Rapid breakthrough of pesticides via biopores into tile drains and shallow groundwater

a combined experimental and model study

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1 Introduction and goals

Earthworms play a pivotal role in agro-ecosystem functioning by modulating soil structure that significantly influences soil hydraulic properties, organic matter dynamics, and plant growth. Preferential flow in macropores is a key process which strongly affects infiltration and may cause rapid transport of pesticides into depths of 80 to 150 cm where they experience a much slower degradation, or can directly enter brooks via tile drains or shallow groundwater bodies. Therefore an experimental study was set up, to gain insight in pesticide transport in agricultural landscapes due to biopores. The used pesticides are typical for the Weiherbach cachment (Isoproturon and Flufenacet). The experiment was performed during September which is the seed time for winter crops. Based on the experimental data a detailed physical based hillslope model will be set up to model pesticde breakthrough into tile drains and the vertical transport in the soil.

Fig. 1: Map of the Weiherbach catchment in the Kraichgau, south-west germany. Agricultural areas cover arround 90% of the 3.6 sqkm catchment size.

Study site

The study site is an agricultural field with shallow groundwater and a tile drain. The plot is directly located at a small brook. The site is located in the Weiherbach catchment an experimental catchment in an intensive used agricultural loess area. The geology is dominated by Keuper and a Loess layer of up to 15 m thickness. The climate is semi-humid with an average annual precipitation of 750-800 mm/yr, average annual runoff of 150 mm/yr and annual potential evaporation of 775 mm/yr. The average annual air temperature is 8.5°C. A typical soil catena following the hillslope morphology exists. The experimental field, located at the hill foot, consists of a colluvisol with gleyic character starting arround 50cm depth. The tile drain drains the site in about 1.2 m depth and shows discharge during the whole year.

2 Irrigation experiment

In September 2008 the irrigation experiment was performed by simulating a typical mid-intensive thunderstorm of aprox. 35 mm/5h at a 400 sqm field plot. Precipitation was measured with ten 200 sqcm precipitation sampler and sprinkeld with eigth Gardena sprinkler at the field plot. The ditch discharge was measured with a pressure sensor and a triangular weir. Pesticides were applied by the farmer according to conventional agricultural practice using a tractor and a mounted spray bar. Brilliant Blue and Bromid were used as additional tracer. The mass of the applied pesticides were 80g IPU and 20g Flufenacet. As Tracers 1600g Bromide and 2000g Brilliant Blue were applied.

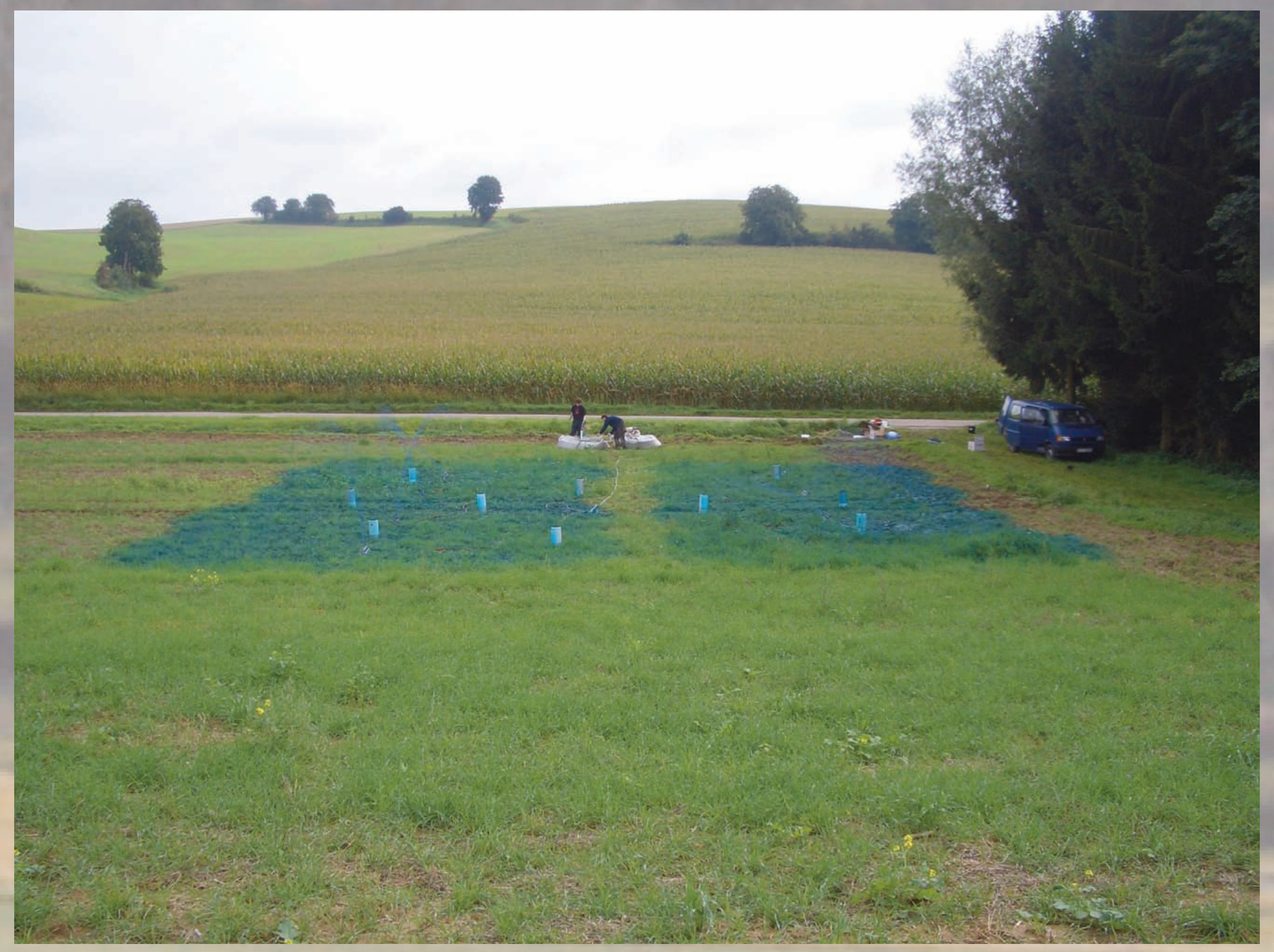

Fig. 2: Irrigation site after the application of the Briiliant Blue dye tracer. The plot is located aprox. 15 m away from a brook and was monitored with 10 precipitation samplers.

Tracer input and sampling

The irrigation was splitted in three blocks, lasting 80, 60 and 80 min. The tracer Brilliant Blue and Bromide where irrigated during the first block of irrigation with 1500 l water. The ditch was sampled 51 times during the experimental day, with time gaps between 5 and 30 min, 14 water samples were taken in the seven days after the experiment. On the day after the experiment three soil profiles and one week after the experiment two profiles where excavated. At those profiles photos were taken to have the Brilliant Blue cover of the vertical profiles, additional soil sampling in a 10*10 cm grid was performed up to 80-100 cm depth.

Analytics

The herbicides were extracted from the water phase by sucking the samples through a 18-C filter with 1g of reversed phase octadecylsilane bonded to silicia gel. After drying the herbicides were extracted from the filter with 2*5 ml methanol. The remaining samples were analysed with a HPLC-MSMS system. Bromide was measured yet, only be the change in electric conductivity of the water and will later on be analysed with ion chromatography. Brilliant Blue concentrations in the soil profiles where analysed by image processing of the photos.

3 Experimental results 1

Ditch discharge and Bromide transport

The ditch discharge showed no significant reaction to the first irrigation impulse. Only at the end of the first irrigation block the discharge showed a small increase. So the first irrigation increased mainly the soil moisture. Starting with the second irrigation block the system reacts instantly and the discharge increased from 0.3 l/s to about 0.5 l/s, after stopping the irrigation the discharge decreased very fast. The system showed an even stronger response to the last irrigation. Eight minutes after the end of the irrigation, discharge reached its peak, after the peak there is a clear recession curve.

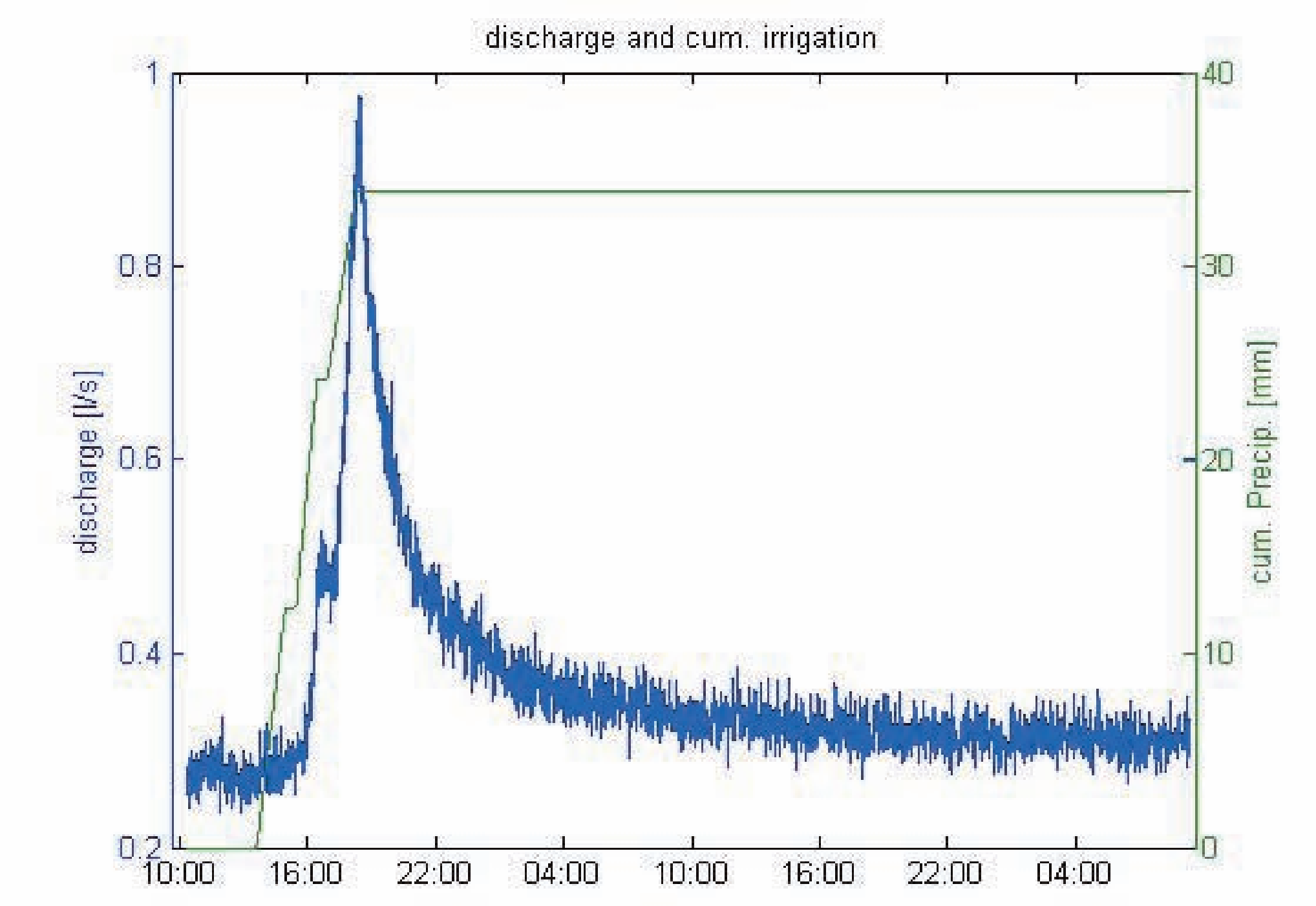

Fig. 3: Green line shows the cumulativ irrigation during the experiment performed on 09/16/08. The blue line is the discharrge from a ditch, draining a part of the irrigation area.

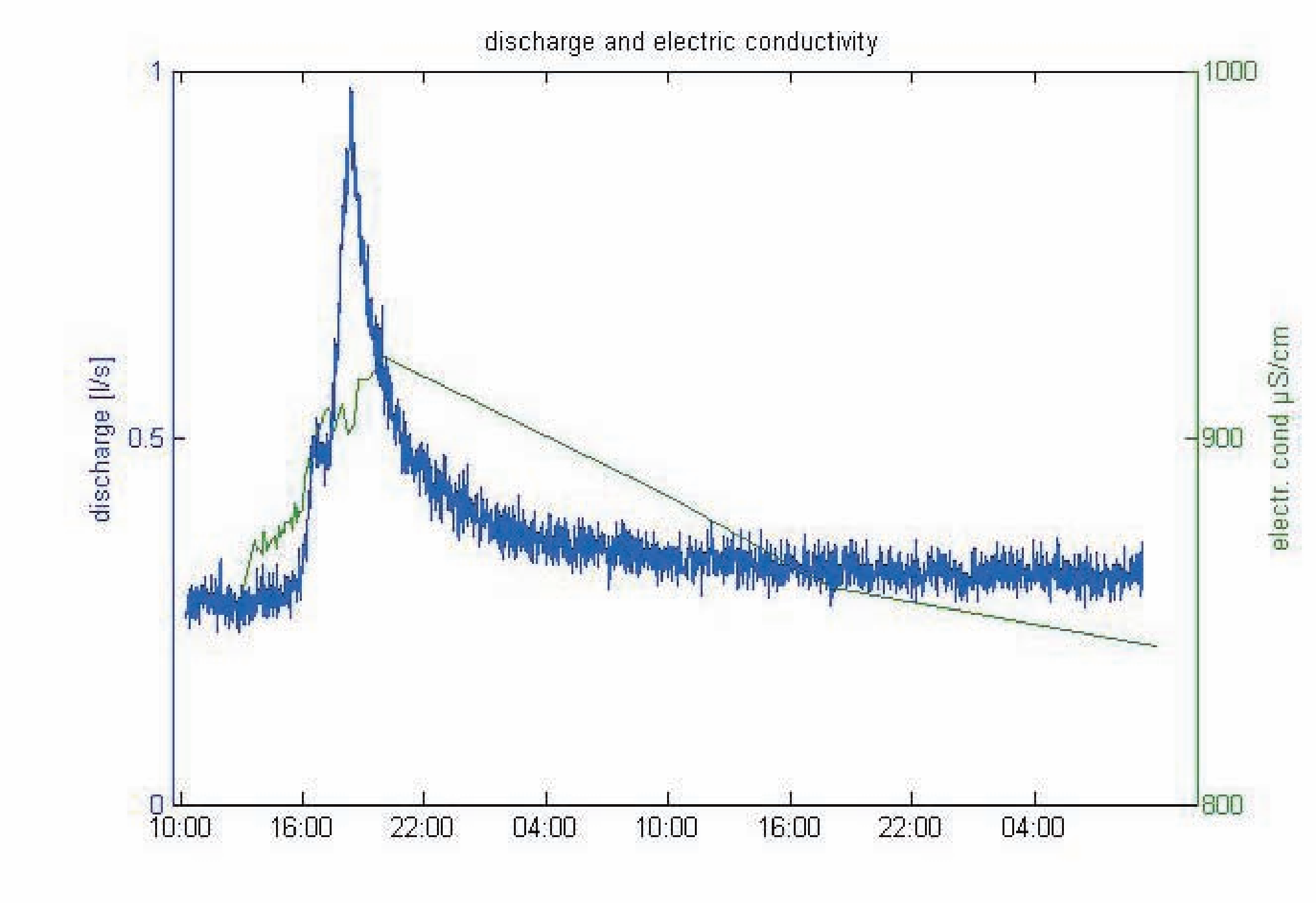

Fig. 4: Green line shows the elctric conductiyity in the ditch. Blue line shows the discharge in l/s.

Electric conductivity, and therefore the bromide concentrations, reacted much faster than the discharge on the irrigation pulse. The conductivity increased minutes before the discharge increased, although the tracer input started 15 min after the irrigation. During the second irrigation step, conductivity increased rapidly. The peak of electric conductivity occurred approx. two hours after the discharge peak. The problem in the recession curve is that the time gap between the samples was to big.

4 Experimental results 2

Pesticide transport and soil profiles

Two different pesticides were used. Isoproturon is banned for the used on sites with till drains as it is known to be transported into surface streams. Flufenacet is a newer chemical agent with significant lower water solubility and higher sorptivity. The analyses of the samples (only partly performed yet) showed a breakthrough of both used pesticides into the ditch. The reaction time of FLU seems to be significantly delayed compared to IPU. As not all samples are analysed yet statements besides the measured breakthrough are not verified yet.

Time (min)	IPU µg/l	FLU µg/l
35	0.018	0.000
60	0.339	0.024
140	*6.009*	0.656
150	0.027	0.541
170	0.048	*3.552*

Tab. 1: The table shows the concentration of the pesticides Isoproturon and Flufenacet in the ditch discharge at five timepoints after the irrigation start (Time). The irrigation started at 13:35. The italic style values denote for very high concentration exceeding the calibration range.

The soil profiles were sampled in a 10*10 cm grid, yet only the distribution of Brilliant Blue was evaluated. The photos of each soil profile were analysed with Photoshop and Matlab. So coverage of Brilliant Blue and concentration over depth could be determined. Brilliant Blue could be clearly identified up to 60 cm depth, below this depth it could not clearly separated from metamorphic soil elements. The profiles after one day and one week show no difference in travel depths.

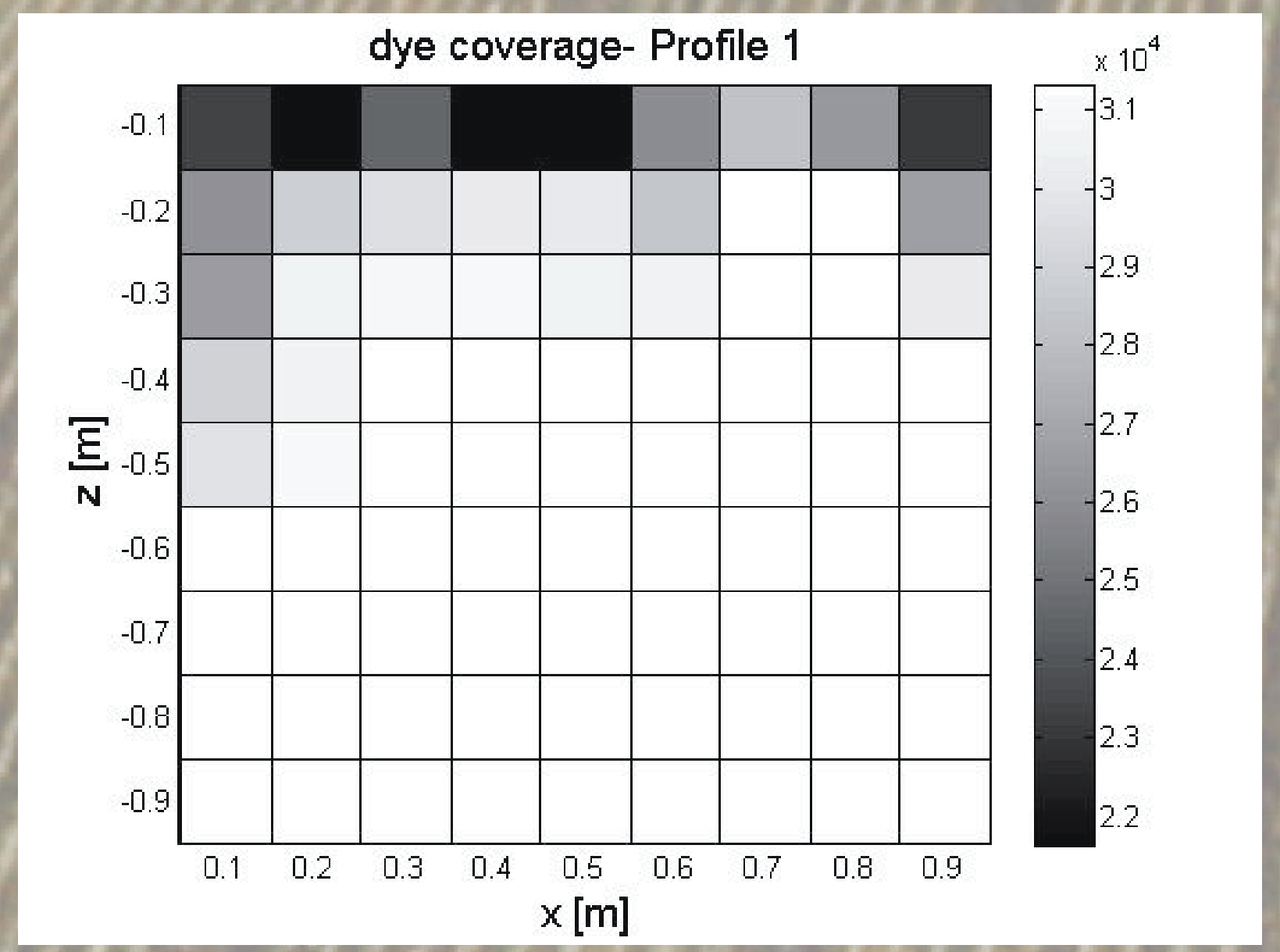

Fig. 5: distribution of Brilliant Blue in one soil profile one day after irrigation. No clear travel of tracer below 0.6m was detected. Most of the tracer was sorbed in the upper 20 cm of the soil.

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5 Modeling and further steps

For an older experiment performed by Zehe and Flühler (2001) just several hundred meters away, a physical based hillslope model was set up (Catflow, Zehe et al. (2001). It was possible to show a fast reaction of the ditch to the irrigation pulse by adding macropores to the soil matrix. Problems in setting up the model are the exact distribution of soil moisture and macropores, the conductivity of the macropores and the exact travel time through the ditch and the gravel layer surrounding the ditch. Further steps are planed to investigate the role of those unknown parameters. Later on the model will be set up for the this experiment to model water and solute transport on field scale. As a next step it is important to analyse the bromide and pesticide concentrations in the samples of the ditch water to understand the temporal dynamics of the transport through the soil, especially to find the factors controlling transport of IPU and FLU.

6 Discussion and Conclusions

Isoproturon is known to be mobile and easy to wash out via tile drains in surface waters and therefore also to be transported into shallow groundwater bodies. In this experiment it was shown that Flufenacet also tends to be transported through connectiv structures in the soil, probably biopores. In this study no significant population of lumbricus terrestirs was found, likley aporecdea longa occurs in the parts of the study site that are regulated by the ditch impact. But the structures leading to the preferentail transport are not identified yet

None of the five soil profiles showed transport below the depth of 0.6 m. So it is to call in question, if it is possible to make predictions on depth transport only based on vertical soil profiles. This experiment therefore, showed clearly that it is possible and necessary to perform large scale experiments on agricultural sites to understand the transport of pesticides to different types of agricultural soils. Although the link between precipitation and ditch discharge is important to understand, as it is the driving force of transport.

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