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Nitrogen and phosphorus: nutrients or pollutants?

The nitrogen and phosphorus balances of Swiss agriculture

Nitrogen (N) and phosphorus (P) are two of the main nutrients of plants. Fertilisers provide agricultural crops with nutrients. If more nitrogen or phosphorus fertilisers are used than the plants can absorb, they find their way into the environment and become potential pollutants. Today fertilisers are used more efficiently and are more targeted to plants' needs than 15 to 20 years ago. Despite improvements, however, the balance is not even. In 2012, the balance showed an average annual surplus of still 57 kg of nitrogen per hectare of agricultural area (including summer pastures). The phosphorus surplus was 2 kg per hectare.

Vital nutrients

Nitrogen is a natural element: it is found in water, in the soil and in the air which is composed of roughly 78% nitrogen. It is essential to all living things: humans, animals and plants contain nitrogen, in particular as a component of proteins and of DNA. Elements and compounds of nitrogen are found in nature in gaseous or water soluble form or bound in organic substances.

Phosphorus is also important to all forms of life. As a component of the carrier for genetic information, it is responsible for the structure of organisms. It also plays an important role in the function and energy supply of cells. Phosphorus exists in nature in the form of organic or inorganic compounds. Inorganic phosphorus fertiliser is obtained from raw phosphates. The natural deposits are running out.

Nitrogen and phosphorus balances of agricultural area, 2012 **F 1**

In thousands of tonnes

Input	Nitrogen	Phosphorus
Manure	130	22
Inorganic and organic fertilisers (without manure)	52	6
Biological fixation by leguminous crops	34	–
Atmospheric deposition	27	…[1]
Seeds and planting material	1	0

→ Agricultural areas, stocks →

Output	Nitrogen	Phosphorus
Uptake of forage crops (temporary and permanent meadows, pastures, green maize)	131	20
Uptake of other crops (arable crops including fodder grain; vegetables, fruit, wine and other special crops)	24	5
Surplus	88	3

[1] The lack of information makes the estimate of atmospheric deposition of phosphorus difficult. It should make for less than 500 t per year.

Source: FSO – Nitrogen and phosphorus balances

Balances of nutrient flows

Agricultural production consists of the life cycles of plants and animals for which the nutrients nitrogen and phosphorus are key. To a large extent, they determine the crop yield that can be attained. With fertilisers and concentrated feed, humans introduce additional nutrients into the natural cycle.

In order to portray such flows, a nitrogen and a phosphorus balance (F1) are calculated for the agricultural area (including summer pastures), which accounts for more than a third of the total surface area of Switzerland. The balance (for methodology see box page 4) compares the quantity of nitrogen/phosphorus available in the agricultural cycle (inputs, mainly manure and inorganic fertilisers) with the quantity of nitrogen/phosphorus which is absorbed by agriculture (output, mainly field crops and feed). A surplus implies potential environmental pollution, whereas a deficit indicates possible problems with regard to sustainable agricultural production.

Nitrogen and phosphorus input

Nitrogen and phosphorus find their way into manure through animal excrement and are thus spread onto agricultural areas. In Switzerland farmyard manure makes the greatest contribution to the nitrogen and phosphorus input. In 2012, 71% of fertiliser nitrogen came from manure (G1), for phosphorus fertilisers this figure was 78% (G2). This means that the input was predominantly influenced by the number of livestock. Cattle were responsible for 78% of nitrogen and for 72% of the phosphorus input, whereas pig farming accounted for 11% of the nitrogen and 16% of the phosphorus. The input of nitrogen through manure fell by 10% between 1990 and 2012, that of phosphorus by 12%. In contrast, the number of cattle as main polluters declined by 16% over the same period. The fact that the decline in nitrogen from manure was weaker than the decline in the number of animals can be explained by an increase in the quantities of nutrients in the excrement of high-performance livestock.

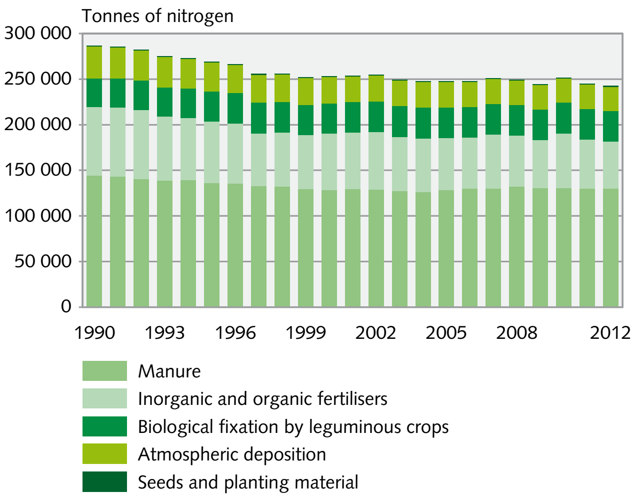
Provided that cattle consume only domestic feed, the nitrogen and phosphorus in the manure will be returned to the soil and are not new in the system. But if the cattle are fed with imported fodder, the nutrients from the country of origin will be transferred to Switzerland and the quantity of nutrients in the system increases. Between 1990 and 2011, the amount of imported feed increased almost fourfold.

Furthermore, nitrogen and phosphorus are also added to the soil in the form of organic or mineral fertilisers. Additional nutrients find their way into the system via inorganic fertilisers. In 2012, 25% of the fertiliser nitrogen input and 17% of the fertiliser phosphorus input came from inorganic fertilisers. Even so, since 1990 the use of inorganic fertilisers has fallen by a third. The decline was particularly strong in the 1990s, which can be attributed to cutbacks in federal market support measures and the introduction of direct payments. For the first time, these were bound by ecological restrictions (proof of ecological performance). Improvements in technology and a reduction in crop cultivation also played a role. Since 1997, the use of inorganic fertilisers has stagnated at a similar level. The use of inorganic phosphorus fertiliser saw an even greater decrease and declined in the same period by 70%.

In 2012, 3% of the fertiliser nitrogen input and 5% of the fertiliser phosphorus input came from organic fertilisers (such as compost). Sewage sludge was also used but was banned from 2003 (with a transitional period until 2008). This resulted in a 3000 tonne decrease in the nitrogen input and an approx. 2000 tonne decrease in the phosphorus input.

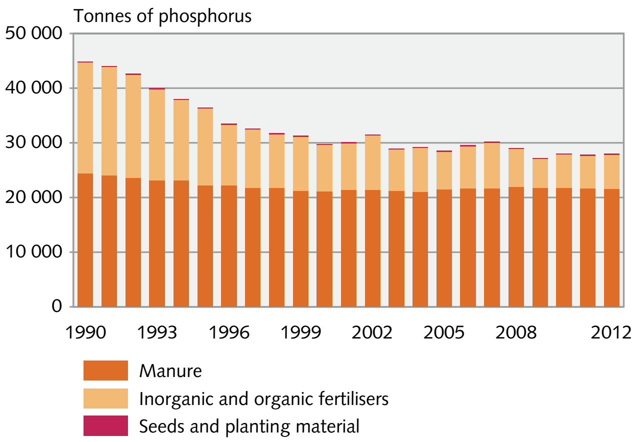
Through the process of nitrogen fixation – in which bacteria of leguminous crops bond atmospheric nitrogen, 34,000 tonnes of nitrogen were added to the agricultural soil in 2012. 27,000 tonnes of nitrogen entered the soil via atmospheric deposition. Seeds and planting material also contain nitrogen and phosphorus which enter the soil (900 and 200 tonnes).

Nitrogen input **G 1**



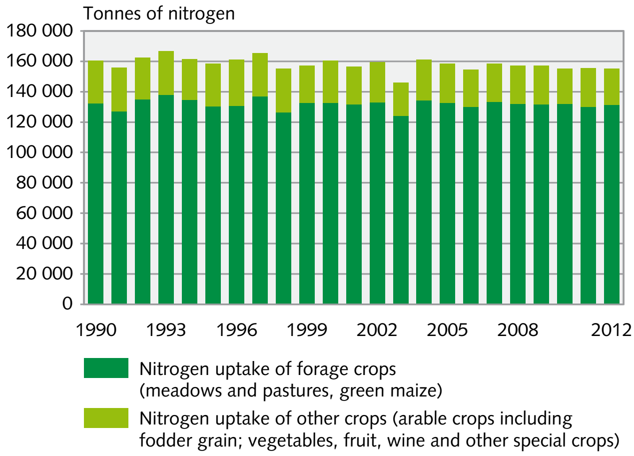
Source: FSO – Nitrogen balance

Phosphorus input **G 2**



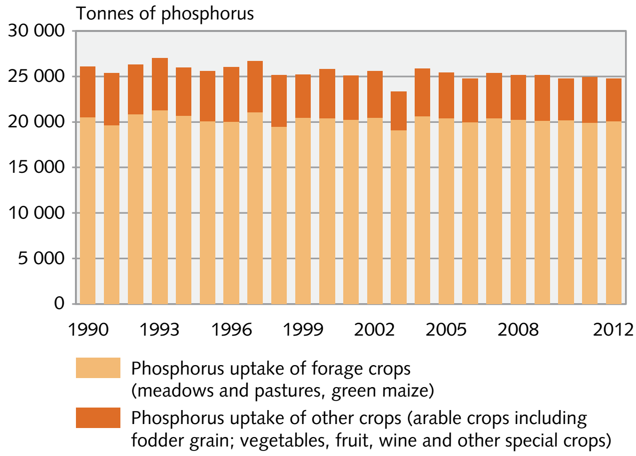
Source: FSO – Phosphorus balance

Nitrogen output **G 3**



Source: FSO – Nitrogen balance © FSO, Neuchâtel 2014

Phosphorus output **G 4**



Source: FSO – Phosphorus balance © FSO, Neuchâtel 2014

Nitrogen and phosphorus output

Agricultural crops obtain the nitrogen and phosphorus they need from nutrients naturally available in the soil and from inputs (fertilisers, biological fixation and atmospheric deposition) and convert these into plant biomass. But only part of the nitrogen and phosphorus fertiliser is utilised this way: depending on the crop production yield which is also dependent on other conditions of growth such as the weather, varying quantities of nutrients are extracted from the soil.

Nitrogen (85%) and phosphorus (81%) were used most on areas of grassland (G3 and G4), this means on meadows and pastures including summer pastures, which makes up the main land use in Swiss agriculture.

In other crop production, cereals absorb the most nitrogen and phosphorus due to their large cultivated areas throughout Switzerland. In the case of nitrogen, its uptake made up two thirds, whereas root crops (potatoes, sugar beets) and other crops together absorbed the remaining third. The year of extreme drought in 2003 resulted in a lower crop yield and both nitrogen and phosphorus uptake were therefore considerably lower than otherwise.

The uptake of nutrients through forage crops, meadows and pastures between 1990 and 2012 remained at a similar level apart from annual fluctuations. Uptake through other crop production fell by 15%, in particular following a reduction of the area under cereals.

Nitrogen and phosphorus surpluses

The nitrogen surplus was able to be reduced in the 1990s (G5) which can be attributed to a decrease in nitrogen quantities from manure and a less use of inorganic fertilisers. Since the mid 1990s, this surplus has been kept under 110,000 tonnes per year. From 1990 to 2012, this surplus was able to be reduced from 78 kg to 57 kg per hectare agricultural area (including summer pastures). Consequently, the efficiency, i.e. the output compared with the input, also increased.

In the case of phosphorus, the surplus in 2012 was around 3200 tonnes or 2 kg per hectare, compared with 12 kg per hectare in 1990. The decrease was particularly noticeable in the 1990s (G6) and an improvement in efficiency was also possible here.

The main reason for these efficiency increases were efforts by farmers to measure the nutrient requirements of the crops using soil samples and taking into consideration the actual growth phase. The inorganic nitrogen and phosphorus fertilisation was thus able to be adapted and costs saved. Reducing nitrogen and phosphorus surpluses has a positive effect on the environment. Nonetheless, on average, Swiss agricultural soil is still oversupplied with nutrients, mainly nitrogen.

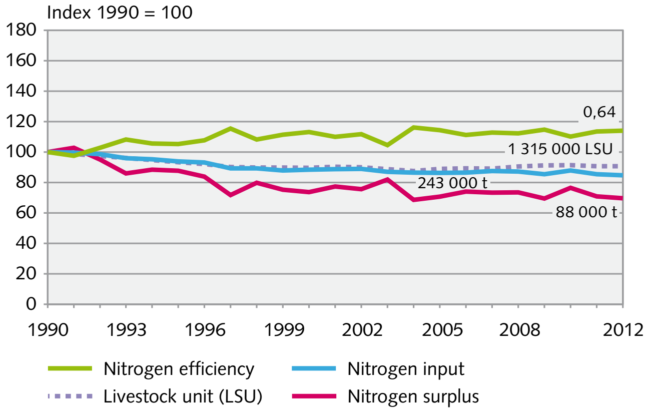
Why can nitrogen be a pollutant for the environment?

Surplus nitrogen which contaminates the environment can result in water and air pollution and may have a negative impact on ecosystems. Nitrate (NO_3^-) can contaminate surface and groundwater and contribute to the over-fertilisation of larger surface waters. The release of ammonia (NH_3) and nitric oxides (NO_x) into the air causes smog, acidification of soil and eutrophication. Nitrous oxide (N_2O) is a greenhouse gas and contributes to the depletion of the ozone layer in the stratosphere. If nitrogen is added to sensitive ecosystems such as swamps or forests (mostly via the air), these ecosystems can react adversely. In particular, biological diversity decreases. Despite efforts to reduce the nitrogen surplus, nitrate concentrations in the groundwater of agricultural areas and emissions into the air are still too high.

Why can phosphorus be a pollutant for the environment?

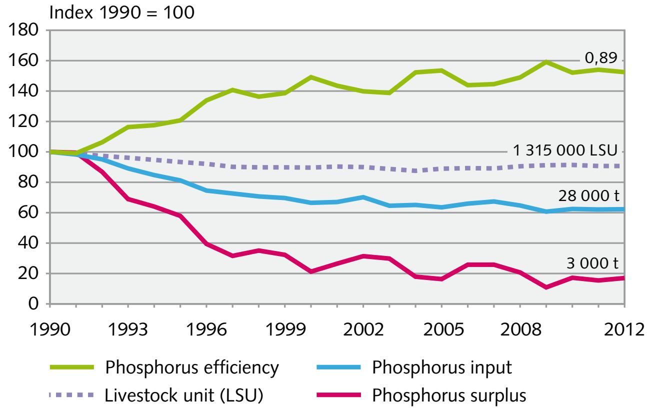
Phosphorus is not a problem for the environment as long as it remains bound to the soil. However, the greater the phosphorus content, the greater the risk that phosphorus will find its way into surface waters and other ecologically sensitive habitats. Phosphorus encourages the growth of algae and plants in surface waters creating a lack of oxygen. If too much phosphorus finds its way into sensitive habitats such as swamps or dry meadows, plant communities change. Natural rock phosphates may contain heavy metals such as cadmium which, via inorganic fertilisers, can find their way into soils. The concentration of phosphorus in Swiss surface waters has already been considerably reduced thanks to waste water treatment plants, the banning of phosphorus in fabric detergents and the decreased use of phosphorus in agriculture.

Nitrogen balance G 5



Source: FSO – Nitrogen balance © FSO, Neuchâtel 2014

Phosphorus balance G 6



Source: FSO – Phosphorus balance © FSO, Neuchâtel 2014

Nitrogen input in the soil, air and surface waters

Of a total of 90,000 tonnes of surplus nitrogen on average due to agricultural activities, around 55,000 tonnes per annum found its way into the air in the form of ammonia, nitric oxides and nitrous oxide according to estimates by the Federal Office for the Environment (average from the last 5 years). These emissions are produced during the application of manure and inorganic fertilisers in the stables or through farmyard manure stocks. The remaining nitrogen, approx. 35,000 tonnes, may be stored in the soil or leached into surface waters. This can cause further environmental damage (see box on page 3).

Methodology

The methodology used in this study to calculate the nitrogen and phosphorus balance was developed by the OECD (Organisation for Economic Cooperation and Development) and Eurostat (Statistical Office of the European Union). The FSO has calculated the balance for Switzerland since the end of the 1990s. It is based on the land budget approach which represents an estimate of all incoming and outgoing nutrient flows (see also F1). The surplus between a system's inputs and outputs covers all possible losses (in the air, water, soil) and the changes in stocks (mainly in the soil). The basic data originate from various sources (for example, from the farm structure survey and crop production statistics).
The Federal Office for the Environment calculates data in the area of the Swiss greenhouse gas inventory pursuant to the Kyoto Protocol (for N_2O) and the inventory of noxious gases pursuant to the Convention on Longrange Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE) (for NH_3, NO_x). The basic data and the calculation coefficients used to estimate the nutrient quantities for these calculations and for the nitrogen and phosphorus balances in this study are coherent. The nitrogen and phosphorus balances contain all of the nutrient flows on utilised agricultural areas and summer pastures.
The data published here are also used for international comparisons. On the national level, the results from the nitrogen and phosphorus balances from Agroscope tend to be used in Switzerland instead pursuant to the "farm gate balance" approach. As these values for Switzerland as a whole are only considered for utilised agricultural areas but not for the summer pastures, the farm gate balance shows higher nitrogen and phosphorus surpluses per hectare than the FSO balances pursuant to the OECD method. Furthermore, the yield from meadows and pastures is particularly difficult to estimate, which can lead to some uncertainty in the results and differences between both methods.

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