Nitrate leaching in different hop production practices

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Abstract

The pollution of groundwater, which presents an important source of drinking water in Slovenia, has been one of the biggest problems of environmental protection in the last decade. The most common reasons for the pollution of groundwater under the agricultural surface are nitrates. Simulation was made by means of field measurements from a test field (hop field) at Latkova vas, where different ways of irrigation and fertilisation had been tested. The study focused on the comparison between the results obtained by the model and the actual state in the test field for the period of two years (1997, 1998). Nitrate leaching process simulation from the ground profile into the groundwater by the use of the model GLEAMS has shown its applicability for the Slovenian region. The conclusion reached suggests that the model is not appropriate for nitrate leaching simulation in case of using fertigation. Second year simulation has shown better compliance of results obtained by the model with the experimental results.

Zusammenfassung

Grundwasser ist die wichtigste Trinkwasserressource, daher ist die Grundwasserverschmutzung eines der größten Umweltprobleme der letzten Jahrzehnte. Die häufigsten Verursacher dieser Verschmutzung in landwirtschaftlich genutzten Gebieten sind die Nitrate. Feldmessungen im Versuchsfeld (Hopfenfeld) in Latkova vas wurden für die Simulierung herangezogen. Dort wurden verschiedene Bewässerungs- und Düngungsmethoden erprobt. Das primäre Studienthema war der Vergleich zwischen den Modellergebnissen und dem tatsächlichen Zustand im Versuchsfeld in den Jahren 1997 und 1998. Die Simulierung der Nitratversickerung im Bodenprofil bis ins Grundwasser mit dem Modell GLEAMS hat sich für den slowenischen Raum sehr bewährt. Das Modell war für die Fertigationssimulierung nicht anwendbar. Die Ergebnisse der Simulierung im 2. Jahr verglichen mit den tatsächlichen Messergebnissen waren erfolgversprechend.

Groundwater is an important source of drinking water in many countries. In Slovenia, almost all important aquifers lie under intensive agricultural areas. Slovenia has a government program aimed to introduce the irrigation in some agriculturally intensive areas where nitrate is the key pollutant found in groundwater. By controlling input of nitrates into the natural environment, it would be possible to influence the quality of groundwater under intensely cultivated agricultural land. However, the design and implementation of controlling the input of nitrates into the natural environment will only be possible if the dynamics of nitrate leaching from the upper soil layer towards groundwater are known. Present mathematical models already enable to anticipate the nitrate leaching through the soil profile and offer a basis to introduce legal measures to prevent potential possible groundwater pollution. Mathematical modelling of nitrate leaching into groundwater is not only instrumental for hop as typical irrigated crop in the Slovenian region, but also for other irrigated and non-irrigated crops. The model GLEAMS was chosen due to its valuable characteristics, enabling evaluation of complicated interactive influences among ground horizon, climate agents and nutritive substances.

The study analysed dynamics of nitrate leaching for four different irrigation and fertilisation practices in intensive hops' production. In addition, the examination was concentrated on comparison between the results obtained by the model and the actual state in the test field for the period of two years (1997, 1998). GLEAMS model enables simulation of different/various soil tillage, therefore for the simulation field measurements from a test field (hop field), where different ways of irrigation and fertilisation had been tested, were used. The soil is eutric cambisol, 60 cm deep, with a lot of skeleton particles on sand and gravel alluvium as a parent material. Water percolating from this soil horizon with low retention capacity directly flows into the groundwater. Groundwater table is 6 - 8 m below surface.

The experiment site of the Institute of hop production and brewery is situated on the hop field at the Latkova vas (2,5 ha). The experiment included several following variations. The first one consists of non-irrigated and surface fertilized hop with 215 kg N/ha in three consecutive rations. The second and the third practices comprise sprinkler and drip irrigated hop making use of the same fertilisation as the first one. The fourth practice is fertigated hop, where the amount of added nitrogen was 115 kg/ha in 13 events and one application of 55 kg N/ha on soil surface. On traditionally irrigated hop field three substantial rations of mineral fertilisers were added (up to 240 kg N/ha annually). As the fertilisation through the irrigation system was possible, the experiment included fertigation as well.

Nitrate ion concentration in percolating water was measured under hop line as well as under between-line area in 30 and 50 cm depth. At first, in the depth of 30 cm, nitrate ion leached from arable layer was measured. Then, in the depth of 50 cm, nitrate ion leached from the soil profile was measured. Soil percolating water was sampled on each individual measuring point with three porous cups suction lysimeters.

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Sample analysis results showed nitrate concentration of soil solution in mg/l. The amount of leached nitrate of experiment variations was calculated on the basis of soil water balance when soil was saturated. The soil water balance calculation did not include the surface runoff, since there were no measured data available. Such calculation suggests that the total precipitation infiltrates in soil profile which it does not. Therefore, for the calculation of the amount of nitrate leached in experiment needed for the simulation, GLEAMS output data were used when the surface runoff is included in water balance. The amount of leached nitrate in the experiment was calculated by multiplying the measured nitrate concentration in the depth of 50 cm with the amount of water percolating through soil profile in the model.

GLEAMS assumes that a test field has homogeneous land use, soils, and precipitation. It consists of four major components: hydrology, erosion/sediment yield, pesticide transport, and nutrients. GLEAMS was developed to evaluate the impact of management practices on potential pesticide and nutrient leaching within, through, and below the root zone. GLEAMS can be used to assess the effect of farm level management decisions on water quality.

Output data for the months of June, July, August and September were selected because in these months the field measurements were conducted and it was possible to compare the results. Amounts of leached nitrate obtained with model calculation and experimental measurements agree with anticipated 60 to 80 kg of nitrate per hectare under different crops being leached in Slovenia annually (CESTNIK, 1986).

It was verified by validation that GLEAMS is a relatively simple and frequently used mathematical model, that can facilitate a sufficiently good prediction and measurement of nitrate leaching (exception is fertigation) towards groundwater in the Slovenian region.

Nitrate leaching process simulation from the ground profile into the groundwater by the use of the model GLEAMS has shown its applicability for the Slovenian region. However, the tests also showed that the model is not appropriate for nitrate leaching simulation in case of using fertigation, and it would be reasonable to test some other models. Sensitivity analysis and calibration of the model provided an optimal value for two parameters (soil porosity and initial nitrate concentration in soil horizon) which were not measured. The second year simulation showed better accordance of results obtained by the model and the experimental results.

Computer simulation of nitrate leaching processes from soil profile into groundwater with computer program GLEAMS showed its applicability for the Slovenian environment. It could be concluded that in case of fertigation GLEAMS was not suitable for the nitrate leaching processes simulation. GLEAMS simulation showed the average amount to be 71 kg nitrogen /ha in the months of June – September. The field experiment results in Latkova vas were 64 kg of nitrogen per hectare. GLEAMS model application for simulation of nitrate leaching processes into groundwater enables quantitative prediction of nitrate leaching from soil profile into the groundwater in sense of time. Also, the change of soil use or agriculture practice provides a good platform to predict changes (when changing soil use or agricultural practices). In combination with GIS, GLEAMS provides the solutions for groundwater quality improvement in broader space.

Acknowledgement

The authors of this article thank the Ministry for agriculture, forestry and food as well as to the Ministry for science and technology for financing the research program V4-6938-95 Nitrate ion in hop production (1.11.1995-30.11.1998) and the Ministry for science and technology for research project L2-1310 Modeling of nitrate leaching to groundwater in Slovenian conditions (1.1.1999 - 30.6.2001).

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