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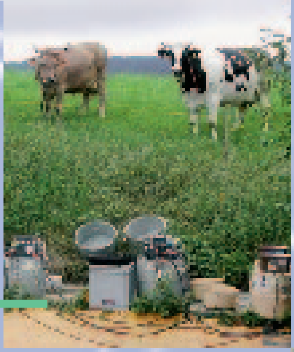
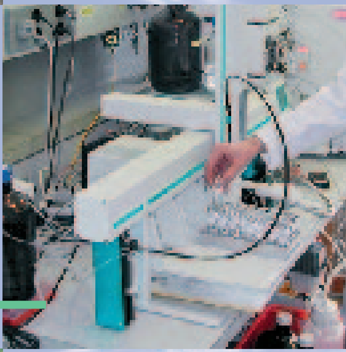
Agriculture and Water Quality





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In Brief

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Editorial

Water Protection and Agricultural Policy Sitting in the Same Boat

Stephan Müller, Head of the Water Protection Department, FOEFL (till April 2004 head of EAWAG's Water and Agriculture Department).

When we think about summer, we think about bathing in our lakes and rivers, swimming from one bank to the other, or navigating gently down the Rhine in a rubber dinghy. From Stein am Rhein to Schaffhausen, for instance – one of the most beautiful river landscapes in Europe. We pass railway bridges, dense forests, camping places and everywhere open, rural areas. Agriculture is one of the dominant uses of land in Switzerland – and its role in water protection is decisive.

Important measures in the agricultural field influencing the improvement of the water conditions were the linking of the direct payment schemes to the Proof for Ecological Performance (PEP), and the introduction of Article 62a in the Water Protection Ordinance, which created the basis for financing the remediation of contaminated water bodies. Although the European Union is currently developing its agricultural policies in a similar direction, these laws place Switzerland in the vanguard of water protection in Europe.

Now, after more than a decade, how is the agricultural policy faring? Most of the contributions in this edition of EAWAG news are in answer to this question. Good results have been achieved in the reduction of nitrate levels in groundwater. Since the mid-90s, impacts have been significantly reduced in two-thirds of the tested sites. Progress has also been made in an other classical problem area – the phosphate emissions to Swiss lakes. Some large lakes are still too heavily contaminated. In addition, the accumulation of phosphorus in soil due to excessive fertilization is a reality and will lead to increasing impacts in the lakes.

The management of the approximately 400 pesticides approved for use in Switzerland leaves much to be desired. The pesticide concentrations measured in small and medium-sized watercourses in many places exceed the legal limit of 0.1 µg/l, laid down by the Water Protection Ordinance, as well as scientifically determined quality values. Furthermore, the BUWAL groundwater monitoring program has detected traces of pesticides in 60 % of the ground water. A more consistent protection of surface waters and ground water is therefore absolutely essential.

In order to reduce the impacts on water bodies from agriculture further, the Direct Payments Ordinance and/or the provisions of the PEP must be adapted accordingly. The implementation of the WTO agreement means that market support funding will be replaced by direct payments, which provide the best mechanism for water quality protection. Recent evaluations developed on the basis of site-specific features demonstrate that this is possible without raising the economic burden.

Meanwhile, we arrive with our boat at the city of Schaffhausen. Does our water protection and agricultural policy journey end here? Or can we pass the Rhine Falls overland and use the time for effective and constructive discussion of the new Agricultural Policy 2011? Refreshed with new ideas on board, we can take to the water again below the Falls and swiftly solve the pressing problems.

Agrochemicals – How Dangerous are They for Lakes and Rivers?

Agriculture relies on large quantities of agrochemicals. Rain transfers at least a portion of these chemicals into lakes and rivers. Therefore, agriculture and water protection seem to be at odds. However, the state is making enormous efforts to improve the situation and is financing measures to prevent agrochemicals from reaching the waterbodies. The various articles contributing to this volume highlight how large the impacts are, whether the measures implemented actually work, and how the total package of measures may be advanced best to meet the future challenges.

Switzerland is no longer an agricultural country. This conclusion might be drawn in view of the gross national product acquired by the agricultural sector. Currently, it contributes just 0.8% to the total (Fig. 1). Does this mean that agriculture is no longer a subject for water protection?

The answer is a clear “No”, since agriculture is still one of the dominant land uses in Switzerland. Around 40% of the total precipitation flows through agricultural land (including alps). Large amounts of nutrients and other agrochemicals are used on this land, and a considerable proportion of these agrochemicals will be transported with the rain into surface and ground waters (see box). The quality of a majority of our water resources is therefore directly dependent on how well agricultural activities are managed (Fig. 1).

At the end of the 1980s, the problems resulting from the use of agrochemicals could no longer be overlooked: excessive concentrations of phosphorus in lakes, nitrate contamination of drinking water, and pesticide pollution of surface waters, are just the worst examples. The policymakers had to respond (see article by Conrad Widmer on p. 6). Since 1993, there has been a new orientation in Swiss agricultural policy. Direct payments by the state have encouraged production forms which are particularly benign for the environment and for animal welfare. Furthermore, since Article 62a was implemented into the Swiss Water Protection Ordinance in 1998, it has been possible to remediate contaminated waterbodies through regional projects with the help of financial incentives to farmers.

Optimizing Nutrient Cycles

Although the number of nutrients used in agriculture (see box) is relatively small, the applied quantities are large. This is particularly the case for nitrogen, phosphorus and potassium. Thousands of tonnes of these major nutrients are spread on Swiss agricultural land every year: in 1995 1.6×10^5 t nitrogen, 2.0×10^4 t phosphorus, and 5×10^4 t potassium [2]. Nutrients are mainly applied onto the agricultural soils in the form of solid and liquid farm manure. Compared to the total nutrient cycle on the farms, additional commercial fertilizers and feeding stuff make up only a relatively small proportion: in 1995 these amounted to only 18% for potassium, 28% for nitrogen, and 42% for phosphorus. Ideally, there would be a nutrient cycle to which only nutrients assimilated by the harvested products are added in the form of fertilizer. Correspondingly, the nutrient cycles must be optimized, to minimize the impact of nutrients on waterbodies. The report by Werner Hediger on p. 27 investigates whether the nitrogen cycle has in fact been optimized by the new agricultural policy since the introduction of the direct payments scheme.

Minimizing Use and Losses of Auxiliary Agents

The situation is different for the auxiliary agents applied in agricultural production. Currently, around 400 pesticides and 1150 animal medicaments are licensed in Switzerland. Since these substances are biologically very active, the amounts used are quite small: around 35 t of veterinary antibiotics

Agrochemicals

Agrochemicals are all chemicals used in agriculture. These include nutrients and auxiliary agents. There are five main nutrients (nitrogen, phosphorus, potassium, sulphur, and magnesium) and about 10 micro elements (e.g. iron and cobalt). Auxiliary agents include mainly pesticides and veterinary pharmaceuticals, but also silage additives to extend the storage time of forage, substances acting as stalk shorteners, and lime to improve soil quality.

The application mode of the various auxiliary agents – and thus their input into the environment – differs greatly. Pesticides, for example, are sprayed directly onto the fields, whereas veterinary substances such as antibiotics arrive indirectly on the fields through animal excrements, e.g., liquid and solid farm manure.

In addition to the agrochemicals, other environmentally harmful substances can enter the environment through agricultural activities. Heavy metals, for instance, are such problematic substances. They are often contaminants of mineralized fertilizers, compost and sewage sludge. As sewage sludge, in addition, contains other harmful substances besides heavy metals, its use as fertilizer has been restrained in Switzerland since 2003, and will be totally banned as of 2006.

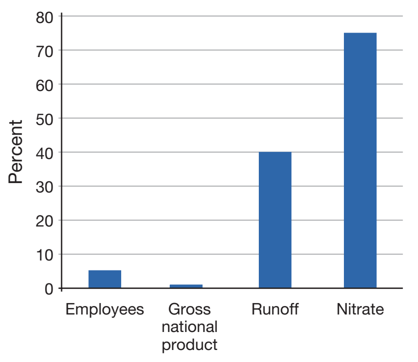

Fig. 1: Agricultural proportion of total employees, of the gross national product [1], as well as of the agricultural influence on runoff formation and on nitrate pollution of ground waters.

Photographs: EAWAG

Extraction of a soil sample.

(year 2001) and about 1.5×10^3 t of pesticides (2003) are sold annually in Switzerland. Auxiliary agents are used in one-off doses and there is no substance cycle. The problem is that most of the auxiliary agents do not just disappear from the environment; instead they are translocated and may reach surface and ground waters where they can have undesirable effects. For auxiliary agents, emphasis is therefore placed on measures minimizing both their usage and their loss to the environment. In his article on p. 16, Heinz Singer estimates whether the pesticide pollution of waterbodies was actually reduced by half as targeted by the Swiss policy.

Induced Impact

It is often forgotten that agricultural activities can also lead to water pollution that is not directly traceable to the external input of substances. This may be referred to as induced impact. A major induced impact is erosion, which carries soil particles into the water. Eroded soil particles may carry with them nutrients and auxiliary agricultural agents.

Agricultural operations may also cause another induced impact, the pollution with undesirable microorganisms. Microorganisms such as cryptosporidia and antibiotic resistant bacteria can enter the environment directly through the excrement of grazing animals, or indirectly through the application of excrements from housed animals. Whether *Cryptosporidium* species pathogenic to humans presents a hazard for drinking water, is the subject of the article by Hans Peter Füchslin on p. 9. Krispin Stoob (p. 12) examines the environmental fate of veterinary antibiotics, and whether the development and spread of antibiotic resistant bacteria is promoted by the use of antibiotics in agriculture.

Differing Input Dynamics of Agrochemicals

Surface and ground waters are contaminated by agrochemicals that are transported with the rain from the soil to the waterbodies. Due to their different input dynamics, we may broadly distinguish two groups of substances: in one group, the concentrations in small streams increase due to a runoff event (Fig. 2A), while in the other group a dilution effect is observed (Fig. 2B). Phosphorus, pesticides or microbial pollutants belong to the first group. High concentrations of these compounds are generally restricted to the upper soil layer. Only when they are removed by rapid transport processes with the rain (surface runoff, macropore flow), do higher concentration levels occur in the waterbody.

Nitrogen in the form of nitrate belongs to the second group. It does not sorb to the soil. Instead, it is dissolved in the soil pore water and thus continuously reaches surface and ground waters. If nitrate is applied in excess to crop needs and is not converted by microbial processes (denitrification), the nitrate concentration in the neighboring waterbodies is high. During rain events, the nitrate concentration can, therefore, be diluted. For an evaluation program, knowledge of the various runoff and input dynamics is essential, so that the appropriate timing for sampling can be properly established.

Most agrochemicals are retained by the soil through sorption, and will be biologically and chemically transformed during time. In this way, the soil acts as a highly efficient filtering system for the waterbodies. This is evident from the quantities of agrochemicals entering the waterbodies which are at most a few percent of the total quantities used (Fig. 3).

Discrepancy between Agriculture and Water Protection

The fact that agriculture comes into conflict with water protection – despite the relatively low emissions – is a consequence of the differing effect of the substances on agricultural and aquatic ecosystems. Concerning nutrients, agricultural ecosystems and waterbodies ideally should have a different trophic status. A high agricultural production is only achieved on nutrient-rich soils. Healthy aquatic ecosystems on the other hand should be nutrient-poor. This means that e.g. the phosphorus contents should be one to two orders of magnitude different: typical phosphorus concentrations of fertilized topsoil range between 300 and 1000 mg per m^3 pore water, whereas those of surface waters should not exceed 30 mg per m^3 water.

The underlying ideas concerning the use of auxiliary agents are completely different with regard to their respective effects on agricultural ecosystems and on waterbodies. Herbicides for example should completely remove weeds on fields. Corre-

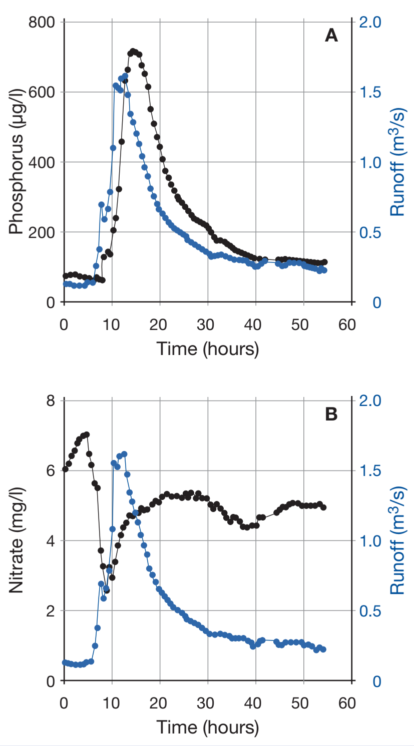

Fig. 2: Concentration dynamics of (A) phosphorus and (B) nitrate (black curves) and runoff (blue curves) during a rain event in a small agricultural catchment area (Kleine Aa at Lake Sempach in the canton of Lucerne) [3]. Pesticides, heavy metals and sediments usually show dynamics similar to phosphorus.

spondingly, this requires a high dosage. In contrast, the herbicide concentration in the water should be very low as to exclude the damage of aquatic organisms.

Evaluating Water Pollution

After decades of research, we are able to formulate scientifically-based quality targets (threshold values) for the nutrient pollution of waterbodies today. This is, however, not the case for other agrochemicals. The definition of scientifically-based quality targets for pesticides and pharmaceuticals is currently an important subject of research. This is mostly due to the fact that the two main nutrients, nitrogen and phosphorus, fulfill the same vital and well-known metabolic functions in basically all organisms, while auxiliary agents such as pesticides act differently on different organism groups. In order to deal with these variable impacts appropriately, we need conceptual guidelines along with specific analytical methods. Nathalie Chèvre presents in her article on p. 20 a new method that allows the definition of sound effect-based quality targets for individual pesticides and pesticide mixtures.

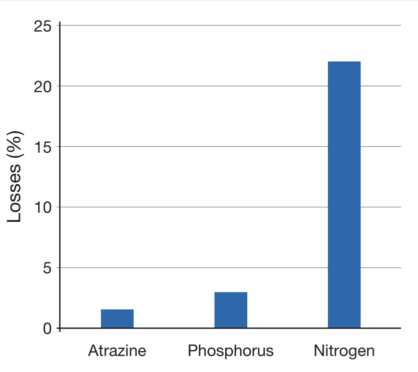

Fig. 3: Estimates of substance loss from agriculture into Swiss waterbodies. The losses refer to the quantities of the substances which are added to agricultural soils (incl. N fixation for nitrogen). The values give orders of magnitude based on investigations of the pesticide atrazine in the Greifensee (see article by Heinz Singer on p. 16) and the national phosphorus and nitrogen balances [4].

Soil profile with instruments to measure the soil water content.

Measures, Evaluation and Policies

Today's multifunctional agriculture should not only take into account food production, but also the protection of natural resources, landscape conservation and the decentralized settlement of the rural landscape [1]. Since these services are of public interest, they are funded by the state through direct payments. Hence the public authorities wish to ensure that the desired public services are really provided. In order to monitor the success of the measures, clear (environmental) targets have been defined, which should be achieved by the year 2005. In terms of water protection, the reduction of nutrient and pesticide inputs into waterbodies is a major aim.

It is not easy to evaluate the effectiveness of the imposed measures. Factors such as the complexity and the delayed reaction of ecosystems to pollutants may hamper the identification of impacts within legislative periods. For this reason, it is important both to register the change in the loads of pollutants in the waterbodies and to acquire a comprehensive understanding of ecosystems.

Such a broad knowledge is necessary if the catalogue of measure is to be advanced. In the field of biodiversity, for example, it has become apparent that the targeted 7% of ecological compensation areas are not sufficient to achieve the desired biodiversity. As a result, and with an understanding of the causes for the lack of success, the catalogue of measure has been subsequently expanded.

In a similar way, our investigations have shown that water pollution by herbicides can probably be greatly reduced if the land use is appropriate to site-specific conditions [5, 6]. This conclusion is also drawn by Christian Flury and Kurt Zgraggen, who have combined the issue of site-specifity with an economic analysis (see article on p. 24). Their predictions calculated with an economical land use model illustrate that the intensity of agriculture and consequently the water problems resulting from agricultural activities may develop very differently depending on the governing political and economic conditions.

Christian Stamm, biologist and soil scientist, is head of the group Water and Agriculture in the Department of Environmental Chemistry. He has been studying the transport of agrochemicals from agricultural soils into waterbodies for years, and is investigating possible measures for reducing the derived impacts

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Agricultural Policy and Water Protection

Switzerland has a leading role in Europe with the reform to its agricultural policy, and in particular with the Proof for Ecological Performance as prerequisite for direct payments. The area-wide measures within the Proof for Ecological Performance meanwhile have positive effects on water quality. Focus points for further improvements to water quality include providing more space to watercourses and reducing local phosphorus excesses in soil.

Increased food self-supply to avoid shortages in times of war and crisis was the aim of Swiss agricultural policy in the postwar period till the end of the 1980s. This was a continuation of the “Wahlen Plan”, proposed by federal minister Friedrich Traugott Wahlen during the Second World War, to guarantee the Swiss population with a reliable food supply. Instruments of this policy included fixed prices and supply guarantee for important agricultural products. The Swiss confederation intervened with threshold prices for imported produce, customs duties, quotas and cost covering acquisition of excesses. By the end of the 1980s, this policy was reaching its limits: costs were increasingly burdening the federal budget, consumer tourism abroad was rising, and efforts to liberalize world trade as part of the GATT agreement (General Agreement on Tariffs and Trade) and the later WTO (World Trade Organization) considerably increased the pressure to bring down the protectionist measures which were favoring Swiss agriculture. In addition, the environmental deficits of agriculture were becoming more evident. Agriculture-derived phosphorus inputs in inland lakes were resulting in excessive algae growth and severe oxygen depletion – some lakes had to be artificially aerated to sustain life – and in many drinking water reservoirs nitrate levels were rising alarmingly.

Reorientation from 1993

In the Seventh Agricultural Report in 1992 [1], the Swiss Federal Council identified the limits of the adopted agricultural policy and proposed a reorientation, which has been successively implemented since 1993. The core of the reform was to separate price and income policies and to introduce product independent direct payments as recompense for agricultural performances which are of common and ecological interests. To achieve the environmental targets, the Federal Council fixed a hierarchy of priorities in the Seventh Agriculture Report for the following, currently effective, strategies:

- Research, education and consulting: farmers should be able to act in an environmentally sound manner based on their own knowledge and conviction.
- Creation of financial and other incentives: an environmentally sound management must also be economically viable.
- Additional regulations and guidelines in different areas.

The focus of agricultural policy since 1993 has been point 2 of this strategy. On 9 June 1996, the public and the parliament included a new agricultural article [2] in the constitution. Since then, the confederation is obliged to ensure that agriculture, via sustainable and market-oriented production, contributes substantially to secure an adequate food supply for the population, the maintenance of the natural life resources, the care of the rural landscape, and a decentralized settlement of the countryside. The confederation subsidized the farmers’ income through direct payments with the aim of a fair and appropriate recompense for the provided services. Prerequisite for this is that agricultural enterprises provide a Proof for Environmental Performance (PEP). In addition, the confederation promotes economic incentives for production forms which are particularly natural, environmentally and animal friendly. The ecological dimension of sustainability becomes, thus, an important objective of agricultural policy.

Direct Payments Since 1999

Since 1999, the constitutional article has become effective law [2]. The proof for environmental performance covers:

- husbandry of livestock in animal-friendly conditions,
- a regulated fertilizer balance,
- a suitable proportion of ecological compensation areas,
- a regulated crop rotation,
- suitable soil protection,
- the choice and targeted use of plant treatment products.

Of particular importance for water protection is the promotion of a regulated fertilizer balance. It demands, on the one hand, that farmers do not apply more nitrogen and phosphorus than the cultivation and pasture require. On the other hand, for environmental compensation, unfertilized grass verges should be provided alongside waterbodies of at least 3 m width (Fig. 1) and along paths of at least 0.5 m width. Such green strips reduce the input of fertilizers and auxiliary agents into waterbodies.

Additional Water Protection Measures

In 1994, federal ministers Ruth Dreifuss and Jean-Pascal Delamuraz commissioned a workgroup with the task of defining targets and measures for the reduction of nitrogen emissions [3]. Using model calculations for the future agricultural policy of Switzerland, the workgroup came to the conclusion that the then current measures – the reduction of produce prices, direct payments and the consistent execution of the Swiss Water Pollution Control Law and the Swiss Ordinance on Environmentally Hazardous Substances – were insufficient to achieve the desired water quality in all locations.

More far-reaching measures could be necessary, for example, in areas with groundwater resources which are impacted by an increased nitrogen runoff resulting from


BLW

Fig. 1: A 3-m wide green strip reduces the input of fertilizer and plant protection agents into waterbodies. Worble in Canton Berne.

agricultural activities. Through Article 62a of the Water Pollution Control Law [4], in 1998 the Federal Parliament created an instrument for improving the quality of ground and surface water bodies exposed to agricultural emissions through targeted financial incentives to farmers. Article 62a of the Water Pollution Control Law provides the confederation with the means of adding federal subsidies to the contributions of cantons or third parties in support of agricultural policy measures. The requisite funds would be provided through direct environmental payments in accordance with the agricultural law. The emphasis is on reducing nitrate loads in ground water and phosphorus loads in surface waters. Included are also measures designed to prevent contamination of water bodies by plant protection agents.

Reducing the Nitrate and Phosphorus Loads

According to the Water Pollution Control Ordinance, the cantons are obliged to delineate inflow areas for above ground and underground water catchments, and to impose remedial action in case of insufficient water qualities. Such measures can have significant constraints with regard to land use and, thus, lead to unsustainable financial consequences for the farms. If the measures, however, are integrated into a project, finance can be requested from the confederation. It can be up to 80 % of the total costs for structural and management adjustments, and up to 50 % for technical production measures. In 2003, around 4 million Swiss francs were allocated.

Typically, problem solving is based on local measures, which can be defined in cooperation with the agricultural stakeholders. Of particular suitability for environmental measures are meadows and arable land with green crop rotations. Since 1999, 18 nitrate and three phosphorus projects have been submitted and approved. They are located in the cantons of Aargau, Berne, Freiburg, Lucerne, Solothurn, Schaffhausen, Vaud and Zurich. Further nitrate and phosphorus projects, and a project in the westerly part of Switzerland dealing with plant protection agents are in the planning stage.

Positive Results in the First Pilot Projects

The first pilot projects in accordance with Article 62a of the Water Pollution Control Law are currently being completed. After 6 obligatory project years, the results are consistently positive. For example, the nitrate project around the drinking water catchment of Frohberg in Wohlenschwil (Canton Aargau) was started as a pilot project in 1996 and has been funded by the confederation since 2001. It covers a catchment area of total 102 hectares. 62 hectares of these are agricultural land, encompassing 12 farms. The use of around 50 hectares is controlled by a drinking water contract. It contains strict, multi-year restrictions on the application of nitrogen-containing mineral and waste fertilizers as well as farm manure, and cultivation restrictions for crops with large runoff potential. In addition, there are far-reaching constraints on soil processing and crop rotation:

- the extension of the utilization period for temporary pastures,
- conversion to extensively used and unfertilized meadows,
- direct sowing of grassland,

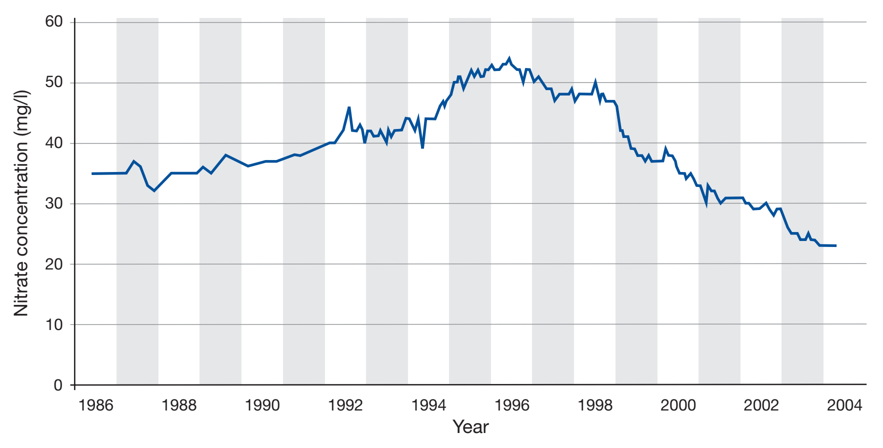

Fig. 2: Change in nitrate content in the Frohberg source in Wohlenschwil, Canton Aargau. The source is located in a project area in accordance with Article 62a of the Water Pollution Control Law [3].

Agroecological area	Measured parameter	Basis	Goals 2005
Agricultural processes: ecological total impact tolerance	N balance	96 000 t N (1994)	Maintain the nitrogen loss potential to the level of 74 000 t N per year. This corresponds to a reduction of about 22 000 t N (circa 23%) compared to the 1994 level.
	P balance	About 20 000 t P (1990/92)	Reduction of P excess by 50% to around 10 000 t P. This level was maintained.
Agricultural practice (consumption)	Plant protection agents	About 2200 t active agents (1990/92)	Reduction of the total applied plant protection agents by 30% to around 1500 t active agents.
Effects on the environment	Nitrate		In 90% of the drinking water catchments, where inflow areas are used by agriculture, the nitrate levels are below 40 mg/l.

Tab. 1: Goals of the Swiss Agricultural Policy till 2005, N = nitrogen, P = phosphorus.

- rotary band seeding of maize,
- direct sowing of winter cereals and
- limitations in free range husbandry of pigs.

These measures have resulted in a reduction of nitrate concentrations to below the target level of 25 mg/l (Fig. 2). If this success in nitrate reduction is to be maintained with certainty, the measures must be continued.

Agricultural Policy 2007

On 1 January 2004, the Agricultural Law of 1999 was revised for the first time. The agroecological aims relevant for water protection, which should be achieved by 2005, are summarized in Table 1 [5].

One aim is the reduction of environmentally relevant nitrogen losses from agriculture by 22 000 t to 74 000 t per year by 2005 starting at the 1994 level of 96 000 t. This target will most likely not be achieved. Although the nitrogen emissions between 1990 and 1998 have fallen, they increased again in 2002. For nitrate, on the other hand, it appears that the target will most likely be achieved. Various investigations indicate a trend in this direction. In addition, the measures according to Article 62a of the Water Pollution Control Law are showing their effectiveness within the nitrate projects. The aim, to reduce the applied quantity of plant protection agents to 1500 t per year, has already been achieved. The environmentally relevant phosphorus losses may not exceed 10 000 t per year. This target has also been achieved, in fact already by the mid 1990s. Regions with high concentrations of livestock remain problematic, and in these areas phosphorus excesses still need to be reduced.

The Federal Office for Agriculture therefore, in conjunction with a workgroup, has developed a recommendation for the reduction of the phosphorus excess. The solution is based on the following principles:

- Remedial action will be undertaken where problems exist.
- The principle behind remediation is oriented on the procedure laid down by Article 62a of the Water Pollution Control Law. Thus, the cantons have both the responsibility and the room for action. The confederation participates subsidiary.
- Monitoring on the basis of the agroecological indicators reveals whether the measures are producing the desired results.

Watercourse Policy Model Switzerland

In a broad co-operation, the Federal Offices for the Environment, Forests and Landscape, for Water and Geology, for Agriculture and for Spatial Development, have designed guiding principles for Swiss watercourses [6, 7].

This document should provide guidelines for a sustainable strategy for water policy on all management levels. Three development objectives stand in the foreground:

- adequate space for watercourses,
- adequate water flows,
- adequate water quality.

In particular the development goal “adequate space for watercourses” is a great challenge for agriculture. Sustainable flood protection and the demands which a watercourse must meet for its environmental functionality, can only be achieved where a sufficiently large area is allocated to the watercourse. This requires innovative solutions to satisfy all the stakeholders involved.

A Glance over the Border

Despite intensive consultation and financial support via state-sponsored environment and support programmes, the agricultural sector in the European Union (EU) remains the main source of widespread pollutant inputs to waterbodies. This is particularly the case for nitrate and plant protection agents. At the end of June 2003, the EU agricultural ministers passed a fundamental reform of the Common Agriculture Policy, which will change the support mechanisms of the Union’s agricultural sector. The environmentally relevant core points of the reform are:

- Decoupling financial assistance from production. In the coming years, most assistance schemes will be provided independently of production volumes. The link to production can be maintained to a limited degree, to avoid production shutdown.
- The new single operative payments will in the future be linked to respecting environment, food safety and animal welfare standards (“Cross Compliance”). Agricultural businesses will be subject to an annual audit. Cross Compliance is fundamental for the area-wide protection of waterbodies and soil.
- Reduction of direct payments to big enterprises (modulation). Thus, funds will be freed for the development of regional areas with new programmes in the fields of environment, quality and animal protection.

Compared to the EU, Switzerland takes a leading role in the protection of waterbodies from agricultural inputs through the Proof for Ecological Performance and the regional programmes.

Conrad Widmer, Dip. Agro-Eng. ETH, head of the Ecological Direct Payments Section in the Federal Office for Agriculture. He is concerned with the promotion of environment and animal friendly production techniques in the agricultural sector.

Co-author: Simone Aeschbacher, Federal Office for Agriculture, Berne.

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Contaminated Drinking Water from Agricultural Areas?

Drinking water from rural catchments is normally either not at all or minimally treated. It is precisely this water which can be contaminated by liquid manure or excrement from grazing animals. The most worrying aspect are the environmentally persistent forms of cryptosporidia. In 9 out of 15 investigated drinking water catchments in rural areas, we could in fact detect cryptosporidia. It is still to be determined whether they present a hazard for humans.

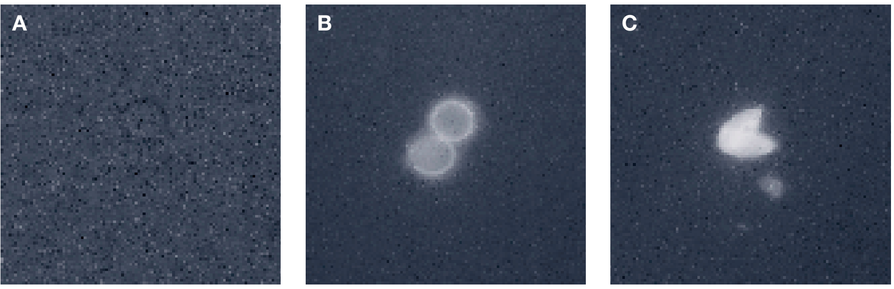
The officially prescribed microbiological drinking water tests are limited to the detection of *E. coli* and enterococci, and the total plate count. Persistent pathogenic bacteria such as cryptosporidia (see box p. 10) therefore remain undetected. While *E. coli* die relatively quickly in the environment, the persistent form of *Cryptosporidium,* the so-called oocyst (Fig. 1), remain infectious for weeks to months. Cryptosporidia also survive in chlorinated drinking water, as opposed to *E. coli*. Therefore, water which otherwise fulfills the quality criteria for drinking water can still contain disease causing pathogens.

Particularly affected are drinking water catchments in agricultural areas, since this water can come into contact with grazing animal excrement and liquid manure. Animals which are infected with cryptosporidia excrete infectious oocysts which can reach drinking water. Since this water is usually not treated in any way, EAWAG wanted to estimate how great the risk was for a *Cryptosporidium* infection through the consumption of drinking water in agricultural areas.

Cryptosporidia are Relatively Widespread

We took water from 15 small rural area drinking water catchments in different parts of Switzerland. The drinking water was examined not only using the analysis prescribed in the food and drink regulations, but also for cryptosporidia (see box p. 10). 9 out of 15 of the water samples were contaminated with cryptosporidia (Fig. 2). To date, *Cryptosporidium* concentrations have been detected in Switzerland of up to 3.83 oocyst/l in surface waters [1], 1.6 oocyst/l in karst spring water [2] and 0.25 oocyst/l in drinking water [3]. Our measurements are comparable to these findings.

In addition, 4 out of 9 *Cryptosporidium* containing drinking water catchments were also contaminated with faecal bacteria *E. coli* (Fig. 2). The water from these catchments, therefore, did not meet the quality criteria for drinking water. For the remaining 5 catchments contaminated with cryp-



Photographs: EAWAG

Fig. 1: Under a standard optical microscope, a *Cryptosporidium* oocyst is hardly visible (A). Specific fluorescent antibodies cause the oocyst surfaces to light up (B). In the small intestine of the host, the *Cryptosporidium* oocysts germinate (C) and release 4 sporocytes – a process known as excystation. The sporocytes enter the intestinal epithelium and create new oocysts there.

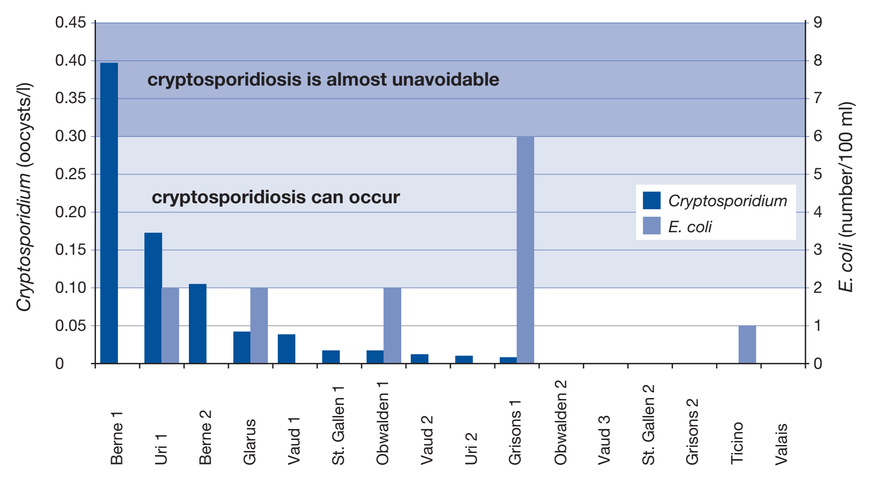


Fig. 2: Measured *Cryptosporidium* and *E. coli* concentrations in 15 drinking water catchments of rural areas displayed in descending order of oocyst concentrations. Berne 1 is a public fountain. In the range of 0.1–0.3 oocysts/l disease outbreaks in the population can be expected, above 0.3 oocysts/l epidemics are possible.

tosporidia, the *E. coli* indicator had not detected the faecal contamination. In another catchment we detected *E. coli* but no cryptosporidia.

Clostridium is not an Indicator for Cryptosporidia

The Drinking Water Guideline from the European Union [4] declares the bacterium *Clostridium perfringens,* which can survive for extended periods in the soil with help of its spores, as persistent faecal indicator on the basis of the following assumption: if in 100 ml drinking water there are no clostridia detectable, the water should also be free of any other persistent parasite forms such as *Cryptosporidium* oocysts.

If this association is correct, then water samples which are contaminated with *Cryptosporidium* should also contain *Clostridium*. We wanted to test this hypothesis and analyzed water samples of the 15 drinking water catchments also for *Clostridium.* However, we found no correlation between the occurrence of *Cryptosporidium* and the persistent faecal indicator *C. perfringens.* Only two drinking water catchments were contaminated with clostridia: in Glarus cryptosporidia as well as clostridia were present (1 spore in 100 ml water), while the investigated drinking water catchment in Ticino contained no cryptosporidia but 96 *Clostridium* sporidia in 100 ml water. It is therefore doubtful that *C. perfringens* can be used as an indicator for *Cryptosporidium*. Most likely, clostridia and cryptosporidia are not similar enough in their environmental behavior.

The Situation in Switzerland

Legal regulations for defining threshold limits for cryptosporidia in drinking water exist neither in Switzerland nor abroad. There is therefore uncertainty as to how to assess the hazard presented by the presence of cryptosporidia in drinking water.

Even a *Cryptosporidium* concentration of 0.1 oocyst/l can lead to disease outbreaks in the population, and concentrations of more than 0.3 oocyst/l will almost certainly lead to cryptosporidiosis cases [5]. In 20% of the drinking water samples we investigated, the *Cryptosporidium* concentration was above 0.1 oocyst/l and exceeded in one case even the value of 0.3 oocyst/l (Fig. 2). In 9 of the 15 drinking water catchments the risk level assessed in the USA as a 10^{-4} residual risk for cryptosporidiosis was exceeded (1 infected person per 10,000 persons per year, at an oocyst concentration of more than 0.0000327 oocyst/l). Since our measurements are just momentary sample extractions, it must be assumed that after large precipitation events, the *Cryptosporidium* concentration will rise considerably.

So Far No *Cryptosporidium* Epidemics in Switzerland

Despite this noteworthy count of cryptosporidia in the tested drinking water, Switzerland has so far been spared an epidemic. The prevalence of diarrhea cases – i.e. the percentage of the *Cryptosporidium* contaminated diarrhea patients at a given time – is in Germany and Switzerland for the general population at 0.4–1.9%. Children are harder hit, at a rate of 1.1–4.8%, while


Photogrphs: EAWAG

Fig 3: Manure spreading and ...

Cryptosporidia

What are cryptosporidia?

Cryptosporidia are protozoal intestinal parasites of considerable diameter (5 µm diameter), which create oocysts in a persistent form (Fig. 1). They belong to the most important pathogenic protozoa in drinking water. The *Cryptosporidium* genus contains 13 species. *Cryptosporidium parvum* is the most widespread and pathogenic also for humans. *C. parvum* is thought to be able to infect any mammal [6].

What are the symptoms of a *Cryptosporidium* infection?

The disease contracted through cryptosporidia, cryptosporidiosis, is a zoonosis – i.e. an animal disease which can be transferred to humans. Human infections were first documented in 1976 and water-borne cryptosporidiosis has been known since 1984. Since then a number of epidemics occurred in the USA, Great Britain and Japan: the largest estimate of cases being 400 000 in 1993 in Milwaukee (Wisconsin, USA) [7]. The oocysts excreted with faeces stay alive in cold water for several months. Cryptosporidiosis begins with the intake of oocysts (Fig. 1A + B). After an incubation period of 2 to 12 days, in which the oocysts germinate in the intestine (Fig. 1C) and multiply, the infection leads to watery diarrhea and stomach cramps, usually without temperature rise, nausea, faintness, or vomiting. The sickness onset is variable, but normally the disease cycle is over within 30 days. However, for people with weakened immune systems, especially HIV positive cases, the infection takes a chronic or fulminant course, and can even lead to death in some exceptional cases. To date, there is no medication available for treating cryptosporidia.

How are Cryptosporidia detected?

The American environmental authorities and the British Drinking Water Inspectorate recommend Detection Method 1623 for *Cryptosporidium* in drinking water. In the field a large volume of water, 100 to 1000 l, is passed through a filter with 1 µm pores. In the laboratory, the particles are dissolved from the filters and the cryptosporidia separated from the other particles with help of immunomagnetic methods. The cryptosporidia are colored by surface antibodies and counted under a fluorescent microscope (Fig. 1B).

Active oocysts from environmental samples can be brought to germination in suitable media and temperatures of 37 °C in laboratory cultures. In this way, the percentual proportion of active oocysts in drinking water can be determined.

... pasture grazing can lead to animal faecal contamination of drinking water catchments.

the value rises for AIDS patients to 11.8 %. It is calculated that in Switzerland annually there are 340 cryptosporidiosis cases [8]. In reality, only a few are clinically identified. This could be due to the following reasons:

- Cryptosporidia originating from cattle are less infectious than first thought. With the detection methods we use, *Cryptosporidium* species which are either not at all or little pathogenic are also detected.
- Cryptosporidia in drinking water are no longer necessarily vital or infectious. Depending on the environmental conditions, oocysts can survive for several months. They die in time, but remain detectable.
- People who are sick with cryptosporidiosis seldom consult a doctor. Consequently, clinical tests are not usually made for cryptosporidia.
- The public consumes very little unboiled water.

Practical Consequences

The regulations in the current legislation for drinking water in specified groundwater protection zones must be better respected. Close to drinking water catchments, in the so-called groundwater protection zone I, all grazing and fertilizer usage is forbidden [9]. These regulations are not always complied with, as Fig. 3 shows. Periodic inspections are therefore necessary. Above all, bad weather can raise the risk of faecal matter being washed into drinking water catchments. Therefore, for certain locations with poor soil filtration, it may be necessary to treat the water by means of, for example, UV disinfection.

Implications for Further Research

There is a general uncertainty whether periodically higher *Cryptosporidium* concentrations, which are to be expected after heavy precipitation, represent a hazard for consumers of drinking water. Too little is known about the exact species allocation of cryptosporidia which occur in Switzerland, and the vitality of oocysts in drinking water, to provide a clear answer to this question.

In a further stage of the project, we would like to close some of these gaps in our knowledge. For this purpose, at three locations with high oocyst concentrations, the vitality should be determined by sporulation tests (see box p. 10), and the exact species of *Cryptosporidium* should be characterized through genotyping. In addition, a risk assessment should be made on the basis of results obtained. We would also like to survey the local authorities and physicians concerning whether in the past years there has been any increase in the number of cryptosporidiosis cases in the population.

Cryptosporidia, even if they are classed as weak pathogens in further investigations, are environment persistent faecal indicators, which should be excluded in any case from drinking water.

We would like to thank "Labor Spiez" for the funding of the project.

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Use of Antibiotics in Agriculture – Consequences for the Environment

After their use in animal husbandry, sulphonamide antibiotics are spread with the liquid manure onto the farmland. Despite an initially rapid decrease of the concentration in the soil, residual amounts remain detectable for months. In addition, rain can wash the antibiotics out of the soil into neighboring water bodies. A further problem is the presence of antibiotic resistant bacteria in the liquid manure. To what extent the use of antibiotics promotes the development and distribution of resistant bacteria is still unclear.

Antibiotics were hailed in the first half of the twentieth century as a miracle cure against bacterial infections. First used in human medication, they are today also indispensable in animal husbandry (see box "Use of antibiotics in animal husbandry"), and around 40 tonnes are applied in Swiss agriculture annually. However, their use involves two basic risks:

The first is that antibiotics, in part still active, in part in a derivative product form, enter the environment through animal excrements which are applied onto the agricultural land as liquid and solid manure. Thus, as much as a few hundred grams of antibiotics per hectare and year might be dispersed. Rain washes the antibiotics into the neighboring water bodies, but the precise fate of the antibiotics in the environment is still little understood. The second risk is that the antibiotics promote the development of resistant bacteria in the animals under treatment. Through the process of natural selection, mutations can create new resistance genes, and these, together with those already present in the bacterial community, can be passed on to other bacterial strains and species, resulting in a rapid dispersal of the resistance genes. If the resistance gene gets transferred to pathogenic bacteria, the results can be fatal, as these bacteria can no longer be combated by available antibiotics. The World Health Organization WHO ranks the problem of development and transfer of resistance genes as particularly serious, and sees the need for urgent action. To date, it is still unclear how great the risk of resistance development and dispersal is for the agricultural environment.

In a joint research project, we are, therefore, studying both the behavior of antibiotics in the environment and – by means of selected resistance genes as probes – the presence of resistant bacteria in agricultural soil. We are specifically interested in knowing whether a relationship exists between the use of antibiotics in agriculture and the appearance of resistance genes in the environment. Our project is part of the Swiss National Fund Research Program 49 "Antibiotics Resistance" [1].

Field Study Under Swiss Agricultural Practice

Starting point of our investigation was the consideration to carry out a field trial under practical conditions. Therefore, we spread liquid manure polluted with antibiotics on two perennial grassland lots of each 0.35 ha. The applications were made at the start of the vegetation period, on 24 March 2003, and after the first cut on 8 May 2003. The manure was applied using the band spreader technique (Photo 1). It was delivered from a pig feeder farm where the sulphonamide antibiotic sulphamethazine had been used as stabling prophylaxis (see box "Special case: sulphonamide antibiotics"). The sulphamethazine concentration in the fresh manure was 15 mg/kg – a heavy but realistic load [2].

Over a time period of four months prior and subsequent to application of the manure, soil samples were taken from the plots (Photo 2). Using a meteorological station directly on the lots, different parameters were recorded continuously, the most important of which was rainfall (Photo 3). Since both pastures were situated alongside a small stream, it was possible to determine the input of antibiotics into the stream wa-

Special Case: Sulphonamide Antibiotics

There were a number of reasons for using liquid manure containing the sulphonamide antibiotic sulphamethazine in our field study:

- **Sulphonamides are common in veterinary medication (e.g. in stabling prophylaxis). Mainly one active substance (sulphamethoxazole) from this group is used in human medicine.**
- **Sulphonamides are only moderately metabolized in animal organisms and relatively quickly excreted [2]. It is exceptional that the metabolites in the manure revert almost entirely to the original active agent form [3]. For our investigation, it is particularly important that the sulphonamides endure in the environment and are, therefore, detectable over a long time period.**
- **At EAWAG methods have been developed for the determinatiom of sulphamethazine in liquid manure [4], in soil [5] and in water [unpublished].**

Use of Antibiotics in Animal Husbandry

Antibiotics used in animal husbandry originate essentially from the same substance groups as human antibiotics: penicillins, tetracyclines, sulphonamides, macrolides, aminoglycosides, and fluorochinolone.

In veterinary medicine, antibiotics are used in the treatment of individual sick animals and in preventive treatment for the entire stock of animals. The procedure of preventive dosing the entire herd with antibiotics once a disease makes an appearance, for example when piglets or calves suffer from diarrhea or respiratory disease, is known as metaphylaxis. Prophylaxis, on the other hand, is applied before any of the animals fall ill, and is used, for example, to prevent infection during stabling of fattening animals from different farms.

Resistance gene	Origin
sul (I)	*Escherichia coli* (non-pathogenic)
sul (II)	*E. coli*
sul (III)	*E. coli*
tet (B)	*E. coli*
tet (C)	*E. coli*
tet (H)	*Pasteurella multocida* (opportunistic pathogen)
tet (M)	*Enterococcus faecalis* (opportunistic pathogen)
tet (O)	*Campylobacter coli* (pathogenic)
tet (Q)	*Bacteroides thetaiotaomicron* (non-pathogenic, found in human gastro-intestinal tracts)
tet (S)	*Listeria monocytogenes* (opportunistic pathogen)
tet (T)	*Streptococcus pyogenes* (opportunistic pathogen)
tet (W)	*Butyrivibrio monocytogenes* (anaerobic rumen bacterium)
tet (Y)	aus Schweinegülle isoliertes Plasmid (unknown bacterium)
tet (Z)	*Corynebacterium glutamicum* (soil bacterium)

Tab. 1: Investigated resistance genes and their origin. The bacteria from which the different resistance genes were first isolated and sequenced are shown. All resistance genes could subsequently be detected in other bacterial strains; *tet* (B), for example, was found up to now in 18 different strains. In most cases the presence of one of the various tetracycline or sulphonamide resistance genes was sufficient to make the carrier bacterium resistant to tetracyclines or sulphonamides, respectively. Opportunistic pathogens do not always cause disease, only for immunologically weakened patients.

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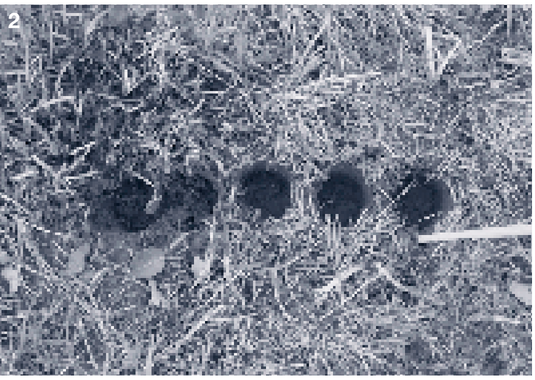

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Photographs EAWAG

ter. For this purpose, we built a measuring station 500 m downstream, which continuously measured the waterflow and automatically took water samples (Photo 4).

At EAWAG, we determinated the sulphamethazine concentrations in the soil (Photo 5) as well as in groundwater and stream water samples. In addition, the manure and soil samples were analyzed at the University of Utrecht by means of molecular biological methods for the presence of 14 different antibiotic resistant genes (Photo 6). 11 of the investigated genes are tetracycline resistance genes, the remainder are oriented against sulphonamides (see Tab. 1). With the applied technique, changes in the presence of the studied resistance genes are detectable providing qualitative or at best semi-quanitative information.

Higher Antibiotic Load in Soil After Manuring

Figure 1 shows the sulphamethazine content of the soil before and after the two manure applications. The sulphamethazine concentrations are expressed as average values over the entire lot, whereas local values can be as much as five times higher due to the heterogeneity. Before the first manuring, no sulphamethazine could be detected in the soil. After the manuring, the concentration leapt up and then fell over time. One day after the manuring, only 10% of the extracted amount was found in the soil pore water. The rest of the sulphamethazine was sorbed to soil particles or had been transformed. Only a few days later, sulphamethazine concentration in the soil had

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IRAS, University of Utrecht

EAWAG

Perennial pasture was used as the test field.

decreased further. During the next weeks, concentration remained relatively stable, so that the values at the time of the second manuring had not returned to zero. After the second application, the sulphamethazine concentration increased again.

13 of the 14 Resistance Genes Detectable

In the liquid manure used, we could detect 13 of the 14 tested resistance genes. We found at most 12 of the 14 genes (Fig. 1) in the soil samples. As opposed to sulphamethazine, various resistance genes were already present in the soil before the first manure application. 8 and 11 genes were clearly detectable in the two lots. Additional 1–4 genes gave only weak signals, indicating a probable low amount in the soil.

After manuring, the intensity of the resistance gene signals increased and 10–12 of the 14 resistance genes were clearly detectable over weeks (Fig. 1). We assume that these additional genes derive from the microflora of the manure.

Weather Determines the Fate of the Antibiotics

Interestingly, the weather after the two manure applications was very different. Whereas the first manuring was followed by a dry week without any rain and a precipitation poor April (60 % of the long-term average), the week after the second application was very wet. This had a decisive effect on the fate of the sulphamethazine in the environment.

We found that the total sulphamethazine content of the soil increased less strongly after the second manure application with subsequent rain than after the first application without rain (Fig. 1). This was also the case for the sulphamethazine concentrations in the pore water: after the first manuring without rain, they were nearly twice as high (approx. 65 µg/l) as after the second manuring with rain (approx. 35 µg/l). In addition, a higher sulphamethazine concentration could be detected in the stream water after the second manure application. It reached a maximum of 4 µg sulphamethazine per liter water (Fig. 2) and was slightly raised during the subsequent rainy period, while the concentration peaks became gradually less pronounced, the more time passed after the application. In contrast, the sulphamethazine concentration in the stream water after the first manuring at the end of March was considerably lower.

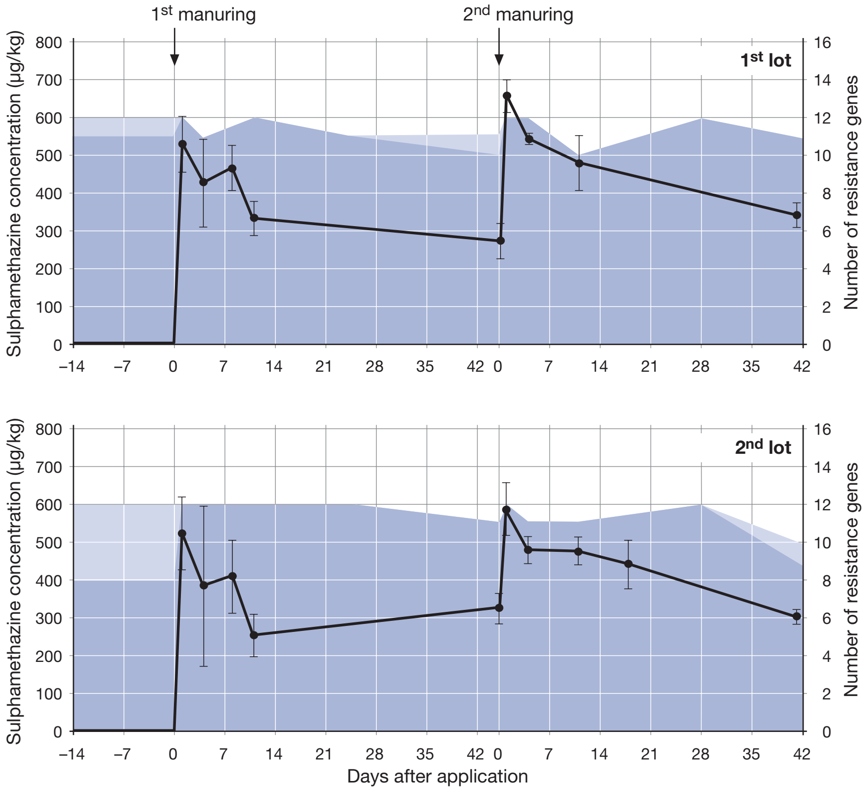

Fig. 1: Concentrations of sulphamethazine (black curve, average values plus standard deviation) and number of resistance genes (dark shaded area = clearly detectable resistance genes, light shaded area = additional, weakly detectable resistance genes) in soil samples of the two perennial pasture lots. On 24 March 2003 and 8 May 2003, sulphamethazine-containing liquid manure (15 mg/kg) was spread onto the fields.

Further Investigation Required

Our field study shows that the sulphonamide antibiotics can still be found in the soil months after the manure applications. The concentrations found in the soil clearly exceeded the so-called trigger value of 100 µg per kg of soil. The trigger value is defined as the threshold limit for the approval of new veterinary medications. If exceeded, environmental impacts must be evaluated in detail [6]. Results from other studies indicate that sulphonamides can have an effect on soil organisms: at a sulphonamide concentration of 1 mg/kg the enzyme activity of soil bacteria changed [7] leading to a reduction of soil respiration [8]. In our field study, these concentrations were locally clearly exceeded due to the heterogeneity in the soil. In addition, we could demonstrate that soil bacteria react with increased tolerance to sulphonamide antibiotics above concentrations of 10 mg/kg [9]. Therefore, it is crucial to investigate the effects of such environmental concentrations closer and to find out more about the bioavailability of sulphonamide in soil.

Our measurements allowed us to confirm the presence of resistance genes in both the manure and the soil. The presence of resistance genes in the environment is also proved by other studies [10, 11]. However, it still remains unclear whether additional antibiotic resistance genes are introduced with the manure into the soil. To be able to answer this question definitively, we need to quantify the genes. In addition, it is important to investigate whether the resistance genes are washed out of the soil by rain into the water bodies, leading to further dispersal of the resistance genes. And finally, it must be clarified whether an increased presence of resistance genes in the environment influences the appearance of resistance in pathogens.

Thus, it is currently not possible to carry out a proper evaluation of the risks that exist in the use of antibiotics in animal husbandry. Too much detailed information is missing. Nevertheless, our investigations lead us to the conclusion that antibiotics should be used carefully and with more awareness of the inherent risks.

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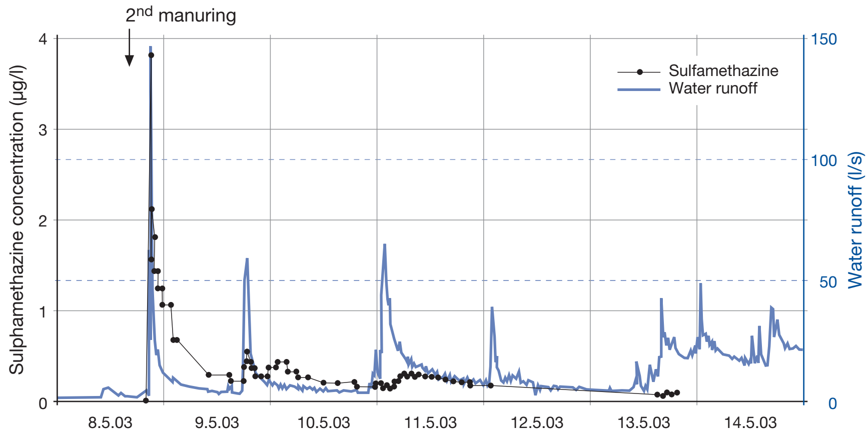

Fig. 2: Water runoff and sulphamethazine concentration in the stream during a rainy period after the second manure application on 8 May 2003.

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Pesticides in Water – Research Meets Politics

Pesticides have been consistently detected in high concentrations in Swiss surface waters over a number of decades. The direct payments scheme introduced in 1993 for ecological measures in agriculture was designed to improve the situation. The goal was to halve the pesticide pollution by the year 2005. A pesticide pollution analysis carried out by EAWAG in the Greifensee region reveals that the target has not been fully achieved. Although there has been a reduction in the total quantity of pesticides used, the measures designed to reduce the pesticide loss from the treated farmland have largely failed to take effect.

With its innovative changeover from a product-subsidized agricultural policy to one that is environmentally and market-oriented, Switzerland acts as a pacesetter in broader Europe. Intangibles corresponding to environmental services claimed by society, which could not be traded on a free market system, could only be funded by a subsidy system involving direct payments by the state to farmers (also see article by C. Widmer, p. 6). This direct payments scheme consumes 5 % of the total federal budget, i.e. around 2.4 billion Swiss francs per year. Agricultural enterprises receive these funds on the condition that they provide a proof for ecological performance (PEP). Along with measures such as regulated fertilizer balance and crop rotation, the PEP also includes requirements for targeted selection and application of pesticides. About 0.4 of the 2.4 billion Swiss francs are allocated for special environmental services, beyond those specified in the PEP. These cover subsidies for water protection and environmental quality as well as contributions for ecological compensation areas used for extensive grain and rape production (Extenso Production), for organic agriculture and for animal-friendly husbandry. With the introduction of the direct payments scheme, the number of farms participant in the PEP has increased rapidly. Whereas in 1993 only about 17 % of agricultural land was managed in compliance with ecological guidelines, today this proportion has increased to 97 %. Considering the enormous costs involved in converting Swiss agriculture to more ecological practices, it begs the question as to how effective the measures are in reality.


Photographs: EAWAG

Filling the tank of a sprayer with a pesticide mixture.

Goal: Halving the Pesticide Pollution of Water Bodies

With the start of the ecological compensation policy in 1993, concrete targets were defined for ecological relevant parameters such as biodiversity, nitrogen, phosphorous, and pesticide loads, which should have been achieved by the end of 2005. The target for pesticides was to reduce the pollution by half. Two actions should be taken: a 30 % reduction in the total quantity of pesticide applied and the remaining 20 % being achieved through loss limitation measures (see box: Measures).

This article attempts to answer the question of whether the pesticide load since the introduction of the ecological measures in 1993 has in fact been reduced. One logical starting point in judging the success of the measures is the analysis of pesticide sales figures. More direct information, though, is available from long-term pesticide pollution analyses of water bodies, for which pesticide concentrations are measured. With interruptions, EAWAG has carried out such investigations since 1991 in the Greifensee (see Box: Pollution Analyses). Since 1997, they have been financed by the Federal Department of Agriculture as part of the project "Evaluation of ecological measures".

Declining Pesticide Sales

Figure 1 shows that pesticide sales by volume [1] decreased between 1993 and 2003 by about 25 %. It is not possible, however,

Measures Involved in the Proof of Ecological Performance

Minimization of pesticides used:

- **Application of the threshold principle: pesticides are only used if the expected damage by pests exceeds the cost of application.**
- **Take advantage of natural regulation mechanisms: indirect plant protection, e.g. adapted variety selection and crop rotation.**
- **Encourage the insecticide and fungicide-free extensive production (Extenso Production) of grain and rape.**
- **Encourage the pesticide-free organic agriculture.**

Minimization of pesticide losses:

- **3-meter wide buffer strips alongside streams and lakes (see article by C. Widmer, p. 6).**
- **Erosion prevention measures (e.g. winter plant cover).**

to conclude from this figure that there has also been a 25 % reduction in pesticide use. One reason for this is that pesticides imported from abroad, and pesticides stored on farms, are not included in this figure. Another reason is that the amount of land under cultivation has reduced significantly over the past 10 years. Adjusting the figures accordingly lowers the effective pesticide reduction to only 20 %, i.e., from 6.5 kg per hectare to 5.4 kg. Furthermore, the market has been supplying an increasing number of new pesticides which require much lower quantities in application to gain the same effects. The increased potency of the new pesticides has consequences not only for agricultural use, but also for the aquatic ecosystems. A more meaningful indicator for pesticide use should be based on an adequate consumption survey and take into account both the treatment intensity and the potency of the pesticide.

Application of pesticides onto farmland.

Prominent Cereal and Maize Herbicides

The collective term pesticide in Switzerland covers around 400 approved individual substances. Sufficiently accurate and sensitive analytical methods are available only for a portion of the pesticides. A comprehensive determination of pesticide pollution is therefore not possible.

For the pollution analysis at Greifensee, around 50 of the 100 pesticides used in this area were investigated. Herbicides from the widespread maize and cereal cultivation are regularly detected. One of these, the maize herbicide atrazine, has been banned in other countries, such as Germany, but remains one of the most used pesticides in Switzerland. Since the only data available for the first half of the 1990s is for atrazine, having been collected as part of other EAWAG research projects before the start of the national evaluation programme, this herbicide was selected for a detailed analysis.

Decreasing Atrazine Pollution

The data available since 1990 for the Greifensee region show that the quantities of atrazine used during the 1990s fell from

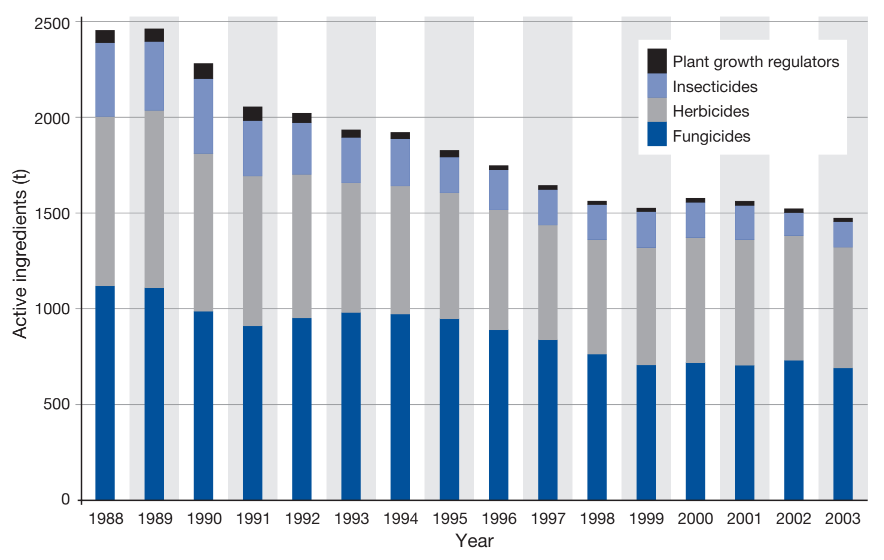

Fig. 1: Pesticide sales data for the period 1988 to 2003 [1].

Pollution Analysis of the Greifensee

Lakes make ideal observation systems for a pollution analysis. With water residence times of usually several hundred days, all of the activities in the catchment area are integrated, and, to the contrary of highly dynamic running waters, the loads (pesticide quantities entering the lake) can be measured at relatively low cost and over extended time periods [2]. On behalf of the Swiss Federal Office for Agriculture, EAWAG has been conducting a pollution analysis of the Greifensee since 1997. The 160 km^2 catchment area of the Greifensee provides a good overall picture of the various agricultural practices and the related pesticide sources and transport pathways. In addition, EAWAG already collected pesticide data from the Greifensee in the periods 1990–1991 and 1993–1994. The most comprehensive data record exists for the maize herbicide atrazine.

over 1100 kg to about 400 kg (Fig. 2A). The reasons for this reduction are the implementation of various application restrictions for atrazine (quantitative and temporal limitations and a general ban of atrazine use on railway tracks) between 1988 and 1994, and the subsequent adoption of substitute products. The reduction of the quantities applied has had positive consequences for the Greifensee atrazine load: whereas the total atrazine load in the lake at the beginning of the 1990s laid between 30 and 45 kg, this value has dwindled to today's 5–10 kg (Fig. 2B). This is a significant reduction, although surprisingly the level of atrazine (atrazine load in Fig. 2A) detected in the Greifensee varies greatly from year to year during or shortly after the application period (May till June). Thus, in 1999, when already more than 90% of agricultural enterprises were participating in the PEP and the applied atrazine volume had fallen by more than 60%, there was more atrazine entering the Greifensee than in 1994 shortly after the implementation of the ecological measures. In order to evaluate the success of the ecological measures, not only the quantities applied, but also those influencing factors which have an effect on the pesticide transport from the field to the water, need to be known.

No Detectable Reduction of Pesticide Losses

The quantity of pesticide entering the water body is chiefly dependant on the point in time and the quantity and intensity of precipitation events following the application of the pesticide. The corollary being that up to half of an annual load can be washed by the rain into a water body in a matter of days or weeks following a pesticide application. Altogether, the proportion of pesticide which is transported from the land to the water body amounts to only a few per cent of the total applied.

Figure 3 shows no variation in the atrazine losses to the Greifensee after introduction of the PEP. Instead, a strong correlation between rain intensity and atrazine runoff is evident. The largest rainfall was registered in 1999: in this year 3.4% of the applied atrazine was transported into the Greifensee. On the other hand, in low rain years, the transported atrazine quantities range between 0.5 and 1.9%.

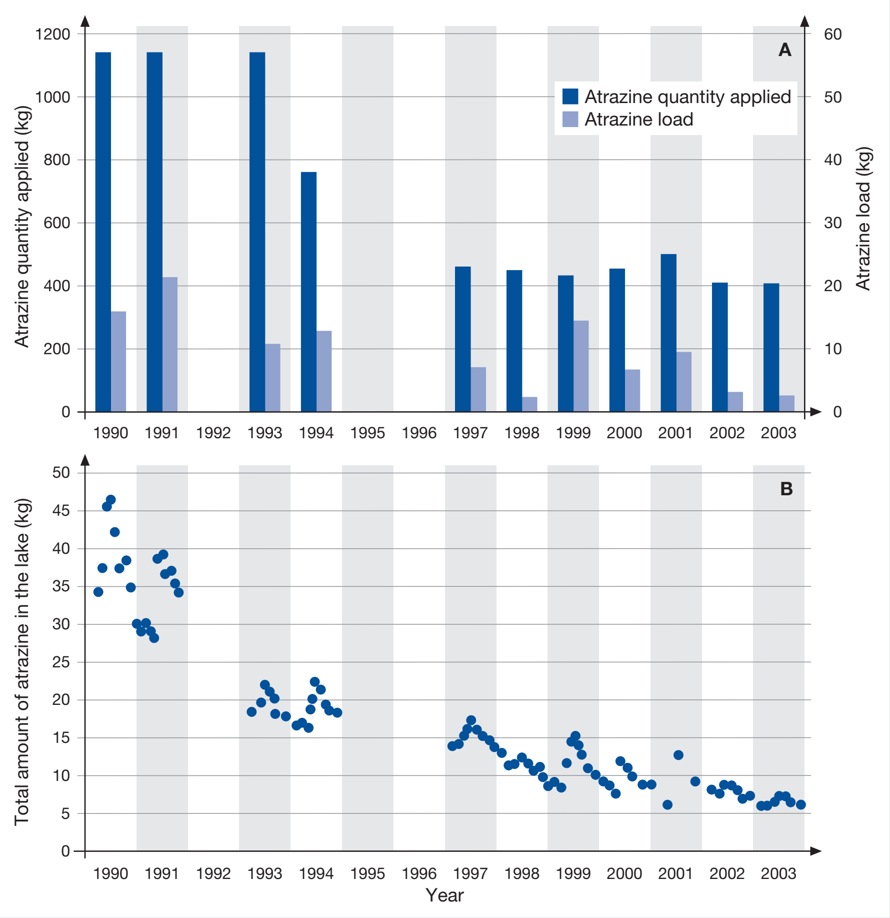

Fig. 2: More than a decade of Greifensee pollution by atrazine – (A) applied quantities in the catchment area and the quantities entering the lake (load), and (B) total quantity in the lake. Through combination of the monthly depth-profile measurements of pesticide concentrations with a lake simulation software, the atrazine load could be determined to sufficient precision [2].

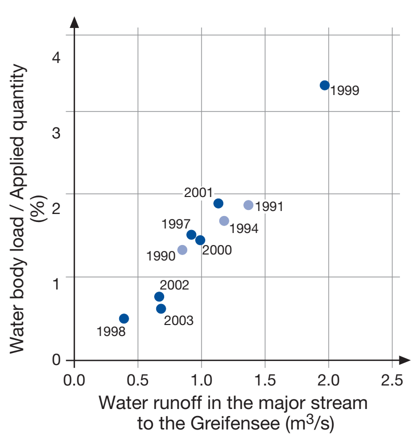

Fig. 3: The percentage of the atrazine transported from the field to the water body during or shortly after the application period increases with increased water runoff during rain events. Data and correlation uncertainties are not shown.

Pollution analysis – taking water samples in Greifensee.

A similar picture appears for other maize herbicides. Results from a field study which investigated the maize herbicides atrazine, dimethenamid, metolachlor, and sulcotrione, in smaller sections of the Greifensee catchment area, show that these substances have a similar transport behavior [3]. Rain washes them away very quickly so that the herbicides dissolved in the rain water could not attach the soil matrix. The rapid transport of pesticides during a heavy rain event is due mainly to surface runoff and rapid flow into subsurface drainage systems.

Further Measures for Success

Further studies in the catchment area of the Greifensee show that waterlogged sites with direct connection to a water body have a great potential for pesticide loss [4]. Also from an agronomical point of view, these sites are not ideal as farmland [5]. On such sites of high risk for pesticide losses, pesticide usage should be avoided. This should be possible in practice since high pesticide losses often appear as local “hot spots”, and Swiss agriculture is structured in relatively small-scale units. Pesticide-free areas could be allocated in part as ecological compensation areas required to obtain subsidies through direct payment. A clear identification of high-risk sites is a great challenge for future pesticide research.

During disposal of pesticide residues, and during cleaning of the field sprayers, pesticides can be transported directly via the sewerage system or indirectly through the sewage plant into the water bodies. In the Greifensee, these point sources for substances which are used exclusively in agriculture make up between 15 and 20% of the total pesticide load [6]. A solution lies in appropriate training in order to learn the correct handling of pesticides, which can be regulated with licenses. Any person who uses pesticides professionally must be in possession of the appropriate license. In addition, the spraying machines must be regularly inspected. Since most spraying machines are quite old, financial assistance in acquiring modern sprayers brings additional improvement potential. Freshwater tanks on modern sprayers make it possible, for instance, to clean the machines directly in the field.

Conclusion

A causal relationship between the implemented policy measures for improving the environmental impact situation in agriculture and for reducing the pesticide load in water bodies is difficult to establish, and necessitates many simplifications and restrictions. On the one hand, the complexity and temporal behavior of environmental systems per se appear not to be compatible with the timeframes of political decision-making. Politics demand simple, clear and rapid answers, whereas research attempts to bring about an understanding of complex and chaotic systems, which normally requires resource-consuming and expensive investigations extending over a long time period. For this reason, it would have been important to have already started the corresponding assessment programme prior to the introduction of the ecological measures in 1993.

Nevertheless, despite data uncertainty and knowledge gaps, certain concrete trends are identifiable: The measures for limiting pesticide usage have led to a visible if only partial success. On the contrary, the transport limiting measures have been less successful and must be reconsidered for the future.

Heinz Singer is a chemist in the group Water and Agriculture in the Department of Environmental Chemistry. He is currently investigating the fate of pesticides in the environment and is developing methods for detecting organic trace elements.

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Pesticides: Risks to Lakes and Streams?

Pesticide residues are most undesirable in surface waters. By applying a global quality criterion of 0.1 µg/l, the Swiss Water Protection Ordinance to date does not discriminate between the different effects of the over 400 registered active substances. To improve this situation, Eawag proposes an effect-based risk assessment approach for individual pesticides and pesticide mixtures.

For many years, Swiss surface waters have been contaminated by a wide variety of pesticides [1]. Due to their toxic function in curbing damaging pests and weeds, pesticides are also hazardous to flora, fauna and microorganisms in lakes and streams.

Water pollution, resulting from agricultural use of pesticides, usually follows a seasonal pattern. Pesticide concentrations are particularly high if applied to fields during or shortly after rain events: values of up to a few µg/l have then been measured in streams and medium-sized rivers [2]. The quantity of pesticides reaching water bodies from farmland is dependent on the physicochemical properties of the substances, topography of the landscape and soil characteristics [2]. Some 20 – mostly herbicides – of the more than 400 active pesticides registered in Switzerland are found regularly in surface waters (Tab. 1).

Some of these substances are extremely toxic, others less toxic. For effective water protection, a realistic assessment of the risks presented by individual pesticides or pesticide mixtures is therefore essential. Such a risk assessment requires the integration of as much ecotoxicity data as possible, currently lacking in most evaluation methods. Eawag is therefore developing an effect-based risk assessment system in collaboration with the Federal Office of Environment, Forest and Landscape (FOEFL). Based on the available ecotoxicity data, this system allocates an individual water quality criterion to each pesticide expressing the specific pesticide concentration, which should not be exceeded in surface waters in order not to endanger aquatic organisms. A second step involves the integration of the effect-based quality criteria in the risk assessment.

Application as	Product
Herbicide	2,4-D, atrazine, dicamba, dimefuron, dimethenamid, diuron, ethofumesat, isoproturon, linuron, MCPA, mecoprop, metamitron, metazachlor, metolachlor, napropamide, propachlor, simazine, tebutam, terbuthryn, terbuthylazine, and triclopyr
Insecticide	Diazinon and primicarb
Fungicide	Metalaxyl, oxadixyl and penconazole

Tab. 1: Some 20 pesticides are regularly detected in Swiss water bodies.

Traditional Risk Assessment

The risk presented by a pesticide is usually calculated by means of Formula 1 (see Box "Formulas") [3]. If the risk factor is below 1, the probability for aquatic organisms to be damaged by the pesticide is relatively low. If the factor is above 1, the damage probability is high. The quality criterion of 0.1 µg/l, established by the Swiss Water Protection Ordinance, allows identification of polluted water bodies, but not performance of a risk evaluation, since this quality criterion has been arbitrarily defined without any consideration of the varying effects of the different pesticides.

In other countries, effect-based quality criteria are used for risk assessment [4–7].

Formulas

Formula 1

$$\text{Risk quotient of a pesticide} = RQ = \frac{\text{pesticide concentration in water body}}{\text{quality criterion}} = \frac{MEC}{\text{quality criterion}}$$

Formula 2

$$\text{Risk quotient of an individual pesticide} = RQ_i = \frac{MEC}{HC5\text{-}95\%}$$

Formula 3

$$\text{Risk quotient of a pesticide mixture} = RQ_m = \sum_{i=1}^{n} RQ_i = \sum_{i=1}^{n} \frac{MEC_i}{HC5\text{-}95\%_i} = \frac{MEC_1}{HC5\text{-}95\%_1} + \ldots + \ldots + \frac{MEC_n}{HC5\text{-}95\%_n}$$

RQ = risk quotient, MEC = see Glossary, i = individual substance, m = mixture, n = number of pesticides in mixture

However, these assessment criteria also have weak points. The currently most widespread, effect-based quality criterion is the PNEC value (see Glossary). When calculating the PNEC value, all ecotoxicity test data (EC50 and NOEC values, see Glossary) are taken into consideration. However, as the PNEC value is ultimately based on the lowest EC50 or NOEC value, criticism to that effect that the PNEC is reliant on a single data point is justified. In addition, the PNEC value is provided with arbitrarily selected security factors (see Glossary).

For some years, the hazardous concentration HC (see Glossary) has been used as an effect-based quality criterion in risk assessment [8]. Calculation of the HC is dependent on the statistical assessment of NOEC data available in the literature (see Box "Hazardous Concentration"). However, one of the difficulties in calculating reliable HC values is the required input of at least 10 NOEC values from chronic toxicity tests – a requirement not currently met by most pesticides.

A New Method to Calculate Sound, Effect-based Quality Criteria

Despite these drawbacks, the HC is currently the most reliable parameter we have. Our project therefore focused on establishing a method allowing calculation of the HC value, even with few or no NOEC data available. Specifically, we have chosen the HC5-95% value (see Box "Hazardous Concentration") as the effect-based quality criterion.

Our method comprises three stages (Fig. 1):

1. SSD curves based on EC50 (see Glossary and Box "Hazardous Concentration") were established for all pesticides in the mixture as well as for a reference pesticide. The more abundant EC50 data were chosen instead of the NOEC values. As a reference, a pesticide is chosen on which 8–10 long-term and short-term tests had been carried out ensuring sufficient NOEC and EC50 data. Subsequently, the so-called "toxicity ratio" is calculated between the individual SSD-EC50 pesticide curves and the SSD-EC50 curve of the reference pesticide.
2. A second SSD curve provided with confidence range is established for the reference substance – based this time on the NOEC values available in the literature.
3. The SSD-NOEC curves of the other substances, including the confidence range, are plotted on the basis of the SSD-NOEC curve of the reference substance. This is possible by using the toxicity ratio calculated at the start. Finally, the HC5-95% for each substance was derived from the new SSD-NOEC curves.

However, our new method can be used in practice only if the following two hypotheses are verified:

- Pesticides with similar action modes show parallel SSD-EC50 and SSD-NOEC curves.

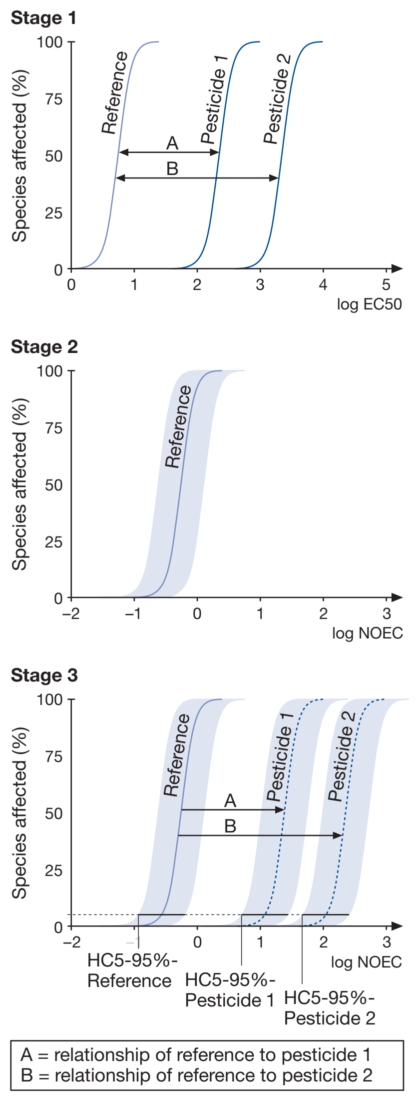
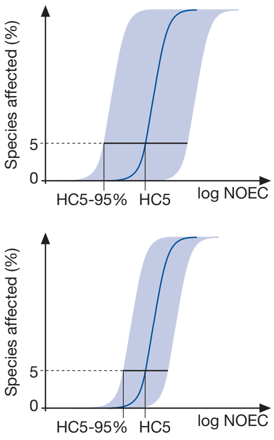


Fig. 1: The three stages of the recently developed calculation method for more consistent HC5-95% values. See text for further explanations.

The "Hazardous Concentration" HC

HC values are calculated from so-called "Species Sensitivity Distribution" curves (SSD curves) [8] in which the distribution of the NOEC data is logarithmically plotted against the percentage of the species affected. In the ideal case, the NOEC data are distributed log-normal, resulting in an S-shaped curve in cumulative plotting of SSD. In practice, HC5 values have become established. They designate the pesticide concentration at which 5% of the total number of species are endangered or 95% of all the species are protected. The SSD curves may also be provided with a confidence interval. The smaller the confidence interval, the better is the quantity and quality of the available ecotoxicity data. This confidence interval allows calculation of the HC5-95% value. It expresses with a 95% probability the pesticide concentration at which 5% of the species are endangered and 95% are protected. The HC5-95% value is always lower than the HC5 value – the smaller the confidence interval, the more the two values converge [9].



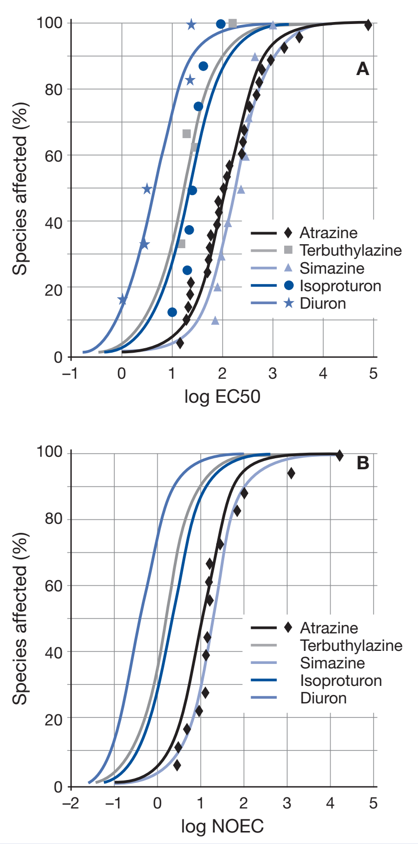


Fig. 2: Individual HC5-95% values for the five pesticides in a pesticide mixture were calculated with the new method. SSD curves were plotted from EC50 data (A), allowing the corresponding SSD-NOEC curves to be derived (B).

- The "toxicity ratio" between the SSD-EC50 and the SSD-NOEC curves is constant.

Since studies on the SSD curves are fairly recent, it is unclear whether these hypotheses are correct. A comparison of the SSD-NOEC curves, derived by this method with the few NOEC data available from literature, indicates that our assumptions are acceptable.

The HC5-95% values will have to be regularly updated if additional effect data become available. Availability of more data increases HC significance.

Our Recommendations

In future, our method will allow calculation of consistent HC5-95% values. We therefore recommend the following measures:

- The global quality criterion of 0.1 µg/l, established by the Swiss Water Protection Ordinance, should be replaced by individual HC5-95% values.
- For risk assessment of individual substances, the individual HC5-95% pesticide values should be used in Formula 2 as effect-based quality criteria (see Box "Formulas").
- The HC5-95% values can also be used in risk assessment of pesticide mixtures, provided the mixtures contain pesticides with similar action modes. This is where the concept of concentration additivity can be applied. According to this theory, concentrations of substances with similar effect mechanisms can be weighted and added according to their toxicity [10], and their risks then calculated by using Formula 3 (see Box "Formulas").

Example: Risk Assessment of 5 Herbicides

The risk of a herbicide mix in the small river Aa near Mönchaltorf, Canton of Zurich was assessed with the method described above. The mixture comprised 5 herbicides, each an inhibitor of photosynthesis affecting the photosystem II. Although their sites of action are not identical [11], these herbicides follow the concept of concentration additivity [Chèvre et al., soon to be published]. Atrazine was chosen as the reference herbicide. To calculate the SSD curves, only toxicity data from tests on aquatic primary producers (algae and aquatic flora) were used, since they are the most sensitive to this type of pollutant. Figure 2A classifies the 5 herbicides according to their SSD-EC50 curves. Diuron is the most toxic herbicide, followed by isoproturon, terbuthylazine, atrazine, and simazine. In Figure 2B, the SSD-EC50 curves are transposed to the SSD-NOEC

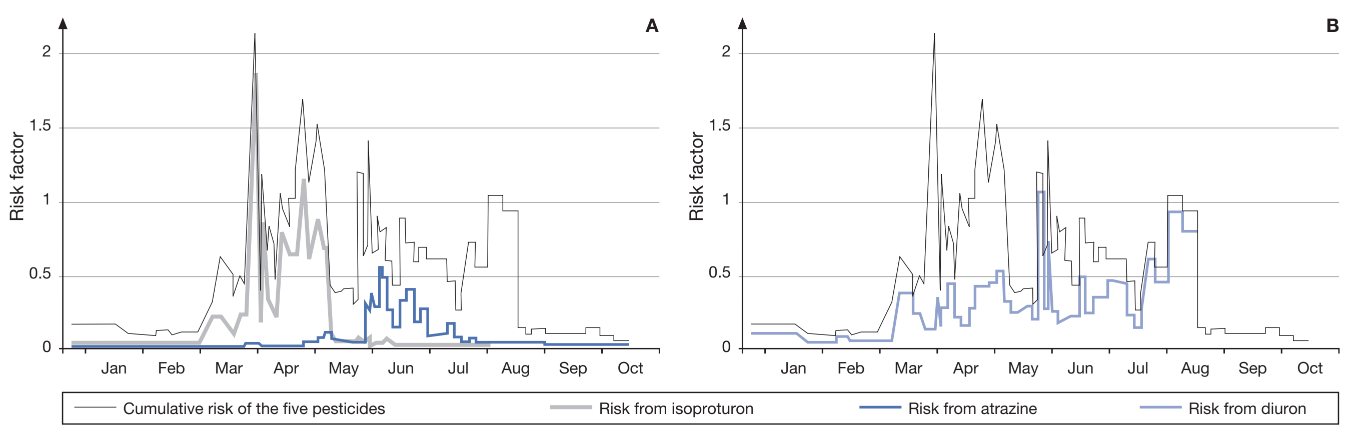


Fig. 3: Risk assessment of the five pesticides in a pesticide mixture.

curves as described in stage 3 of our method.

The risk of damage of this herbicide mixture to aquatic ecosystems in spring (March to May) sometimes clearly exceeds 1 (Fig. 3A). If we consider the risks posed by the individual herbicides in the mixture, two phenomena can be observed: Firstly, the impact risks for the herbicides in water can also be superimposed if they are applied at different times. This is the case for isoproturon and atrazine used in March to April and May to June respectively, showing a risk of superposition in May (Fig. 3A). Secondly, some herbicides occur not only during their application period, but have also been regularly detected throughout the year. These substances reveal a constant baseline load as in the case of our study on diuron, which is not only used as a herbicide, but also as a preservative in paints. Diuron appears to be continuously washed off from house surfaces and subsequently transported into lakes and streams (Fig. 3B). In our research region, diuron is not used as a herbicide, but mainly applied in viticulture. Nevertheless, this should not be underestimated, since it largely contributes to the total risk, along with the baseline risks of the other herbicides.

Our results indicate the importance of integrated herbicide management.

Risk Parameter Glossary

MEC = Measured Environment Concentration – indicates the pollutant concentration actually detected in the water body.

EC50 = Effect Concentration 50% – usually determined by laboratory testing for acute toxicity. It expresses the pollutant concentration at which 50% of the exposed organisms show the tested effect. Mortality is generally used as the indicator.

NOEC = No-Observed Effect Concentration – usually determined by laboratory testing for chronic toxicity. It expresses the pollutant concentration at which no effect is detectable. Usually reproduction or growth is used as the indicator.

PNEC = Predicted No-Effect Concentration – calculated from EC50 and NOEC data. It expresses the pollutant concentration at which no effect is expected in the field. The PNEC is based on the lowest EC50 and/or NOEC values and is also provided with a security factor. The lower this factor, the greater the availability of chronic toxicity data (NOEC data) and number of tested trophic levels (levels in the nutrition pyramid). The security factor includes the uncertainty obtained when the limited amount of laboratory toxicity data are extrapolated to natural conditions.

HC = Hazardous Concentration, derived from SSD curves, indicates the concentration corresponding to a given level of environmental protection (see Box "Hazardous Concentration").

SSD Curves = Species Sensitivity Distribution Curves – represent the percentage of species affected as a function of the pollutant concentration (log NOEC) (see Box "Hazardous Concentration").

Outlook

The recommended method is currently used to calculate new quality criteria for the most commonly detected herbicides in water (triazine, phenylurea, chloroacetanilide), as well as for a specific group of insecticides, the organophosphates, of which diazinon is detected regularly in the water. Further pesticide groups will soon follow.

In the context of standardization, it is of utmost importance to establish clear rules for pesticide sampling. Definition of these rules and selection of sampling sites are the subject of a parallel project. The results of both projects could be useful as reference material for revision of the Swiss Water Protection Ordinance.

Nathalie Chèvre, Environmental Engineer and Ecotoxicologist, now heads the group Applied Ecotoxicology in the Department of Environmental Toxicology. A further research focus is the modular stepwise procedure for ecotoxicological assessment of running waters.

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Promoting Location Suitable Land Use

Changing demands on the cultivated and natural landscape lead to land use conflicts between agricultural production, work and recreation purposes, and environmental protection. An economic land use model also integrating environmental factors enables us to assess the developments in agrarian structures and agricultural land use and to deduce their impacts on the environment.

Agricultural land use is associated with both negative and positive effects. The positive effects are primarily the productive use and the cultivation of the landscape. Among the most serious negative effects is the input of nitrogen, phosphorus, and pesticides into surface and ground waters, resulting from losses during use. In addition, these inputs are increased by land use activities which are unsuitable to their location.

Where Is Swiss Agriculture Heading to?

The scale of the positive and negative effects of land use depends on two interconnected factors: the choice of land use activities by landowners and the allocation of land use activities to a particular location. The decisions of farmers are determined by production techniques and other business management considerations, such as prices, direct payments and technical regulations. On top of these considerations, location choice is influenced by the availability of suitable land. If a farm has little suitable land at its disposal, there is a risk that some land will be used for unsuitable purposes. And furthermore, the agricultural basic conditions are constantly changing, requiring farm management to adapt appropriately.

In order to assess structural developments and future land use, we have developed a so-called sectoral land use model as part of the project "Sustainable land use and forestry production in Greifensee Watershed Area". Our model allows us to predict the development of the agricultural sector at a regional level, in our case for the Greifensee region. The model shows, on the one hand, how agricultural enterprises react economically to changing agricultural basic conditions. On the other hand, the model was extended to a series of environmental parameters [1]. It is therefore possible to investigate the effects of land use changes on the environment. In this article, we focus on the question of whether expected land use is suitable to the specific location and what effects land use activities will have on the pesticide load in the environment.

Land Use Model and Scenarios

Using the land use model, the total income of the agricultural sector in the Greifensee region was maximized. In addition, it derived optimal land use and animal husbandry for the farms and the region as a whole. Agricultural production is therefore modeled so as to reflect the real farms in the Greifensee region. For the model calculations, a series of assumptions has to be made, the most important of which concern:

- the available production factors like land and manpower,
- the production functions,
- the labor costs of family-owned manpower,
- the structural changes: the total number of enterprises should not decrease by more than 2.6 % per annum, corresponding to the structural change seen over recent years.

The agricultural structural development was calculated for a reference scenario and two future scenarios (see box). 2011 was chosen as the time horizon. Table 1 summarizes the key figures for the two future scenarios.

Scenario Swiss Way 2011

If in the Swiss Way 2011 scenario full labor costs are assumed, today's structures shift in the direction of more extensive farming. Livestock is relatively heavily reduced, which is primarily the result of a lower milk production. With the assumed milk price of 55 centimes per litre, only 80 % of the current milk volume would be produced. In comparison to dairy animals, the reduction of livestock in labor-extensive animal husbandry is less pronounced. Suckler cow husbandry would, on the other hand, increase considerably. As a result of the changes in animal husbandry, the feed crop farming would decrease. Ecological compensation areas would increase greatly, mainly fallow land on arable land and extensively used meadows. The increase in ex-

Scenarios and Basic Conditions

Reference Scenario 2000: In this scenario the year 2000 was simulated, meaning that all the prevailing basic conditions (political and market environment) which the farmer was confronted with in 2000 were used. Due to the census of agricultural holdings and the geo-referenced land use database [2], there are no gaps in the knowledge of factors which are important for the model. We are therefore in the position to validate the land use model, and to identify the effects of the model's assumptions.

Scenario Swiss Way 2011: In this scenario, no further liberalization steps are implemented other than decided in the Agricultural Policy 2007. The greatest changes are the lifting of the production quotas and the liberalization of the cheese market. So for milk in 2011, a price of 55 centimes is assumed, while the remaining produce prices sink by 20–30 % compared to 2000. For costs there is no clear trend and the direct payments system is maintained in its current form.

Scenario Opening 2011: In comparison to the scenario Swiss Way 2011, this scenario assumes that the market price support is entirely abolished, and border protection with the EU is eliminated. Produce prices re-orient towards the European prices and lie at 35–75 % below the initial level in the year 2000. The decline in costs is primarily felt in the concentrated feedstuffs sector in an European environment.

	Swiss Way 2011		Opening 2011	
	Exclusive labor costs	Inclusive labor costs	Exclusive labor costs	Inclusive labor costs
Sector income	98 %	72 %	83 %	65 %
Income/labor unit	64 %	104 %	54 %	94 %
Arable land/ASA	110 %	76 %	106 %	40 %
Open arable land/ASA	79 %	89 %	76 %	42 %
Fodder cultivation/ASA	192 %	59 %	189 %	47 %
Livestock (LU)	147 %	76 %	149 %	83 %
LU/Fodder cultivation area	121 %	75 %	121 %	72 %
Milk production	335 %	80 %	338 %	95 %
Ecological compensation areas/ASA	127 %	237 %	146 %	287 %

Tab. 1: Agricultural structural development in the future scenarios Swiss Way 2011 and Opening 2011 (relative to Reference Scenario 2000). Labor unit = one fully employed person, ASA = agricultural surface area, LU = livestock unit (e.g. 1 cow = 1.0 LU or 1 bull = 0.6 LU).

tensively used meadows is related to the lower labor requirements, high direct payments, and the lower fodder quality requirements of suckler cows.

Clearly, the level of the assumed labor costs has a strong influence on the agricultural structures. Should these costs be disregarded, then the decrease of product prices in animal husbandry is compensated by higher stock levels and more intensive production. In this case, the entire sector income stabilizes at today's level, whereby the income per labor unit falls significantly. If one includes labor costs and the changeover to (labor-)extensive systems, the opposite picture appears: despite reductions in sector incomes, agricultural enterprises achieve today's income levels per labor unit.

Scenario Opening 2011

Basically, the effects described for the scenario Swiss Way 2011 also apply for the scenario Opening 2011 (Tab. 1). The differences between the two scenarios are due to the different assumptions regarding prices, costs and direct payments. In particular, falling prices for cash crops have considerable impacts in this scenario. As a result, arable farming is reduced significantly. As in the scenario Swiss Way 2011, lower product prices have an effect on incomes. Taking full labor costs into account, income per labor unit in the scenario Opening 2011 is 10 % lower than in the scenario Swiss Way 2011.

Is Today's Land Use Optimized for Location?

Along with the general structural developments in agriculture, we were interested to know to what extent land use would change and whether land would be cultivated in a location suitable way. In Figure 1A, the land use distribution for the year 2000 is shown as derived from a supervised classification of air photographs [2]. Figure 1B shows the optimal land use in Reference Scenario 2000. Clearly, there is unfavorably located arable farming in the current situation: approximately 20 % of land which is suitable for extensive perennial grassland only is used for arable farming, and only 44 % of land which is classed as unrestricted crop rotation area is used for arable farming (Fig. 1A). On the contrary, the Reference Scenario 2000 chooses more arable farming on the yield rich locations and uses the land predestined for perennial grassland exclusively for roughage production (Fig. 1B).

This raises the question why agricultural enterprises do not use their land for location suitable activities. An important reason is ownership and leasehold. In the current situation, there is a shortage of suitable arable land for single operators, who are consequently obliged to use unsuitable land. In the model, on the other hand, individual single-operator ownership and leasehold are not represented [1]. The model farms are therefore much more flexible in the composition of their properties, so that in Reference Scenario 2000 exclusively crop rotation land is used for arable farming.

Is Future Land Use Optimized for Location?

The land use model does not answer this question in an unambiguous way:

- On the one hand, the share of open arable land in the two future scenarios declines (Tab. 1). This induces a corresponding decrease in the shortage of crop rotation land in the future scenarios, so that it would be theoretically possible to re-establish arable farming in suitable locations.
- On the other hand, in the future scenarios the land area for cereals, potatoes and sugar beet declines, while fallow land area on arable land increases. As a conse-

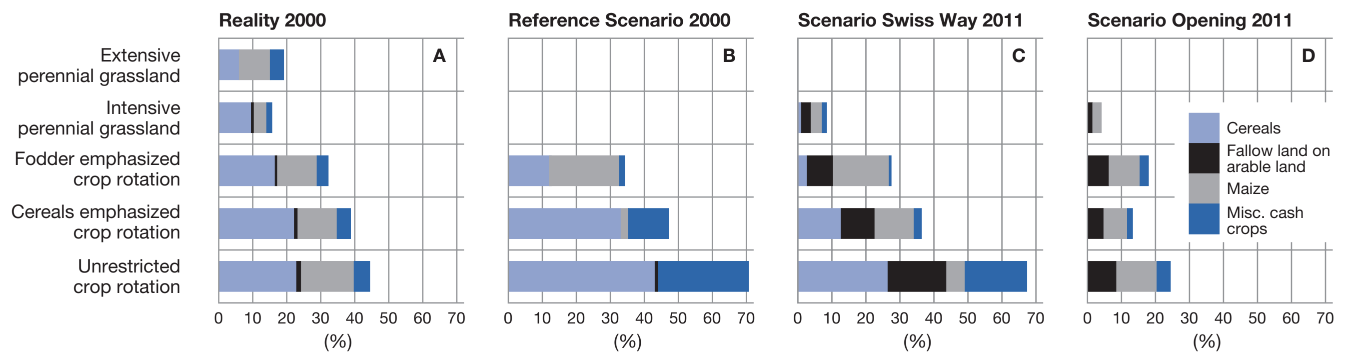

Fig.1: Arable farming by land use suitability in reality [2] (A), in the Reference Scenario 2000 (B), and in the two future scenarios Swiss Way 2011 (C) and Opening 2011 (D). See box for the description of the scenarios. Miscellaneous cash crops: potatoe, sugar beet, rapeseed.

quence, there is an increase in the planting of maize, a crop which can also be planted in less suitable locations. Very likely, a certain share of grassland will continue to be used for arable farming, which is not compatible with location suitability (Fig. 1C + D).

Environmental Impacts

With the expected animal husbandry and land use, the impacts on the environment also change. Table 2 shows how nitrogen and phosphorus losses change, as does the share of cultivated land in pesticide risk locations. While the nitrogen losses remain more or less proportional to the arable farming area, phosphorus losses fall with the livestock sizes. On the other hand, the share of pesticide risk locations used for arable farming clearly increases with full labor costs in the scenario Swiss Way 2011: more than 10% of the risk locations are used for arable farming, instead of around 3–6% as in the other scenarios. This is due to the fact that more land will be used with a lower degree of suitability, and that these locations are often pesticide risk locations [3].

Requirements for Location Suitable Land Use

From our results, it is clear that an extensification of agriculture is to be expected in the future: decreasing animal stocks, lower intensity in roughage production, and expansion of ecological compensation areas. This trend will be further emphasized by structural changes. Evaluations of the current structures in the Greifensee region show that large farms hold fewer animals per land unit than smaller farms [4]. The increasing flexibility due to the structural change makes it possible for farm managers to limit the inappropriate use of land for arable farming, so that in comparison to today's use, a more suitable farming of the arable land can be expected. It can also be expected that the negative effects of agriculture on the environment will decline.

Independent of this long-term development, location suitable use of land can be promoted by the design of the direct payments system, i.e. the requirements for the right to receive direct payments. Under the current system, with the exception of the Ecological Quality Regulation [5], no criteria for location suitability are considered: the hazard potential for water and the revaluation potential for biodiversity, which varies in response to location factors, are not taken into account. Further results obtained with the land use model show that the network of environmental compensation areas can be significantly improved by linking the environmental direct payments to location selectivity [6]. Likewise, the cultivation of crops with high plant protection demands can be limited on pesticide risk locations with incentives or bans. Since there are relatively few pesticide risk locations in the Greifensee region, a ban on cultivation of arable crops with high plant protection demands on these risk locations will have only limited effects [6]. However, in particular areas or on individual farms the structural effects of a ban can be considerably greater. The extent of the effect depends on the shortage of crop rotation land and its classification as risk locations. Furthermore, it must be taken into account that pesticide losses do not only depend on location (un)suitable land use [3]. Along with a restriction of pesticide use in high risk locations, other measures which are designed to reduce the application of pesticides and their losses should also be applied.

The investigations in the Greifensee project highlight that the location characteristics of land should be included in any future agricultural policy. At the same time, it has become clear that the existing state of understanding – in particular regarding the question of how agricultural activities, location characteristics of land, and the resulting environmental impacts, are interrelated – is insufficient. These gaps in knowledge must be closed quickly.

	Swiss Way 2011		Opening 2011	
	Exclusive labor costs	Inclusive labor costs	Exclusive labor costs	Inclusive labor costs
N losses	→	↘	→	↓
P losses	→	↘	→	↘
Proportion of arable farming on pesticide risk locations	→	↑	→	→

Tab. 2: Changes in substance losses in the Greifensee watershed area in the future scenarios Swiss Way 2011 and Opening 2011 (relative to Reference Scenario 2000). The risk locations for pesticide loss were identified with the help of a simple indicator [3].

Kurt Zgraggen, agricultural economist at the Institute of Agricultural Economics at ETH Zurich, developed the sectoral land use model for the integrated research project "Greifensee – sustainable land use and forestry production in the Greifensee Watershed Area" as part of his PhD thesis.

Christian Flury, agricultural economist at the Institute of Agricultural Economics at ETH Zurich, is the project leader of the integrated research project "Greifensee" and, as a partner in the firm Flury & Giuliani GmbH, offers consulting services in the fields of agriculture and regional economics.

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National Strategy for Agricultural Nitrogen Reduction

For the reduction of environmentally harmful nitrogen emissions from agriculture, the project group Nitrogen Balance Switzerland formulated environmental targets that have also found consideration in current agricultural policy. Recent calculations show that the intermediate goal for 2005 cannot be achieved. Responsible for this is, amongst others, the lack of sufficient and targeted economic incentives. These could be created through a system of steering levies on nitrogen fertilizer and a spatially differentiated land use tax.

In Switzerland, around 50% of ecologically relevant nitrogen emissions come from agriculture [1]. The reduction of these emissions constitutes a challenge for politics, research and agriculture. However, this is not straightforward. Nitrogen compounds are an integrated part of natural material cycles and to some extent can be transported over great distances. Moreover, the majority of nitrogen emissions originate from nonpoint sources. As a result, the generator cannot be easily identified, which makes the implementation of incentives and efficiency oriented instruments in environmental policy more difficult [2, 3].

Nitrogen Strategy in Switzerland

To protect humans and the environment against harmful and annoying effects of nitrogen compounds, targets have been established in national legislation and international agreements which aim at achieving precautionary emission reductions that are technically feasible and economically viable. In addition, the project group Nitrogen Balance Switzerland [1] developed on behalf of the federal government strategies for a stepwise minimization of environmentally relevant nitrogen emissions. These are also reflected in the environmental targets of the current agricultural policy (AP 2007) [4, 5]. Amongst others, the project group elaborated on the basis of scientific investigations, the medium-term objective for overall reductions in total emissions of environmentally relevant nitrogen compounds into air and water. For Swiss agriculture, this would require emission reductions of about 14 kt nitrogen until 1998, and 22 kt nitrogen per year until 2002 [1]. The Federal Parliament postponed the fulfillment deadline within the frame of AP 2007 to the year 2005 [4, 5].

Furthermore, the project group Nitrogen Balance Switzerland formulated ecologically-based long-term goals for the emissions of nitrous oxides and ammonia, as well as for nitrogen runoff from agriculture [1]. In addition, it proposed that the total nitrogen losses to the environment must be halved in the long run, i.e. the annual fluxes must be reduced from 96 kt nitrogen in 1994 to the ecological target of 48 kt nitrogen [4]. In contrast, no concrete targets exist for nitrous oxide emissions. These should, however, be taken into account in connection with the Kyoto Protocol obligations for reducing total Swiss greenhouse gas emissions.

Methods for Assessing Nitrogen Losses

In conjunction with the project group Nitrogen Balance Switzerland, the Institute of Agricultural Economics (IAW) of the Swiss Federal Institute of Technology (ETH) Zurich developed a method [6] to calculate the nitrogen loss potential and nitrogen losses to the environment from agriculture for different farm types. The approach is based on a random sampling of farms, taken from the totality of the balance sheet declarations of the Swiss Farmers Union (SBV) and the Service romande de la vulgarisation de l'agriculture (SRVA), the agricultural information service for the French speaking part of Switzerland. These provide data about purchases of seeds and marketed fertilizers, sales of plant and animal products, as well as changes of livestock. For the estimation of nitrogen quantities used in Swiss agriculture and the related loss potential, key figures were assessed for the different farm types and extrapolated to the entire agricultural area of Switzerland. Complementary, using statistical data provided by the SBV, a global calculation was provided, in which Swiss agriculture is regarded as only one enterprise.

Nitrogen Loss: Down and Up Again

Recent calculations with these two methods show an initial decline of the nitrogen loss potential after 1993/4 and an increase since 1997/98 [5, 7]. This result is also supported by other assessments. The OSPAR method [8], for instance, reveals the same development in the annual nitrogen balance. The excess of nitrogen inputs clearly declined between 1990 and 1997, and is currently rising again [5].

Figure 1 shows the development through time of the nitrogen loss potential calculated with the IAW method, which accounts for stable, storage, application and utilization losses. It becomes apparent that the estimated nitrogen loss potential is slightly higher when taking into account new scientific knowledge and the progress in agricultural production [9], than with the old coefficients from 1994. This might particularly be due to changes in animal husbandry and a lower plant availability of farm manure.

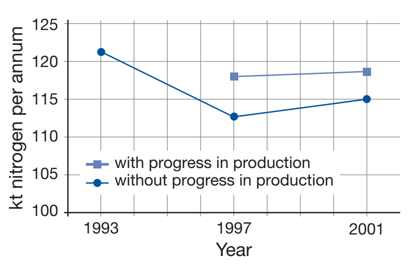

Fig. 1: Development of the nitrogen loss potential according to the global calculation [5, 9].

Unfortunately, problems emerged with the extrapolation of the sample data that limit the interpretability of the results for the individual farm types and the partition of the loss potential to the various nitrogen forms. These problems trace back to the fact that the calculation method was originally designed for the validation of calculations with an agricultural economic model, rather than as a monitoring tool. In addition, the continuity and representability of the data is negatively affected by fluctuations in the set of bookkeeping farms with SBV and SRVA, as well as structural shifts between farm types. This particularly affects the composition of the nitrogen loss potential and the calculation of the environmentally relevant nitrogen losses. For this reason, no reliable statements can be made about the level and development of nitrogen losses to the environment for 2002 with the IAW method.

Alternatives are however available. One option is the use of the nitrogen loss potential without breaking it down to individual losses. According to the project group Nitrogen Balance, the corresponding stage target for 2002 would correspond to a reduction of 28 kt nitrogen per annum compared to 1994. As illustrated in Figure 1, this target is still far from being achieved.

A second option is the calculation of environmentally relevant nitrogen loads using the IULIA method [10] and the national greenhouse inventory, provided annually according to international guidelines [11].

Table 1 shows the corresponding values for selected years. Since these values are slightly higher than those used to date, the effectiveness of agricultural policy measures can only be evaluated with regard to proportional changes compared to 1994. These support the assumption [5] that the agro-ecological stage target might not be achieved even in the year 2005.

Explanation

Reasons for this development, which is undesirable from an ecological point of view, are [5, 7]:

- the re-increase of mineral nitrogen fertilizer use,
- the higher nitrogen requirement of the cultivated plants,
- the increase in the number of free-movement stables,
- changes in the feeding recommendations,
- the increase in imported fodder,
- the temporary storage of organically bound nitrogen in the soil.

Moreover, the uncertainty in the calculation of nitrogen fluxes into the environment and the complexity and dynamics of natural systems [10], together with technological and economic developments may have an effect. From an economic point of view in particular, changes in relative prices and restrictions on individual management options through regulations play a decisive role in the choice of individual activities and factor inputs as well as for the diffusion of new production alternatives.

A Double Research Need

Correspondingly, the requirements on research double. On the one hand, we must better understand the effects of changing agricultural production systems on the nitrogen balance, and, on the other hand, integrate this knowledge into appropriate mathematical-scientific models (including error estimations). This creates at the same time a basis for reliable economic analyses, which can react very sensitively to changes in relative prices, political framework conditions and new technological possibilities. In particular with regard to changes in relative prices and production techniques, the real development since 1994 has diverged from the predictions in model calculations used by the project group Nitrogen Balance [1, 6]. This explains at least to a certain extent the existing gap to the policy targets for reducing the nitrogen loss potential.

Evaluation and Policy Recommendations from an Economic Perspective

In view of this gap, the question arises about adequate measures for reducing nitrogen losses from Swiss agriculture. From an economic point of view, priority must be given

(in kt N/year)	1990	1994	1998	2002	2005	Ecological target [d]
Nitrous oxide [b]	4.2	4.1	3.9	3.8		
Ammonia	54.4	51.3	49.7	47.8		
Nitrogen oxides	3.3	3.1	2.9	2.8		
Nitrate	44.9	41.7	39.2	38.5		
Environmentally relevant N-loads	106.8	100.1	95.7	93.0		
Changes since 1994			–4.6 %	–7.1 %		
Agro-environment stage targets [c]			–14.6 %	–22.9 %	–22.9 %	–50 %

Table 1: Environmentally related nitrogen losses and agro-environmental targets [a].

[a] Own calculation as described in the text.
[b] Without indirect emissions.
[c] According to the project group Nitrogen Balance Switzerland and Agricultural Policy 2007, respectively [1,5].
[d] Long-term ecological target [4].

to the introduction of input charges (“steering taxes”), even if they have repeatedly been rejected with reference to other measures [1, 4].

Steering taxes are incentive-oriented economic instruments which, in contrast to regulative legislation, enable a cost-effective (i.e. cost-minimizing and resource-protecting) attainment of environmental targets through the correction of relative prices. This can theoretically be achieved by levying a charge (a price) on nitrogen emissions, and by this means creating an incentive for the internalization of external costs [2]. Such a policy is however complicated by the fact that emissions originate from a wide range of sources and cannot be easily observed. As an alternative to charging emissions, environmental economists therefore proposed a system of taxes on all inputs that are responsible for the generation of emissions. This taxation system has the same efficiency characteristics as emission or effluent charges [12].

Related to the nitrogen problem, the solution requires the combination of a nationally uniform charge on nitrogen fertilizers (mineral and manure, and not only on excess manure) with a spatially differentiated land use tax. This discriminating land use tax makes it possible to appropriately take into account individual location characteristics and management practices [3, 13, 14]. Hence, past views regarding nitrogen taxes must be reconsidered, and at the same time investigated in a broader context of several environmental problems and targets. This implies the necessity for a reassessment of the prior experience and understanding with regard to the introduction of nitrogen taxes in agro-environmental policy.

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To increase yields, the fields are sprayed with fertilizers, a part of which enters the environment unused.

In the conflicting area of agriculture and water protection

Andreas Zehnder, Agric. Eng. HTL, is leader of the Monitoring and Control Service of the Agriculture Office Schaffhausen and is active as a consultant in the fields of cultivation and ecology.

Water protection is an important basis to the economic viability of the Swiss agricultural enterprises in respect of the proof for environmental performance (PEP). If a farmer breaks the rules of the Water Protection Legislation, his direct payments could be withheld.

Subjects such as the influence of antibiotics, natural and mineral fertilizers, and pesticides to aquatic ecosystems are current issues and cannot be brushed aside in discussions of agriculture. It is therefore indispensable that the risks that these substances present for the water are investigated and that from this knowledge, targeted measures for the minimization of water loads are developed. On the other hand, policy-makers must integrate this knowledge into the future orientation of Swiss agricultural policy.

As a consultant for an environmentally friendly agricultural production, one question concerning the water protection discussion lies particularly close to my heart: “How do I say this to the farmers?”

Water protection is not the only nor the greatest problem farmers face today. Besides the impositions regulated by the environmental legislation, operational and production technical questions are essential for the survival of an agriculture enterprise. Our main task is, therefore, to pass on the knowledge gained from research and policy in a comprehensible form to the farmers, so that they are convinced of the necessity of ecological measures. My experience shows that in agricultural consulting the following expression is most applicable: For the transfer of ideas, the language is more important than the dialect.

Jürg Hertz, Deputy Head of the Departement for Environment Protection in Canton Thurgau.

Agriculture lies in the contradictory context between private management and public commitment. More than 4 billion francs of direct payments and subsidies flow annually into farming – a part of which is allocated for ecological services.

These services must be defined, controlled and communicated. The requirements should be clear, unambiguous and meaningful, and be equal between all cantons in validity and application. Restrictions in entrepreneurial management are unwelcome and are viewed as chicanery. Policy and public demand consistent but not too strict control, and expect in addition an improvement of the environmental situation by means of the applied measures, and the production of healthy, tasty, and competitive foodstuffs.

Swiss agriculture operates in a conflicting area also affecting the accomplishment of environmental protection. The balance between interventions and self responsibility must be maintained, as well as the harmonization of the intercantonal implementation, to minimize regional differences. These are just two issues to which the environmental protection authorities are confronted in the field of agriculture.

The central point is communication at all levels: on the political level the demands of environmental protection need to be well-founded, well-represented and balanced between all stakeholders. In implementation, it is necessary to provide good explanations to all those affected by the measures, to gain their acceptance. And the public must become more aware of the ecological services which have already been achieved by the agricultural sector.

Ueli Bundi, Acting Director of EAWAG, is concerned with questions of environmental policy, water industry and water-course assessment.

The integration of environmental protection into industrial sectors is a central postulate of environmental, economic and regional policy. Agriculture has accepted the challenge and has been following this path now for 15 years. There still remains, however, a great need for further action.

The rural landscape in intensively used areas is still strongly depleted, with its streams completely destroyed or stripped of their protective and landscape forming riparian vegetation. The re-establishment of a natural stream network requires agricultural land and is one of the most important future tasks.

The nitrogen targets of the 1999 agricultural policy could not be achieved. The main reason for this is the nitrogen imported in the form of fertilizer and fodder. An optimized management system would allow nitrogen to be better used and thereby losses to be reduced. This would also limit the quantities of importable auxiliary agents. This is the case for both Swiss agriculture as a whole and for many individual agricultural enterprises.

Agro-ecological goals should be primarily pursued by means of an economic incentives system. These incentives will encroach the borders of international regulation regimes and economic acceptability.

Thus, agriculture as well as the rural areas as a whole see a difficult future ahead. In this context, enormous structural, economic and social problems have to be solved across Europe. New visions for a sustainable development of rural areas and agriculture as its vital industry are urgently required.

Publications

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IN BRIEF

Multi-level Groundwater Flows near Rivers

Eawag researchers and specialists of the Canton of Thurgau revealed the existence of multi-level groundwater flows of varying origins below and alongside the river Thur. In simple terms: The deeper the water flow, the longer it has remained in the underground. This is important for drinking water catchment, as the legal provisions prescribe that water must remain in the underground for at least ten days before it can be tapped to prevent contamination of drinking water. The situation at the Thur is typical for many sites where drinking water is conveyed from gravel-sandy valley soils. However, the ten-day flow time cannot be observed in all catchment areas. During flood events, this situation is further aggravated due to shorter flow paths and increased infiltration. Even if rivers are given more space by flood protection and revitalization measures, they could move closer to the drinking water catchment areas. Eawag researchers therefore suggest a concept of new measuring and simulation methods to obtain differentiated solutions to the respective problems.


EAWAG

Tracking Down Whitefish Decline in Lake Brienz

In the project "Changes in the Ecosystem of Lake Brienz", EAWAG jointly with other partners aim at determining the reasons for the massive collapse (approx. 90%) of whitefish yields in 1999. Preliminary results from the seven subprojects were presented at the symposium "Lake Brienz – Between Hydroelectric Power Use and Nutrient Reduction" at the University of Berne on 23 September. The subprojects study for instance the effects of the power station in the catchment of Lake Brienz as well as the input of nutrients and suspended particles to the lake. The study revealed, inter alia, a far smaller but seasonally different input of suspended particles than observed prior to construction of the power plant. In addition, the water pollution control measures, which led to a marked nutrient decrease in Lake Brienz and significant decline in algae production, limited the number of Daphnia (water fleas) available as fish food. On completion of the project in summer of 2006, the different pieces of the subproject puzzle will be assembled to obtain an overview and provide an objective assessment of the conflicting questions.


U. Ochsenbein, GBL

Further information: www.eawag.ch/research_e/apec >Brienzersee and www.eawag.ch/events/brienzersee

Personnel

Jukka Jokela is head of the Department of Limnology and Professor for aquatic ecology at ETH Zurich since 1 June 2005. He is particularly interested in evolutionary ecology.

Juliane Hollender joined the Eawag on 1 September 2005. The chemist heads the new Department of Environmental Chemistry created by the merged departments of Water and Agriculture and Chemical Pollutants.

Agenda

9 December	**«Blyb gsund» in Dar es Salaam** Brigit Obrist van Eeuwijk, Swiss Tropical Institute, Basel Seminar, EAWAG Dübendorf, 11:00–12:00
13 January	**Policy Principles and Implementation Guidelines for Public-Private Partnership in Water Supply and Sanitation: Improving Performance through Transparency and Participation** Dieter Rothenberger, SECO; François Münger, SDC Seminar, EAWAG Dübendorf, 11:00–12:00
20 January	**Entwicklung von sozialen Techniken für die Verbreitung von SODIS** Hansi Mosler, EAWAG Seminar, EAWAG Dübendorf, 11:00–12:00
27 January	**From SODIS to Household Water Treatment and Safe Storage** Martin Wegelin, EAWAG Seminar, EAWAG Dübendorf, 11:00–12:00
3 February	**The Challenge of Fluoride Removal in Drinking Water** Annette Johnson and Kim Müller, EAWAG Seminar, EAWAG Dübendorf, 11:00–12:00
10 February	**Simplified Sewerage: An Option for Low- and Middle-Income Countries** Duncan Mara, University of Leeds UK Seminar, EAWAG Dübendorf, 11:00–12:00