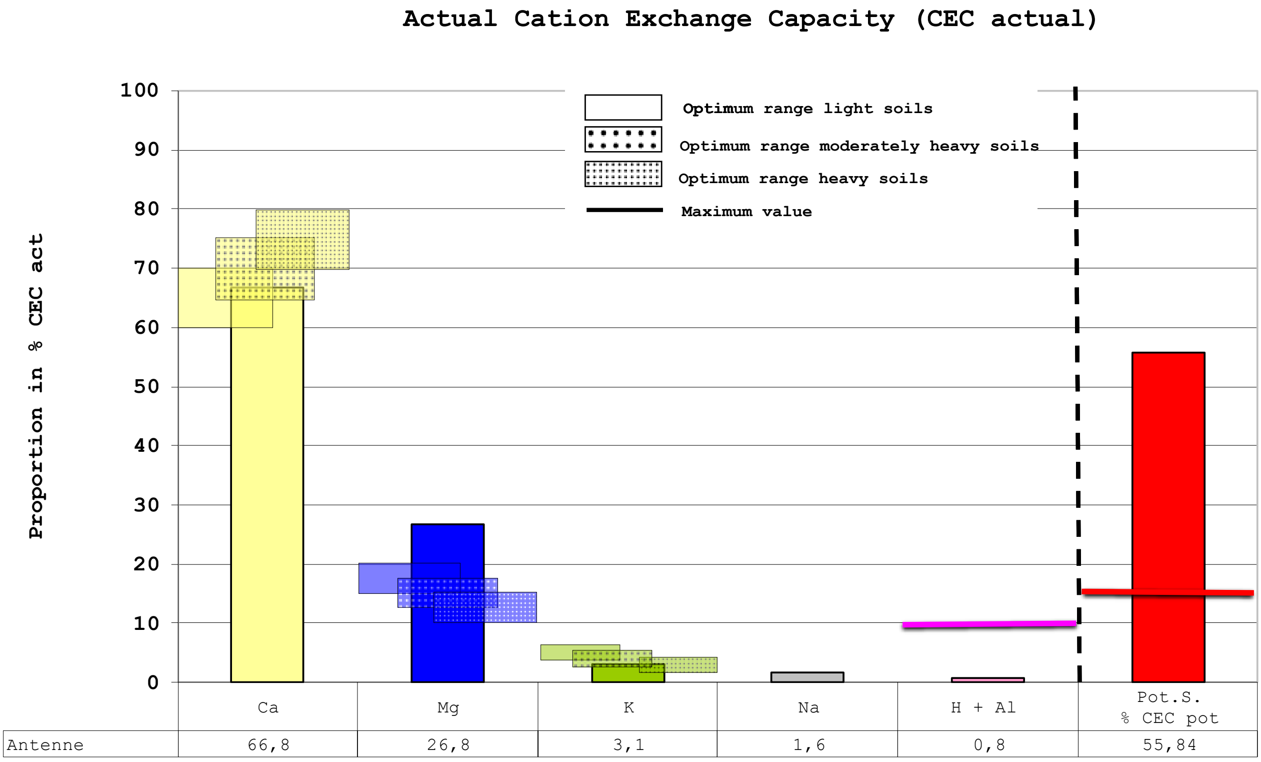


Figure: **Composition of the actual cation exchange capacity (CEC act) and proportion of potential acid in the CEC pot**

Plant roots and microorganisms encounter an **unfavourable** distribution of substances in the currently used proportion of the sorption complex (**CEC act**).

The proportions of **Ca** and of **K** are within the optimum range, **Mg** is very high. **Mg** is an element that, like Ca, has the ability to bond two clay particles together. The difference between Ca and Mg is that the hydration shell surrounding Ca is relatively stable. Mg is only about half the size of Ca and changes the size of the hydration shell depending on the soil moisture. In humid conditions, the Mg is surrounded by a large hydration shell, the clay minerals are transferred to a very labile phase as if by "ball bearings", the clay particles shift even under low pressure (caution: danger of soil compaction and silting). In dry conditions, the hydration envelope decreases to a minimum and the positively charged Mg ion "sticks" two negatively charged clay particles together, the soil becomes extremely hard (soil cracks). In contrast, Ca ions keep the bond distances to the clay particles relatively constant and elastic. The addition of gypsum causes an increase in the Ca content and promotes the leaching of Mg (through content of sulphate).

The proportion of **potential acid** (pot. S.) is very high (see above).

➔ For **amelioration** (improvement of soil fertility), potential acid must be mobilised and neutralised in a targeted manner. At the same time, the "free" sorption sites should be filled with the desired substances in the optimal ratio. Mixtures of dolomite, gypsum and calcium carbonate should be used, e.g. AKRA DGC* (see section “Amelioration”, note quantities and ratios!). The maximum annual amount should not exceed 1,500 kg/ha.
Potassium can be supplemented via organic or mineral products; the amount should be applied in several partial applications annually in autumn.
➔For **soil care** measures (preservation of soil fertility) following the completed amelioration, the same product combination in the same mixing ratio as for amelioration should be applied every 3rd year with a quantity of 900 to 1,200 kg/ha.

*a product of Karner fertilizer production, DGC = dolomite/gypsum/calcium carbonate

Assessment of nutrients (see overview sheet "Plant Nutrition"))

In the overview sheet "Plant Nutrition", **nutrients** and **potentially toxic substances** in different fractions (water-soluble, exchangeable, reserve) are compared in tabular form. The sum of the ***water-soluble* + *exchangeable*** fraction is defined as ***plant-available***. Substances from the reserve fraction can be partially mobilised (= available to plants) by various processes in the course of the vegetation period.

The following tables show the different fractions (pools) for the main nutrients calcium (**Ca**), magnesium (**Mg**), potassium (**K**), phosphorus (**P**), nitrogen (**N**) and sulphur (**S**).
Considering this ***analytical snapshot***, it does not make sense that the entire amount of nutrients required by the indicated crop at the specified yield level over the entire vegetation period is available in a readily available form. It is essential to take into account the mobilisation and processes of subsequent delivery. If necessary, a supplement should be made (consider time, quantity, form of binding, interactions!).

Calcium

Calcium (**Ca**) is one of the most essential nutrients. Ca stabilizes the plant tissue by acting as a ***cementing agent*** of cells and thus allows the absorption of many other nutrients. This function requires that Ca is ***not mobile*** within the plant and must therefore be absorbed from the roots over the entire vegetation period. Certain crops such as ***legumes, rapeseed, maize, vegetables, fruits*** and ***hop*** have a particularly ***high calcium requirement***.

Ca is present in the soil in ***various binding forms*** (carbonatic e.g. as calcium carbonate, siliceous e.g. as feldspar and organic, e.g. bound in humus). Subsequent delivery takes place via the processes of weathering and acidification as well as through the mineralisation of organic substances. ***Exchangeable Ca*** at the sorption complex is in ***dynamic equilibrium*** with the Ca in the ***soil solution***.
The extraction methods of soil analyses often detect high values and do not always reflect the natural conditions in situ. In order to estimate the actual Ca provision, further parameters must therefore be taken into account (e.g., soil activity and water conditions, see below).

The ***Ca content*** in the ***soil*** is often between *0.1 and 1.2%*; higher in calcareous soils, usually lower in soils of quartz-rich sands and in extremely acidified forest soils. A significant proportion of the total Ca is always present in exchangeable form. The ***Ca content*** in ***plants*** is between *0.5 and 50 g/kg* dry matter (DM).

Table 3: Different Ca-pools of he soil, Antenne

Element	Availability	Amount kg/ha	Remark
Ca	watersoluble	22,4	sufficient
Ca	exchangeable	1469	sufficient
Ca	subsequently deliverable	1833	high reserves

In the examined soil**, calcium** is **potentially sufficiently** present in all fractions.

In total, about **1,500 kg/ha of** calcium are present in a potentially **plant-available** form. This amount is **mathematically sufficient** for the entire vegetation period. Nevertheless, it can happen that the cultivated crops suffer from Ca deficiency, as soil activity and water conditions play an important role. The "Ca-flow" to the root and the absorption only function properly under optimal conditions. If it is too dry, too wet, too cold or too hot, less Ca reaches the root surface and despite high Ca contents in the soil, Ca deficiency may occur in the plant.

➔ To **ensure** an **optimal Ca provision,** the supply of a mixture of finely ground carbonatic and sulphatic calcium products is recommended. Attention should be paid to the ratio to magnesium.

Magnesium

In the plant, magnesium (**Mg**) is a ***component of essential plant ingredients*** (chlorophyll, phytin, ATP, ...), it activates many enzymes and is involved in the energy transfer as Mg-ATP.

The ***Mg content*** of Central European ***soils*** low in salt and carbonate is usually *0.5 to 5 g/kg*, with the majority present in silicates. Quartz-rich sandy soils are therefore usually low in Mg, silicate-rich clay soils are rich in Mg. In carbonatic soils, Mg may also be present in carbonates such as dolomite or magnesite. Mg released from weathering is partly bound to the exchangers (sorption complexes) as exchangeable Mg.
The ***Mg contents*** in the ***plant*** are usually *1 to 10 g/kg DM* in the green parts of the plant. For the Mg supply of the plant, the Mg concentrations in the soil solution and the content of exchangeable Mg in the soil are of particular importance.

Table 4: Different Mg-pools of he soil, Antenne

Element	Availability	Amount kg/ha	Remark
Mg	water-soluble	9,6	sufficient
Mg	exchangeable	357	Supply for amelioration
Mg	subsequently deliverable	500	high reserves

In the **soil solution,** magnesium is dissolved in **sufficient** concentration. In total, about **365 kg/ha** Mg are present in **plant-available** form. This amount is sufficient for the entire vegetation period.
The **reserves** are **high** at **500 kg/ha**. The proportion of Mg on the potential exchanger **(CEC pot)** is **low**.

➔ To ensure an **optimal Mg provision** and to compensate for plant uptake and leaching, the regular supply of finely ground dolomite is recommended. Attention should be paid to the ratio to calcium.

Potassium

In the plant, potassium (**K**) is responsible, among other things, for the adjustment of the ***osmotic pressure*** and the regulation of the ***water balance*** and increases ***frost resistance***. It also activates various ***enzymes***.

The total content of ***potassium*** in the ***soil*** increases with the clay content (in the clay fraction, the content of potassium is 2 to 4%) and can be divided into dissolved potassium (soil solution), exchangeable potassium (sorption complex) and bound potassium (intermediate layers of clay minerals). These different forms of potassium are in ***dynamic equilibrium*** at an ***optimal pH value*** in the soil (5.9 to 6.9 in neutral salt).
In ***plants***, potassium is usually present as a positive K^+ ion and does not form any organic compounds. Potassium levels are often between *5 and 50 g per kg of DM*.

Table 5: Different K-pools of he soil, Antenne

Element	Availability	Amount kg/ha	Remark
K	water-soluble	4,3	deficiency
K	exchangeable	133	deficiency
K	subsequently deliverable	150	low reserves

In the soil under investigation, the dissolved K concentrations (**water-soluble K**) are **not sufficient** in relation to Ca and Mg. The **plant-available** potassium is high at about **135 kg/ha**, this amount is not sufficient for the entire vegetation period. The proportion of K on the potential exchanger (**CEC pot**) is **beneath** the **favourable range** (see above, the proportion can be increased via amelioration). The **K reserves** are **low**.

➔ In order to sustain the **K provision** of crops, the **supply** of potassium is recommended.
Note: if only the grains of cereals, rapeseed or maize are harvested and the crop residues remain on the field, the actual withdrawal of potassium is 20 to 25 kg/ha.

Phosphorus

In the plant, phosphorus (**P**) is important, among other things, for ***energy transfer*** (ADP, ATP), the ***synthesis*** of organic substances (e.g. strand of DNA) and as a ***cell building constituent***.
Phosphorus is present in the ***soil*** in a small amount in dissolved form (usually < 0.1% of the total phosphorus), furthermore bound to oxides and clay minerals (exchangeable P) as well as phosphate mineral (subsequently deliverable P) and in organic matter (organic P).
In ***unfertilized soils***, the P contents are, for example, *< 100 mg/kg* in sandy soils, and between *200 and 800 mg/kg* in many silty, loamy and clayey soils of temperate latitudes. Following decades of ***high P application***, up to *more than 2000 mg/kg* P can be present in European agricultural soils nowadays.
In the ***plant***, the phosphorus content is usually between *1 and 5 g/kg TS*.

Table 6: Different P-pools of he soil, Antenne

Element	Availability	Concentration mg/l	Amount kg/ha	Amount in % of total P	Remark
P	water-soluble	0,91	0,8	0,05	surplus
P	exchangeable		4	0	significant deficiency
P	subsequently deliverable		800	49	min. reserves high
P	organic		320	20	org. reserves low
P	total		1625		Total contents average

The P concentration in the **soil solution** is **0.91** ***mg/l*** and thus **above** the **optimum range** for **proper plant development**. With an optimal concentration between *0.2 and 0.8 mg/l* in the main growth phase, almost all crops, even those with a high yield level, can be adequately supplied.

In addition to considering the concentration in the soil solution, the equipment of the various reserve pools and the environmental (milieu) conditions that control the subsequent delivery are important for optimal ***P-dynamics***.

A total **of < 5 kg/ha** P are available in a **plant-available** form. This amount is **not sufficient** for the entire vegetation period. However, it can be expected that, depending on the temperature and humidity conditions, P will be continuously mobilised from the reserve fractions by microbiological and chemical processes. The **acid-soluble** reserve pool is well replenished, with approx. **800 kg/ha**. The **organic** reserves are high at about **320 kg/ha**.

➔ In order to **sustainably ensure the P provision**, measures should be taken to continuously mobilise P from the reserve pools**.** Several strategies are suitable for this:

- Improvement and stabilization of the buffer system, e.g. by supply of dolomite, calcium carbonate
- Promotion of microbial activity, e.g. by improvement of aeration, supply of trace elements, green manure, catch crops, leaving straw and crop residues on the field after harvesting (straw rot)
- Ion competition, e.g. via the application of silicic acid
- Cultivation of P-mobilising plants, e.g. buckwheat, white lupine, phacelia
- Application of P-mobilising bacteria, e.g. *Bacillus megaterium phosphaticum*

Nitrogen

Nitrogen (**N**) is one of the ***main nutrients*** of plants and microorganisms, it is a component of many organic N compounds such as proteins, vitamins and chlorophyll.

The ***nitrogen*** in the ***soil*** is usually more than 90% organically bound, the total N content (N_t) is between *3 and 9 t/ha* in a regularly tilled A horizon ("arable topsoil") of the temperate-humid climate, in deep black soils (chernozems) it can be up to *14 t/ha*. Mineral N forms (N_{min}) are of particular importance, as they are immediately plant-available N-compounds. Nitrogen is usually present in the ***plant*** at concentrations of *10 to 50 g/kg DM*.

Table 7: Different N-pools of the soil, Antenne

Element	Availability	Amount kg/ha	Remark
NH_4-N	water-soluble	1,40	deficiency
NO_3-N	water-soluble	0,80	
NH_4-N	exchangeable	13,33	
N_{org}	organic	3520	high reserves
N_{total}	total	3535	high reserves

Plant-available nitrogen (water-soluble and exchangeable) is **in deficiency** at the time of sampling. The **organic** nitrogen **reserves** are **high** at **3,500 kg/ha**, the **potential** for **mineralisation** at this site is approximately **28 to 53 kg/ha/year**. The mineralisation rate depends on the humidity and temperature conditions as well as on the environmental (milieu) conditions for the microorganisms (e.g., soil acidity, nutrient supply, redox potential).

➔ The **nitrogen supply** of the plants can be supported by various **measures**:

- Increase the N-usage efficiency by ensuring that the “supporting” substances are present in favourable concentrations (e.g, calcium, manganese, magnesium, phosphorus, sulphur, iron, cobalt, molybdenum)
- Biological N-fixation (e.g., via nodule bacteria of legumes, free-living N-fixing bacteria)
- Supply of organic substances (*Note*: in liquid manure, N is partly present in mineral form as NH_4^+ and thus immediately available, partly as an organically bound molecule which can only be absorbed by the plants via microbiological degradation and conversion processes)
- Supply of mineral N-fertilizers (e.g., ammonium, urea).

Which N-forms and which quantities contribute to the best yield depends on the specific conditions of the site (e.g., humidity, temperature, air capacity) and the requirements of the crop. In general, nitrate-containing fertilizers should be avoided, as nitrate puts extreme strain on the energy balance of the plant (nitrate can only be used by the plant after conversion into ammonium) and the risk of nitrate contamination in water bodies is significantly increased. Attention should be paid to the ratio of nitrogen to sulphur.

Sulphur

Sulphur (**S**) is a component of many ***plant ingredients*** (e.g., amino acids and thus of proteins, enzymes and vitamins, flavours, odours and leek oils). Sulphur is of particular importance as a component of organic compounds that can suppress harmful organisms (e.g., pathogenic fungi, harmful insects and pests).

The ***sulphur content*** in the ***soil*** in humid climates is *0.1 to 0.5 g/kg*, in peatlands the content can rise to up to 10 g/kg, in sulphate-acid marshes up to 35 g/kg. Apart from these exceptions, there is no significant accumulation of sulphates in humid climates, as they are easily soluble and become readily leached. Most of the sulphur in the soil is present in organic compounds. Plants absorb sulphur mainly as sulphate (SO_4^{2-}), the ***S content*** in ***plants*** is usually *1 to 10 g/kg DM*.

Table 8: Different S-pools of the soil, Antenne

Element	Availability	Amount kg/ha	Remark
SO_4	water-soluble	14	deficiency
S_{org}	organic	435	high reserves
S_{total}	total	440	high reserves

The **plant-available** sulphur (***sulphate or water-soluble sulphur***) is **not sufficient** for the entire vegetation period. The **organic S contents** are **very high**, the mineralisation potential is **3 to 7 kg/ha per year** (1 kg S corresponds to about 3 kg SO_4^{2-}).

➔ To optimise plant nutrition and to compensate for plant uptake and leaching, the **supply of sulphur** is recommended. A combination with foliar fertilizers may be useful.

Attention should be paid to the ratio of sulphur to nitrogen.

Trace elements and useful elements

Trace elements are essential for plant nutrition and (micro)biological activity. Useful elements (e.g., silicon) can cause benefits for certain crops in terms of vitality, the defense against harmful organisms or the binding/mobilization of nutrients.

Iron (**Fe**) is usually present as a mineral reserve in large quantities in the soil (org. reserve mostly insignificant => absolute deficiency on highly organic soils such as those commonly found in highland moors, **frequent levels** in **soil** *5,000 to 40,000 mg/kg*). The **content** in **plants** is between *50 and 1,000 mg/kg DM*. Fe is involved in redox reactions, photosynthesis and breathing.

Manganese (**Mn**) is contained in the soil in many minerals and can be partially bound in humus (common **contents** in **soil** *200 to 400 mg/kg*). The **content** in **plants** varies between *20 and 200 mg/kg DM*. Manganese activates enzymes and is involved in redox reactions.

Zinc (**Zn**) is contained in various minerals and can be partially precipitated or bound in humus (common **levels** in **soil** range from *10 to 300 mg/kg*). The **contents** in **plants** are between *10 and 100 mg/kg DM*. Zinc activates enzymes, is involved in the photosynthesis and promotes the production of growth substances.

Copper (**Cu**) is contained in various minerals and ores, can be precipitated as a secondary mineral or bound in humus (common **contents** in **soil** *5 to 100 mg/kg*). The **contents** in **plants** are between *2 and 15 mg/kg DM*. Copper is a component of redox systems (e.g., photosynthesis).

Boron (**B**) is contained in the mineral tourmaline, in mica, and is often precipitated as a secondary mineral (common **levels** in **soil** *5 to 100 mg/kg*). The contents in **plants** are between *2 and 100 mg/kg DM*. Boron supports the displacement of assimilates and is responsible for the formation of certain RNA sequences.

Molybdenum (**Mo**) is present in silicates such as olivines and iron oxides, and it often precipitates after weathering (common **levels** in **soil** *0.5 to 5 mg/kg*). The contents in **plants** range from *0.2 to 3 mg/kg DM*. Molybdenum is a component of enzymes (nitrate reductase, nitrogenase, and phosphatase).

Silicon (**Si**) is the main component of many soils (30%), but very immobile. The **content** in **plants** is high (*1,000 to 10,000 mg/kg DM*) and is roughly equivalent to the phosphorus content. Silicon strengthens the cell walls and the supporting tissue, promotes vitality and strengthens the defense against harmful organisms.

Cobalt (**Co**) is strongly related to the iron content. **Common levels** in **soil** are *1 to 10 mg/kg*. Cobalt is not essential for plant nutrition but is absolutely necessary for all bacteria and animals as well as humans (vitamin B12). The **contents** in **plants** are between *0.03 and 0.3 mg/kg DM*.

Table 9: Trace elements in different pools of the soil, Antenne

Element	Plant-available kg/ha	Reserve kg/ha	Recommended supply via soil* kg/ha
Fe	2,6	6600	none
Mn	2,34	430	none
Cu	0,24	15,0	none
Zn	1,96	20,0	none
Mo	0,02	0,00	0.05
B	0,16	0,00	0.29
Si	22,0	1570	none
Co	0,002	3,3	0.01

*) Difference in plant requirements throughout the entire vegetation period at the moment of sampling.

Attention: Surplus of Mn, Zn!

➔ In order to **optimise** and **ensure** the provision of **trace elements** as well as to compensate for plant uptake, the regular supply of substances via the soil is recommended. These inputs should contain many micronutrients (not in water-soluble form) and should supplement the soil solution if necessary (cobalt and molybdenum are particularly important for soil life).

➔To **ensure** the optimal nutrition of the standing crops, **foliar fertilizers** could be supplemented. No individual nutrients should be applied, but rather products that contain many micronutrients in low concentrations and optimal proportions.

Toxic elements

The water-soluble aluminium (**Al**) content can endanger adjacent systems (e.g., water bodies). Al in the soil solution can severely affect the plant uptake of phosphorus (P), calcium (**Ca**) and magnesium (**Mg**) and can therefore be the cause of visible P, Ca and Mg deficiency symptoms.

➔ **Dissolved aluminium** indicates the decay of valuable clay particles and thus the loss of soil fertility. Through the targeted neutralisation of acids (see section “amelioration”), further soil degradation is inhibited, and regenerative processes are initiated.

With best regards

Univ.Lek. DI. Hans Unterfrauner

Note: The interpretation and the recommended measures refer to the received soil sample. No liability is assumed for the accuracy of the sampling and the quality of the soil sample.