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Where is herbicide use particularly critical?

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Although herbicides can be detected in surface waters throughout Switzerland, herbicide-intensive crops are mainly cultivated in low-risk areas. This was shown by an assessment involving GIS-based modelling of discharge processes on the Central Plateau. With this approach, critical areas can also be identified.

Is chemical pollution of surface waters responsible for declining fish stocks in various parts of Switzerland? Can adequate supplies of safe water be assured for the growing population in an age of climate change? In addressing these and many other issues, monitoring of water quality remains a priority concern, particularly in regions as densely populated as the Swiss Central Plateau, where a wide variety of interests confront each other in a relatively small area – hydropower generation, agriculture, flood control and protection of natural habitats. Assessment of water quality calls for a knowledge both of the sources of water pollution and of the processes whereby pollutants enter surface waters. Among the most important diffuse (i. e. non-point) sources of water pollution are herbicides used in agriculture.

Lack of soil data for Switzerland. Scientists seeking to understand and quantify herbicide losses to surface waters have car-

On the Central Plateau, agricultural herbicides are mainly applied in areas where their use is appropriate from a water protection viewpoint.

agenda/Michael Kottmeier

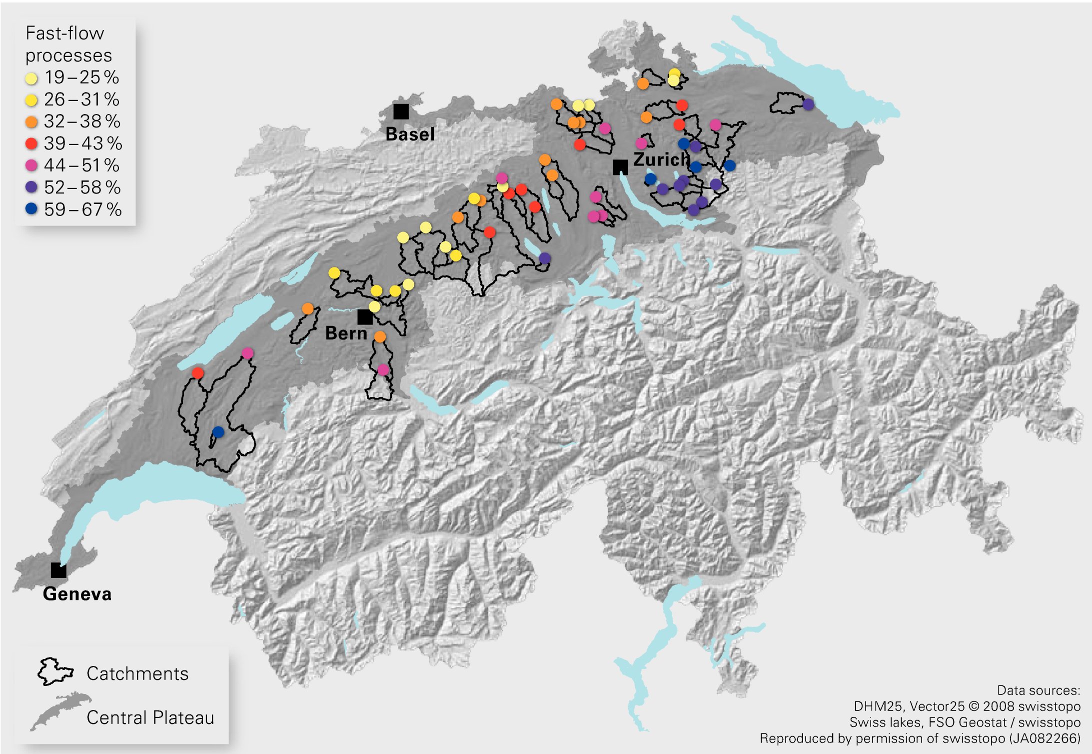

Fig. 1: National discharge stations in the Central Plateau and their catchments. The colours represent the relative contribution of fast-flow processes to total flow. The higher this percentage is, the higher herbicide losses are expected to be.

ried out field studies [1, 2]. However, such studies are costly and require considerable effort. Mathematical models can therefore be useful in assessing diffuse losses for extensive areas. Over the last 20 years, numerous complex models have already been developed for inputs of pesticides to surface waters [3]. But the applicability of these models in Switzerland is limited, mainly due to a lack of adequate soil and drainage data.

Christian Stamm of the Environmental Chemistry department and Peter Reichert and Rosi Siber of the Systems Analysis, Integrated Assessment and Modelling department of Eawag have therefore developed a simpler model which, while capturing the main processes underlying herbicide losses, is still applicable in practice with the data available [4]. The aim of this modelling was not to predict possible concentrations in surface waters, but to assess the risk of herbicide losses for agricultural areas – in other words, to identify areas that are particularly susceptible to such losses, e.g. on account of soil properties. Inputs to surface waters can then be estimated by combining the results of modelling with the spatial distribution of estimated herbicide use. We confined our study to the Central Plateau because intensive agriculture – associated with high levels of pesticide use – is primarily concentrated in this region.

Although the processes determining herbicide losses are highly complex, the temporal dynamics of herbicide concentrations in surface waters follow a simple pattern: these substances are mainly transported to waterbodies during and shortly after application, if they are simultaneously washed out of the soil by rain or as a result of irrigation. Herbicide transport from fields to surface waters mainly involves what are known as "fast-flow" processes, such as surface run-off or tile drain flows [5]. Accordingly, the extent of losses to surface waters is largely determined by the level of fast-flow processes in a catchment.

Higher risks in the east and in the pre-Alps. For our modelling, we therefore used the predicted level of fast-flow processes [6] as a good proxy for herbicide transport [7]. Information on flow processes was provided by long-term measurement data from the national discharge stations operated by the Federal Office for the Environment (Fig. 1). In addition, using a GIS, we delineated individual catchments on the basis of a digital elevation model and Swiss river network data, and for each catchment we calculated the parameters relevant for discharge patterns. These included data on topography, climate, soil and land use (Table).

To eliminate gaps in coverage, a prediction model including climate and soil data as well as topographical parameters was used for areas where discharge measurements were not available. In order to find out which factors have a major influence on the level of fast-flow processes, we subjected the discharge data and catchment parameters to statistical (regression) analysis. The results indicated that fast-flow processes are influenced by three factors in particular – soil permeability, river density (ratio of the total length of all watercourses to the area of the catchment) and precipitation frequency. With a discharge model, we were able to account for the level of fast-flow processes to a high degree (62 per cent) using the combination of soil permeability and river density alone.

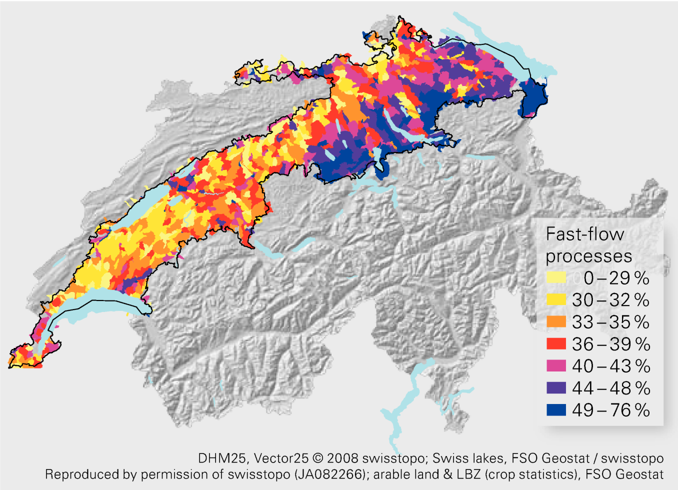

Fig. 2: The risk of herbicide losses, indicated by the relative contribution of fast-flow processes to total flow. A higher percentage corresponds to a higher risk.

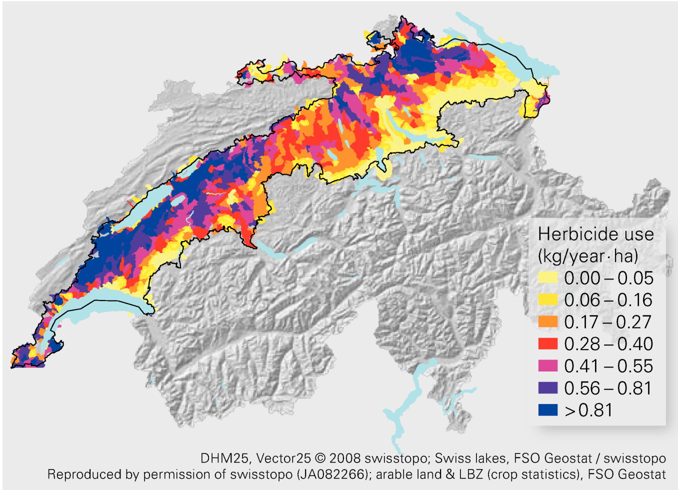

Fig. 3: Estimated herbicide use: the amount used in a particular catchment depends on the crops cultivated there.

With the aid of this model, discharge patterns for the catchments with no data could now also be predicted and visualized in the GIS together with the catchments for which data were available. This complete picture of the Central Plateau shows, for all areas, the relative contribution of fast-flow processes to total flow and hence the risk of herbicide losses. This risk can be seen to increase from the west to the east, and also towards the pre-Alps and Alps (Fig. 2).

Table: Parameters relevant for discharge patterns in individual catchments.

		Data sources
Topography	Slope	swisstopo: DHM 25 © 2004-8, reproduced with the permission of swisstopo (JA 082266)
	Minimum elevation	
	Maximum elevation	
	Mean elevation	
	River density	swisstopo: Vector25 © 2004-8, reproduced with the permission of swisstopo (JA 082266)
Climate	Mean annual precipitation	Hydrological Atlas of Switzerland (2008): www.hades.unibe.ch
	Precipitation frequency	Wüest M., Frei C., Altenhoff A., Hagen M., Litschi M., Schär C. (2008): A gridded hourly precipitation dataset for Switzerland using rain-gauge analysis and radar-based disaggregation. Intern. J. of Climatology
Soil	Permeability	Soil suitability map (BEK 200, FSO Geostat)
	Waterlogging	
Land use	Herbicides used per crop	Keller L., Amaundruz M. (2004): Pflanzenschutzmittelverbrauchserhebung der Jahre 1997–2003 in den Einzugsgebieten Greifensee, Murtensee, Baldeggersee. LBL, Lindau, SRVA, Lausanne
	Arable land	FSO (2004): Ackerland, ackerfähige Böden, Dokumentation. FSO Geostat, Neuchâtel
	Crop types	FSO (2002): LBZ (annual crop statistics). FSO Geostat, Neuchâtel

Herbicide use higher in the north-east. The amounts of herbicides used in agriculture vary according to the type of crop cultivated [8]. Although field-scale crop data are lacking in Switzerland, a raster dataset on land use categories (including arable land) was available. By combining this with current crop statistics from the Federal Statistical Office, we were able to estimate the total amount of herbicide used for each catchment of the Central Plateau; again, this was visualized in the GIS.

The spatial distribution of individual crops across the Central Plateau varies considerably. For example, cereals and maize are distributed more or less evenly throughout this region – they are grown wherever arable farming is possible. In contrast, the cultivation of potatoes, sugar beet and vegetables is concentrated in certain areas. The fact that these crops require higher quantities of chemicals is reflected in the spatial distribution of herbicide use, which is particularly high, for example, in the north-east (Zurich Weinland and Thurtal region) and in the Seeland (Three Lakes) region (Fig. 3).

If one compares herbicide use with the risk of losses, it is striking that in many areas – such as the west and the north-east – high use is associated with a low risk. In other words, on the Central Plateau, intensive agriculture is mainly practised in areas where high levels of herbicide application are acceptable from a water protection perspective.

Floodplains: critical areas. However, the comparison also reveals certain exceptions – areas where high herbicide use coincides with a high risk of losses. These are the critical areas where the possible need for mitigation should be investigated. The deviations from the general trend are mainly demonstrated by analysis at a higher spatial resolution. The sites concerned frequently lie in former floodplains.

Even though in this case further studies are needed, modelling based on fast-flow processes can help to identify particularly vulnerable areas where, if necessary, intensive agricultural use could even be prohibited. Such models are therefore suitable for targeted monitoring efforts and can make a significant contribution to the improvement of water quality and the quality of surface waters as habitats for animals and plants.

Nonetheless, for a more precise evaluation, better data availability would be desirable. Studies of input pathways of herbicides to surface waters clearly indicate that soil properties are an important factor [9], but detailed soil data are not available for the whole of Switzerland. In addition, owing to the lack of long-term herbicide measurements, it was fairly difficult to test the model with real data. For example, only three atrazine monitoring datasets were available. However, these agreed closely with the results of the model – which again underlines the essential suitability of fast-flow processes as a proxy for vulnerability to diffuse herbicide losses. Although our modelling method cannot be transferred directly, it does point the way towards the construction of relatively simple and practical models for regions other than the Central Plateau. ○ ○ ○

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Swiss waterbodies information system

The Swiss waterbodies information system (GEWISS) is an online GIS portal, hosted by the Federal Office for the Environment, which presents interdisciplinary data and overviews covering all aspects of the country's waterbodies. The portal is designed to facilitate integrated analysis and delivery of data to national or international organizations and agencies, to support the enforcement of legislation at the federal level, and to inform the general public. Based on consolidated (published) national statistical datasets, it offers a variety of simple viewing and data search/retrieval functions. (aj)

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