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Nutrient Supply in the Soil

Soils highly loaded with nutrients—particularly nitrogen, phosphorus, and potassium compounds—generally result in a decline in plant diversity. Due to their ability to benefit from an overly rich nutrient supply, a small number of species will grow rapidly, displacing weak competitors that prefer soils poor in nutrients.

As E6 indicator results show, changes in soil nutrient supply take place very slowly. This comes as no surprise, since vegetation tends to be rather sluggish in adapting. However, there is one exception: Within 14 years, the mean nutrient value of forest soils in the colline zone has been increasing slightly, but significantly.

Assessing nutrient values from a biodiversity point of view, any increase is harmful and any decline helpful.

Status: December 2015

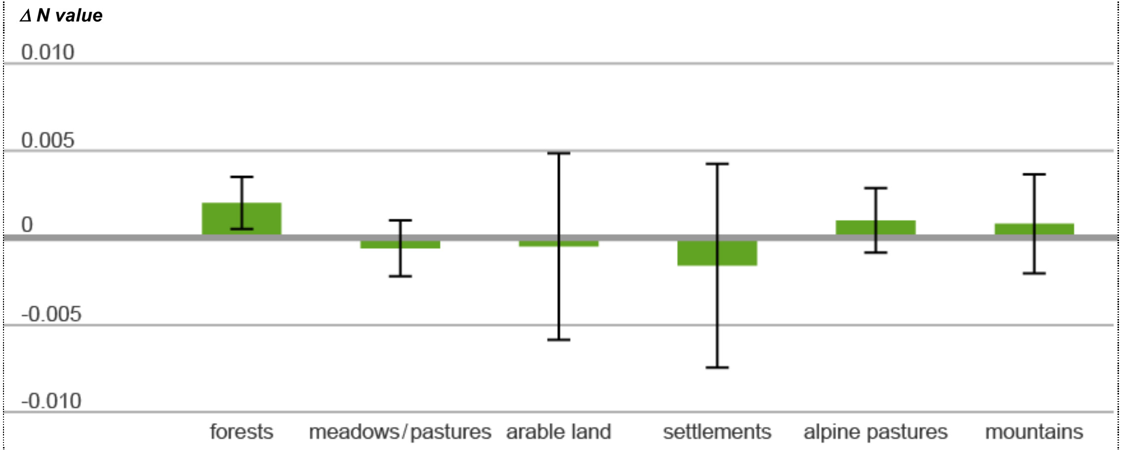
Contents

Development in Switzerland

Figure 1 below illustrates changes in mean nutrient values of various soil types subjected to different forms of land use in the past 14 years (arithmetic mean with a 95% confidence interval, based on sampling areas of 10 square meters each). “Mountains” represent areas not used for alpine farming (such as scree plant communities, turf, and dwarf shrub heath) excluding glaciers and inaccessible rocks.

Fig. 1: Mean soil nutrient values

Annual changes of mean soil nutrient values in Switzerland by types of land use between 2001 and 2014



Comments

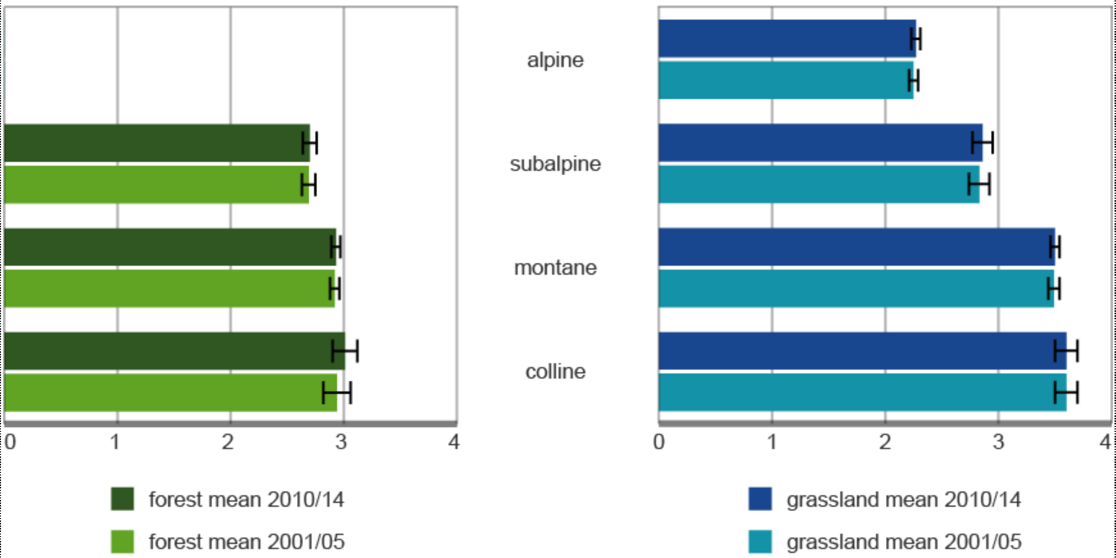
- Unsurprisingly—given the rather slow adaptation rate displayed by vegetation—, mean soil nutrient values have hardly changed at all within the period under observation. The only exception was found in forest soils, where the mean nutrient value has been increasing slightly, but significantly in the past 14 years.
- At a mean nutrient value of 3.84 ± 0.04, soils of arable land are richest in nutrients, followed by settlements. Areas under extensive or no land use at all, such as alpine pastures or mountain regions, are poorer in nutrients (2.2 ± 0.06).
- For complete data tables and complementary information, please refer to Appendix 1.

Comparison by altitudinal zones

Figure 2 below illustrates mean soil nutrient values (with a 95% confidence interval) of forests and grassland (meadows/pastures and alpine pastures) registered in different altitudinal zones.

Fig. 2: Mean soil nutrient values of forests and grassland by altitudinal zones

Mean soil nutrient values (with a 95% confidence interval) of forests and grassland (meadows/pastures and alpine pastures) in different altitudinal zones in 2001/05 and 2010/14



© BDM (E6 indicator). Analysis of plants surveyed for BDM indicator "Species Diversity in Habitats (Z9)". Status: December 2015

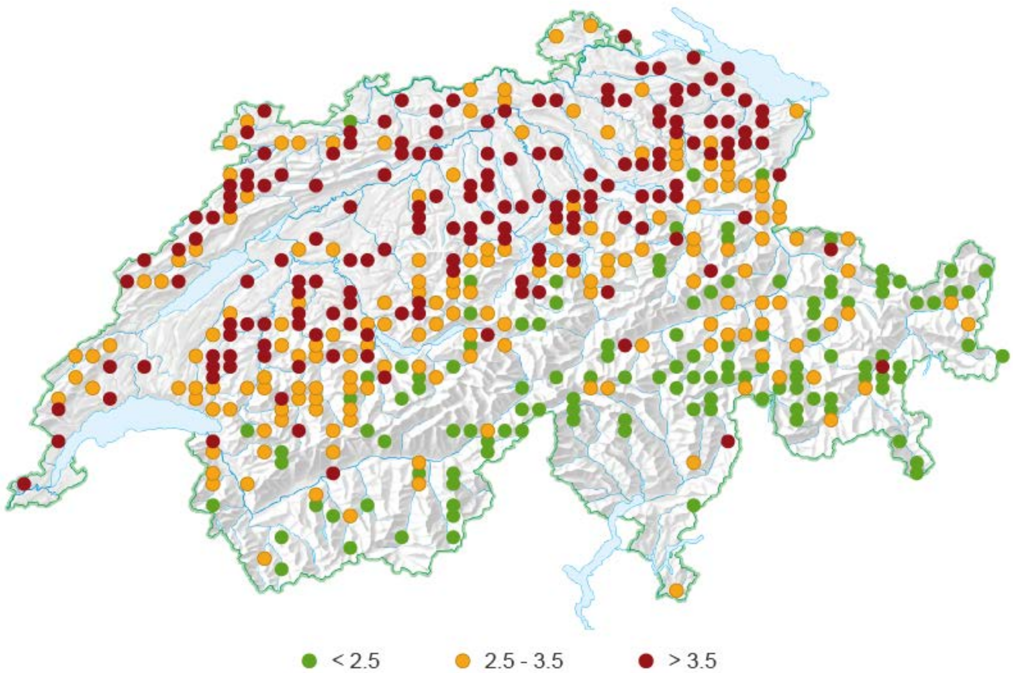
Comments

- On average, alpine and subalpine soils are poorer in nutrients than colline and montane soils.
- Mean soil nutrient values have hardly changed at all within the period under observation. The only exception was found in colline forest soils, where the mean nutrient value has been increasing slightly, but significantly in the past 14 years. This development has been caused by poorness indicator plants disappearing, increasingly being replaced by species indicative of richer soils. As light conditions did not change, more intense thinning may be excluded as a possible cause.

Figure 3 below illustrates the distribution of soil nutrient values in Switzerland's grassland (meadows, pastures or alpine pastures, based on sampling areas of 10 square meters each).

Fig. 3: Mean soil nutrient values in grassland

Distribution of soil nutrient values in Switzerland's grassland (meadows, pastures or alpine pastures, based on sampling areas of 10 square meters each) in the 2010/14 surveying period



Comments

- The mean nutrient value of colline meadows/pastures varies between 3.5 and 3.7, compared to subalpine meadows/pastures with a mean nutrient value of 2.8 to 2.9.
- On average, alpine and subalpine soils are poorer in nutrients than colline and montane soils. However, almost exclusively located in those same colline and montane zones, agricultural areas generally have a higher nutrient supply due to fertilization. Meadows in the Prealps reach astonishingly high nutrient values as well.
- Soils at high altitudes predominantly hold only a very thin humus layer or lack a humus layer altogether. Due to their steep inclination, erosion hampers the formation of the nutrient-rich humus layer. Soils at lower altitudes tend to be more level and thus less prone to erosion, favoring humus buildup and a higher nutrient supply.
- Altitudinal categorization applied by this indicator is based on *Wärmegliederung der Schweiz* (Schreiber et al., only available in German). For the purposes of BDM analysis, categories used in that publication have been condensed into four altitudinal zones: colline, montane, subalpine, and alpine

Additional findings

Airborne nitrogen deposition

Nitrogen not only enters the soil by way of active fertilization of agricultural land, but also by way of air pollution. Nitrogen air pollutants such as nitrogen oxides (NO_X) produced by combustion processes or ammonia (NH_3) from agricultural sources are transported by air over both short and extended distances. Wherever they end up being deposited, they may contribute to soils, groundwater and surface waterbodies being acidified and overfertilized.

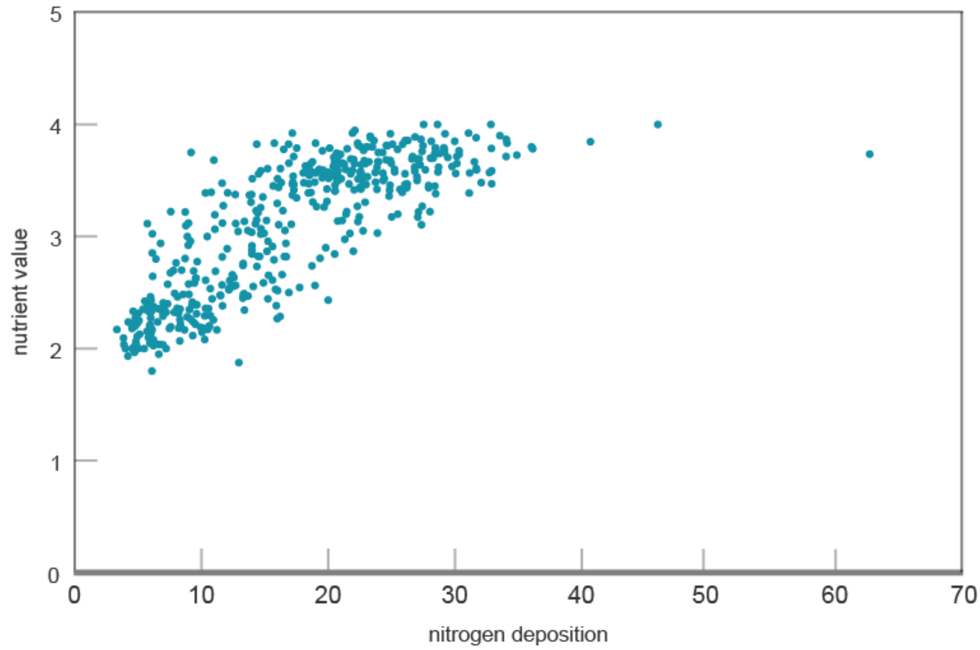
In 2005, roughly 80,000 tons of nitrogen were released into the air above Switzerland. Of that total amount, 65% originated in agriculture, 22% in traffic, 10% in industry, and 3% in private households. Meteotest, a specialized Swiss company, modeled variations in airborne nitrogen deposition in the country’s soils depending on location. On average, the mean airborne nitrogen deposition was computed to reach 19 kilograms per hectare each year, with numbers decreasing as the altitude increases. In sampling areas surveyed for the Z9 indicator “Species Diversity in Habitats”, values vary between 3 and 63 kilograms of nitrogen per hectare.

Using this data, Roth et al. (2013) investigated a possible correlation between nitrogen deposition and species diversity. The study found that, for example, plant species diversity in normally species-rich mountain meadows is low whenever they are affected by high nitrogen entries. At the same time, the share of plants able to make better use of nitrogen increases. As other site factors known to impact plant species diversity were cancelled out of calculation, they are not apt to provide an explanation for this development.

Applying the same method, BDM verified whether there is a connection between nitrogen deposition and nutrient supply in the soil. Regarding grassland, there is a striking match between the amount of airborne nitrogen being deposited and the nutrient values recorded (fig. 4).

Fig. 4: Airborne nitrogen deposition and mean nutrient values

Connection between airborne nitrogen deposition (in kilograms per hectare and year) and mean nutrient values in grassland



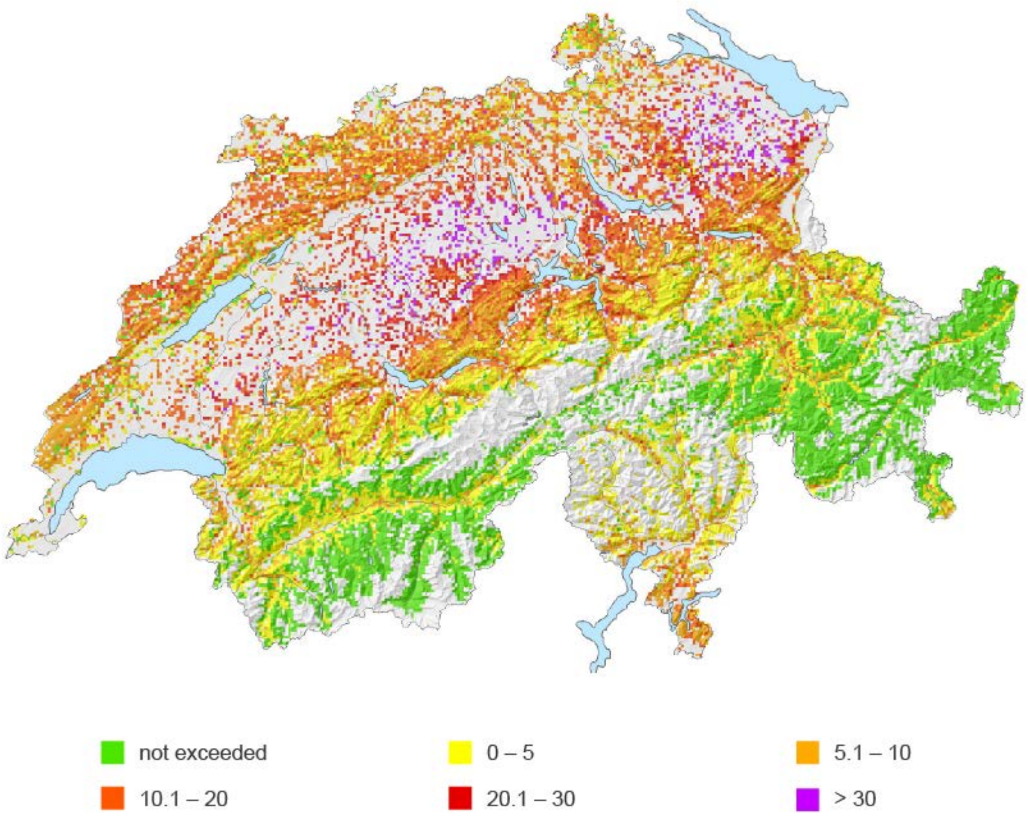
Comment

- In grassland, nutrient supplies in the soil grow with increasing airborne nitrogen deposition, suggesting that there might be a connection between nitrogen deposition and nutrient supply. However, since both airborne nitrogen deposition and nutrient values decline with increasing altitude, this seeming connection might exclusively be caused by an altitude effect. Yet even when this altitude effect and other site factors impacting plant species diversity are cancelled out of available data, results still evidence a significant connection between airborne nitrogen deposition and nutrient supply.

Stipulated by the Convention on Long-range Transboundary Air Pollution—the observance of which is monitored by the United Nations Economic Commission for Europe UNECE—, critical loads are defined as follows: “Quantitative estimates of nitrogen entries (in the form of NH_Y and/or NO_X) below which, according to current knowledge, there will be no detrimental effects exerted on an ecosystem’s function and structure.”

Fig. 5: Exceedance of critical loads

Exceedance of critical loads caused by nitrogen deposition in near-natural ecosystems and forests (in kilograms per hectare and year)



Comments

- Critical loads above which species compositions of habitats may change are exceeded in a large number of Swiss regions.
- Airborne nitrogen deposition causes critical loads to be exceeded in all raised bogs, 95% of forests, 84% of fens and 42% of species-rich meadows and pastures.

Nitrogen balance in agriculture

The nitrogen balance of agricultural areas is based on the difference between the amount of nitrogen added to the soil by fertilization (nitrogen input) and the amount of nitrogen extracted from the soil by agricultural products such as cereals or grass (nitrogen output). Both Swiss authorities and the Organization for Economic Cooperation and Development OECD use the nitrogen balance as an indicator for sustainability in agriculture. Lowered by 15% since 1990, nitrogen excess in agriculture has been stagnating since 2000. In 2011, Switzerland overall totaled a nitrogen excess of roughly 113,000 tons, which corresponds to 108 kilograms of nitrogen per hectare of agricultural land.

Significance for biodiversity

While nitrogen is vital for all plant survival, plant diversity starts to dwindle once the nitrogen level in the soil gets too high. An excess supply of other important nutrients such as phosphorus and potassium has a similar effect.

Plants are constantly competing for growth factors such as light, water, space or nutrients. When these factors change, so do the plant species that prevail. Given enough nutrients, a chosen few plants will grow particularly fast, displacing other species unable to make similar good use of such rich supplies. For this reason, fat soils support a smaller number of plant species than substrates poor in nutrients. Wherever the number of plant species is low, small animal and insect diversity is reduced as well. For example, meadows featuring a wide variety of plants attract a much larger number of butterflies than monotonous park areas. Consequently, increasing the soil's nutrient supply is harmful from a biodiversity point of view.

Aside from active fertilization due to agricultural land use, industrial and traffic sources also contribute to boosting soil nutrient supply. Airborne nitrogen reaches near-natural, nutrient-poor ecosystems such as forests, raised bogs and fens or dry meadows and pastures as well, triggering fertilization and acidification effects even there. During the past century, growing industrialization and intensified agricultural use have caused a massive increase in soil nutrient supply throughout Europe.

In some forest areas, for example, there are up to 50 kilograms of nitrogen per hectare being deposited each year, three times as much as fifty years ago. Deposits of 10 to 20 kilograms are already considered to be critical, since increasing nitrogen fertilization acidifies soils. Acidified soils, however, diminish the ability of plant roots to develop deterrents against noxious fungi. Furthermore, they lower the number of earthworms that are important for soil formation.

Definition

Changes in mean nutrient indicator values of vascular plants occurring on sampling areas of ten square meters. The E6 indicator uses nutrient indicator values as determined by Landolt et al. (2010). These values express plant preference for low or high nutrient supply in the soil. On a scale from 1 to 5, high values signify soils rich in nutrients, while low values stand for soils poor in nutrients:

1) very infertile, extremely poor

2) infertile

3) medium infertile to medium fertile

4) fertile

5) very fertile to excessively fertilized

Surveying methods

The Z9 indicator "Species Diversity in Habitats" surveys plant species composition in roughly 1500 sampling areas of ten square meters each. Nutrient indicator values of all vascular plant species found in a sampling area (excluding unidentified species and collective species) are averaged (arithmetic mean). Analysis by altitudinal zones is based on the thermal zones of Switzerland established by Schreiber et al. (1997).

Further information

In charge of this indicator

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Related indicators

> E7: "Intensity of Agricultural Land Use"

Additional sources of information

> Federal Office for the Environment FOEN http://www.bafu.admin.ch/index.html?lang=en

> Magazin «umwelt» 2/2014 - Stickstoff – Segen und Problem (not available in English): http://www.bafu.admin.ch/dokumentation/umwelt/13233/index.html?lang=de

> Research on the nitrogen load of forests: http://www.iap.ch/english/english.html

> Co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe: http://www.emep.int

> Statistical data on the nutrient balance of agricultural land (no information in English) http://www.bfs.admin.ch

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This information is based on the German-language document 1360_E6_Basisdaten_2015_v1.docx dated May 26, 2016.