Movement of water, bromide ion and the pesticides ethoprophos and bentazone measured in a sandy soil in Vredepeel (The Netherlands)

J.J.T.I. Boesten
L.J.T. van der Pas

Report 122

DLO Winand Staring Centre, Wageningen (The Netherlands), 1999

ABSTRACT

Boesten, J.J.T.I. & L.J.T. van der Pas, 1999. *Movement of water, bromide ion and the pesticides ethoprophos and bentazone measured in a sandy soil in Vredepeel (The Netherlands).* Wageningen, DLO Winand Staring Centre. Report 122. 98 blz.; 23 fig.; 3 tab.; 15. Refs; 22 Annexes; 1 diskette.

The aim of this study was to collect a data set suitable for testing pesticide leaching models in the case of a Dutch sandy soil with a shallow groundwater table. The movement of water, bromide ion and the behaviour of the pesticides ethoprophos and bentazone was studied. The substances were applied after sowing winter wheat in autumn 1990. This late application time is unusual for bentazone: it was selected on scientific grounds (without agricultural purpose). Rainfall, groundwater level and soil temperature were monitored continuously at the experimental field (80 m long and 54 m wide) until spring 1992. Soil profiles were sampled at 1, 22, 42, 103, 214, 278 and 474 d after application (16 profiles at each date). In the laboratory, pesticide transformation rates were measured with soil material from 0-25, 50-100 and 100-200 cm depth. Sorption isotherms were measured with material from 0-25 cm depth. Concentration profiles showed that mobility increased in the sequence ethoprophos - bentazone - bromide ion. Ethoprophos movement was limited to the top 25 cm layer whereas bentazone leached to below 1 m depth. At the end of the study, the concentrations of ethoprophos and bentazone were below the detection limit (0.2-2 $\mu g\ dm^{-3}$) in all soil layers between 25 and 120 cm depth.

Keywords: field experiment, soil, modelling, pesticides, bromide ion, ethoprophos, bentazone

ISSN 0927-4537

This report can be ordered by paying 35.- Dutch guilders into bank account number 36 70 54 612 in the name of DLO-Staring Centrum, Wageningen, the Netherlands, with reference to Report 122. This amount is inclusive of VAT and postage.

P.O. Box 125, NL-6700 AC Wageningen (The Netherlands).
Phone: +31 317 474200; fax: +31 317 424812; e-mail: postkamer@sc.dlo.nl

Projectnummer 80561 [Report 122/IS/04-99]

Contents

Annexes

Preface

The research to collect the dataset described in this report was funded by the Dutch Ministry of Agriculture, Nature Management and Fisheries. The report itself was partly funded by the Commission of the European Union (Environmental research programme, contract EV5CV-CT94-0480).

A draft version of the report has been distributed in 1996 to modellers that participated within COST Action 66 'Pesticides in the soil environment' organised by DG XII of the Commission of the European Union. Using this draft version some 20 modellers used this dataset to test some ten different models. The dataset was one of the four European datasets that were used within this COST Action. The results of all model tests will be published in a special issue of the international journal 'Agricultural Water Management' due to appear late 1999. We would like to thank these modellers for useful comments to the draft version of the report.

Summary

The aim of this study was to collect a dataset suitable for testing pesticide leaching models in the case of a Dutch sandy soil with a shallow groundwater table. The movement of water, bromide ion and the behaviour of the pesticides ethoprophos and bentazone was studied. The substances were applied after sowing winter wheat in autumn 1990. This late application time is unusual for bentazone: it was selected on scientific grounds (without agricultural purpose). Rainfall, groundwater level and soil temperature were monitored continuously at the experimental field (80 m long and 54 m wide) until spring 1992. Soil profiles were sampled at 1, 22, 42, 103, 214, 278 and 474 d after application (16 profiles at each date). In the laboratory, pesticide transformation rates were measured with soil material from 0-25, 50-100 and 100-200 cm depth at 5, 15 and 25 °C. Sorption isotherms were measured with material from 0-25 cm depth.

Cumulative rainfall over the experimental period was 768 mm. The groundwater level fluctuated between 0.5 and 1.7 m depth. Concentration profiles showed that mobility increased in the sequence ethoprophos - bentazone - bromide ion. Ethoprophos movement was limited to the top 25 cm layer whereas bentazone leached to below 1 m depth. During the first weeks of the study the total amount of ethoprophos in the soil decreased with some 50% whereas the decrease levelled off strongly thereafter. Probably the loss in these first weeks was the result of loss processes at the soil surface (e.g. volatilisation). At the end of the study, the concentrations of ethoprophos and bentazone were below the detection limit (0.2-2 μg dm^{-3}) in all soil layers between 25 and 120 cm depth.

The laboratory studies with the material from the 0-25 cm layer showed that transformation rates increased with increasing temperature. For ethoprophos, the transformation rate slowed down with depth. For bentazone, the transformation rate for the 50-100 cm layer was very low (no measurable decrease in 1 year), but for the 100-200 cm layer the transformation proceeded at a rate comparable to that in the 0-25 cm layer. Surprisingly, the sorption of ethoprophos was lower at 5 than at 25 °C. The sorption of bentazone was very low both at 5 and 15 °C.

1 Introduction

Leaching of pesticides to groundwater is an important environmental aspect of the use of these chemicals in agriculture. In the Dutch registration procedure a first assessment of pesticide leaching is based on calculations with the PESTLA model for a standard scenario. This scenario consists of a humic sandy soil with a shallow groundwater table and with a low organic matter content in the subsoil. The scenario assumes a maize crop that is grown every year. The scenario is representative for soils near water pumping stations in the eastern part of the Netherlands. However, back in 1990, PESTLA had not been tested so far at a field scale for a situation similar to that assumed in the scenario. Therefore a field experiment was set up to obtain an appropriate data set. Also flow of water and movement of bromide ion were included in the experiment because this enables testing or calibration of the submodels for water flow and solute movement. Two pesticides were selected: a mobile pesticide (bentazone) with a high leaching potential and a moderately sorbing pesticide (ethoprophos) with a low leaching potential. The aim of this report is to describe the results of the field study in such a way that the dataset accessible to interested modellers.

Van den Bosch & Boesten (1994) tested the 2.3 version of the PESTLA model against the results of this field experiment.

2 Procedures for the field study

2.1 Experimental field

The experimental field was located at the experimental farm 'Vredepeel' located in the municipality Vredepeel in the province Limburg in the south-eastern part of the Netherlands (North Latitude 51° 32', East Longitude 5° 52', altitude above sea level of 27 m). It was part of an agricultural field that was 60 m wide and about 160 m long. There were two systems for subsurface drainage (one at 80 cm depth and one at 120 cm depth) but all drains were closed before the start of the field experiment to exclude sub-surface drainage. The soil was a gley podzol (FAO classification).

The experimental field was 80 m long and 54 m wide. It was divided into 16 plots each 10 m long and 27 m wide; the plots were indicated by the characters A to P (see Fig. 1). Each plot was subdivided into 27 sub-plots (not shown in Fig. 1) each 3.3 m long and 3.0 m wide. The groundwater sampling tubes were installed in the sub-plot in the centre of the plot. Nine sub-plots of each plot were intersected by wheel tracks; these were not used for sampling. So there were 17 sub-plots per plot left for sampling of the soil profile. At each sampling time, one soil profile from each plot was sampled. Before the start of the experiment, the sub-plots to be sampled at the subsequent sampling times were selected at random. A sub-plot could only be used once because of disturbance of the crop and soil surface around the sampling site.

The field was practically flat in the direction A-H (see Fig. 1). In the direction A-P there was a small slope: the soil levels of the left and right parts of the field were practically flat but the right part was about 20 cm lower than the left part.

A few weeks before spraying the chemicals, groundwater sampling tubes were installed. The tubes consisted of PVC and their internal diameter was 2.7 cm. At their bottom there was a PVC filter that was perforated over a length of 20 cm. At the centre of each plot three tubes were installed in the same bore hole (which had a diameter of about 10 cm). One tube had a filter between 100 and 120 cm depth, one between 140 and 160 cm depth and one between 210 and 230 cm depth. The tops of the tubes were located 10-30 cm above the soil surface and were closed by a lid. After the installation of the tubes, a PVC tube (diameter 12.5 cm; length 50-70 cm) was placed over each set of three sampling tubes to prevent flow of spray liquid and water along the walls of the sampling tubes. The PVC tube was closed with a lid.

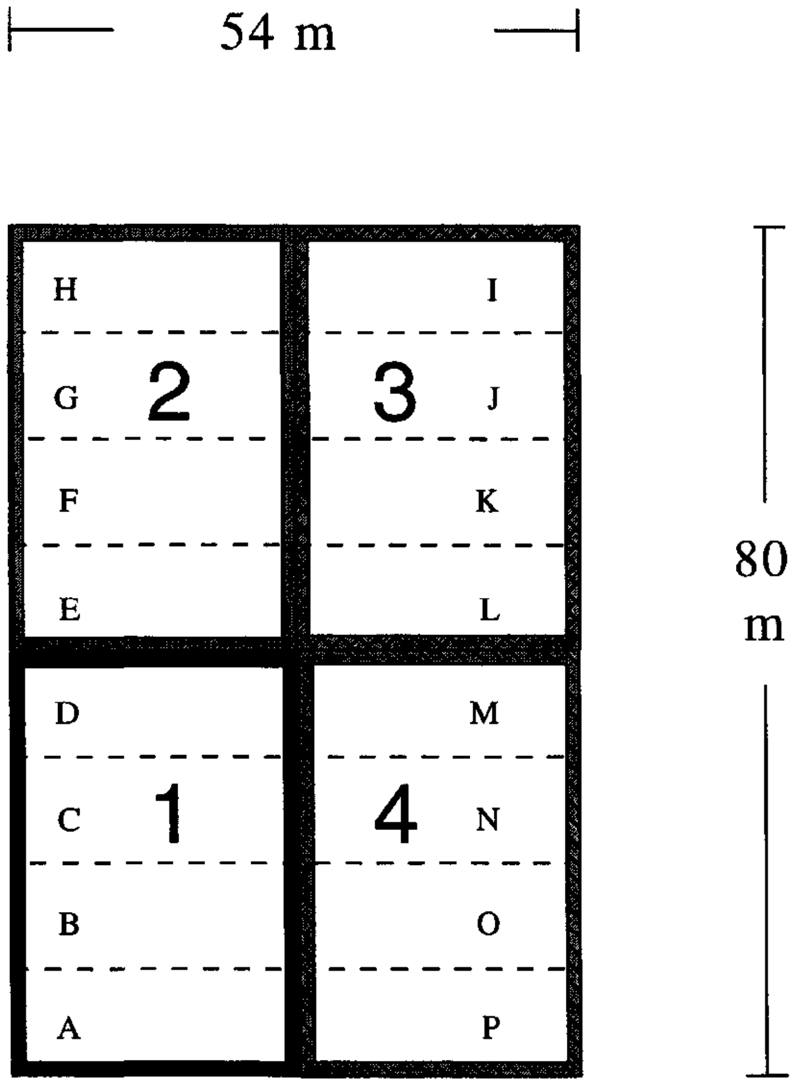

Fig. 1 Map of the experimental field indicating the codes of the plots with the characters A to P. The numbers 1 to 4 refer to the sectors that were defined to combine and mix soil samples from corresponding depths before pesticide analysis

All chemicals were sprayed on 22 November 1990. The crop grown in 1990 was sugar beet which was harvested in October 1990. Then the leaves of the beets were chopped and ploughed into the soil up (ploughing depth was about 25 cm). On 22 November 1990 winter wheat was sown at a depth of 3-5 cm and at a row distance of 15 cm with a machine that combined sowing and a soil cultivation. The chemicals were sprayed a few hours after sowing. In March 1991, a nitrogen fertilizer was applied. In May/June 1991 the wheat was sprayed with the following pesticides: fenpropimorph, pirimicarb, triadimenol and anilazine. The winter wheat was harvested at 14 August 1991. At 28 August 1991 pig slurry (dry-matter content of 6%) was applied at a rate of 28 m^3 ha^{-1}. The slurry was incorporated in the top 15 cm at the same day. In September 1991 yellow mustard was sown as green manure. At 29 November 1991 the mustard was incorporated into the top 15-20 cm of the soil by rotary cultivation. The field experiment was stopped at 10 March 1992.

According to the records of the experimental farm, ethoprophos had so far never been applied to this experimental field.

Until May 1991 the development of the winter wheat crop was normal according to the farmer. In April 30-40% of the soil surface was covered by the wheat which was then about 10 cm high. By the end of May the soil became too dry: from that time the growth of the wheat on the experimental field was less than the growth of the wheat on the surrounding fields (the surrounding fields were sprinkler irrigated, whereas the experimental field was not irrigated). At 4 June 1991 the height of the wheat crop was 60-80 cm. By the end of July the maturing stage of the crop started.

On 24 June 1991, rooting depth of the winter wheat was examined visually by inspection of the sampled soil columns (see Section 2.5 for the sampling procedure of the columns). Up to 40 cm depth rooting was intensive. Below that depth almost no roots were present although individual roots were observed up to about 1 m depth.

2.2 Application of the chemicals

All chemicals were applied between 15 and 17 h on 22 November 1990 with a common field sprayer (18 m long) provided with ceramic Teejet nozzles (type 11004). Before spraying, the water flow rate from 12-36 individual nozzles was measured: the coefficient of variation between the nozzles was 2-3%. The water flow rate was 1.8 L/min at the spraying pressure of 400 kPa. The experimental field was sprayed twice. The first time bentazone, ethoprophos and isoproturon were mixed in the tank and sprayed. The second time KBr was sprayed. The formulated products used were the wettable powder Basagran, the liquid formulation MOCAP^{R}20 and the flowable IP-flo. The concentrations of bentazone, ethoprophos and isoproturon in the spraying solution were estimated to be 1.8, 7.7 and 2.1 g L^{-1}, respectively, on the basis of the amount of formulated product added to the tank and the volume of water in the tank. The concentrations of bentazone and ethoprophos in the spraying solution were measured in six samples taken before, during and after spraying. The concentration range was 1.78 to 2.00 g L^{-1} for bentazone and 6.9 to 7.4 g L^{-1} for ethoprophos. The speed of the spraying machine was measured during spraying; with this speed and the water flow rate from the nozzles, an areic volume of water of 430 L ha^{-1} (i.e. a water layer of 0.04 mm) was calculated. This gives a calculated dose of bentazone of 0.80 kg ha^{-1} and of ethoprophos of 3.35 kg ha^{-1}. Isoproturon was sprayed but not further analyzed.

The spray liquid of potassium bromide was made by dissolving 100 kg of KBr in approximately 250 L warm water. To measure the bromide dose, 48 aluminium trays were placed on the soil surface distributed over the experimental field. The surface area of each tray was 60 cm^2. The amount of bromide in each tray was determined via extraction with 500 cm^3 demineralized water and via chemical analysis (described in Section 2.7). The average dose was 111 kg ha^{-1} with a standard deviation of the individual trays of 10 kg ha^{-1}. This is a low variability for a field sprayer.

The temperature during spraying was about 8°C and no rain fell. There was practically no wind.

2.3 Monitoring of meteorological data

Rainfall was recorded continuously using a Lambrecht rain gauge installed at about 400 m distance of the experimental field. The speed of the recording paper was 0.2 m d^{-1}. The surface area of the aperture was 200 cm^2 and it was located 1.2 m above the soil surface.

Cumulative rainfall over periods of 1 to 3 weeks was recorded with a Hellmann rain gauge installed at the border of plot A of the experimental field. The surface area of the aperture was also 200 cm^2 and the rim of this gauge was flush with the soil surface. The gauge was placed in a pit with a diameter of about 50 cm. Around the gauge a metal grid (0.8 × 1.0 m) was placed on the soil surface to prevent rain splashing from the soil surface into the gauge. This grid consisted of iron strips, 20 mm high and 2 mm thick with a mesh width of 30 mm. In the centre of the grid there was a hole (250 mm diameter), which was positioned above the gauge. A circle around the gauge with a diameter of 2 m was kept free of vegetation. The measurements with this second gauge were made because measurements made flush with the soil surface are more accurate than measurements at 1.2 m height: in general the amount of rainfall recorded decreases with increasing height of the aperture (Beese and Van der Ploeg, 1978).

For the period between 25 January and 22 February 1991, cumulative rainfall was recorded with a third gauge. This was done because snow fell during this period: the Hellmann gauge could not be used because the snow filled the pit (and the gauge) almost completely. The third gauge was the standard type as used by the Royal Dutch Meteorological Institute and it was located at about 10 m distance from the Lambrecht gauge. Its aperture was also 200 cm^2 and was located 40 cm above the soil surface.

Cumulative rainfall recorded with the Lambrecht rain gauge (at 1.2 m height) was compared with that recorded with the Hellmann rain gauge (flush with the soil surface) for the whole experimental period (from 22 November 1990 to 10 March 1992) with the exception of the period between 25 January and 22 February. The Hellmann rain gauge catched 16% more rain than the Lambrecht rain gauge (747 mm compared to 645 mm).

Cumulative rainfall recorded with the Lambrecht rain gauge was compared with that recorded with the standard type gauge for the period between 25 January and 22 February. The standard type gauge catched 90% more rain or snow than the Lambrecht rain gauge (11.8 mm compared to 6.2 mm).

The complete time series of daily rainfall was established as follows. For each recording period of 1-3 weeks the quotient of the cumulative rainfall from the Hellmann gauge divided by cumulative rainfall from the Lambrecht gauge was calculated. The daily figures derived from the Lambrecht gauge were multiplied with this quotient to correct for the error due to the height of 1.2 m. Only for the period between 25 January and 22 February 1991 a different procedure was followed. Then the cumulative rainfall from the standard type gauge was used to correct the daily values from the Lambrecht gauge.

At the experimental farm, the daily minimum and maximum air temperature was measured (rounded off to full degrees). Data on daily global radiation, average windspeed and air humidity are from weather station 'Beek' (5° 46' East Longitude 50° 55' North Latitude) at about 65 km distance from the experimental field as collected by the Royal Dutch Meteorological Institute. Global radiation was measured at 1.5 m heigth and windspeed at 10 m heigth.

Data on potential evapotranspiration are from the Royal Dutch Meteorological Institute. This institute produces daily values of the so-called maximum possible evapotranspiration of grass according to Makkink, E_r (see Feddes, 1987). E_r is calculated as follows:

$$E_r = 0.0229\ [s/(s+\gamma)]\ G$$

in which s is the slope of the relationship between the saturated water vapour pressure and the daily average of the air temperature, γ is the psychrometer constant and G is the daily average of global radiation (W m^{-2}).

For the period between 22 November 1990 and 1 January 1991, decade values of E_r were obtained from the weather station 'Vredepeel' at about 1 km distance. For the period between 1 January and 12 February 1991, daily values were obtained from the weather station 'Eindhoven' which is located at about 30 km distance from the experimental field. For the remaining period (12 February 1991 to 10 March 1992), daily values were obtained from the weather station 'Arcen' (6° 11' East Longitude 51° 28' North Latitude) which is at about 25 km distance from the experimental field. The reason for this complicated procedure is that the weather station 'Vredepeel' stopped at 1 January 1991 and that the weather station 'Arcen' started at 12 February 1991.

2.4 Monitoring of groundwater level and soil temperature

It was the intention to monitor the groundwater level continuously at the experimental field. For that purpose two groundwater tubes were installed. One at the border of the experimental field in plot C (see Fig. 1) and one at the border in plot J (see Fig. 1). The groundwater level was measured mechanically or electronically. The measurements started at both plots at 6 December 1990. They continued at plot C until 6 January 1992 and at plot J until 4 October 1991. The difference between daily average values measured in plot C and J was usually only a few centimetres. At the last day of the field experiment (10 March 1992) the groundwater level was measured manually in all 16 plots in the tubes installed for collecting groundwater.

The following calculation procedure was applied. For the period between 6 December 1990 and 4 October 1991 the results from plots C and J were averaged. For the period between 4 October 1991 and 6 January 1992 the result from plot C was used. For 10

March 1992, the average groundwater level was calculated by averaging the groundwater levels of the 16 plots.

Soil temperature at 2.5 cm depth was measured at the experimental field (in plot C) and at two sites at 300 to 400 m distance of the experimental field. From the available information daily values for the whole experimental period were estimated as follows. Data in the period between 22 November 1990 and 5 March 1991 were derived from the sites at 300 to 400 m distance. Data in the period between 6 March 1991 and 10 March 1992 were derived from the measurements at the experimental field with the exception of the periods from 20 to 29 October 1991 and from 7 to 21 January 1992. The data from these two periods were derived from soil temperature measurements in Wageningen at 5 cm depth (at 100 km distance from the experimental field). It was checked that the results obtained in Wageningen were similar to those obtained at the experimental field by comparing results of both sites for a few periods: the average difference between daily values was 0.4°C.

2.5 Sampling of soil profiles

Soil profiles were sampled at seven times (at 1, 22, 42, 103, 214, 278 and 474 days after application). The first sampling was started in the morning of 23 November, less than 1 d after spraying. No rain fell between spraying and this first sampling.
At each sampling time, 16 soil profiles were sampled (one from each plot and taken from a sub-plot that was randomly selected). The top 30 cm of soil was sampled with a split-tube auger with a cutting ring of inner diameter 95 mm. The auger was hammered into the soil. The diameter of the auger tube was 3 mm larger to prevent compression of the soil column. After the auger had been dug out, it was put in a horizontal position. One half of the tube was removed and the soil core was sliced into 4 sections 7.5 cm thick (the top layer was subdivided in two sections of 4.0 and 3.5 cm). Each soil sample was put immediately into a plastic bag.

The hole left by the split-tube auger was enlarged and the bottom cleaned. For sampling of deeper layers a motor-driven soil core sampler was used as described by Hendrickx et al. (1991). This sampler consisted also of a split tube, about 150 cm long with an inner diameter of 10 cm. The sampler was driven into the soil in the hole at approximately the spot where the 0-30 cm had been sampled (the error was about 1 cm). The sampler was pulled out of the soil and put in a horizontal position. This procedure probably caused flow of water and solutes from the water-saturated zone out of the column. We considered samples from the water-saturated layer and from the 20 cm above the level of the groundwater table to be not reliable; only samples taken more than 20 cm above this table were considered to be reliable.

The split tube with the sample was opened and the outer few millimetres of soil were scraped from the soil column to remove any contamination with soil from a shallower layer (by driving the tube into the soil, soil particles may move downwards along the wall of the tube). Below 30 cm depth two types of sample were taken from marked 7.5-cm thick layers: samples taken with a steel ring for determination of bulk density, volume fraction of liquid and bromide concentration and samples taken by a scoop for determination of pesticide concentrations. The steel rings (diameter 5 cm and volume 100 cm^3) were pushed in the centre of the marked 7.5-cm layers. The remaining soil around the ring was carefully collected with a scoop and put into a plastic bag. The top and bottom soil surfaces of each steel ring were smoothed so that the volume of the soil sample was 100 cm^3. Each steel ring was placed in a glass jar that was closed with a lid. The soil samples taken for pesticide analysis were combined for the layers 30-45 cm, 45-60 cm, 60-90 cm and 90-120 cm.

2.6 Treatment of soil samples in the lab

The soil samples from the 0-30 cm layer were stored at 5°C overnight. The next day these samples were mixed and the total mass of the soil sampled from each layer was determined. The samples were divided into two parts: one part was used for determination of volume fraction of liquid, dry bulk density and bromide concentration and the other part was used for pesticide analysis. The samples used for pesticide analysis were stored at –18 °C until extraction. The samples used for bromide analysis were stored at room temperature.

As described before, there were two types of sample from the deeper layers: one for bromide analysis (the steel-ring subsamples) and one for pesticide analysis. The samples for bromide analysis were stored at room temperature and those for pesticide analysis were stored at 5°C overnight and thereafter at –18 °C.

Because pesticide analysis is laborious, the soil samples from all spots were not analyzed individually. The experimental field was divided into four sectors which consisted of four plots each (ABCD, EFGH, IJKL, MNOP; see Fig. 1). Equal masses of moist soil from the layers sampled between the same depths and from the four plots in one sector were combined and mixed before extraction.

2.7 Procedure for determination of volume fraction of liquid, dry bulk density and bromide concentration

The measurement of the bulk density for the 0-30 cm layer was based on the mass of soil sampled with the auger tube. The bulk density for the deeper layers was based on the mass in the steel rings. The soil sample was dried for three days at 70°C. The decrease in mass was measured. From these measurements the volume fraction of liquid and the dry bulk density were calculated. Bromide ion was extracted by shaking each sample (usually about 150 g) with 200 cm^3 of demineralized water. The bromide ion concentration in the extracts was measured with HPLC using a Ionospher-A column. The mobile phase was water containing K_2SO_4 (0.1 mol dm^{-3}), KH_2PO_4 (0.02 mol dm^{-3}) and sodium azide (10 g dm^{-3}). Bromide ion was detected with a spectrophotometer at a wave lenght of 210 nm. The detection limit varied between 0.7 and 50 mg dm^{-3} depending on the nitrate concentration (the nitrate peak interferes with the bromide peak in the chromatogram). The extraction efficiency was not measured.

2.8 Procedure for extraction and analysis of ethoprophos

Ethoprophos was extracted by shaking 100 g of moist soil with 50 cm^3 CaCl2 solution (0.01 mol dm^{-3}) and 50 cm^3 hexane for 1 h. The hexane layer was collected and stored at –20 °C until analysis. The extraction efficiency was determined in a series of experiments in which ethoprophos was incubated for 1 day. For the 0-25 cm layer the average extraction efficiency was found to be 89%; for the 50-100 cm layer it was 93% and for the 100-200 cm layer it was 87%. The measured concentrations have not been corrected for the extraction efficiency.

The concentration of ethoprophos in the hexane extracts was determined by GLC. Two different procedures were followed. Concentrations of ethoprophos in hexane higher than 50 μg dm^{-3} were analysed with a HP 5890 gas chromatograph with an nitrogen-phosporus detector and a Chrompack WCOT fused silica column (25 m long and with inner diameter of 0.53 mm) coated with a CP-Sil5 film which was 5.1 μm thick. The temperatures of the inlet port, the oven and the detector were 240, 190 and 280 °C, respectively. The flow rate of the carrier gas nitrogen was 15 cm^3 min^{-1}. The detector gasses were hydrogen, medicinal air and nitrogen with flow rates of 3.3, 90 and 23 cm^3 min^{-1}, respectively. A volume of hexane of 3 mm^3 was injected in the split/splitless inject port in the splitless mode; the inlet purge was set off for 20 s after each injection. The retention time of ethoprophos was 3.5 min. The signal was processed with the software package Multichrom. Concentrations were determined on the basis of peak heights from standards in the concentration range 50 to 2000 μg dm^{-3}.

Concentrations of ethoprophos in hexane lower than 50 μg dm^{-3} were measured with a Pye Unicam gas chromatograph because false-positive results were obtained with the HP 5890 gas chromatograph at low concentration levels. The Pye Unicam gass chromatograph was equipped with a flame photometric detector (phosphorus filter, 526 nm) and a glass column (1.8 m long and with inner diameter of 4 mm) filled with 3% Silicone OV 225 on Chromosorb (0.25-0.32 mm). The temperatures of the inlet port, the oven and the detector were 200, 175 and 250 °C, respectively. The flow rate of the carrier gas nitrogen was 60 cm^3 min^{-1}. The detector gasses were hydrogen and medicinal air both with a flow rate of 30 cm^3 min^{-1}. A volume of hexane of 5 mm^3 was injected by hand. The signal was recorded with a HP-3388 integrator. Concentrations were determined on the basis of peak heights from standards in the concentration range 10 to 250 μg dm^{-3}. The detection limit was 10 μg dm^{-3} (in hexane). The detection limit for soil was 0.2 to 0.5 μg dm^{-3}.

2.9 Procedure for extraction and analysis of bentazone

Bentazone was extracted by shaking 100 g of moist soil with 50 cm^3 of a mixture of acetone and water (50/50 by volume) for 1 h. The supernatant was collected and acidified with 0.5 cm^3 concentrated HCl (12 mol dm^{-3}). Dichloromethane (25 cm^3) was added and the mixture was shaken for 1 h. The dichloromethane layer was collected and then evaporated under a nitrogen stream at 40 °C. The residue was dissolved in 2.5 cm^3 acetone which was stored at –20 °C until analysis. If high bentazone concentrations were expected, the extraction was done by shaking 25 g of moist soil with 25 cm^3 of acetone/water and the dichloromethane was not evaporated but directly stored at -20 $^{\circ C}$ until analysis. Just before the chemical analysis, a known volume of the acetone or dichloromethane was transferred into a HPLC vial and evaporated. The residue was dissolved in distilled water by ultrasonic vibration. The extraction efficiency was determined in a series of experiments. The average extraction efficiency for the 0-25 cm layer was 86% (at contents between 1 to 4 mg kg^{-1}). For the 50-100 cm layer it was 96% and for the 100-200 cm layer it was 86%. The concentrations were not corrected for the extraction efficiency.

The bentazone concentrations were measured with HPLC. The chromatograph consisted of a Waters 590 HPLC pump, a Perkin Elmer ISS 100 automatic injector and a LC 90 UV spectrophotometric detector (Perkin Elmer) which operated at a wave lenght of 224 nm. For separation a Chromspher C 8 column was used (20 cm long and with inner diameter of 3 mm) which was provided with a precolumn (filled with reversed-phase material; 10 cm long; inner diameter of 2.1 mm) and which operated at room temperature. The elution liquid was a mixture of an aqueous solution and methanol (3/1 by volume). The aqueous solution consisted of HPLC-water to which CH_3COONa (0.1 mol dm^{-3}) had been added and which was set at a pH of 5.0 with concentrated acetic acid. The flow rate was 0.6 cm^3 min^{-1}. A volume of 20 or 100 mm^3 was injected. The signal was processed with the software package Multichrom. Concentrations were determined on the basis of peak heights from standards in the concentration range 10 to 10000 μg dm^{-3}. The detection limit in soil was 1 to 3 μg dm^{-3}.

3 Procedures for laboratory experiments

3.1 Measurement of soil hydraulic properties

Three types of measurements of soil hydraulic properties were carried out:

- water retention characteristic by the 'hanging water column' method (described by Stolte et al., 1992);
- water retention and conductivity characteristics by the evaporation method of Wind (described by Boels et al., 1978, and Stolte et al., 1992);
- saturated hydraulic conductivity by the constant head method (described by Klute, 1986).

Samples for the first two types of measurement were taken at the experimental field in the same pit in November 1990. Samples for the measurement of the saturated hydraulic conductivity were taken after the end of the experimental period from two pits (one on the left side of the experimental field and one on the right side).

For the determination of the water retention characteristics by the 'hanging water column' method, duplicate samples were taken from the 10-18, 45-53 and 70-78 cm layers using steel rings with a volume of 300 cm^3. For the determination of the water retention and conductivity characteristics by the evaporation method of Wind, duplicate samples were taken from the 10-18, 45-53 and 65-73 cm layers using PVC cylinders (8 cm high and with inner diameter of 10 cm). Samples for the measurement of the saturated hydraulic conductivity were taken with the same PVC cylinders in duplicate from three soil layers at two spots. The samples from the 45-53 cm layer were taken from the brown layer as defined in Section 5.6.

3.2 Incubation studies with pesticides

3.2.1 Soil sampling and soil treatment

The transformation rate of both pesticides was measured in samples from the 0-25 cm, 50-100 cm and 100-200 cm layers. The sample from the 0-25 cm layer was taken in October 1990 before harvest of the sugar beets. It was taken using an auger 5 cm in diameter which was pushed into the soil at 70 spots distributed regularly over the experimental field.

The soil samples from the 50-100 and 100-200 cm layers were taken during the installation of the groundwater sampling tubes, so from the 16 holes made to install these tubes (see Section 2.1 for the procedure). At the time of sampling the groundwater level was at about 120 cm depth so the 100-200 cm sample was taken from a zone that was almost completely water-saturated. The samples taken from the 100-200 cm layer were therefore collected in a polypropylene vessel to which sufficient groundwater was added in the field to fill it completely.

The soil sample from the 0-25 cm layer was stored in the laboratory at 5 °C and the 50-100 and 100-200 cm samples were stored at 10 °C. Time between collection of samples in the field and the start of the corresponding incubation study was about 1 month.

The soil samples from the 0-25 cm and 50-100 cm layers were thoroughly mixed in the laboratory (20 min in Hobart mixer). For each layer samples were taken for determination of soil properties which were determined by the Bedrijfslaboratorium voor Grond- en Gewasonderzoek located in Oosterbeek. Soil organic matter and organic carbon were determined in three sub-samples (see Table 1 for the results).

Table 1 Characteristics of the Vredepeel soil samples used for the laboratory measurements on pesticide sorption and transformation. Figures between parentheses indicate standard deviations of individual measurements.

Property	Soil layer		
	0-25 cm	50-100 cm	100-200 cm
pH-KCl	5.3	4.7 4.6	
Mass fraction of			
Organic matter (%)	4.9 (0.0)		
Organic carbon (%)	2.29(0.03)	0.11 (0.02)	0.12 (0.06)
$CaCO_3$ (%)	0.1		
Clay (0-2 µm in %)	3	2	3
Silt (2-50 µm in %)	6	2	9
Sand (50-2000 µm in %)	91	96	88

3.2.2 Incubation in soil from the 0-25 cm layer

The pesticides were added to the soil systems in distilled water. The solution used for the studies with ethoprophos contained about 120 mg dm^{-3} of this chemical and the solution for bentazone contained about 25 mg dm^{-3} bentazone.

Ethoprophos was incubated at three temperatures (5, 15 and 25 °C) and of bentazone at two temperatures (5 and 15 °C). Portions of 50 g of moist soil were added to glass jars with a volume of 0.25 dm^{-3}. The jars were pre-incubated for three days at the corresponding incubation temperature. Then 2 cm^3 of the aqueous solution containing either ethoprophos or bentazone were added to the glass jars. The aqueous solution was mixed through the soil by rolling and shaking the jars. The jars were closed with aluminium foil in which a hole (3 mm) was made to ensure aerobic conditions in the headspace of the system.

While the soil was added to the jars, soil samples were taken periodically for determination of soil moisture content which was 0.10 kg kg^{-1} (on the basis of dry soil). After the addition of the water containing the pesticides, the moisture content was 0.15 kg kg^{-1}. The dose of ethoprophos corresponded with an initial content of 5.7 mg kg^{-1} and the dose of bentazone corresponded with 1.2 mg kg^{-1}.

The jars were incubated in constant-temperature cabinets. Their initial mass was measured and it was also measured at some sampling dates: the change in mass was used to calculate the mass of liquid phase in the soil in the jar at the sampling time.

Half of the incubated jars were used to follow the transformation by extraction with organic solvent. The other half were used to measure the concentration in liquid phase to assess effects of long-term sorption kinetics.

The first half of the jars were treated as follows. The soil in the jars containing ethoprophos was extracted by adding 25 cm^3 of water containing $CaCl_2$ (0.01 mol dm^{-3}) and 25 or 50 cm^3 of hexane. The soil in the jars containing bentazone was extracted by adding 50 cm^3 of a mixture of acetone and water (50/50 by volume). The further procedures for the extractions and the chemical analyses were identical to those used for the samples from the soil profile.

The second half of the jars were treated as follows. The liquid phase of the moist soil was collected with a centrifuge tube (Boesten, 1986). The tube consisted of two compartments separated by a glass filter which was 16 mm in diameter and 3 mm thick. The pore diameters in the filter were between 10 and 16 µm. The moist soil was transported from the jar into the upper compartment. By centrifugation for 10 min at a rotation frequency of 40 s-1, 0.5 to 2.5 cm^3 of water was collected in the lower compartment. The concentration of bentazone was measured by direct analysis in the water and that of ethoprophos after extraction with hexane. The hexane/water ratio was always higher than one. Extracting 1 c m^3 of a solution of ethoprophos in water once or five times with 1 c m^3 hexane resulted in the same concentration of ethoprophos in water. So the concentrations in hexane were not corrected for extraction efficiency. The procedures for the chemical analyses were the same as before.

Adsorption of the pesticides to the glass filter was tested by centrifuging 1 c m^3 of a solution in water through the filter. The concentrations of bentazone at levels of 0.5 and 2 mg dm^{-3} did not decrease as a result of centrifuging. However, concentrations of ethoprophos at levels of 0.2, 1.0 and 10 mg dm^{-3} decreased to 83 % ($s = 2$ %, $n = 5$) after centrifuging. Concentrations of ethoprophos in the liquid phase were therefore corrected for sorption to glass filters by dividing them by 0.83.

3.2.3 Incubation in soil from the 50-100 and 100-200 cm layers

The transformation rates in the 50-100 and 100-200 cm layers were measured at 10 °C. Portions of 100 g of moist soil from the 50-100 cm layer were weighed into glass jars with a volume of 0.5 dm^3. While filling the jars, samples of soil were taken for determination of the soil moisture content. The moisture content at the start of the incubations was 0.11 kg kg^{-1} (this included the 1 cm^3 of distilled water). The pesticides were added to a jar in 1 cm^3 of distilled water that contained either 1.09 mg dm^{-3} of ethoprophos or 10.5 mg dm^{-3} of bentazone. The content of ethoprophos was about 12 µg kg^{-1} at the start and that of bentazone was about 120 µg kg^{-1}.

The material from the 100-200 cm layer had been stored under water-saturated conditions in a vessel. Portions of this material were transferred to glass jars (volume 0.5 dm^3) with a small cylinder as described by Boesten et al. (1991). While filling the jars, soil samples were taken for determination of soil moisture content. The mass of dry soil added to the jars was on average 93 g and the mass of water added was on average 25 g. This implied that the soil in the jars was water-saturated with a water layer of a few millimetres thickness on top. The pesticides were added in the same way as for the 50-100 cm layer. The initial contents (on a dry soil basis) of both pesticides were about equal to those for the 50-100 cm layer.

Both the glass jars containing the 50-100 cm material and those containing the 100-200 cm material were covered with aluminium foil in which a hole with a diameter of 3 mm was made to ensure aerobic conditions in the headspace. They were placed at 10 °C in a temperature cabinet.

The jars containing ethoprophos were extracted by adding 25 cm^3 of aqueous $CaCl_2$ solution (0.01 mol dm^{-3}) plus 50 cm^3 hexane. The jars with bentazone were extracted by adding 50 cm^3 of a mixture of acetone and water (50/50 by volume). The further procedures and analyses were identical to those for the samples from the soil profile.

3.3 Measurement of sorption of the pesticides in soil-water suspensions

The sorption of ethoprophos was determined at 5 and 25 °C with soil material from the 0-25 cm layer. The sorption of bentazone was determined at 5 and 15 °C with soil material from the 0-25 cm layer.

The soil sample from the 0-25 cm layer was from the same batch as that used for the incubation studies. It had been stored in the laboratory for 13-15 months at 5 °C before the sorption studies started.

Immediately before the start of the sorption studies with ethoprophos, the moisture content of the soil sample from the 0-25 cm layer was determined by drying at 105 °C. It was found to be 0.102 kg kg^{-1}. Solutions of ethoprophos with concentrations of 0.5, 5 and 50 mg dm^{-3} were made in distilled water containing $CaCl_2$ at a concentration of 0.01 mol dm^{-3}. A mass of 50 g of moist soil was added to centrifuge tubes with a volume of 90 cm^3. Then 50 cm^3 of one of the aqueous ethoprophos solutions was added. The centrifuge tubes were closed with a glass stopper and placed on a rotating disk which was at an angle of 1.4 rad. The disk was placed in a cabinet that was kept at a constant temperature (one disk at 5 °C and one at 25 °C). The rotation frequency of the disks was 0.3 s^{-1}. After rotating the tubes for 24 h, the glass stopper of the tubes was replaced by aluminium foil and the tubes were centrifuged for 20 min at a rotation frequency of 40 s^{-1} at the same temperature as the corresponding cabinet. This was done in a Varifuge 3.2RS Heraeus centrifuge, equipped with a swing-out rotor with a diameter of 20 cm. After centrifugation, a sample of the water layer (about 25 cm^3) was collected and extracted with 25 cm^3 hexane by shaking for 1 h at a Gerhardt reciprocating shaker.

For each temperature and each ethoprophos concentration, three centrifuge tubes were used. The concentration of ethoprophos in the aqueous solution added to the centrifuge tubes was determined by extracting 50 cm^3 of each solution (in duplicate for each temperature, so in total four samples per concentration) by 25 cm^3 hexane in the same way as the sample of the water layer. The recovery of this extraction procedure was checked by comparing it to an extraction of 1 cm^3 of aqueous $CaCl_2$ solution with 10 cm^3 of hexane. The latter extraction was assumed to have a recovery of 100%. This check was done at a concentration of ethoprophos of 0.01 mg dm^{-3}. The recovery was found to be 95%. All concentrations of ethoprophos measured in the sorption studies were corrected for this recovery.

The concentration of ethoprophos in all hexane layers was determined with the HP 5890 gas chromatograph as described in Section 2.8. It was assumed that the decrease of the concentration in the liquid phase was completely attributable to sorption.

Immediately before the start of the sorption studies with bentazone the moisture content of the soil sample from the 0-25 cm layer was determined by drying at 105 °C. It was found to be 0.098 kg kg^{-1}. Solutions of bentazone with concentrations of 0.1, 0.5, 2 and 10 mg dm^{-3} were made in distilled water containing $CaCl_2$ at a concentration of 0.01 mol dm^{-3}. A mass of 50 g of moist soil was added to centrifuge tubes with a volume of 90 cm^3. Then 25 cm^3 of one of the aqueous bentazone solutions was added. The solid/liquid ratio was set to about 2 g cm^{-3} to increase the accuracy of the measurement (see Boesten, 1990) because a preliminary test at a solid/liquid ratio of about 1 g cm^{-3} had shown low sorption. The further procedure was identical to that for ethoprophos as described above. After the centrifugation of the tubes, about 4 cm^3 of the supernatant was passed through a Millex-HV_{13} filter with a pore diameter of 0.45 μm (Millipore). It was checked that the bentazone concentration did not decrease due to the passage of the filter. The bentazone concentration in the filtrate was determined by HPLC as described in Section 2.9. The concentration of bentazone in the aqueous solution added to the centrifuge tubes was determined in duplicate samples for each concentration by HPLC as above. It was assumed that the decrease of the concentration in the liquid phase was completely attributable to sorption.

4 Numerical description of the results in files

The results of the study are available in digital form on a diskette entitled 'Dataset Vredepeel 1990-1992 Field 38' (the number 38 is to identify the field uniquely based on the map of the experimental farm). This diskette is part of this report. The format and the names of the files used to describe the data are based on Van Geelen (1995) who developed it for data sets on nitrate leaching. His format is an improved version of the format set up by Kragt & Jansen (1991). We had to modify the format of Van Geelen for a number of files and to define additional files with additional formats because his format did not apply fully to studies with pesticides. The files should be self-explanatory. The results described in the files will be described graphically in the chapters 5 and 6. There is (or should be) a 1 : 1 correspondence of the graphical and numerical results.

Table 2 gives an overview of the files and their contents. The first part of each file can be found in the annexes as described in Table 2. The names of the variables in the files consist of the two-character codes explained in Annex 1.

Note that the standard deviations of all measured profiles (bulk density, moisture, solute concentrations) are standard deviations of the average which equals the standard deviations of the individuals divided by the square root of the number of observations. We did so because our samples were not uniform as described in Section 2.5: e.g. individual bromide concentration profiles from 16 plots were measured at each sampling time whereas the samples from plots within one section (see Fig. 1) were mixed before pesticide analysis (resulting in four measured profiles).

We limit the information made available on the moisture profiles and the concentration profiles here to four of the seven sampling times: at 1, 103, 278 and 474 d after application (i.e. one immediately after application, one at the end of the first winter, one at the end of the summer and one at the end of the experiment in the second winter). A graphical description of the profiles at the other sampling dates can be found in Van den Bosch & Boesten (1994).

Table 2 Explanation of the contents of the files on the diskette 'Dataset Vredepeel 1990-1992. Field 38'. In the indicated Annex the first page of the corresponding file is given

Name of file	Number of Annex	Description of content
NLVP038.BEA	2	Adsorption isotherms of bentazone
NLVP038.BEL	3	Concentration in liquid phase of bentazone in incubation studies with topsoil (layer 0-25 cm)
NLVP038.BEP	4	Bentazone concentration profiles
NLVP038.BET	5	Data on transformation of bentazone in topsoil (layer 0-25 cm), in unsaturated subsoil (layer 50-100 cm) and in water-saturated subsoil (layer 100-200 cm)
NLVP038.BRP	6	Bromide concentration profiles
NLVP038.CLI	7	Meteorological data: daily values of minimum and maximum air temperature, rainfall, global radiation, wind speed and air humidity
NLVP038.CRP	8	Crop sowing and harvesting dates
NLVP038.EPA	9	Adsorption isotherms of ethoprophos
NLVP038.EPL	10	Concentration in liquid phase of ethoprophos in incubation studies with topsoil (layer 0-25 cm)
NLVP038.EPM	11	Average areic mass ethoprophos in the soil on each sampling date
NLVP038.EPP	12	Ethoprophos concentration profiles
NLVP038.EPT	13	Data on transformation of ethoprophos in topsoil (layer 0-25 cm), in unsaturated subsoil (layer 50-100 cm) and in water-saturated subsoil (layer 100-200 cm)
NLVP038.ETR	14	Daily values of Makking reference crop evapotranspiration
NLVP038.GWL	15	Daily average groundwater level
NLVP038.HCU	16	Hydraulic characteristics as determined by the evaporation method of Wind
NLVP038.MAN	17	Soil management (soil tillage, dairy manure)
NLVP038.SBD	18	Bulk density profile
NLVP038.SCP	19	Soil chemical data and particle size distribution
NLVP038.SMO	20	Soil moisture profiles
NLVP038.STE	21	Daily average soil temperature at 2.5 cm depth
NLVP038.WRC	22	Water retention characteristics as determined by the 'hanging water column' method

5 Results of the field study

5.1 Time series of meteorological data, soil temperature and groundwater level

Figure 2 shows cumulative rainfall as a function of time. Rainfall in the first winter was about 200 mm and the amount at the end of the experimental period was about 800 mm. As shown by Figure 3, daily Makkink reference evapotranspiration fluctuated considerably with values below 1 mm d^{-1} in winter and up to 5 mm d^{-1} in summer. Daily global radiation (Fig. 4) showed a pattern that was similar to that of the Makkink reference evapotranspiration (as could be expected); note that the Makkink reference evapotranspiration data and the global radiation data are from different weather stations.

Air temperatures were in the range between -15 and 35 °C (see Fig. 5). Daily average soil temperatures at 2.5 cm depth were in the range between -7 and 25 °C (Fig. 6) and were nearly always in the range between the daily minimum and maximum air temperature.

Figure 7 shows that the groundwater level varied from about 50 cm to about 170 cm depth. Combination of the information in Figures 2 and 7 indicates that periods with intensive rainfall in winter (e.g. after about 40 d and just before 400 d) resulted in sharp increases of the groundwater level whereas the rainfall in summer influenced the groundwater level hardly. Obviously, the water from the rainfall in summer did not reach the groundwater table in that period. Van de Veen & Boesten (1996) showed via simulations with PESTLA (using weather data from a 30-year period) that groundwater level fluctuations as shown in Figure 7 are quite common for such a soil under Dutch conditions.

5.2 Bulk density and moisture profiles

The average bulk density increased with depth as expected (see Fig. 8) except in the top layers: the 0-4 cm layer had a larger density than the 4-7.5 cm layer. This phenomenon is caused by the uncertainty in the definition of the location of the soil surface. This location was arbitrarily defined by the person who defined in the field where '4 cm depth' was located. So the measured bulk density of the 0-4 cm layer may not be representative for a sample from this layer but taken from below the soil surface (e.g. the 1-4 cm layer).

The measured moisture profiles (in Fig. 9) show that the volume fraction of liquid in the top 30 cm was always higher than that in the 30-60 cm layer. This is probably caused by the much larger organic matter content of the top 30 cm which leads to a higher water retention capacity. Below 60 cm the volume fraction of liquid increased always with increasing depth probably due to the influence of the groundwater table.

5.3 Concentrations of bromide ion

At 1 d after spraying the average recovered areic[1] mass of bromide was 105 kg ha^{-1}; the standard deviation of this average was 7 kg ha^{-1}. So the areic mass recovered from soil corresponded well with the areic mass sprayed onto the soil surface (111 kg ha^{-1} as described in Section 2.2). At this first sampling date almost all bromide was recovered from the 0-4 cm layer whose bromide concentration was 258 mg dm^{-3}. In the 4-7.5 cm layer a concentration of 1.0 mg dm^{-3} was found (probably an artifact resulting from contamination from the top layer during sampling in the field). At greater depths the average concentration was always below the detection limit of 0.7 mg dm^{-3}.

The results for the other sampling dates are shown in Figure 10. Note that the concentration of bromide in the soil system is given, i.e. mass of bromide per volume of soil. After 103 d (at the end of the first winter) the bromide concentration increases with increasing depth. After 278 d the distribution of bromide with depth is very flat. At the end of the study (after 474 d), the distribution is also flat but at a lower concentration level.

5.4 Concentrations of ethoprophos

At 1 d after spraying the average recovered areic mass of ethoprophos was 2.7 kg ha^{-1}; the standard deviation of this average was 0.1 kg ha^{-1}. The measured concentrations were not corrected for recovery which was 89% for the 0-25 cm layer (see Section 2.2). So correction for recovery results in an recovered amount of 3.0 kg ha^{-1}. This corresponded reasonably well with the areic mass sprayed onto the soil surface (3.35 kg ha^{-1} as described in Section 2.2). The highest concentrations of ethoprophos after 1 d were measured in the 0-4 cm layer: the average concentration in the 4-7.5 cm layer was only 0.2% of that in the 0-4 cm layer. Because no rain fell between spraying and sampling this 0.2% must be the result of contamination due to the sampling procedure: transfer of 0.2% to the next layer implies a very limited sampling contamination. Concentrations in the 60-67.5 and 90-97.5 cm layers (which were measured to check the sampling procedure) were below the detection limit (0.5 μg dm^{-3}).

As shown by Figure 11, the amount of ethoprophos in soil decreased drastically in the first few weeks: at 22 days after application only about 50% was left. It is likely that this was not due to transformation within the soil but to some loss process at the soil surface.

The ethoprophos concentration profiles measured after 103, 278 and 474 days (Fig. 12) show that the highest concentrations were always found in the top layer (0-4 cm). Only low concentrations penetrated to below 20 cm depth. After 474 days (i.e. at the end of the study) concentrations below 30 depth were always below the detection limit of 0.2 μg dm^{-3}.

---

[1] 'Areic' means 'divided by area' (Rigg et al., 1985).

5.5 Concentrations of bentazone

At 1 d after spraying the average recovered mass of bentazone was 0.63 kg ha^{-1} with a standard deviation of 0.04 kg ha^{-1}. Correction for the recovery of 86%, results in an average areic mass of 0.73 kg ha^{-1} which is about 90% of that calculated to be applied. This figure is almost identical to that found for ethoprophos. Almost all bentazone was found in the top 0-4 cm layer after 1 d: the concentration in the 4-7.5 cm layer was on average only 0.5% of the concentration in the 0-4 cm layer. All concentrations in the layers between 7.5 and 30 cm depth sampled after 1 d were below the detection limit.

The bentazone concentration profile measured after 103 days (Fig. 13) shows that bentazone penetrated to about 90 cm depth at a comparatively high concentration in soil (about 35 μg dm^{-3}). The profile after 278 days shows a peak in the 60-90 cm layer. Comparison of Figures 10, 12 and 13 shows that bentazone is less mobile than bromide but much more mobile than ethoprophos (as could be expected). At the end of the study (after 474 days), the bentazone concentrations in all sampled layers (ranging from 0 to 120 cm depth) were below the detection limit (1-2 μg dm^{-3}).

5.6 Thickness of the soil layers

Table 1 indicates that there is a sharp gradient in the organic carbon profile (2.3% in the 0-25 cm layer and 0.1% below 50 cm depth). This gradient could easily be observed in the field by the gradient in the color of the soil: the color of the soil follows with increasing depth the sequence black - brown - yellow - grey. To estimate the depth of the humic top layer, we measured the depth of transition between the black and brown layers in the soil colums sampled at two sampling dates (in total 31 observations). The average depth of transition was 32 cm and the standard deviation of this average was 0.6 cm. The minimum value observed was 27 cm and the maximum was 40 cm. We measured also the depth of transition between brown and yellow. We found an average depth of 49 cm with a standard deviation of 1.7 cm (minimum was 35 and maximum was 70 cm). We did not measure organic matter and soil particle size distribution of the brown layer.

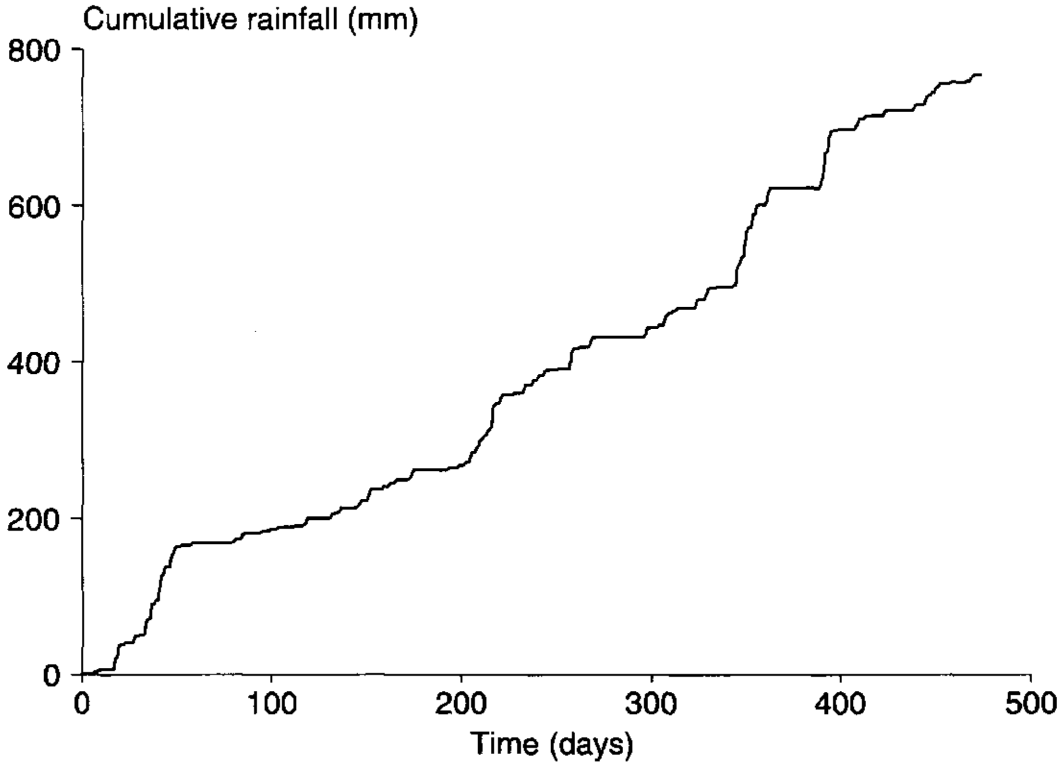

Fig. 2 Cumulative rainfall as a function of time measured at the experimental field. Time zero corresponds with 0.00 h at 23 November 1990. Daily values measured at 1.2 m height were multiplied with a correction factor based on results measured flush with the soil surface

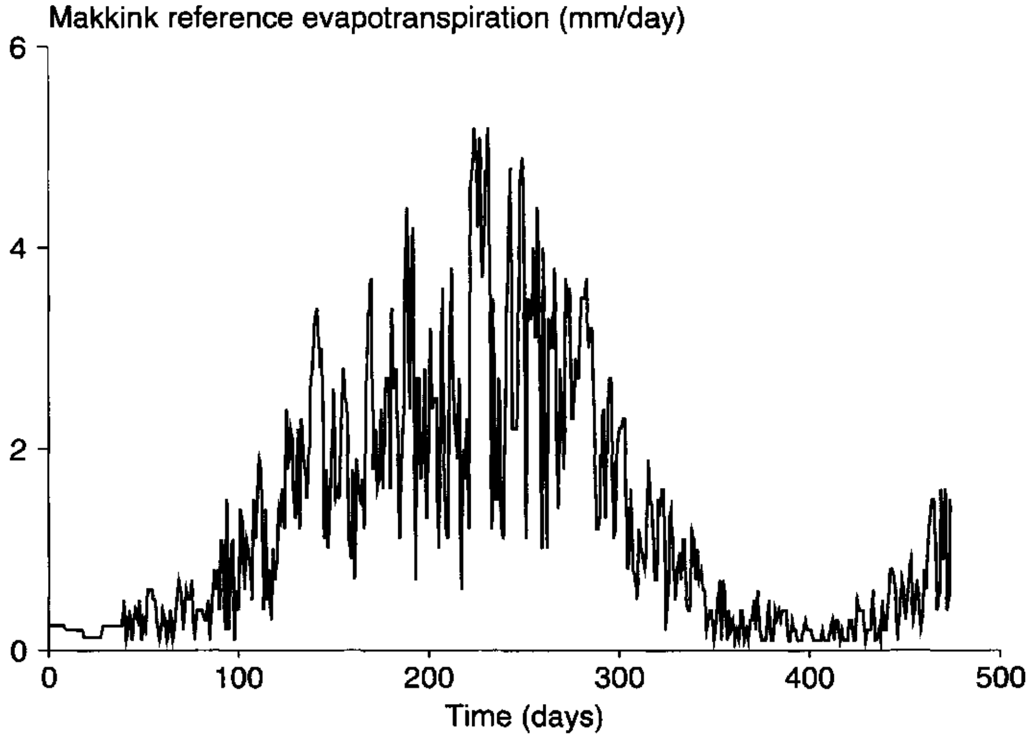

Fig. 3 Daily Makkink reference crop evapotranspiration as a function of time. Data are from the Royal Dutch Meteorological Institute (mainly from weather station 'Arcen'). Time zero corresponds with 0.00 h at 23 November 1990

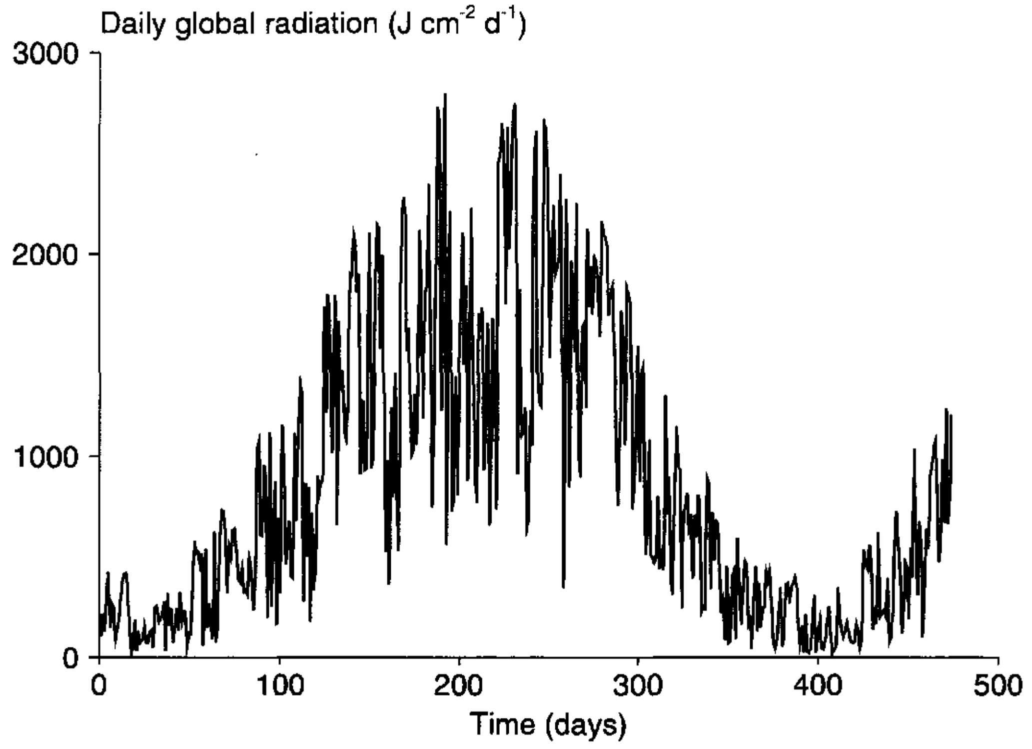

Fig. 4 Daily global radiation as a function of time. Data are from the Royal Dutch Meteorological Institute (from weather station 'Beek'). Time zero corresponds with 0.00 h at 23 November 1990

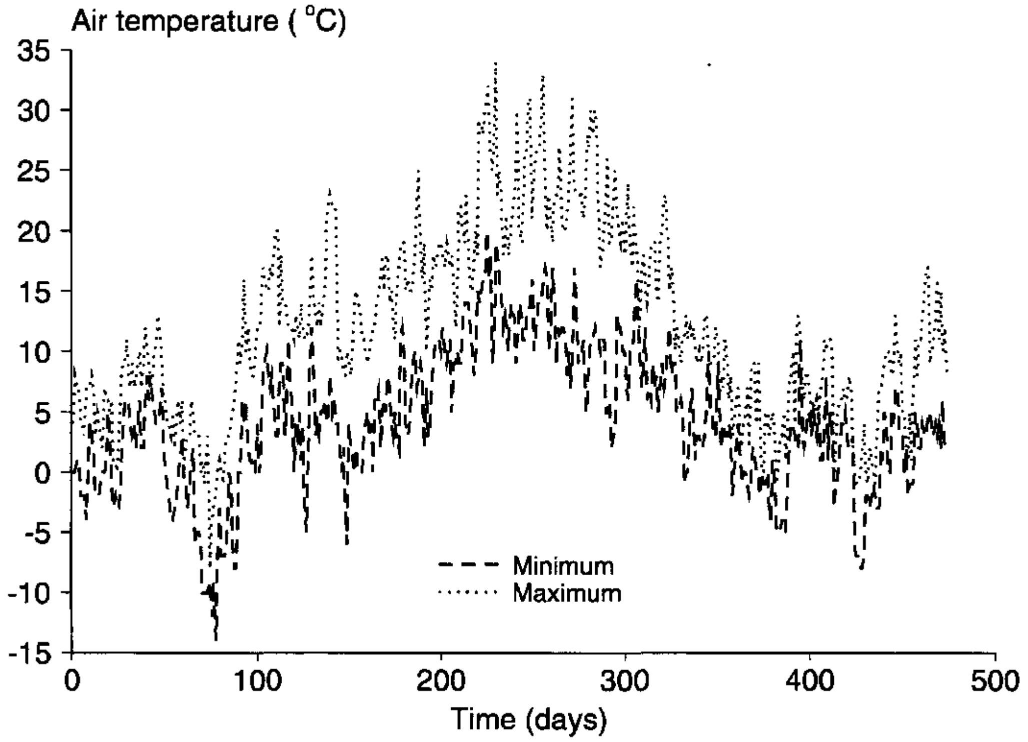

Fig. 5 Daily maximum and minimum air temperatures as a function of time measured at the experimental farm 'Vredepeel'. Time zero corresponds with 0.00 h at 23 November 1990

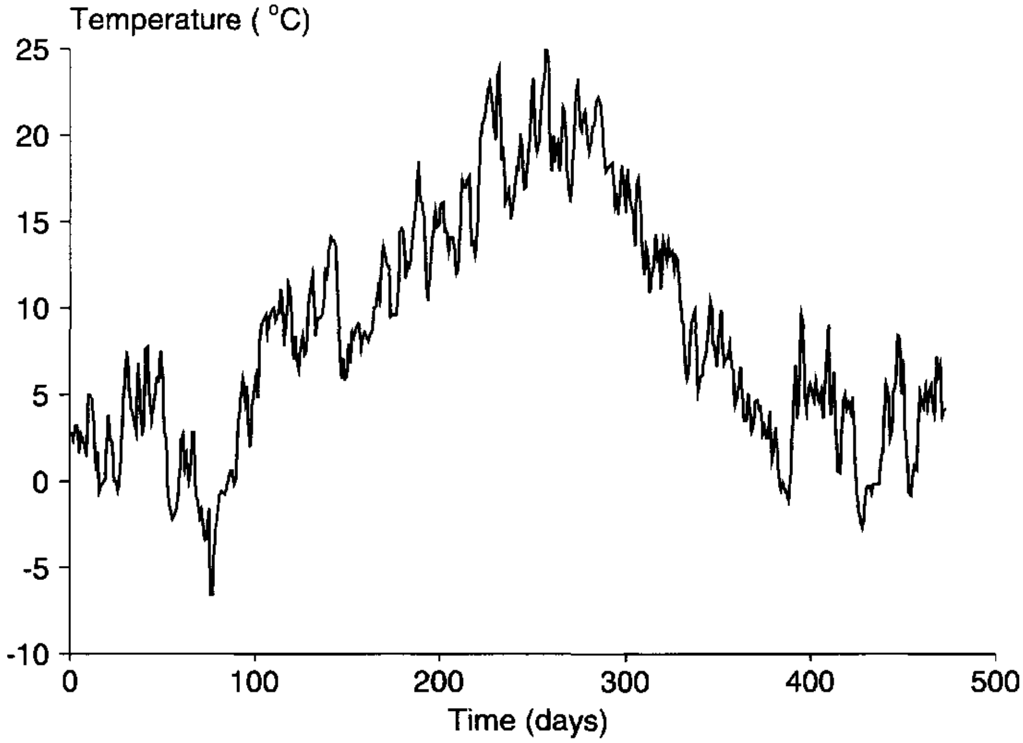

Fig. 6 Daily average soil temperature at 2.5 cm depth as measured at experimental field Vredepeel-38. Time zero corresponds with 0.00 h at 23 November 1990

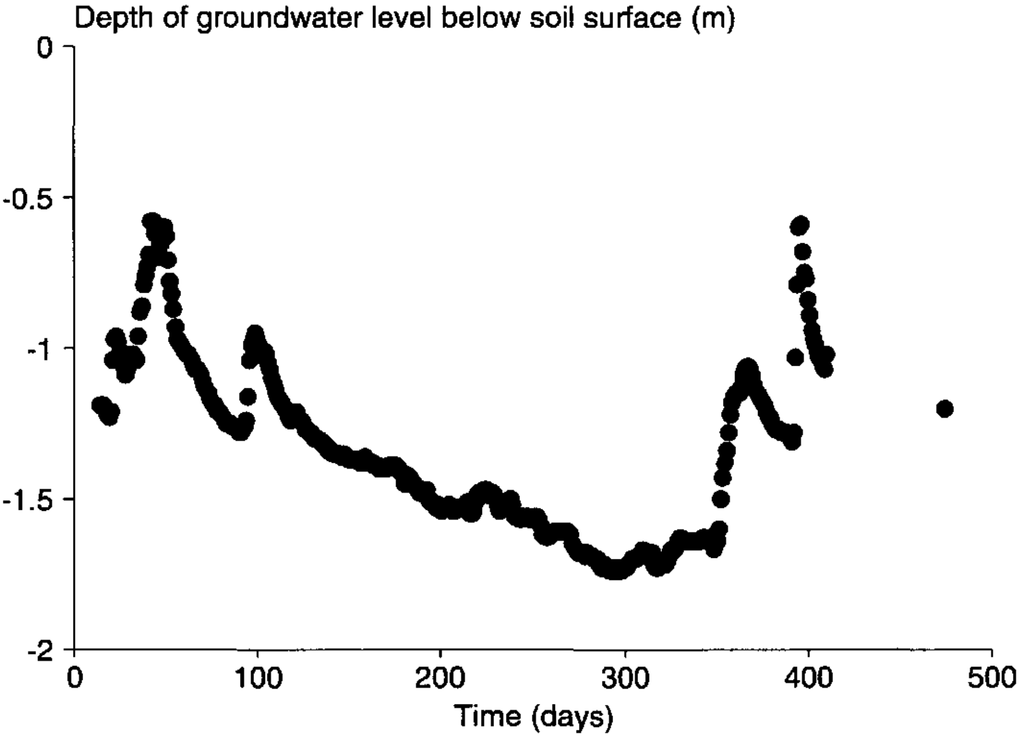

Fig. 7 Daily average groundwater level as measured at experimental field Vredepeel-38. Time zero corresponds with 0.00 h at 23 November 1990

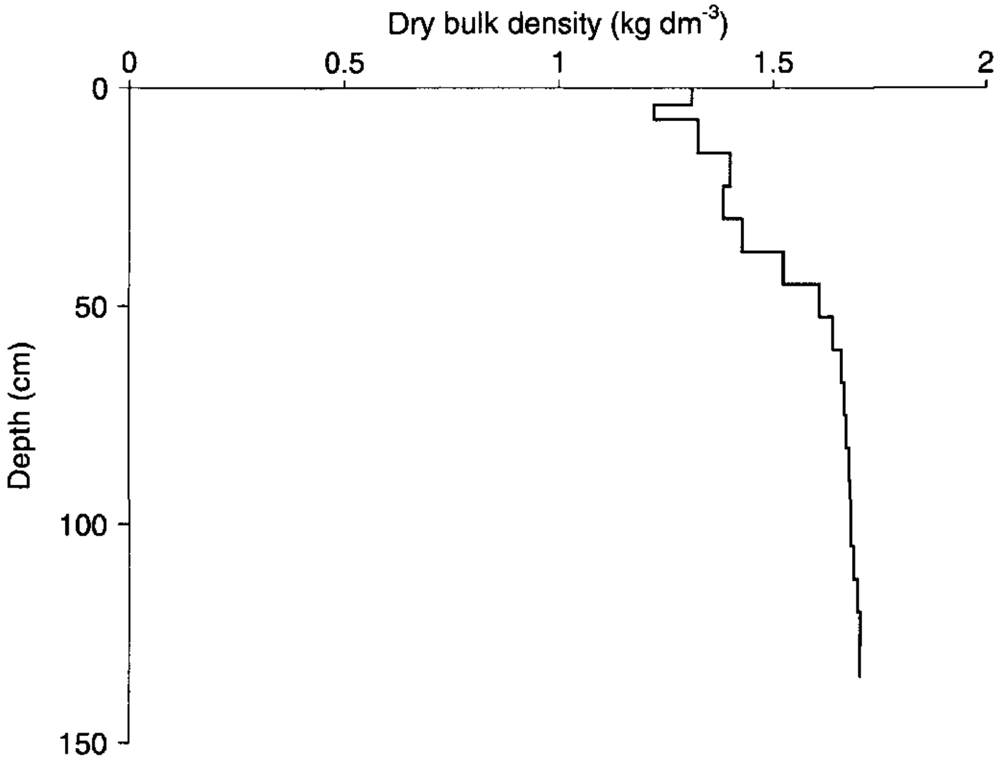

Fig. 8 Dry bulk density as a function of depth as measured at experimental field Vredepeel-38. The results are averages of all sampling times

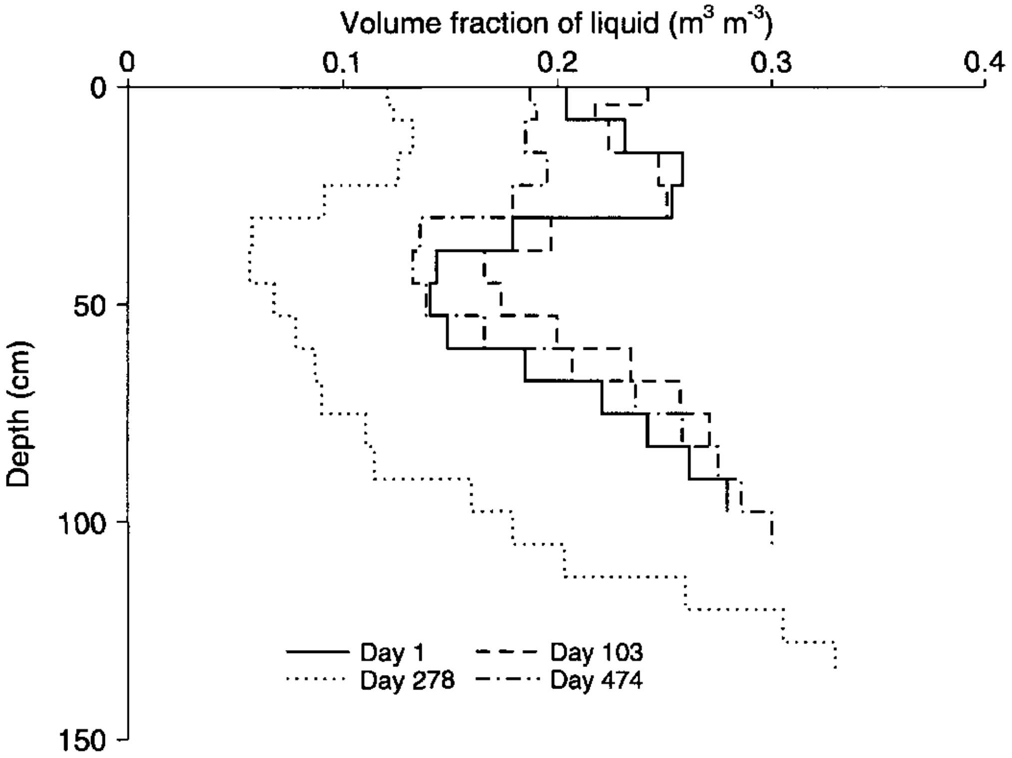

Fig. 9 Average volume fraction of liquid as a function of depth as measured at experimental field Vredepeel-38 at 1, 103, 278 and 474 days after application

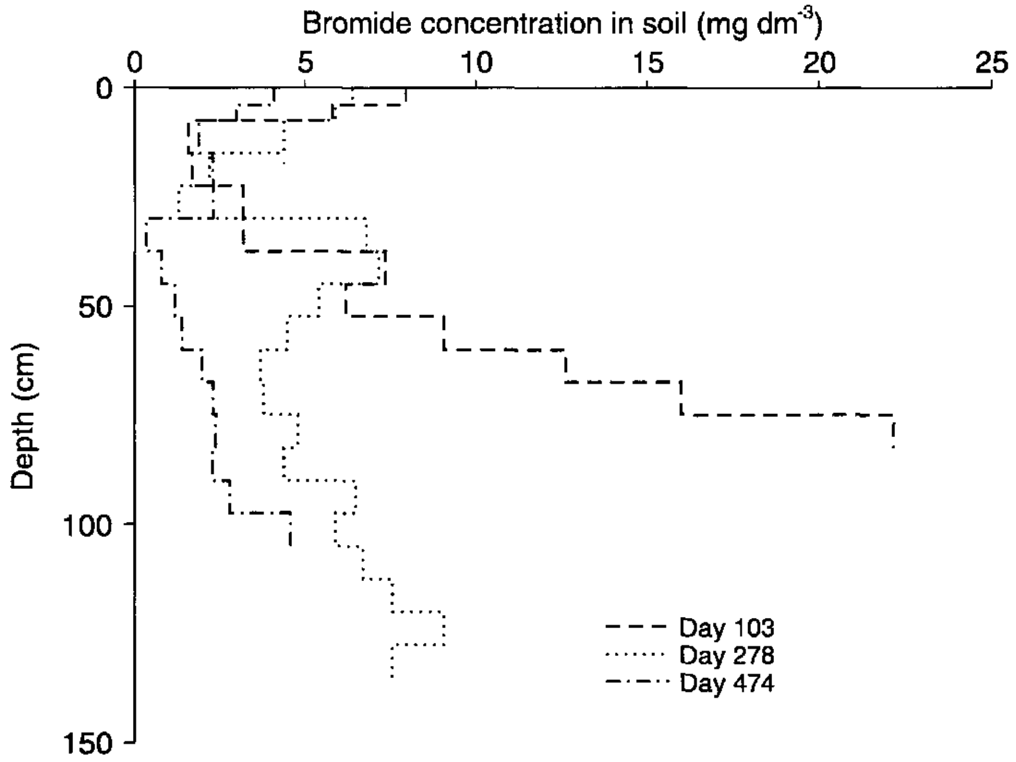

Fig. 10 Average concentration of bromide ion in soil as a function of depth as measured at experimental field Vredepeel-38 at 103, 278 and 474 days after application. The concentration is defined as mass of bromide per volume of soil

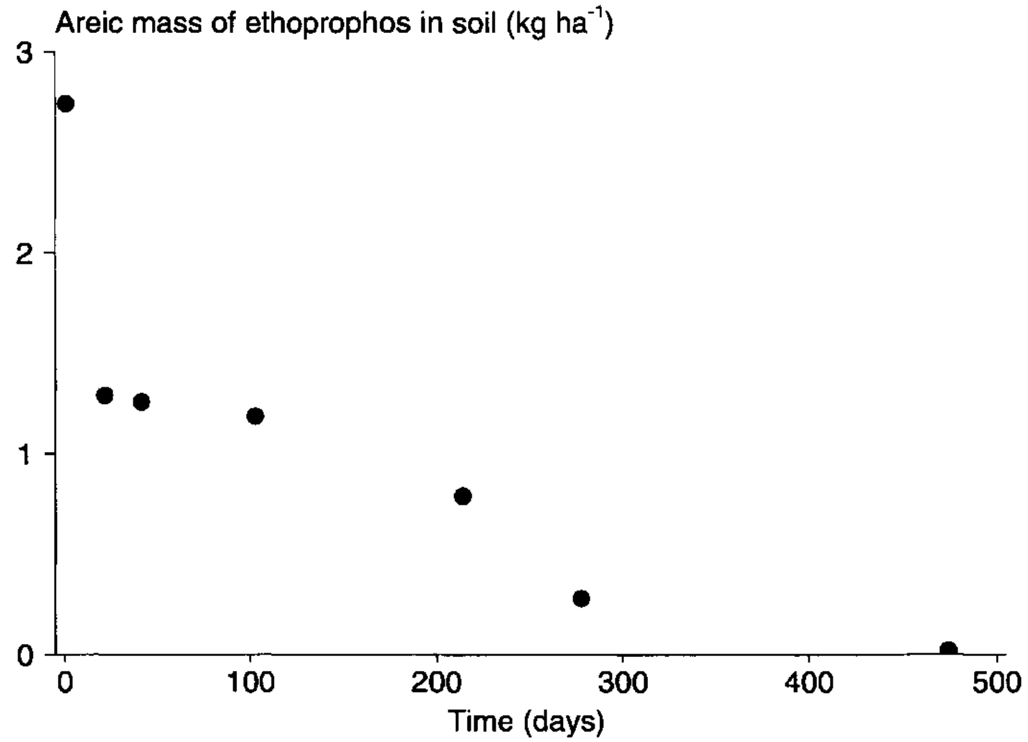

Fig. 11 Average areic mass of ethoprophos in soil as a function of time as measured at experimental field Vredepeel-38. Time zero corresponds with 0.00 h at 23 November 1990

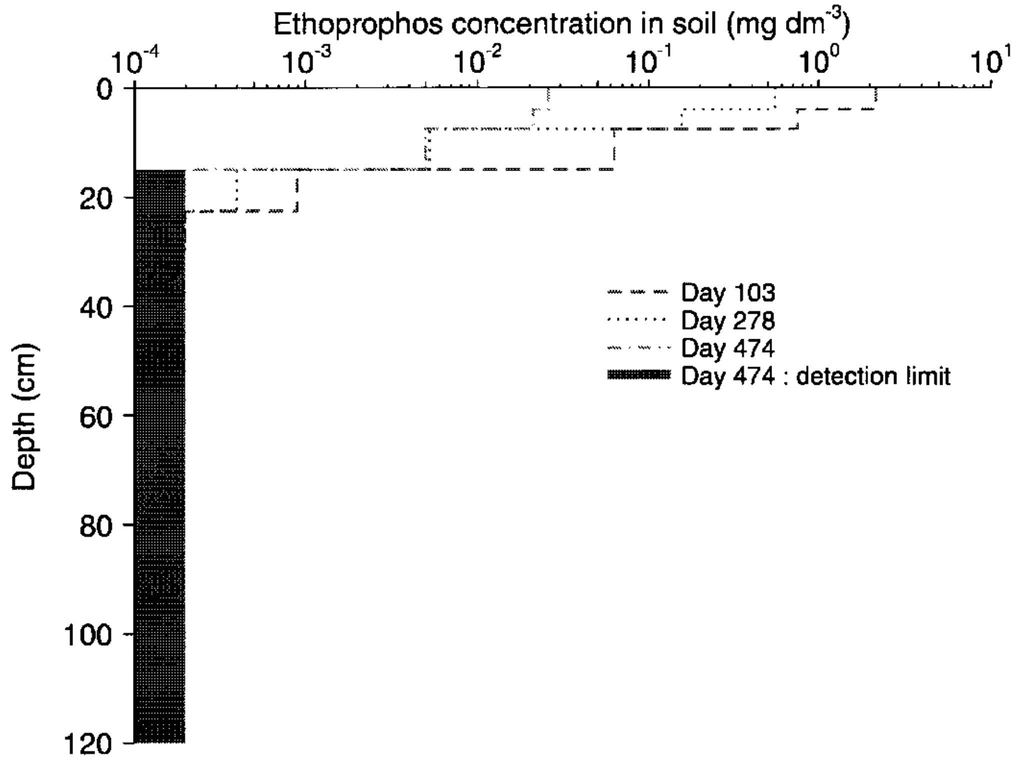

Fig. 12 Average concentration of ethoprophos in soil as a function of depth as measured at experimental field Vredepeel-38 at 103, 278 and 474 days after application. Concentrations in the 30-45, 45-60, 60-90 and 90-120 cm layers were only measured after 474 days and were all below the detection limit of 0.0002 mg dm^{-3} as indicated by the area

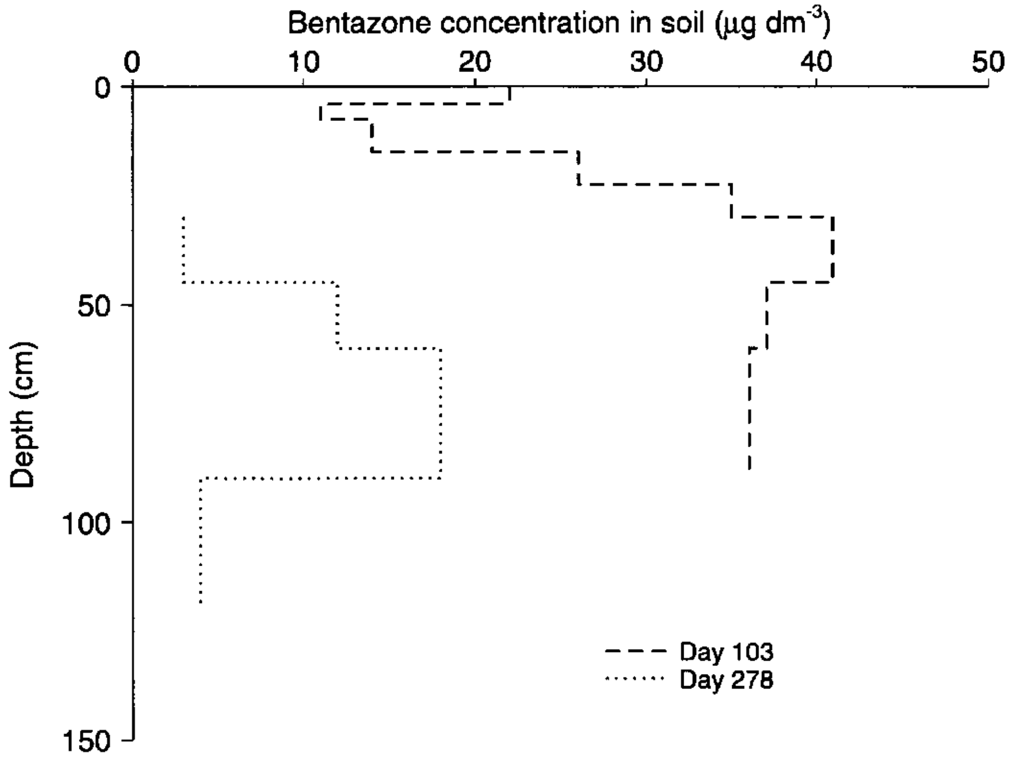

Fig. 13 Average concentration of bentazone in soil as a function of depth as measured at experimental field Vredepeel-38 at 103 and 278 days after application

6 Results of the laboratory studies

6.1 Soil hydraulic properties

Figures 14A-C show that the variability between the results obtained for a given layer is considerable, especially at volume fractions of liquid above 0.2. It is remarkable that the water retention characteristics of the 10-18 and 45-53 cm layers do not differ much because the 10-18 cm layer has a much higher organic matter content than the 45-53 cm layer (see Table 1). For all layers there is a measurable difference between the wetting and drying curves (hysteresis).

Figures 15A-C show that there was considerable scatter in the relationship between the hydraulic conductivity and matric head. Differences between the layers are remarkably small. Table 3 shows that the saturated hydraulic conductivity was very high for all samples (130-440 cm d^{-1}) and that differences between layers were usually limited if compared to the variability obtained on different samples from one layer.

Table 3 Measured saturated hydraulic conductivity as a function of soil depth. Results are from duplicate samples collected at the experimental field Vredepeel-38 at two spots (one left and one right)

Soil layer	Saturated hydraulic conductivity (cm/day)			
	Left		Right	
	Sample 1	Sample 2	Sample 1	Sample 2
13-22 cm	129	207	142	189
26-34 cm	172	168	395	35
46-60 cm	157	443	142	2526

6.2 Transformation rates of the pesticides

The results of the incubation study with ethoprophos and soil material from the 0-25 cm layer show that temperature had a distinct effect on the transformation rate (see Fig. 16). Figure 16 shows also that the transformation at 5 °C proceeded very slowly. We observed a similar slow decline in the field between 22 and 100 days (see Fig. 11) when soil temperatures did not differ much from 5 °C (see Fig. 6). The results at 15 and 25 °C indicate that the transformation rate slowed down somewhat between 100 and 400 days; this is probably attributable to a decreasing activity of the microbial activity in the incubation systems.

Figure 17 shows that the transformation rate of bentazone in soil material from the 0-25 cm layer proceeded very slowly at 5 °C (comparable to the rate of ethoprophos at 5 °C). However, the transformation rate of bentazone at 15 °C proceeded much faster. At this temperature, the transformation rate slowed down somewhat between 100 and 400 days as was also the case with ethoprophos at 15 and 25 °C.

The results of the transformation rate study with ethoprophos and material from the 50-100 and 100-200 cm layers show that there was a considerable variability between results obtained at the different sampling times (Fig. 18). The variability between sampling times seems larger than that between duplicates: this indicates systematic differences between analysis procedures at the different times. Such extraction problems were not foreseen in view of the extraction efficiencies of 87-93% measured before (see Section 2.8) and in view of the low content of organic material in these layers (see Table 1). A possible explanation for the variability is the low content of ethoprophos (10 μg kg^{-1}) in the incubation systems. Figure 18 shows that there was no systematic difference between the decline in the two layers: a decline of 50% was reached after roughly 1 year.

The results of the transformation rate study with bentazone and material from the 50-100 and 100-200 cm layers show that there was a remarkable difference between the two layers (Fig. 19). For the 50-100 cm layer there was no measurable decrease at a time scale of 1 year whereas for the 100-200 cm layer a decrease of 50% was reached after about 100 days. The variability between duplicates for the 50-100 cm layer was very small whereas this variability was considerable for the 100-200 cm layer at the sampling times later than 100 days. As indicated in Table 1, the properties of the 50-100 and 100-200 cm layers were very similar. The difference in bentazone transformation behaviour is therefore probably attributable to the difference in the incubation procedure: the 50-100 cm layer was incubated under unsaturated conditions whereas the 100-200 cm layer was incubated at water-saturated conditions.

6.3 Sorption of pesticides

The sorption isotherms for ethoprophos as shown in Figure 20 showed an increase of sorption with increasing temperature. This is unexpected. The difference between the two temperatures was highest at the highest concentration. We fitted Freundlich isotherms using linear regression with the restriction of an equal value of the Freundlich exponent for both temperatures. The results in Figure 20 indicate that the description was acceptable at both temperatures. The fitted Freundlich coefficient at 25 °C was about 40% higher than that found at 5 °C.

The sorption isotherms with bentazone (Fig. 21) show a large scatter at both temperatures. As described by Boesten (1990), the experimental error in sorption coefficients is controlled by the dimensionless product of the solid-liquid ratio and the sorption coefficient. In these measurements this product was about 0.2 which indicates low accuracy. The results imply that bentazone sorption was very weak. Figure 21 shows that the differences between the two temperatures were not significant given the large experimental error.

Keller (1995) conducted a sorption study in a soil-water suspension for bentazone with soil material from the 0-30 cm layer of our experimental field Vredepeel-38. His sample was not identical to ours: it consisted of samples taken at 474 d after application and stored in the laboratory for 3 years. The solid-liquid ratio was 2 kg dm^{-3} and the study was done at 20-25 °C. The results could be described well with a Freundlich isotherm: the accuracy of his measurements was higher probably because he measured the concentrations with ^{14}C liquid scintillation counting whereas we used HPLC. Comparison of Keller's results with ours in Figure 21 shows that his sorption was about two times as high as ours. A possible cause for this difference is the difference in pretreatment of the soil. Keller (1995) used air-dry soil whereas we used moist soil. Boesten (1986, p. 149) studied cyanazine sorption to a non-water repellent sandy soil. He found that sorption was about 20% higher when starting with air-dry soil as compared to starting with moist soil. A rewetting period of 2 weeks was needed to obtain results that were about equal to those obtained with moist soil. The effect found here is considerably larger. However, the Vredepeel soil is water repellent which may lead to a larger effect on the sorption.

Figure 22 shows that there was considerable variation between duplicates and sampling times in the concentration in the liquid phase during the incubation studies with ethoprophos. For the measurements at 5 °C the values after 100 days seem to be higher than before. This is possibly an artifact caused by systematic errors. Figure 23 shows that the variation for bentazone was much less: differences between duplicates are small. Comparison of the concentrations in the liquid phase with the concentrations expected on the basis of the adsorption isotherms (results not shown) indicated that in almost all cases the sorption in the incubation systems was higher than expected on the basis of the isotherms.

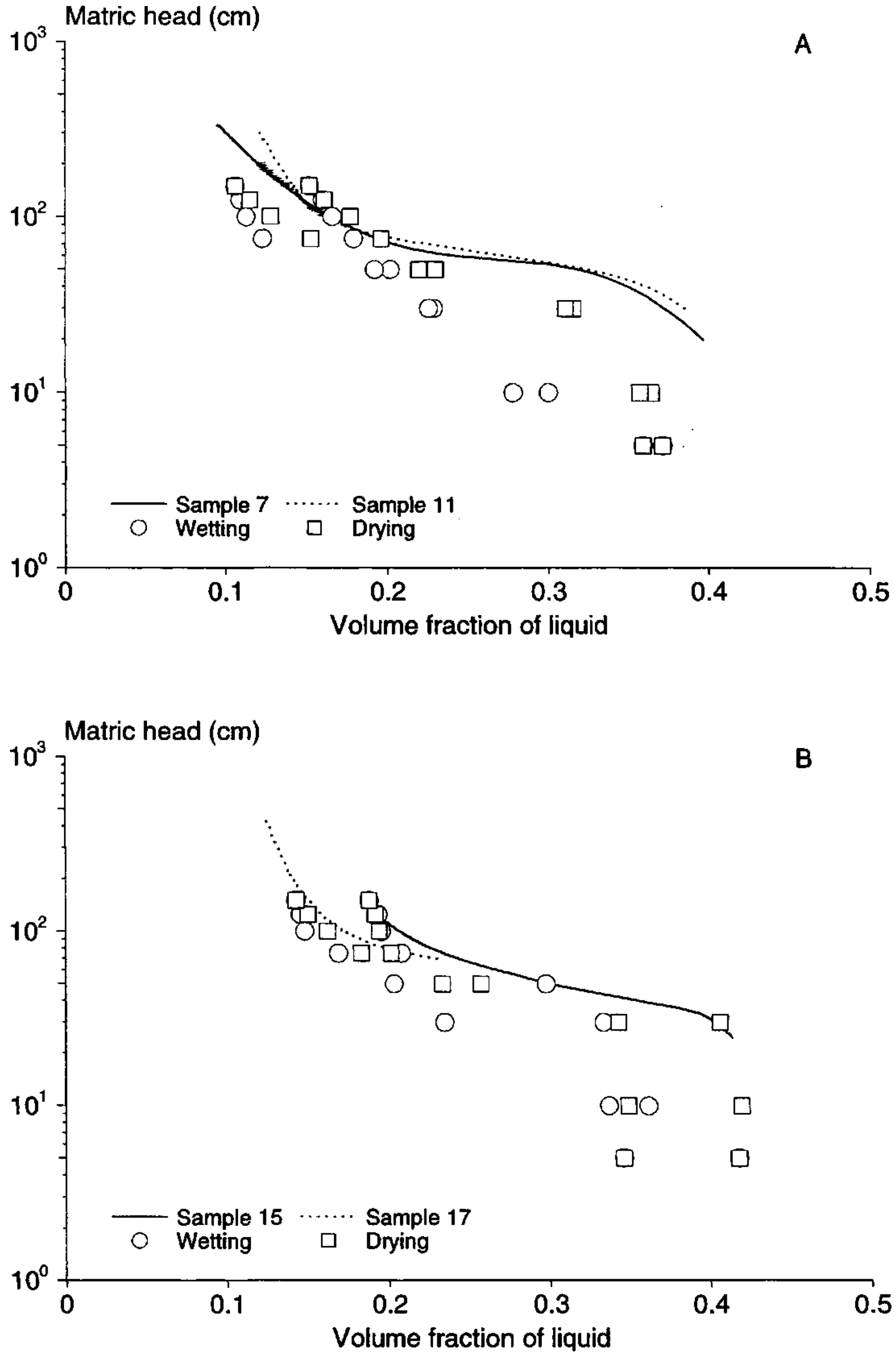

Fig. 14 Relationship between matric head and volume fraction of liquid ('pF-curves') as measured on samples from experimental field Vredepeel-38. Part A: 10-18 cm layer; part B: 45-53 cm layer; part C: 70-78 cm layer. The solid and dotted lines are duplicate samples measured with the evaporation method of Wind. The points are duplicate samples measured with the 'hanging water column' method. A sample number that is identical to a number in Fig. 15 indicates that the results were obtained on the same sample

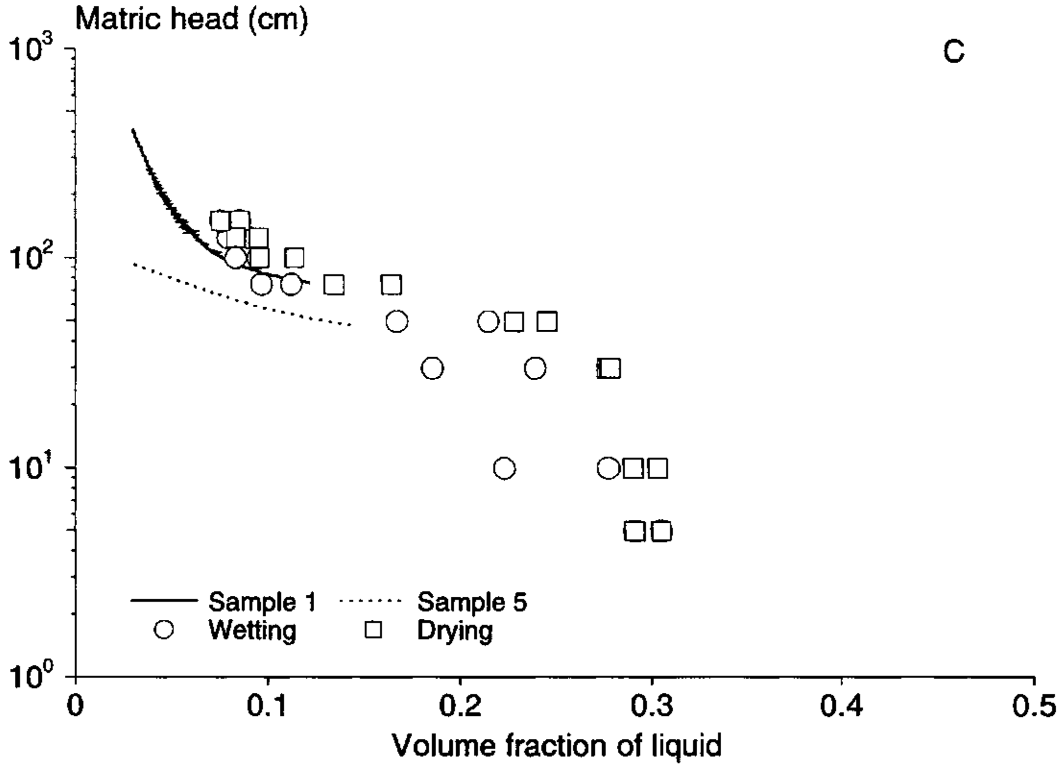

Fig. 14 (Continued)

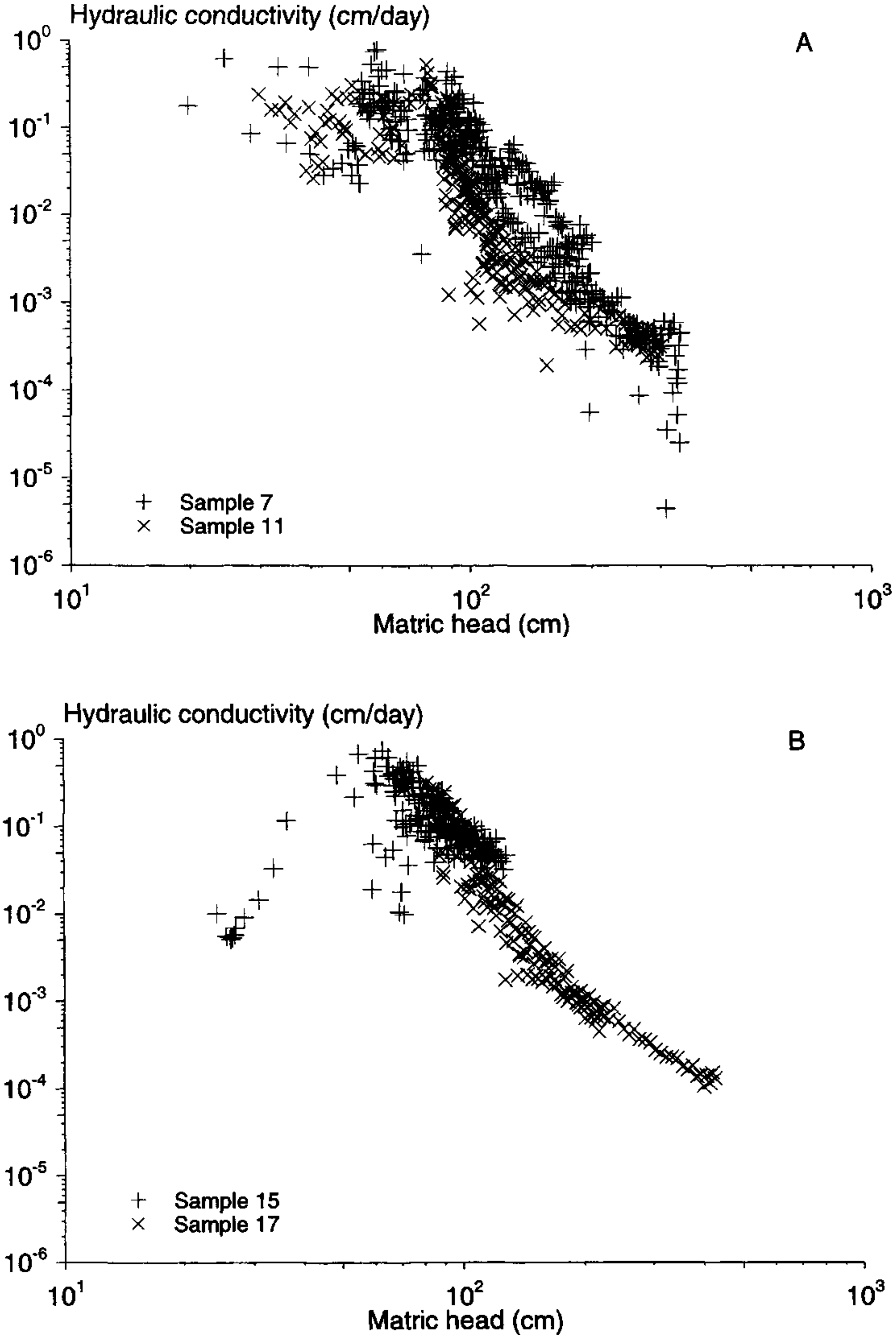

Fig. 15 Hydraulic conductivity as a function of matric head as measured on samples from experimental field Vredepeel-38. Part A: 10-18 cm layer; part B: 45-53 cm layer; part C: 70-78 cm layer. The two symbols are duplicate samples as measured with the evaporation method of Wind. A sample number that is identical to a number in Fig. 14 indicates that the results were obtained on the same sample

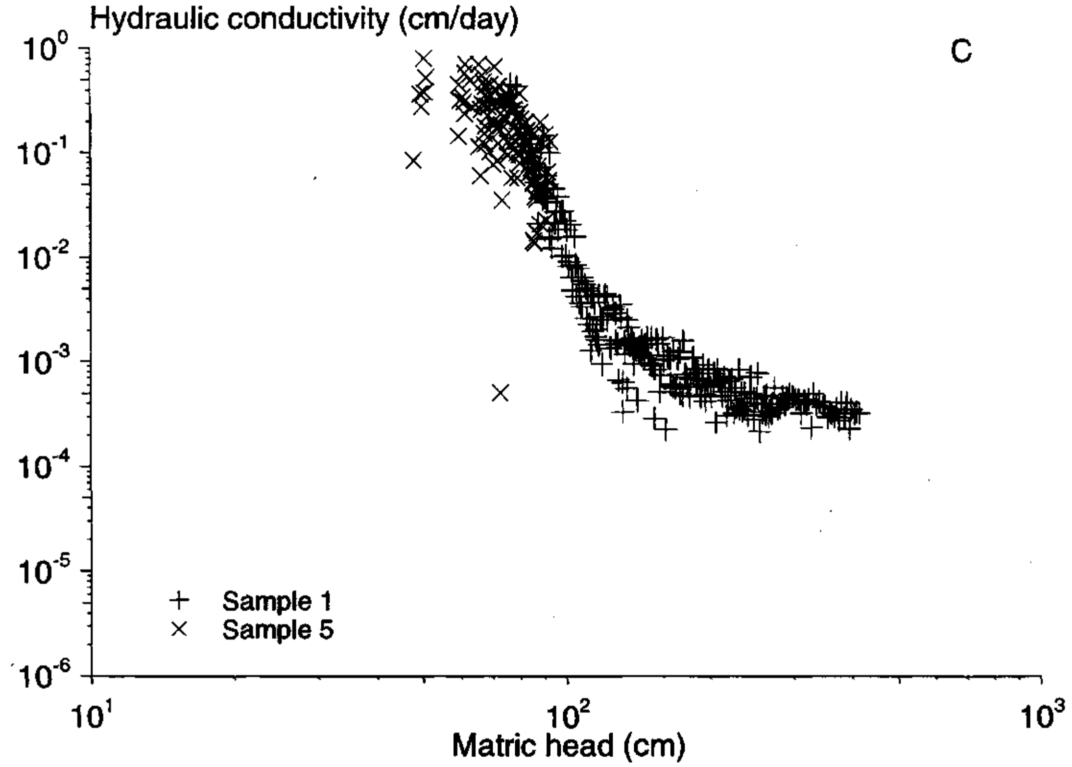

Fig 15 (Continued)

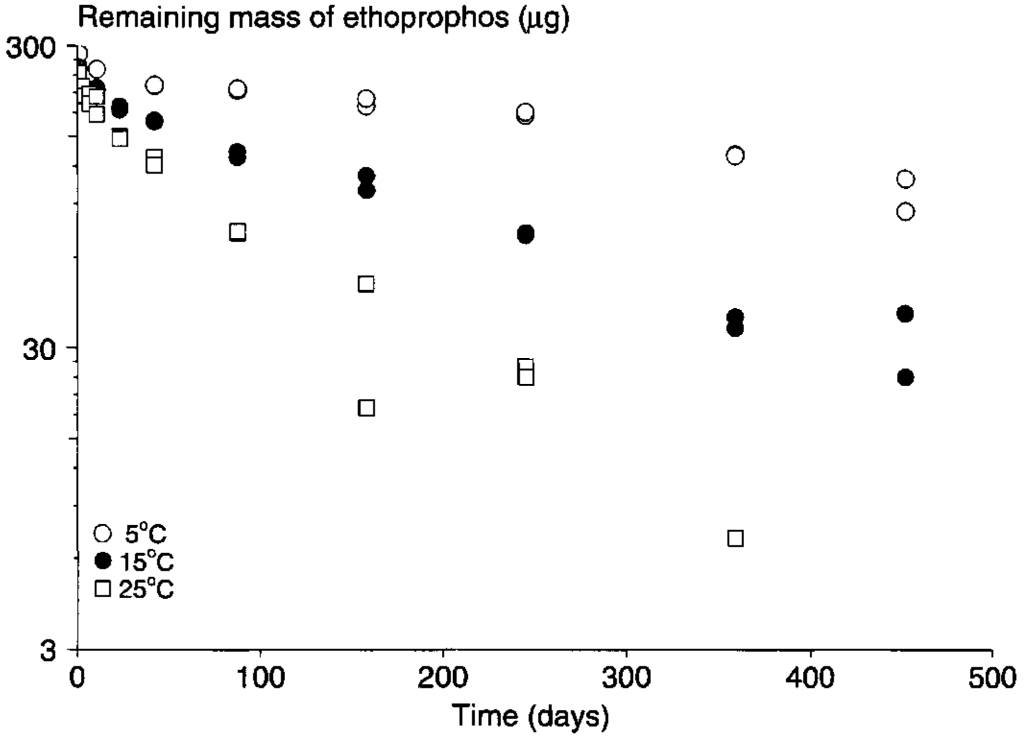

Fig. 16 Remaining mass of ethoprophos as a function of incubation time as measured in laboratory incubations at 5, 15 and 25 °C with soil sampled from the 0-25 cm layer of experimental field Vredepeel-38

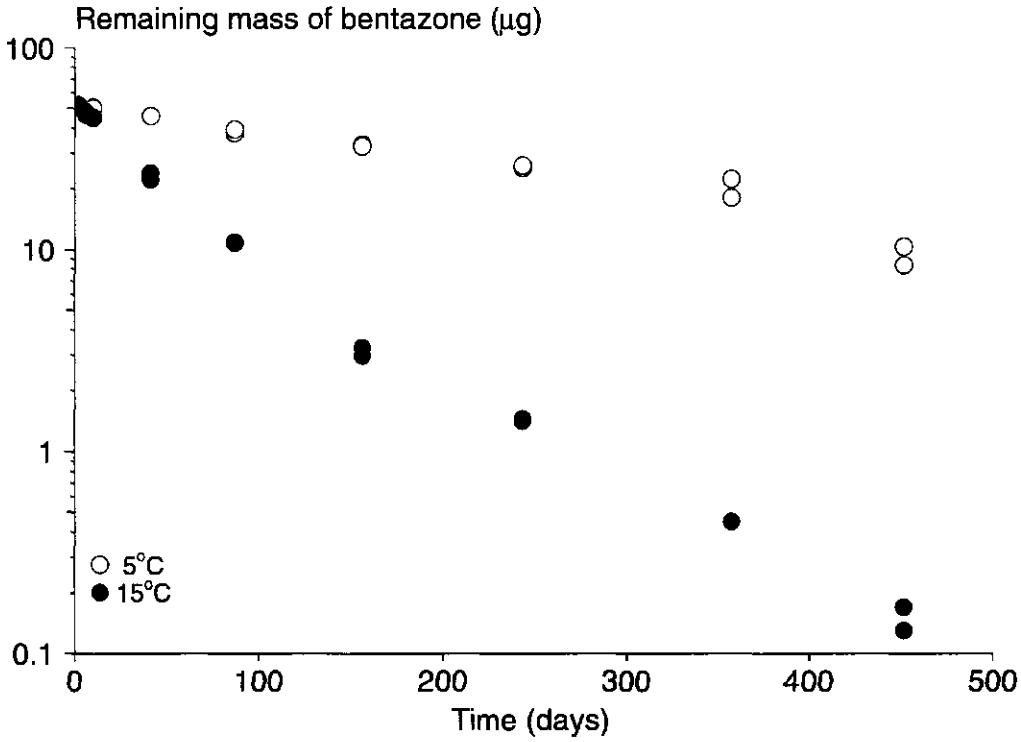

Fig. 17 Remaining mass of bentazone as a function of incubation time as measured in laboratory incubations at 5 and 15 °C with soil sampled from the 0-25 cm layer of experimental field Vredepeel-38

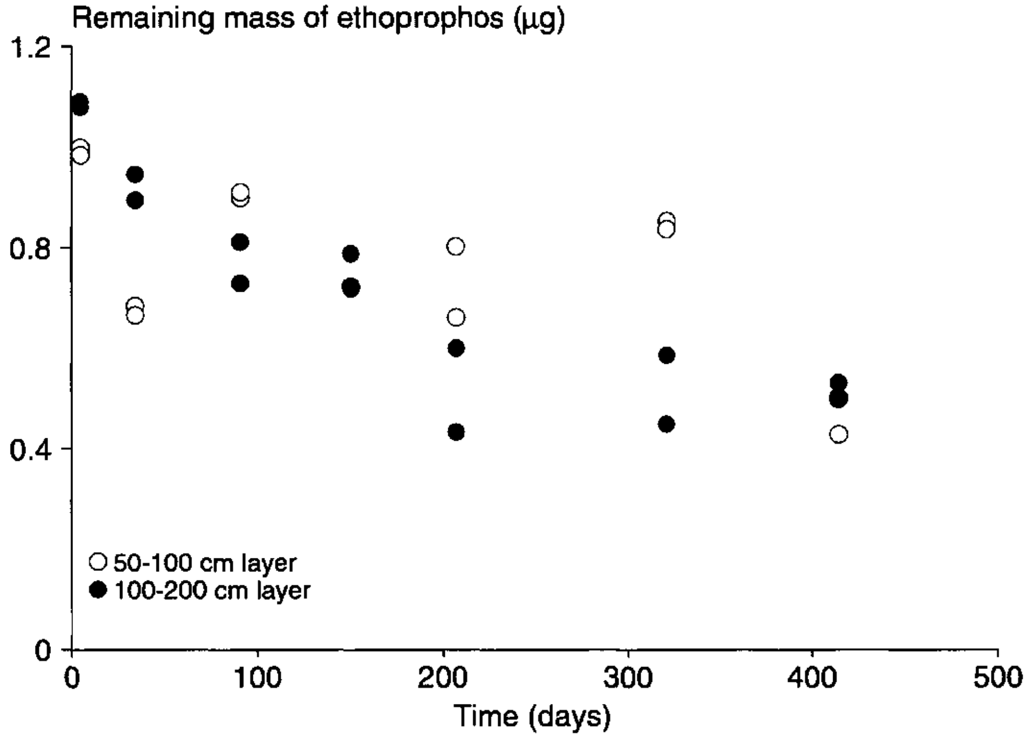

Fig. 18 Remaining mass of ethoprophos as a function of incubation time as measured in laboratory incubations at 10 °C with soil sampled from the 50-100 and 100-200 cm layers of experimental field Vredepeel-38

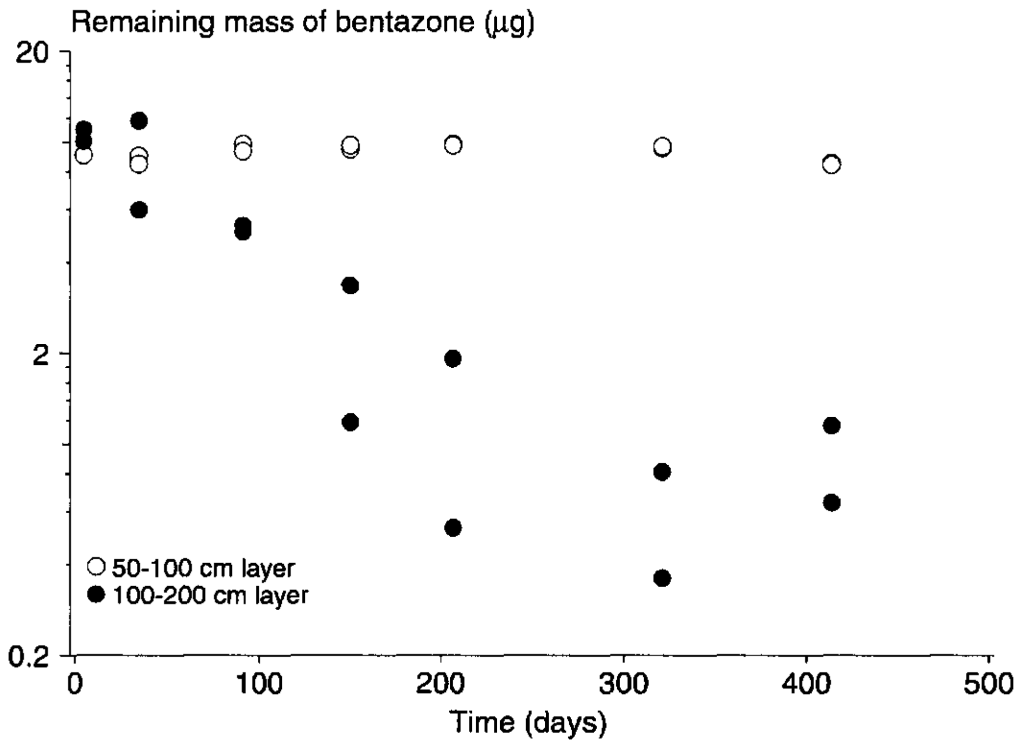

Fig. 19 Remaining mass of bentazone as a function of incubation time as measured in laboratory incubations at 10 °C with soil sampled from the 50-100 and 100-200 cm layers of experimental field Vredepeel-38

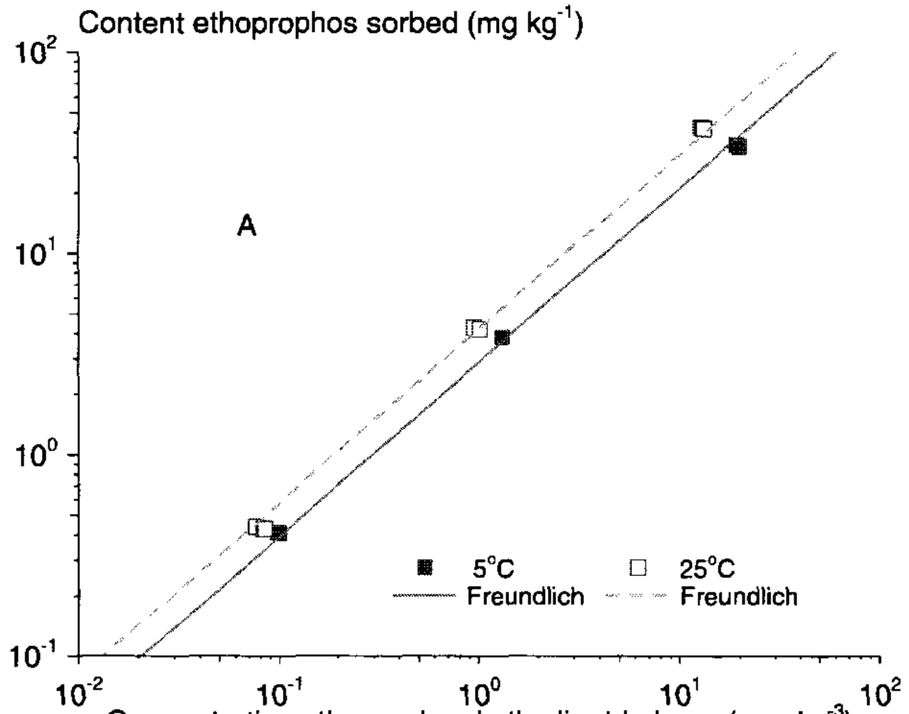

Fig. 20 Sorption isotherms as measured for ethoprophos at 5 and 25 °C using soil sampled from the 0-25 cm layer of experimental field Vredepeel-38. The points are the measurements and the lines are fits of a Freundlich isotherm assuming equal Freundlich exponents for the two temperatures

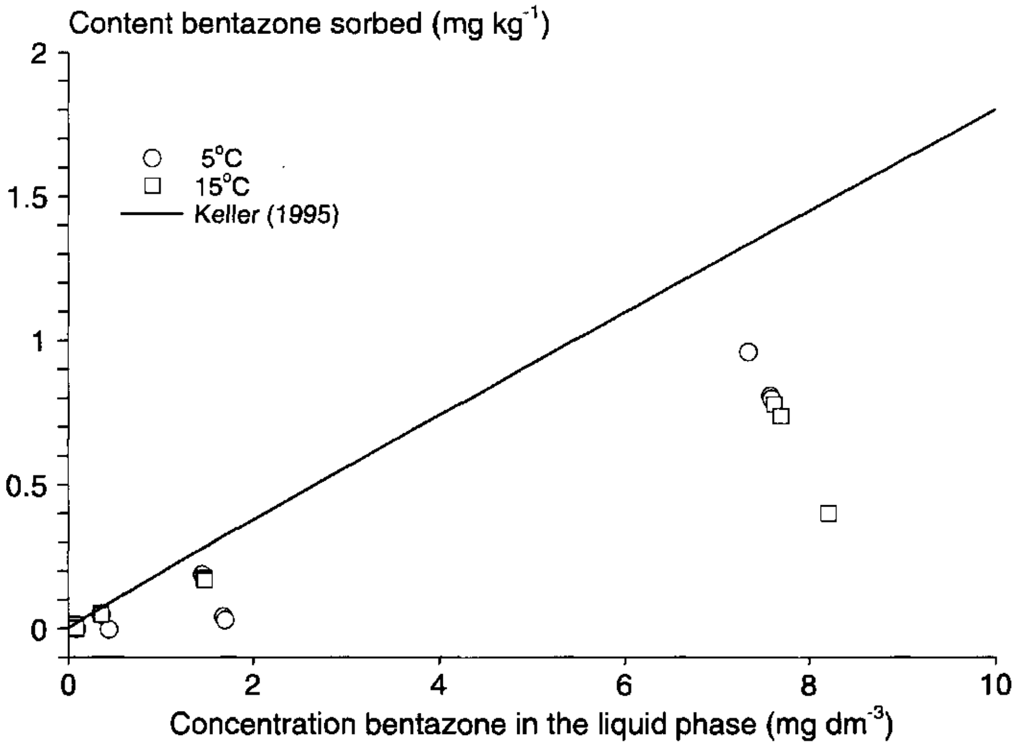

Fig. 21 Sorption isotherms as measured for bentazone at 5 and 15 °C using soil sampled from the 0-25 cm layer of experimental field Vredepeel-38. The points are our measurements and the line is the Freundlich isotherm as measured by Keller (1995)

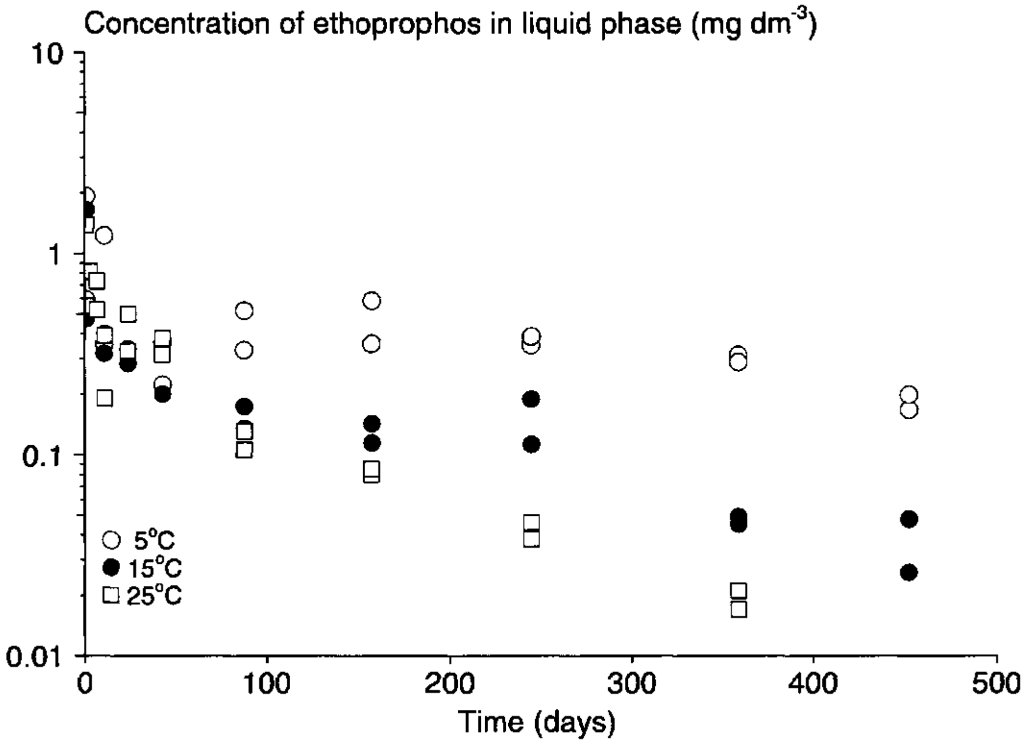

Fig. 22 Concentration of ethoprophos in the liquid phase as a function of incubation time as measured in laboratory incubations at 5, 15 and 25 °C with soil sampled from the 0-25 cm layer of experimental field Vredepeel-38

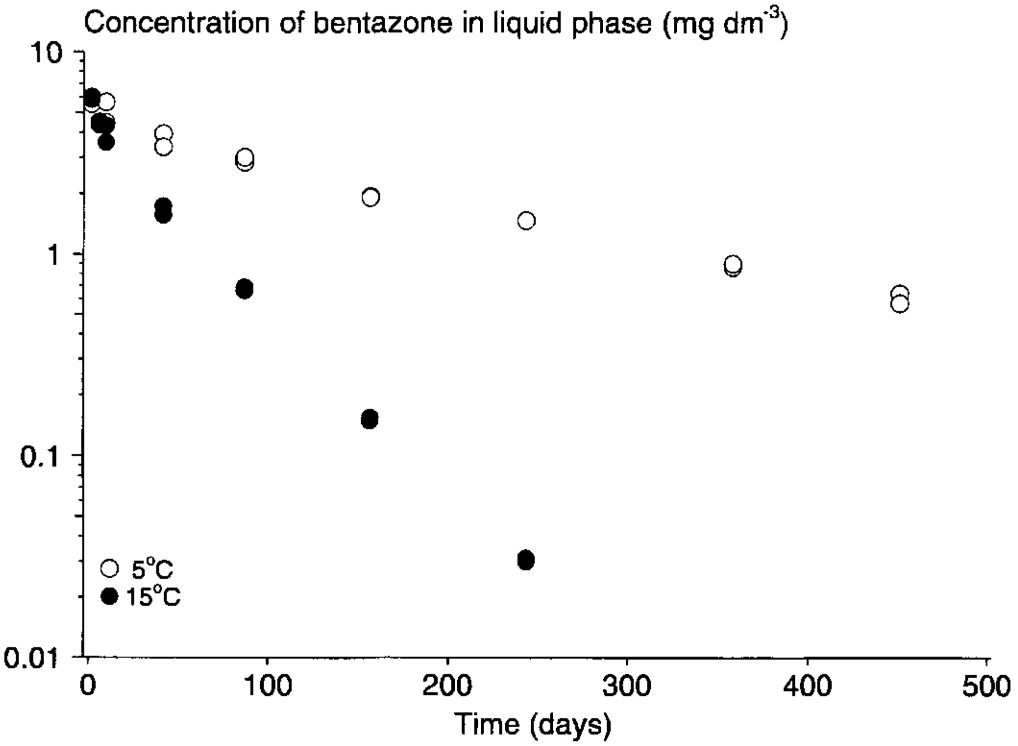

Fig. 23 Concentration of bentazone in the liquid phase as a function of incubation time as measured in laboratory incubations at 5 and 15 °C with soil sampled from the 0-25 cm layer of experimental field Vredepeel-38

References

Beese, F. & R.R. van der Ploeg, 1978. *Computermodelle in der Boden-hydrologie - Praktische Ansaetze.* Mitteilungen Deutsche Bodenkundliche Gesellschaft 26: 152-172.

Boels, D., J.B.M.H. van Gils, G.J. Veerman & K.E.Wit, 1978. *Theory and system of automatic determination of soil moisture characteristics and unsaturated hydraulic conductivities.* Soil Science 126: 191-199.

Boesten, J.J.T.I., 1986. *Behaviour of herbicides in soil: simulation and experimental assessment.* Doctoral Thesis, Institute for Pesticide Research, Wageningen, Netherlands, 263 pp.

Boesten, J.J.T.I., 1990. *Influence of solid/liquid ratio on the experimental error of sorption coefficients in pesticide/soil systems.* Pesticide Science 30: 31-41.

Bosch, H. van den & J.J.T.I. Boesten, 1994. *Validation of the PESTLA model: field test for leaching of two pesticides in a humic sandy soil in Vredepeel (the Netherlands).* Report 82, DLO Winand Staring Centre, Wageningen, Netherlands, 59 p.

Feddes, R.A., 1987. *Crop factors in relation to Makkink reference-crop evapotranspiration.* Evaporation and weather. Proceedings and Information/TNO Committee on Hydrological Research no. 39. TNO, the Hague, the Netherlands, p. 33-46.

Geelen, T. van, 1995. *Standardization of data files for testing simulation models; Version 1.0; a contribution to the FOMA project 'Nitrate leaching of agricultural areas'.* Technical Document 27, DLO Winand Staring Centre, Wageningen, The Netherlands, 74 p.

Hendrickx, J.M.H, C.J. Ritsema, O.H. Boersma, L.W. Dekker, W. Hamminga & J.W.H. van der Kolk, 1991. *Motor-driven portable soil core sampler for volumetric sampling.* Soil Science of America Journal 55: 1792-1795.

Keller, W., 1995. *Adsorption study of bentazon in a Vredepeel soil from the Netherlands.* Reg.Doc. BASF 95/10689. BASF, Limburgerhof, Germany, 17 p.

Klute, A., 1986. *Methods of soil analysis. 1. Physical and mineralogical methods.* Second Edition, Agronomy 9, Part 1. ASA, SSSA. Madison, Wisconsin, USA.

Kragt, J.F. & E.J. Jansen, 1991. *Standardization of data files for the testing simulation models; a contribution to the EC project 'Nitrate in soils'.* Report 25, DLO Winand Staring Centre, Wageningen, The Netherlands, 75 p.

Rigg, J.C., B.F. Visser & H.P. Lehmann, 1985. *Nomenclature of derived quantities.* Chemistry International 7: 29-33.

Stokkermans, J.S.C. & E.C. Vos, 1987. *Handleiding voor bemonstering in het veld en uitvoering van laboratoriumwerkzaamheden voor de bepaling van bodemfysische karakteristieken.* Internal report 78, Stiboka, Wageningen, The Netherlands.

Stolte, J., G.J. Veerman, M.C.S. Wopereis, 1992. Manual soil physical measurements, version 2.0. Technical Document 2, DLO Winand Staring Centre, Wageningen, 49 pp.

Veen, J.R. van de, & J.J.T.I. Boesten, 1996. *Evaluation of field and lysimeter studies on the leaching of pesticides from soil using the PESTLA model.* Report 117, DLO Winand Staring Centre, Wageningen, 94 pp.

Annex 1 Explanation of the 2-character codes used to describe the names of the variables in the files

AE = Areic
AV = Average
BD = Bulk density
BE = Bentazone
BR = Bromide
CC = Calcium carbonate
CD = Conductivity
CL = Clay
CO = Concentration
CT = Content
DA = Day
DP = Depth
DY = Drying
EP = Ethoprophos
ET = Evapotranspiration
EQ = Equilibrium
FR = Fraction
GL = Global
GW = Groundwater
HD = Head
HM = Air humidity
HY = Hydraulic
IN = Initial
KC = KCl
LA = Layers
LI = liquid phase
LO = Lower
LV = Level
MA = Maximum
MC = Matric
MH = Month
MI = Minimum
MO = Moisture content
MS = Mass
NU = Number
OB = Observations
OC = Organic carbon
OM = Organic matter
PF = pF
PH = pH
PR = Precipitation (rainfall)
RA = Radiation
SA = Sand
SD = Standard error
SI = Silt
SO = Soil
SM = Sample
TE = Temperature
TI = Time
UP = Upper
WS = Wind speed
YR = Year

Annex 2 Contents of the file NLVP038.BEA.

```
*File:          NLVP038.BEA
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          26 February 1996
*Source:        Measurements by SC-DLO
*                 Sorption of bentazone to soil of the 0-25 cm layer
*                 at two temperatures, Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       TE     = Temperature (degree Celsius) during the sorption study
*       INCOBE = Initial concentration of bentazone (mg dm**[-3]) in the
*                liquid phase. INCOBE was calculated by dividing the mass
*                of bentazone added by the total volume of liquid in the
*                system (29.46 cm**3).
*       EQCOBE = Concentration of bentazone (mg dm**[-3]) in the liquid
*                phase after equilibration
*       EQCTBE = Content of bentazone (mg kg**[-1]) in the solid phase
*                after equilibration (content is defined as mass per
*                mass of dry soil).
*
*       System properties
*           Mass of dry soil  = 45.54 g
*           Mass of liquid    = 29.46 g
*           Measurements in the liquid phase without extraction
*
*TE   INCOBE EQCOBE EQCTBE
**********************************************************************

5     0.0872 0.066  0.0137
5     0.0872 0.069  0.0118
5     0.0872 0.089 -0.0012
5     0.4326 0.356  0.0495
5     0.4326 0.357  0.0489
5     0.4326 0.438 -0.0035
5     1.748  1.458  0.1877
5     1.748  1.685  0.0408
5     1.748  1.704  0.0285
5     8.828  7.345  0.9591
5     8.828  7.580  0.8071
5     8.828  7.595  0.7974

15    0.0872 0.067  0.0131
15    0.0872 0.067  0.0131
15    0.0872 0.087  0.0001
15    0.4326 0.352  0.0521
15    0.4326 0.358  0.0482
15    1.748  1.478  0.1748
15    1.748  1.480  0.1735
15    1.748  1.487  0.1689
15    8.828  7.625  0.7780
15    8.828  7.695  0.7372
15    8.828  8.210  0.3996
```

Annex 3 Contents of the file NLVP038.BEL (only the first part).

```
*File:          NLVP038.BEL
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          6 May 1996
*Source:        Measurements by SC-DLO
*                 Concentration of bentazone in the liquid phase during
*                 the incubation studies, Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR      = Year
*       MH      = Month
*       DA      = Day within month
*       TI      = Time (days) elapsed since the start of each
*                 incubation study
*       NULA    = Number of layers sampled
*       UPDP    = Upper boundary (cm) of the layer
*       LODP    = Lower boundary (cm) of the layer
*       TE      = Temperature (degree Celsius) during the incubation
*       COBELI  = Concentration (mg dm**[-3]) of bentazone in the liquid
*                 phase of moist soil
*       MSLI    = Mass (g) of liquid phase in moist soil at the sampling
*                 time
*
*       System properties: layer 0-25 cm
*           Mass of dry soil                = 45.36 g
*           Initial mass of water           =  6.64 g
*           Mass of bentazone added         = 54.64 ug (sd=0.18 ug, n=6)
*                                             (sd=standard error of mean)
*
*           No sorption to glass filter observed
*           The incubation started on 6 November 1990.
*
*YR    MH    DA    TI  NULA UPDP LODP  TE    COBELI   MSLI
***********************************************************************

1990   11     8     2    1    0    25    5    5.934
1990   11     8     2    1    0    25    5    5.523
1990   11    16    10    1    0    25    5    4.467
1990   11    16    10    1    0    25    5    5.645
1990   12    18    42    1    0    25    5    3.934
1990   12    18    42    1    0    25    5    3.393
1991    2     1    87    1    0    25    5    2.856    6.70
1991    2     1    87    1    0    25    5    3.008    6.73
1991    4    12   157    1    0    25    5    1.939    6.66
1991    4    12   157    1    0    25    5    1.917    6.66
1991    7     8   244    1    0    25    5    1.464    6.70
```

Annex 4 Contents of the file NLVP038.BEP (only the first part).

```
*File:          NLVP038.BEP
.
*Code:          ASCII
.
*Access:        sequential
.
*Author:        L.J.T. van der Pas
.
*Version:       1.0
.
*Date:          26 February 1996
.
*Source:        Measurements by SC-DLO
*                 Average concentrations of bentazone in soil
*                 Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR     = Year
*       MH     = Month
*       DA     = Day within month
*       DANU   = Day number (value is 1 at 23 November 1990)
*       NULA   = Number of layers sampled
*       UPDP   = Upper boundary (cm) of the layer
*       LODP   = Lower boundary (cm) of the layer
*       AVCOBE = Average concentration of bentazone (mg dm**[-3])
*       SDCOBE = Standard error (mg dm**[-3]) of the average concentration
*                of bentazone (replicates=4)
*
*YR    MH    DA  DANU  NULA  UPDP  LODP    AVCOBE   SDCOBE
**********************************************************************

1990   11    23     1     5   0.0   4.0     1.58    0.05
1990   11    23     1     5   4.0   7.5     0.006
1990   11    23     1     5   7.5  15.0    <0.001
1990   11    23     1     5  15.0  22.5    <0.001
1990   11    23     1     5  22.5  30.0    <0.001

1990   12    14    22     8   0.0   4.0     0.166   0.016
1990   12    14    22     8   4.0   7.5     0.189   0.040
1990   12    14    22     8   7.5  15.0     0.442   0.051
1990   12    14    22     8  15.0  22.5     0.035   0.014
1990   12    14    22     8  22.5  30.0     0.004   0.002
1990   12    14    22     8  30.0  45.0    <0.001
1990   12    14    22     8  45.0  60.0    <0.001
1990   12    14    22     8  60.0  90.0    <0.001

1991    1     3    42     8   0.0   4.0     0.031   0.002
1991    1     3    42     8   4.0   7.5     0.014   0.001
1991    1     3    42     8   7.5  15.0     0.032   0.008
1991    1     3    42     8  15.0  22.5     0.083   0.023
1991    1     3    42     8  22.5  30.0     0.225   0.033
1991    1     3    42     8  30.0  45.0     0.072   0.022
1991    1     3    42     8  45.0  60.0     0.017   0.008
1991    1     3    42     8  60.0  90.0    <0.001

1991    3     5   103     8   0.0   4.0     0.022   0.003
1991    3     5   103     8   4.0   7.5     0.011   0.001
1991    3     5   103     8   7.5  15.0     0.014   0.003
1991    3     5   103     8  15.0  22.5     0.026   0.010
1991    3     5   103     8  22.5  30.0     0.035   0.018
1991    3     5   103     8  30.0  45.0     0.041   0.009
1991    3     5   103     8  45.0  60.0     0.037   0.011
1991    3     5   103     8  60.0  90.0     0.036   0.013

1991    6    24   214    10   0.0   4.0     0.004   0.001
1991    6    24   214    10   4.0   7.5    <0.003
1991    6    24   214    10   7.5  15.0    <0.003
1991    6    24   214    10  15.0  22.5    <0.003
1991    6    24   214    10  22.5  30.0    <0.003
1991    6    24   214    10  30.0  45.0     0.003   0.001
1991    6    24   214    10  45.0  60.0     0.015   0.006
1991    6    24   214    10  60.0  90.0     0.034   0.004
1991    6    24   214    10  90.0 120.0     0.007   0.002
1991    6    24   214    10 120.0 135.0    <0.001
```

Annex 5 Contents of the file NLVP038.BET (only the first part).

```
*File:          NLVP038.BET
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       2.0
*Date:          2 May 1996
*Source:        Measurements by SC-DLO
*                 Transformation of bentazone in soil from three
*                 layers, Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR      = Year
*       MH      = Month
*       DA      = Day within month
*       TI      = Time (days) elapsed since the start of each
*                 incubation study
*       NULA    = Number of layers sampled
*       UPDP    = Upper boundary (cm) of the layer
*       LODP    = Lower boundary (cm) of the layer
*       TE      = Temperature (degree Celsius) during the incubation
*       MSBE    = Mass of bentazone (ug)
*       MSLI    = Mass (g) of liquid phase in moist soil at the sampling
*                 time
*
*       System properties: layer 0-25 cm
*           Mass of dry soil               = 45.36 g
*           Initial mass of water          =  6.64 g
*           Mass of bentazone added        = 54.64 ug (sd=0.18 ug, n=6)
*                                            (sd=standard error of mean)
*           Extraction efficiency          = 86 % (sd=5 %, n=3)
*
*           Mass of bentazone in soil was corrected for the extraction
*           efficiency.
*           The incubation started on 6 November 1990.
*
*       System properties: layer 50-100 cm
*           Mass of dry soil        = 91.4 g (sd=0.1, n=5)
*           Mass of water           =  9.6 g (sd=0.1, n=5)
*           Mass of bentazone added = 10.5 ug (sd=0.1 ug, n=5)
*           Extraction efficiency   = 96 % (sd=6 %, n=2)
*           Mass of bentazone in soil was corrected for the extraction
*           efficiency.
*           The incubation started on 13 December 1990.
*
*       System properties: layer 100-200 cm
*           Mass of dry soil        = 90.3 g (sd=1.6, n=14)
*           Mass of water           = 26.5 g (sd=0.6, n=14)
*           Mass of bentazone added = 10.5 ug (sd=0.1 ug, n=5)
*           Extraction efficiency   = 86 % (sd=4 %, n=2)
*           Mass of bentazone in soil was corrected for the extraction
*           efficiency.
*           The incubation started on 13 December 1990.
*
*YR    MH   DA    TI  NULA UPDP LODP  TE    MSBE     MSLI
***********************************************************************

1990   11    8     2   3    0    25    5    52.24
1990   11    8     2   3    0    25    5    51.02
1990   11   16    10   3    0    25    5    50.78
1990   11   16    10   3    0    25    5    50.40
1990   12   18    42   3    0    25    5    46.02
1991    2    1    87   3    0    25    5    37.82    6.72
1991    2    1    87   3    0    25    5    39.40    6.71
1991    4   12   157   3    0    25    5    33.18
```

Annex 6 Contents of the file NLVP038.BRP (only the first part).

```
*File:          NLVP038.BRP
.
*Code:          ASCII
.
*Access:        sequential
.
*Author:        L.J.T. van der Pas
.
*Version:       1.0
.
*Date:          26 February 1996
.
*Source:        Measurements by SC-DLO

*                 Average concentrations of bromide in soil
*                 Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR     = Year
*       MH     = Month
*       DA     = Day within month
*       DANU   = Day number (value is 1 at 23 November 1990)
*       NULA   = Number of layers sampled
*       UPDP   = Upper boundary (cm) of the layer
*       LODP   = Lower boundary (cm) of the layer
*       AVCOBR = Average concentration of bromide (mg dm**[-3])
*       SDCOBR = Standard error (mg dm**[-3]) of the average concentration
*                of bromide
*       NUOB   = Number of observations
*
*YR   MH   DA   DANU  NULA  UPDP  LODP  AVCOBR SDCOBR  NUOB
***********************************************************************

1990  11   23     1    19    0.0   4.0   258     17      16
1990  11   23     1    19    4.0   7.5    1.0    0.6     16
1990  11   23     1    19    7.5  15.0   <0.7            16
1990  11   23     1    19   15.0  22.5   <0.7            16
1990  11   23     1    19   22.5  30.0   <0.7            16
1990  11   23     1    19   30.0  37.5   <0.7            15
1990  11   23     1    19   37.5  45.0   <0.7            16
1990  11   23     1    19   45.0  52.5   <0.7            16
1990  11   23     1    19   52.5  60.0   <0.7            16
1990  11   23     1    19   60.0  67.5   <0.7            16
1990  11   23     1    19   67.5  75.0   <0.7            16
1990  11   23     1    19   75.0  82.5   <0.7            15
1990  11   23     1    19   82.5  90.0   <0.7            15
1990  11   23     1    19   90.0  97.5   <0.7            15
1990  11   23     1    19   97.5 105.0   <0.7            15
1990  11   23     1    19  105.0 112.5   <0.7            13
1990  11   23     1    19  112.5 120.0   <0.7             5
1990  11   23     1    19  120.0 127.5   <0.7             2
1990  11   23     1    19  127.5 135.0   <0.7             1

1990  12   14    22    19    0.0   4.0    1.6    0.2     16
1990  12   14    22    19    4.0   7.5    2.0    0.6     16
1990  12   14    22    19    7.5  15.0   53.3    6.7     16
1990  12   14    22    19   15.0  22.5   74.7    8.5     16
1990  12   14    22    19   22.5  30.0    9.6    3.2     16
1990  12   14    22    19   30.0  37.5    2.3    1.2     16
1990  12   14    22    19   37.5  45.0   <0.7            16
1990  12   14    22    19   45.0  52.5   <0.7            16
1990  12   14    22    19   52.5  60.0   <0.7            16
1990  12   14    22    19   60.0  67.5   <0.7            16
1990  12   14    22    19   67.5  75.0   <0.7            16
1990  12   14    22    19   75.0  82.5   <0.7            16
1990  12   14    22    19   82.5  90.0   <0.7            16
1990  12   14    22    19   90.0  97.5   <0.7            16
1990  12   14    22    19   97.5 105.0   <0.7            16
1990  12   14    22    19  105.0 112.5   <0.7            16
1990  12   14    22    19  112.5 120.0   <0.7             7
1990  12   14    22    19  120.0 127.5   <0.7             2
1990  12   14    22    19  127.5 135.0   <0.7             1
```

Annex 7 Contents of the file NLVP038.CLI (only the first part).

```
*File:    NLVP038.CLI
*Code: ASCII
*Access:  sequential
*Author:  Jos Boesten
*Version: 1.0
*Date: 6 February 1996
*Source:  air temperatures: measured by the experimental farm Vredepeel
*         rainfall: measured by SC-DLO at the site
*         global radiation: measured by the Royal Dutch Meteorological
*                           Institute at weather station 'Beek'
*         windspeed: see global radiation
*         air humidity: see global radiation
*
*  Description of the quantities and their units
*       YR    = year
*       MH    = month
*       DA    = day within month
*       DANU  = day number (value is 1 at 23 November 1990)
*       MITE  = minimum air temperature (deg.Celsius)
*       MATE  = maximum air temperature (deg.Celsius)
*       PR    = rainfall (mm/d)
*       GLRA  = global radiation (J cm**[-2] d**[-1])
*       AVWS  = average windspeed (m/s)
*       AVHM  = average air humidity (%)
*
*
*YR   MH  DA  DANU   MITE    MATE    PR     GLRA    AVWS  AVHM
************************************************************************
1990  11  23   1       .0     4.0    .00    105     2.5   100
1990  11  24   2       .0     8.0    .64    216     5.0    88
1990  11  25   3      1.0     7.0    .38    127     3.0    96
1990  11  26   4      1.0     7.0    .13    315     4.5    89
1990  11  27   5     -2.0     4.0    .00    425     3.0    98
1990  11  28   6     -2.0     4.0    .00    143     4.0    98
1990  11  29   7     -2.0     3.0   2.93    264     3.0    99
1990  11  30   8     -4.0     7.0    .00    246     3.0   100
1990  12   1   9       .0     7.0    .89     82     3.5   100
1990  12   2  10      4.0     7.0   1.40    130     2.5   100
1990  12   3  11      4.0     8.0    .00    185     4.0    98
1990  12   4  12      2.0     7.0    .64    285     4.0    93
1990  12   5  13     -2.0     3.0    .00    373     2.5    89
1990  12   6  14     -2.0     5.0    .00    414     3.0    89
1990  12   7  15     -2.0     4.0    .00    421     3.0    68
1990  12   8  16     -1.0     3.0    .00    288     5.5    75
1990  12   9  17       .0     2.0    .00    128     4.0    83
1990  12  10  18       .0     7.0  12.60     16     6.5    94
1990  12  11  19      1.0     6.0   2.87     51     4.0    99
1990  12  12  20      5.0     6.0  15.47    189     6.5    94
1990  12  13  21      3.0     5.0    .32     31     7.5    92
1990  12  14  22     -1.0     6.0    .00    109     3.0    92
1990  12  15  23     -3.0     1.0   2.55     71     4.0    93
1990  12  16  24     -2.0     1.0    .00     90     3.5    89
1990  12  17  25     -3.0      .0    .00    153     3.0    92
1990  12  18  26     -3.0     3.0    .00     71     3.0    86
1990  12  19  27     -1.0     7.0    .00     72     3.5    96
1990  12  20  28      3.0     9.0   8.15    125     8.5    95
1990  12  21  29      6.0     9.0    .38    134     5.0    97
1990  12  22  30      6.0    11.0    .47     47     5.5    98
1990  12  23  31      6.0     8.0    .00    246     4.0    91
```

Annex 8 Contents of the file NLVP038.CRP.

```
*File: NLVP038.CRP
*Code: ASCII
*Access:  sequential
*Author:  L.J.T. van der Pas
*Version: 1
*Date: 27 February 1996
*Source:  observations by SC-DLO and by the experimental
*      farm 'Vredepeel'
*
*  Description of the quantities and their units
*
*       YR    = year
*       MH    = month
*       DA    = day within month
*       DANU  = day number (value is 1 at 23 November 1990)
*       CRTY  = crop type
*      (1 = winter wheat, 2 = yellow mustard)
*       AC    = action
*      (1 = sowing, 2 = harvest, 3 = harvest and immediate
*                incorporation of the crop into the soil)
*
*  Comment: the date of sowing the yellow mustard is not exactly
*       known: it was estimated afterwards by the farmer.
*
* YR   MH   DA    DANU    CRTY   AC
*******************************************************************
1990   11   22       0       1    1
1991    8   14     265       1    2
1991    9   15     297       2    1
1991   11   29     372       2    3
```

Annex 9 Contents of the file NLVP038.EPA.

```
*File:          NLVP038.EPA
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          28 February 1996
*Source:        Measurements by SC-DLO
*                 Sorption of ethoprophos to soil of the 0-25 cm layer
*                 at two temperatures, Vredepeel, The Netherlands
*
*    Description of the quantities and their units
*    TE     = Temperature (degree Celsius) during the sorption study.
*    INCOEP = Initial concentration of ethoprophos (mg dm**[-3]) in
*             the liquid phase. INCOEP was calculated by dividing the
*             mass of ethoprophos added by the total volume of
*             liquid in the system (54.64 cm**[3]).
*    EQCOEP = Concentration of ethoprophos (mg dm**[-3]) in the
*             liquid phase after equilibration.
*    EQCTEP = Content of ethoprophos (mg kg**[-1]) in the solid phase after
*                equilibration (content is defined as mass per mass
*                of dry soil).
*
*       System properties
*           Mass of dry soil         = 45.36 g
*           Mass of water            = 54.64 g
*           Extraction efficiency    = 95 % (sd=1 %, n=2)
*                                      (sd=standard error of mean)
*           Measured concentrations in water were corrected for extraction
*           efficiency of ethoprophos.
*
*TE  INCOEP   EQCOEP   EQCTEP
***********************************************************************

5     0.439    0.0975   0.4114
5     0.439    0.0981   0.4106
5     0.439    0.0998   0.4085
5     4.496    1.320    3.827
5     4.496    1.321    3.826
5     4.496    1.323    3.824
5    47.82    19.12    34.58
5    47.82    19.71    33.87
5    47.82    19.90    33.64

25     0.4405   0.0760   0.4390
25     0.4405   0.0825   0.4312
25     0.4405   0.0845   0.4288
25     4.484    0.946    4.261
25     4.484    0.947    4.261
25     4.484    1.013    4.181
25    47.79    12.73    42.22
25    47.79    13.05    41.85
25    47.79    13.27    41.59
```

Annex 10 Contents of the file NLVP038.EPL (only the first part).

```
*File:         NLVP038.EPL
*Code:         ASCII
*Access:       sequential
*Author:       L.J.T. van der Pas
*Version:      1.0
*Date:         2 May 1996
*Source:       Measurements by SC-DLO
*                Concentration of ethoprophos in the liquid phase during
*                the incubation studies, Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR      = Year
*       MH      = Month
*       DA      = Day within month
*       TI      = Time (days) elapsed since the start of each incubation
*                 study
*       NULA    = Number of layers sampled
*       UPDP    = Upper boundary (cm) of the layer
*       LODP    = Lower boundary (cm) of the layer
*       TE      = Temperature (degree Celsius) during the incubation
*       COEPLI  = Concentration (mg dm**[-3]) of ethoprophos in the liquid
*                 phase of moist soil
*       MSLI    = Mass (g) of liquid phase in moist soil at the sampling
*                 date
*
*       System properties (layer 0-25 cm)
*           Mass of dry soil              =  45.36 g
*           Initial mass of water         =   6.64 g
*           Mass of ethoprophos added     = 256 ug (sd=6 ug, n=10)
*                                           (sd=standard error of mean)
*           Correction factor for sorption =  0.832 (sd=0.009, n=5)
*           to glass filter
*
*           Concentration of ethoprophos in the liquid phase was
*           corrected for sorption to the glass filter.
*           The incubation started on 5 November 1990.
*
*YR    MH    DA    TI  NULA UPDP LODP  TE    COEPLI  MSLI
**********************************************************************

1990   11     6     1    1    0   25    5    0.593
1990   11     6     1    1    0   25    5    1.928
1990   11    16    11    1    0   25    5    0.356
1990   11    16    11    1    0   25    5    1.227
1990   12    18    43    1    0   25    5    0.363
1990   12    18    43    1    0   25    5    0.223
1991    2     1    88    1    0   25    5    0.521   6.74
1991    2     1    88    1    0   25    5    0.332   6.72
1991    4    12   158    1    0   25    5    0.582   6.69
1991    4    12   158    1    0   25    5    0.357   6.73
1991    7     8   245    1    0   25    5    0.351   6.72
1991    7     8   245    1    0   25    5    0.388   6.71
1991   10    30   359    1    0   25    5    0.313   6.73
1991   10    30   359    1    0   25    5    0.288   6.79
1992    1    31   452    1    0   25    5    0.168
1992    1    31   452    1    0   25    5    0.199

1990   11     6     1    1    0   25   15    1.644
1990   11     6     1    1    0   25   15    0.474
1990   11    16    11    1    0   25   15    0.320
1990   11    16    11    1    0   25   15    0.401
1990   11    29    24    1    0   25   15    0.336
1990   11    29    24    1    0   25   15    0.286
```

Annex 11 Contents of the file NLVP038.EPM.

```
*File:          NLVP038.EPM
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          28 February 1996
*Source:        Measurements by SC-DLO
*                 Areic mass of ethoprophos
*                 Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR       = Year
*       MH       = Month
*       DA       = Day within month
*       DANU     = Day number (value is 1 at 23 November 1990)
*       AVAEMSEP = Average areic mass of ethoprophos (kg ha**[-1]) in
*                  the soil (sum of all sampled layers)
*       SDAEMSEP = Standard error (kg ha**[-1]) of the average areic mass
*                  of ethoprophos (replicates=4)
*
*YR    MH   DA   DANU  AVAEMSEP  SDAEMSEP
***********************************************************************

1990   11   23     1   2.739     0.126
1990   12   14    22   1.291     0.078
1991    1    3    42   1.260     0.042
1991    3    5   103   1.186     0.045
1991    6   24   214   0.792     0.100
1991    8   27   278   0.280     0.019
1992    3   10   474   0.0214    0.0010
```

Annex 12 Contents of the file NLVP038.EPP.

```
*File:          NLVP038.EPP
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          26 February 1996
*Source:        Measurements by SC-DLO
*                 Average concentrations of ethoprophos in soil
*                 Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR      = Year
*       MH      = Month
*       DA      = Day within month
*       DANU    = Day number (value is 1 at 23 November 1990)
*       NULA    = Number of layers sampled
*       UPDP    = Upper boundary (cm) of the layer
*       LODP    = Lower boundary (cm) of the layer
*       AVCOEP  = Average concentration of ethoprophos (mg dm**[-3])
*       SDCOEP  = Standard error (mg dm**[-3]) of the average concentration
*                 of ethoprophos (replicates=4 except for the first day
*                 where replicates=16)
*
*YR    MH   DA   DANU  NULA  UPDP  LODP    AVCOEP  SDCOEP
***********************************************************************

1990   11   23     1     4   0.0   4.0    6.84     0.32
1990   11   23     1     4   4.0   7.5    0.014    0.011
1990   11   23     1     4  60.0  67.5   <0.0005
1990   11   23     1     4  90.0  97.5   <0.0005

1990   12   14    22     5   0.0   4.0    3.16     0.22
1990   12   14    22     5   4.0   7.5    0.079    0.049
1990   12   14    22     5   7.5  15.0    0.0004   0.0001
1990   12   14    22     5  15.0  22.5   <0.0002
1990   12   14    22     5  22.5  30.0   <0.0002

1991    1    3    42     5   0.0   4.0    2.69     0.17
1991    1    3    42     5   4.0   7.5    0.506    0.085
1991    1    3    42     5   7.5  15.0    0.007    0.003
1991    1    3    42     5  15.0  22.5    0.0003   0.0002
1991    1    3    42     5  22.5  30.0    0.0003   0.0002

1991    3    5   103     5   0.0   4.0    2.19     0.23
1991    3    5   103     5   4.0   7.5    0.75     0.20
1991    3    5   103     5   7.5  15.0    0.063    0.019
1991    3    5   103     5  15.0  22.5    0.0009   0.0007
1991    3    5   103     5  22.5  30.0    0.0002   0.0001

1991    6   24   214     5   0.0   4.0    1.24     0.09
1991    6   24   214     5   4.0   7.5    0.601    0.074
1991    6   24   214     5   7.5  15.0    0.105    0.084
1991    6   24   214     5  15.0  22.5    0.0114   0.0110
1991    6   24   214     5  22.5  30.0   <0.0002

1991    8   27   278     5   0.0   4.0    0.551    0.066
1991    8   27   278     5   4.0   7.5    0.156    0.019
1991    8   27   278     5   7.5  15.0    0.0053   0.0020
1991    8   27   278     5  15.0  22.5    0.0004   0.0001
1991    8   27   278     5  22.5  30.0    0.0002   0.0001

1992    3   10   474     9   0.0   4.0    0.0258   0.0024
1992    3   10   474     9   4.0   7.5    0.0210   0.0010
1992    3   10   474     9   7.5  15.0    0.0050   0.0004
1992    3   10   474     9  15.0  22.5   <0.0002
1992    3   10   474     9  22.5  30.0   <0.0002
1992    3   10   474     9  30.0  45.0   <0.0002
1992    3   10   474     9  45.0  60.0   <0.0002
1992    3   10   474     9  60.0  90.0   <0.0002
1992    3   10   474     9  90.0 120.0   <0.0002
```

Annex 13 Contents of the file NLVP038.EPT (only the first part)

```
*File:          NLVP038.EPT
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       2.0
*Date:          2 May 1996
*Source:        Measurements by SC-DLO
*                 Transformation of ethoprophos in soil of three
*                 layers, Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR     = Year
*       MH     = Month
*       DA     = Day within month
*       TI     = Time (days) elapsed since the start of each incubation
*                study
*       NULA   = Number of layers sampled
*       UPDP   = Upper boundary (cm) of the layer
*       LODP   = Lower boundary (cm) of the layer
*       TE     = Temperature (degree Celsius) during the incubation
*       MSEP   = Mass of ethoprophos (ug)
*       MSLI   = Mass (g) of liquid phase in moist soil at the sampling
*                date
*
*       System properties (layer 0-25 cm)
*           Mass of dry soil                =  45.36 g
*           Initial mass of water           =   6.64 g
*           Mass of ethoprophos added       = 256 ug (sd=6 ug, n=10)
*                                             (sd=standard error of mean)
*           Extraction efficiency (soil)    =  89 % (sd=2 %, n=6)
*
*           Mass of ethoprophos in soil was corrected for extraction
*           efficiency.
*           The incubation started on 5 November 1990.
*
*       System properties (layer 50-100 cm)
*           Mass of dry soil            =  91.4 g (sd=0.1 g, n=5)
*           Mass of water               =   9.6 g (sd=0.1 g, n=5)
*           Mass of ethoprophos added   =   1.09 ug (sd=0.01 ug, n=6)
*           Extraction efficiency       =  93 % (sd=8 %, n=6)
*           Mass of ethoprophos in soil was corrected for extraction
*           efficiency.
*           The incubation started on 13 December 1990.
*
*       System properties (layer 100-200 cm)
*           Mass of dry soil            =  93 g (sd=3 g, n=7)
*           Mass of water               =  25 g (sd=1 g, n=7)
*           Mass of ethoprophos added   =   1.09 ug (sd=0.01 ug, n=6)
*           Extraction efficiency       =  87 % (sd=1 %, n=2)
*           Mass of ethoprophos in soil was corrected for extraction
*           efficiency.
*           The incubation started on 13 December 1990.
*
*YR    MH    DA    TI  NULA UPDP LODP  TE    MSEP   MSLI
**********************************************************************

1990   11     6     1    3    0   25    5    284
1990   11     6     1    3    0   25    5    282
1990   11    16    11    3    0   25    5    215
1990   11    16    11    3    0   25    5    251
1990   12    18    43    3    0   25    5    222
1990   12    18    43    3    0   25    5    223
1991    2     1    88    3    0   25    5    214    6.73
1991    2     1    88    3    0   25    5    217    6.72
```

Annex 14 Contents of the file NLVP038.ETR (only the first part).

```
*File: NLVP038.ETR
*Code: ASCII
*Access:   sequential
*Author:   Jos Boesten
*Version:  1.0
*Date: 28 February 1996
*Source:   Royal Dutch Meteorological Institute:
*           - data from period 23-11-1990 to 31-12-1990 are from
*           weather station 'Vredepeel' based on decade averages
*           - data from period 1-1-1991 to 11-2-1991 are from
*           weather station 'Eindhoven'
*          - data after 12 February 1991 are from weather station 'Arcen'
*
*       Description of the quantities and their units
*       YR    = year
*       MH    = month
*       DA    = day within month
*       DANU  = day number (value is 1 at 23 November 1990)
*       ET    = Makkink reference-crop evapotranspiration (mm/d)
*
*
* YR  MH  DA   DANU    ET
*************************
1990  11  23    1     .25
1990  11  24    2     .25
1990  11  25    3     .25
1990  11  26    4     .25
1990  11  27    5     .25
1990  11  28    6     .25
1990  11  29    7     .25
1990  11  30    8     .25
1990  12   1    9     .20
1990  12   2   10     .20
1990  12   3   11     .20
1990  12   4   12     .20
1990  12   5   13     .20
1990  12   6   14     .20
1990  12   7   15     .20
1990  12   8   16     .20
1990  12   9   17     .20
1990  12  10   18     .20
1990  12  11   19     .13
1990  12  12   20     .13
1990  12  13   21     .13
1990  12  14   22     .13
1990  12  15   23     .13
1990  12  16   24     .13
1990  12  17   25     .13
1990  12  18   26     .13
1990  12  19   27     .13
1990  12  20   28     .13
1990  12  21   29     .24
1990  12  22   30     .24
1990  12  23   31     .24
1990  12  24   32     .24
1990  12  25   33     .24
1990  12  26   34     .24
1990  12  27   35     .24
1990  12  28   36     .24
1990  12  29   37     .24
```

Annex 15 Contents of the file NLVP038.GWL (only the first part).

```
*File: NLVP038.GWL
*Code: ASCII
*Access:   sequential
*Author:   Jos Boesten
*Version:  1.0
*Date: 28 February 1996
*Source:   measurements SC-DLO at Vredepeel, The Netherlands
*
*   Description of the quantities and their units
*       YR     = year
*       MH     = month
*       DA     = day within month
*       DANU   = day number (value is 1 at 23 November 1990)
*       GWLV   = daily average of depth (m) of groundwater level
*                (below the soil surface)
*
* YR   MH   DA   DANU   GWLV
*************************
1990   12    6    14    1.19
1990   12    7    15    1.19
1990   12    8    16    1.19
1990   12    9    17    1.20
1990   12   10    18    1.22
1990   12   11    19    1.23
1990   12   12    20    1.21
1990   12   13    21    1.04
1990   12   14    22     .97
1990   12   15    23     .96
1990   12   16    24     .98
1990   12   17    25    1.01
1990   12   18    26    1.03
1990   12   19    27    1.06
1990   12   20    28    1.09
1990   12   21    29    1.07
1990   12   22    30    1.03
1990   12   23    31    1.02
1990   12   24    32    1.02
1990   12   25    33    1.03
1990   12   26    34    1.04
1990   12   27    35     .96
1990   12   28    36     .88
1990   12   29    37     .86
1990   12   30    38     .79
1990   12   31    39     .76
1991    1    1    40     .73
1991    1    2    41     .69
1991    1    3    42     .58
1991    1    4    43     .58
1991    1    5    44     .62
1991    1    6    45     .61
1991    1    7    46     .70
1991    1    8    47     .66
1991    1    9    48     .61
1991    1   10    49     .60
1991    1   11    50     .63
1991    1   12    51     .71
1991    1   13    52     .78
1991    1   14    53     .82
```

Annex 16 Contents of the file NLVP038.HCU (only the first part).

```
*File: NLVP038.HCU
*Code: ASCII
*Access:   sequential
*Author:   Jos Boesten
*Version:  1.0
*Date: 28 February 1996
*Source:   laboratory measurements by SC-DLO
*
*       Description of the quantities and their units
*       NULA  = total number of layers
*       UPDP  = depth of top of the layer (cm)
*       LODP  = depth of bottom of the layer (cm)
*       SMNU  = sample number (duplicate samples for each layer
*               are indicated by different numbers; note that SMNU
*               in file NLVP038.WRC refers to samples taken with
*               a different procedure)
*       HYCD = hydraulic conductivity (cm/day)
*       MOFR = volume fraction of liquid
*       MCHD = matric head (cm); negative values indicate suction
*
* NULA   UPDP   LODP   SMNU     HYCD       MOFR     MCHD
********************************************************
   3      10     18      7    .180E+00     .397    -19.9
   3      10     18      7    .629E+00     .386    -24.6
   3      10     18      7    .869E-01     .377    -28.6
   3      10     18      7    .499E+00     .366    -33.5
   3      10     18      7    .665E-01     .363    -35.0
   3      10     18      7    .499E+00     .351    -40.0
   3      10     18      7    .505E-01     .351    -40.1
   3      10     18      7    .287E-01     .342    -43.4
   3      10     18      7    .345E-01     .335    -45.8
   3      10     18      7    .392E-01     .327    -48.2
   3      10     18      7    .564E-01     .319    -50.0
   3      10     18      7    .286E-01     .315    -50.9
   3      10     18      7    .675E-01     .313    -51.3
   3      10     18      7    .557E-01     .310    -51.9
   3      10     18      7    .626E-01     .308    -52.3
   3      10     18      7    .378E-01     .305    -52.7
   3      10     18      7    .229E-01     .303    -53.1
   3      10     18      7    .190E+00     .301    -53.4
   3      10     18      7    .344E+00     .295    -54.1
   3      10     18      7    .178E+00     .295    -54.2
   3      10     18      7    .256E+00     .294    -54.3
   3      10     18      7    .218E+00     .290    -54.6
   3      10     18      7    .278E+00     .286    -55.1
   3      10     18      7    .151E+00     .282    -55.6
   3      10     18      7    .159E+00     .279    -55.9
   3      10     18      7    .127E+00     .274    -56.4
   3      10     18      7    .258E+00     .272    -56.5
   3      10     18      7    .170E+00     .270    -56.8
   3      10     18      7    .538E+00     .267    -57.1
   3      10     18      7    .249E+00     .263    -57.6
   3      10     18      7    .180E+00     .261    -57.8
   3      10     18      7    .753E+00     .257    -58.2
   3      10     18      7    .797E+00     .249    -59.0
   3      10     18      7    .393E+00     .245    -59.5
   3      10     18      7    .308E+00     .243    -59.7
```

Annex 17 Contents of the file NLVP038.MAN.

```
*File: NLVP038.MAN
*Code: ASCII
*Access:   sequential
*Author:   L.J.T. van der Pas
*Version:  1.0
*Date: 28 February 1996
*Source:   observations by SC-DLO and by the experimental
*       farm 'Vredepeel'
*
*   Description of the quantities and their units
*
*       YR    = year
*       MH    = month
*       DA    = day within month
*       DANU  = day number (value is 1 at 23 November 1990)
*       AC    = action
*               (1 = ploughing
*                2 = combination of sowing and harrowing
*                3 = incorporation of dairy manure into the soil with a
*                    cultivator
*                4 = milling of the yellow mustard crop into the soil)
*       DPST  = estimated range of depths (m) of the soil tillage
*
*       Comment: the date of ploughing is not exactly known, ploughing
*                was done in Oktober 1990
*
* YR   MH   DA    DANU      AC    DPST
****************************************************************
1990   10   31     -22       1    0.25-0.30
1990   11   22       0       2    0.15-0.20
1991    8   28     279       3    0.10-0.20
1991   11   29     372       4    0.15-0.20
```

Annex 18 Contents of the file NLVP038.SBD.

```
*File:          NLVP038.SBD
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          26 February 1996
*Source:        Measurements by SC-DLO
*                 Bulk density
*                 Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       NULA  = Number of layers sampled
*       UPDP  = Upper boundary (cm) of the layer
*       LODP  = Lower boundary (cm) of the layer
*       AVBD  = Average bulk density (g cm**[-3]) of each layer of all
*                 soil cores taken during the field experiment
*       SDBD  = Standard error (g cm**[-3]) of the average bulk density
*       NUOB  = Number of observations
*
*NULA UPDP   LODP  AVBD   SDBD   NUOB
**********************************************************************

19     0.0    4.0  1.312  0.020  112
19     4.0    7.5  1.226  0.014  112
19     7.5   15.0  1.325  0.010  112
19    15.0   22.5  1.399  0.007  112
19    22.5   30.0  1.385  0.007  112
19    30.0   37.5  1.427  0.010  111
19    37.5   45.0  1.525  0.009  112
19    45.0   52.5  1.610  0.007  112
19    52.5   60.0  1.642  0.006  112
19    60.0   67.5  1.663  0.005  112
19    67.5   75.0  1.670  0.005  112
19    75.0   82.5  1.675  0.005  111
19    82.5   90.0  1.681  0.003  111
19    90.0   97.5  1.685  0.004  111
19    97.5  105.0  1.684  0.003  111
19   105.0  112.5  1.691  0.003  109
19   112.5  120.0  1.700  0.003   78
19   120.0  127.5  1.707  0.003   51
19   127.5  135.0  1.706  0.004   40
```

Annex 19 Contents of the file NLVP038.SCP.

```
*File:          NLVP038.SCP
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          26 February 1996
*Source:        Measurements by the Laboratory for Soil and Crop
*               Testing in Oosterbeek (the Netherlands).
*               Soil chemical data, Vredepeel, The Netherlands
*               The soil samples were those used in transformation
*               and sorption studies with ethoprophos and bentazone.
*
*       Description of the quantities and their units
*       NULA  = Number of layers sampled
*       UPDP  = Upper boundary (cm) of the layer
*       LODP  = Lower boundary (cm) of the layer
*       FROC  = Fraction of organic carbon (%)
*       FROM  = Fraction of organic matter (%)
*       FRCL  = Fraction of clay (%)
*       FRSI  = Fraction of silt (%)
*       FRSA  = Fraction of sand (%)
*       FRCC  = Fraction of calcium carbonate (%)
*       PHKC  = pH KCl
*
*NULA UPDP  LODP FROM FROC  FRCL FRSI FRSA  FRCC PHKC
***********************************************************************

  3     0    25  4.9  2.29  2.7  6.3  91.0  0.1  5.3
  3    50   100       0.11  2.1  2.3  95.6       4.7
  3   100   200       0.12  3.0  8.8  88.2       4.6
```

Annex 20 Contents of the file NLVP038.SMO (only the first part).

```
*File:          NLVP038.SMO
*Code:          ASCII
*Access:        sequential
*Author:        L.J.T. van der Pas
*Version:       1.0
*Date:          26 February 1996
*Source:        Measurements by SC-DLO
*                 Soil moisture content
*                 Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       YR     = Year
*       MH     = Month
*       DA     = Day within month
*       DANU   = Day number (value is 1 at 23 November 1990)
*       NULA   = Number of layers sampled
*       UPDP   = Upper boundary (cm) of the layer
*       LODP   = Lower boundary (cm) of the layer
*       AVMOFR = Average volume fraction of liquid (cm**[3] cm**[-3])
*       SDMOFR = Standard error (cm**[3] cm**[-3]) of the average volume
*                fraction of liquid
*       NUOB   = Number of observations
*
*YR    MH   DA   DANU  NULA  UPDP   LODP  AVMOFR  SDMOFR  NUOB
**********************************************************************

1990   11   23     1    19    0.0    4.0  0.204   0.008   16
1990   11   23     1    19    4.0    7.5  0.204   0.011   16
1990   11   23     1    19    7.5   15.0  0.232   0.008   16
1990   11   23     1    19   15.0   22.5  0.259   0.008   16
1990   11   23     1    19   22.5   30.0  0.254   0.010   16
1990   11   23     1    19   30.0   37.5  0.179   0.015   15
1990   11   23     1    19   37.5   45.0  0.144   0.013   16
1990   11   23     1    19   45.0   52.5  0.141   0.016   16
1990   11   23     1    19   52.5   60.0  0.149   0.011   16
1990   11   23     1    19   60.0   67.5  0.185   0.009   16
1990   11   23     1    19   67.5   75.0  0.221   0.008   16
1990   11   23     1    19   75.0   82.5  0.243   0.006   15
1990   11   23     1    19   82.5   90.0  0.262   0.006   15
1990   11   23     1    19   90.0   97.5  0.279   0.004   15
1990   11   23     1    19   97.5  105.0  0.291   0.008   15
1990   11   23     1    19  105.0  112.5  0.314   0.005   13
1990   11   23     1    19  112.5  120.0  0.318   0.005    6
1990   11   23     1    19  120.0  127.5  0.326   0.005    2
1990   11   23     1    19  127.5  135.0  0.326            1

1990   12   14    22    19    0.0    4.0  0.218   0.008   16
1990   12   14    22    19    4.0    7.5  0.212   0.007   16
1990   12   14    22    19    7.5   15.0  0.253   0.006   16
1990   12   14    22    19   15.0   22.5  0.275   0.008   16
1990   12   14    22    19   22.5   30.0  0.263   0.009   16
1990   12   14    22    19   30.0   37.5  0.165   0.013   16
1990   12   14    22    19   37.5   45.0  0.145   0.009   16
1990   12   14    22    19   45.0   52.5  0.131   0.007   16
1990   12   14    22    19   52.5   60.0  0.150   0.012   16
1990   12   14    22    19   60.0   67.5  0.202   0.009   16
1990   12   14    22    19   67.5   75.0  0.227   0.010   16
1990   12   14    22    19   75.0   82.5  0.263   0.007   16
1990   12   14    22    19   82.5   90.0  0.280   0.006   16
1990   12   14    22    19   90.0   97.5  0.294   0.006   16
1990   12   14    22    19   97.5  105.0  0.301   0.007   16
1990   12   14    22    19  105.0  112.5  0.316   0.006   16
1990   12   14    22    19  112.5  120.0  0.319   0.005    7
1990   12   14    22    19  120.0  127.5  0.326   0.005    2
1990   12   14    22    19  127.5  135.0  0.326            1
```

Annex 21 Contents of the file NLVP038.STE (only the first part).

```
*File: NLVP038.STE
*Code: ASCII
*Access:   sequential
*Author:   Jos Boesten
*Version:  1.0
*Date: 28 February 1996
*Source:   measurements SC-DLO at Vredepeel, The Netherlands
*
*       Description of the quantities and their units
*       NUDP  = number of depths
*       DP1   = soil depth (m) at which SOTE1 was measured
*       YR    = year
*       MH    = month
*       DA    = day within month
*       DANU  = day number (value is 1 at 23 November 1990)
*       SOTE1 = daily average soil temperature (deg. Celsius) at depth DP1
*
* NUDP  DP1       YR    MH   DA   DANU     SOTE1
*****************************************************
    1   0.025    1990   11   23     1       2.8
    1   0.025    1990   11   24     2       2.4
    1   0.025    1990   11   25     3       3.2
    1   0.025    1990   11   26     4       3.2
    1   0.025    1990   11   27     5       1.6
    1   0.025    1990   11   28     6       2.7
    1   0.025    1990   11   29     7       2.4
    1   0.025    1990   11   30     8       2.0
    1   0.025    1990   12    1     9       1.4
    1   0.025    1990   12    2    10       5.0
    1   0.025    1990   12    3    11       5.0
    1   0.025    1990   12    4    12       4.8
    1   0.025    1990   12    5    13       3.3
    1   0.025    1990   12    6    14        .6
    1   0.025    1990   12    7    15       1.7
    1   0.025    1990   12    8    16       -.6
    1   0.025    1990   12    9    17       -.3
    1   0.025    1990   12   10    18       -.1
    1   0.025    1990   12   11    19        .1
    1   0.025    1990   12   12    20       2.2
    1   0.025    1990   12   13    21       3.8
    1   0.025    1990   12   14    22       2.4
    1   0.025    1990   12   15    23       2.3
    1   0.025    1990   12   16    24        .0
    1   0.025    1990   12   17    25        .0
    1   0.025    1990   12   18    26       -.6
    1   0.025    1990   12   19    27       -.1
    1   0.025    1990   12   20    28       2.0
    1   0.025    1990   12   21    29       4.8
    1   0.025    1990   12   22    30       6.1
    1   0.025    1990   12   23    31       7.5
    1   0.025    1990   12   24    32       5.9
    1   0.025    1990   12   25    33       4.4
    1   0.025    1990   12   26    34       3.8
    1   0.025    1990   12   27    35       3.3
    1   0.025    1990   12   28    36       2.8
    1   0.025    1990   12   29    37       6.8
    1   0.025    1990   12   30    38       5.1
    1   0.025    1990   12   31    39       2.6
    1   0.025    1991    1    1    40       3.3
    1   0.025    1991    1    2    41       7.6
    1   0.025    1991    1    3    42       7.7
    1   0.025    1991    1    4    43       5.1
```

Annex 22 Contents of the file NLVP038.WRC (only the first part).

```
*File: NLVP038.WRC
*Code: ASCII
*Access:   sequential
*Author:   Jos Boesten
*Version:  1.0
*Date: 28 February 1996
*Source:   laboratory measurements by SC-DLO
*
*       Description of the quantities and their units
*       NULA  = total number of layers
*       UPDP  = depth of top of the layer (cm)
*       LODP  = depth of bottom of the layer (cm)
*       PFDY & PFWE  = variables that indicate whether the data
*                      are wetting or drying curves:
*                      wetting curve: PFDY = 0 and PFWE = 1
*                      drying curve : PFDY = 1 and PFWE =0
*       SMNU = sample number (for each layer duplicate samples
*              so SMNU = 1 or SMNU = 2; note that SMNU in file
*              NLVP038.HCU refers to samples taken with a
*              different procedure)
*       MCHD = matric head (cm); negative values indicate suction
*       MOFR = volume fraction of liquid
*
* NULA  UPDP    LODP    PFDY    PFWE    SMNU    MCHD    MOFR
**************************************************************
   3     10.     18.     1       0       1       - 5.    0.372
   3     10.     18.     1       0       1       -10.    0.365
   3     10.     18.     1       0       1       -30.    0.316
   3     10.     18.     1       0       1       -50.    0.220
   3     10.     18.     1       0       1       -75.    0.196
   3     10.     18.     1       0       1      -100.    0.177
   3     10.     18.     1       0       1      -125.    0.161
   3     10.     18.     1       0       1      -150.    0.152

   3     10.     18.     0       1       1       - 5.    0.372
   3     10.     18.     0       1       1       -10.    0.300
   3     10.     18.     0       1       1       -30.    0.229
   3     10.     18.     0       1       1       -50.    0.202
   3     10.     18.     0       1       1       -75.    0.179
   3     10.     18.     0       1       1      -100.    0.166
   3     10.     18.     0       1       1      -125.    0.160
   3     10.     18.     0       1       1      -150.    0.152

   3     10.     18.     1       0       2       - 5.    0.360
   3     10.     18.     1       0       2       -10.    0.358
   3     10.     18.     1       0       2       -30.    0.311
   3     10.     18.     1       0       2       -50.    0.230
   3     10.     18.     1       0       2       -75.    0.153
   3     10.     18.     1       0       2      -100.    0.128
   3     10.     18.     1       0       2      -125.    0.115
   3     10.     18.     1       0       2      -150.    0.106
```