2.2 Soil

■ **Approximately half of all the forest soil in Switzerland is either not acid or only slightly acid. One third is highly acid, and 5% of the soil is even extremely acid.**

■ **About one third of the forest soils in Switzerland contain in at least one soil layer a concentration of aluminium that can endanger the growth of plant roots.**

Acid soils

Plants find important nutrients such as nitrogen and phosphorous in humus. Additional nutrients for plants are made available in the soil through physical processes: forest soils are dotted with negative particles (anions) on which positively charged particles (cations) can dock. These docking points are also called "ion-exchange sites", and, in the ideal situation, are filled with nutrient cations such as calcium, magnesium, or potassium. Nutrient cations are also called "base cations" or "bases". The more nutrient cations docked at the ion-exchange sites, the higher the base saturation and, accordingly, the better supplied with nutrients the soil. In acid soil, on the other hand, other cations that are worthless or even harmful for plants take over the ion-exchange sites. These cations may be, for example, positively charged hydrogen particles (protons) or poisonous aluminium released from otherwise harmless compounds by acid rain or by acids from natural processes. Aluminium cations displace nutrient cations from their ion-exchange sites because they adhere more strongly to the ion-exchange sites (stronger conversion energy). As a result of the displacement the nutrients can no longer cling to the soil and are washed out. The base saturation decreases, and with it, the nutrient concentration in the soil.

Soil quality can be measured on the basis of base saturation, but determining this is difficult. Therefore, researchers at Swiss Federal Research Institute WSL take the pH value of the soil as an indicator of its quality, because pH values and base saturation are related. The lower the pH value, the more acid the soil and, as a rule, the lower the base saturation as well. At WSL the pH values of 258 soils were ex-

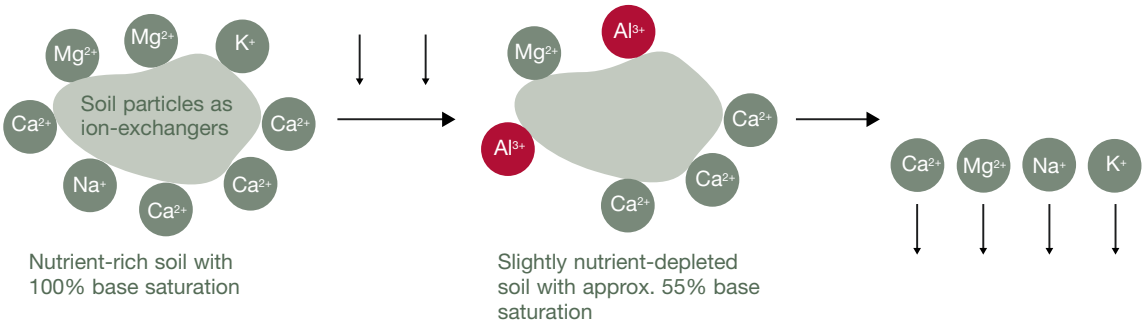
2.2.1 Soil particles as ion-exchangers

Acids dissolve aluminium bonds in the soil. The released aluminium cations (Al^{3+}) displace the nutrient cations (Ca^{2+}, Na^{+}, Mg^{2+}, K^{+}) in the soil particles. The free nutrient cations are washed out and are then no longer available for the roots.

1. Acid deposition (e.g. via acid rain) dissolves aluminium bonds and releases Al^{3+}. Soil particles as exchangers.

2. Al^{3+} cations displace nutrient cations in the soil particle.

3. Nutrients are then washed out (see main text for further explanation).



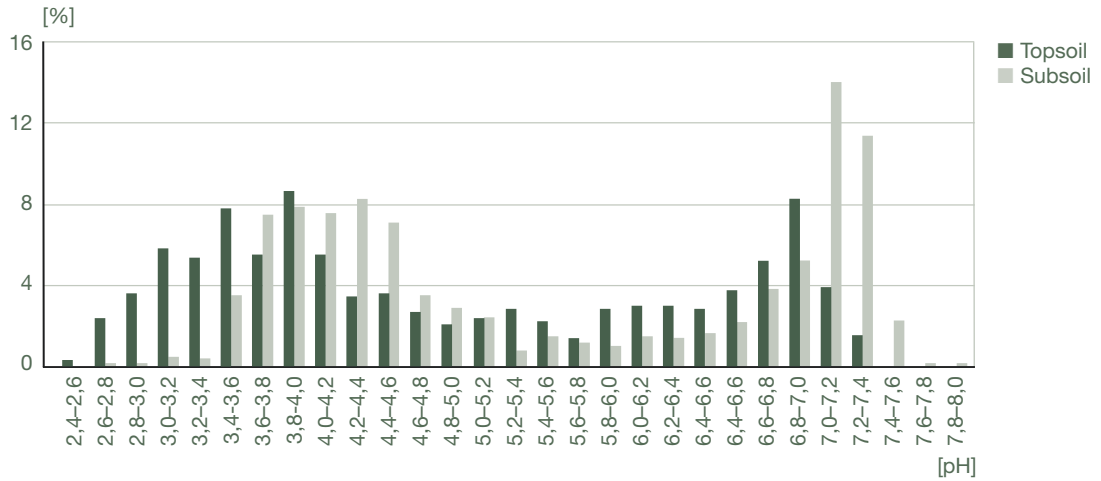
Nutrient-rich soil with 100% base saturation

Slightly nutrient-depleted soil with approx. 55% base saturation

Legend:
Al^{3+} aluminium cation
Ca^{2+} calcium cation
Na^{+} sodium cation
Mg^{2+} magnesium cation
K^{+} potassium cation

2.2.2 pH values of forest soil

Frequency distribution of pH values in the soil samples from the topsoil and subsoil. The topsoil generally has a higher pH value than the subsoil.



amined. This is a representative selection of almost every kind of forest soil there is in Switzerland. The researchers measured the pH- values at various depths and found that, as a rule, the topsoil had lower pH values, and is more acid than the subsoil. Experts also noticed regional differences. The spectrum ranges from base saturated, nutrient-rich soils with a pH value of 7.5 to very acid soils with values that are even lower than 3.

In acid soil cations that are worthless or even harmful for plants take over the ion-exchange sites. These cations may be, for example, positively charged hydrogen particles (protons) or poisonous aluminium released from otherwise harmless compounds by acid rain.

Base saturation

Soils with pH values over 5.5 are almost completely base saturated. As the pH values decrease, however, base saturation declines rapidly. Slightly fewer than half the forest soils studied are basic to slightly acid. One third are highly acid and 5% of the soils are even extremely acid. In the highly acid and extremely acid soils the average base saturation of the fine earth is less than half as high as in slightly acid or basic soils. However, even in highly acid soils it is still 40% on average.

Research at WSL has also shown that acid soils on calcareous rock are significantly richer in bases and thus richer in nutrients than similar acid soils on siliceous rock. This shows that it is not the pH value alone that determines base saturation. The difference in base saturation between calcareous and other soils can be as much as 60%. This is because the lime dissolved in water neutralizes acids and thus protects the soil.

2.2.3 Soil profile

Soil profile in a pine-mixed forest in Canton Valais. The topsoil is rich in humus and very dark in colour. Below it is a brown subsoil (weathering horizon) with a lime border 40 centimetres deep. The floor is a calcareous bedrock.

2.2.4 Classification of soil acidity

Definition, frequency and mean base saturation of the individual categories.

Category (n=258)	*pH value of soil horizon*	*Mean base saturation %*	*Frequency %*
alkaline	pH value of all soil horizons over 7	100	12
slightly acid	pH value of soil horizons between 4.6 and 7	99	33
moderately acid	pH value of fewer than half the soil horizons less than 4.6	70	18
highly acid	pH value of more than half the soil horizons less than 4.6, but fewer than half of them under 3.8	39	32
extremely acid	pH value of more than half the soil horizons less than 3.8	33	5

Research at WSL has also shown that acid soils on calcareous rock are significantly richer in bases and thus richer in nutrients than similar acid soils on siliceous rock. This shows that it is not the pH value alone that determines base saturation.

Plant growth

The ratio of the nutrients calcium, magnesium, and potassium to the toxic element aluminium influences plant growth. If this so-called BC/Al ratio in the soil solution falls below the value 1, i.e. if there is more aluminium than nutrients in the soil solution, sensitive plants like the beech, for example, can be harmed. Because the composition of the soil solution has been determined for only a few soils, WSL focuses on the BC/Al ratio on the cation-exchange sites. If the aluminium cations replace the nutrient cations on the ion-exchange sites, the ratio of nutrients to aluminium becomes unfavourable. A BC/Al ratio of less than 0.2 at the ion-exchange sites indicates that the aluminium concentration in the soil solution is at a level that can damage the roots of sensitive plants.

Researchers at WSL found no shortfall in the BC/Al values in most of the 258 soils taken for this purpose. In 83 soils, however, the value in at least one of the soil layers was too low; in 7 soils the value was even too low throughout all layers. If the BC/Al value declines, then so too does the base saturation and thus the concentration of nutrients. If the BC/Al ratio in all the layers of soil is more than 0.2, then the base saturation is on average higher than 90%. In soils with an unfavourable ratio between nutrient cations and aluminium, on the other hand, the base saturation may sink to around 5%.

FURTHER INFORMATION

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