Basic data sets description and preliminary results of EFEDA-Spain

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RAPPORT 37

Juli 1993

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ISSN 0926-230X

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I INTRODUCTION

To improve the understanding of the interaction between soil, vegetation and atmosphere ECHIVAL (European International Project on Climatic and Hydrological Interactions between the Vegetation, the Atmosphere and the Land-surface) has been established. The first phase in this research program is EFEDA (ECHIVAL Field Experiment in a Desertification-threatened Area). EFEDA was started with an extensive field experiment in the area of Castilla - La Mancha in Spain aimed at the measurement of the energy and water fluxes during the month of June, 1991. This desertificating area was selected because of its flatness, uniform land-use in relative large fields, and its semi-arid climate. For further information on the complete experiment, the area characteristics and contributions, one may consult the EFEDA Field Experiment Plan (Bolle, 1991).

As one of the contributors to EFEDA Spain, the Department of Water Resources of the Agricultural University Wageningen the work program consisted of:

- Determination of the energy balance above an aerodynamic homogeneous terrain by the profile method, and fluctuation method;
- Determination of soil hydraulic properties and their spatial variability;
- Monitoring the local waterbalance at several locations;
- Monitoring soil moisture in the surface layer in support of remote sensing activities.

In order to realize this work program the following activities in the field were undertaken during the EFEDA experimental period of June 1991:

- On a bare field in Tomelloso (TOM1), radiation and energy balance masts were installed;
- In Tomelloso and Barrax a large number of undisturbed soil samples were collected for determination of the hydraulic properties in the laboratory in Wageningen, afterwards;
- Furthermore, the disc permeameter method was frequently applied in order to collect soil hydraulic data at near-saturated conditions;

- As part of the remote sensing activities during the EFEDA experiment extensive near-surface water content measurements by TDR were undertaken in Tomelloso and Barrax at the 19th of June;
- To monitor local waterbalances, 46 plots were instrumented in Tomelloso and Barrax.

Tensiometers, a neutron probe tube and Time Domain Reflectometry (TDR) sensors were installed at 18 plots in Tomelloso. The plots were situated in six fields: three vineyards, two vetch and one bare soil field. In Barrax, 28 plots were instrumented with tensiometers and TDR sensors in close corporation with the hydrology group of Grenoble. These 28 plots were distributed over 9 fields of mainly irrigated maize, but also include were irrigated alfalfa, irrigated and non-irrigated barley, and a bare soil field. For a full overview of the fields and plots and their abbreviations, one is referred to table 1 and Appendices 2a and 2b. To illustrate plot layouts, examples are depicted in detail in Appendix 3.

field	plots	land use
BAR1	B1 B2 B3	maize irrigated
BAR2	B4 B5 B6	fallow land
BAR3	B7 B8	barley
BAR4	B9 B10 B11	alfalfa irrigated
BAR5	B12..B20	maize irrigated
BAR6	B21 B22	barley irrigated
BAR7	B23 B24	barley
BAR8	B25 B26 B27	maize irrigated
BAR9	B28	fallow land
TOM1	T1 T2	fallow land
TOM2	T3..T6	wine
TOM3	T7..T10	vetch
TOM4	T11 T12	wine
TOM5	T13..T16	vetch
TOM6	T17..T18	wine

Table 1 Fields with plots and vegetation.

This report consists of two parts. The first part describes methods and materials; the second part gives an overview of the data, that have been checked. As much as possible, data are listed in separate appendices. All data described in this report is also available on diskette.

II METHODS AND MATERIALS

II.1 Energy balance

A full description of the energy balance measurements is given in Moors (1993) and will not be described here.

II.2 Moisture content

Moisture content measurements were done with Time Domain Reflectometry (TDR) and neutron probe technique. The locations and depths of these measurements are summarized in Appendix 4. To get an impression of short range spatial variability of soil moisture content during the full experimental period, five profiles (B16-B20) at mutual distances of 25 cm were installed in Barrax. To obtain information on the small scale spatial variability in a vineyard, identical moisture measurements were undertaken at variable distances away from a vine in Tomelloso (field TOM2) on June 21. See Appendix 5 for the layout of this activity.

TDR measurements are based on the difference in dielectric constant between water (80), air (1) and soil particles ($\approx$4). By applying an electromagnetic impulse through the soil, the apparent dielectric permittivity (K_a) of the soil can be obtained by:

$$K_a = \left(\frac{c \Delta t_s}{2L} \right)^2 \qquad (1)$$

where c is speed of light ($3.0 * 10^8$ ms^{-1}), Δt_s is travel time of the pulse in soil [s], and L is probe length [m]. Using the dielectric permittivity, the volumetric water content (θ) [cm^3cm^{-3}] can be calculated with the empirical relation derived by Topp (Topp, 1980):

$$\theta = \frac{-530 + 292K_a - 5.5K_a^2 + 0.043K_a^3}{10^4} \qquad (2)$$

The TDR measurements in Tomelloso were done with a cabletester in combination with automatic waveform analysis (Heimovara, 1990). In Barrax the TDR measurements were done with two systems of Easy Test (Malicki, 1989) from Poland. TDR measurement

were carried out by two-rod sensors with a length of 10 cm, which results in a sampling volume of approximately 500 cm^3.
Data of the neutron probe should be calibrated with other water content data (e.g. volumetric water content measurements or by TDR). Ideally calibration should be done for every soil type, and thus for every field and depth. However, because of the small water content range in Tomelloso during the month of June, calibration could only be done by using the TDR measurements of all depths together.

For the selected fields in Tomelloso also gamma probe measurements were carried out by 'Institut de Mécanique de Grenoble, France'. Using the gamma probe and gravimetric moisture content data, bulk density and porosity could be determined.

At June 19 a long series of surface moisture content measurements with TDR were realized in four fields in Barrax (BAR2, BAR4, BAR5, BAR7) and three fields in Tomelloso (TOM1, TOM2, TOM3). These measurements were done in regular grid patterns with grid spacing ranging from 40 to 100 m (see Table 2 and 3). In Appendix 6, the full layouts of these grids are shown. In fields BAR2 and BAR5, additional measurements were carried out by collecting volumetric moisture contents at two depths and from the crust. Parts of the crust were collected in order to determine the gravimetric moisture content, the thickness and area of the sampled crust.

	grid spacing [m]	points	depths [cm]
TOM1	60 x 60	16	5 10 30
TOM2	41 x 44	40	5 15 25
TOM3	50 x 50	21	5 15 25

Table 2 Surface moisture content measurements Tomelloso

	grid [m]	points	TDR [cm]	volumetric [cm]	crust [cm]
BAR2	40 x 40	29	5 10 30	0-5 5-10	0-1
BAR5	40 x 40	25	2 5 10	0-5 5-10	0-1
BAR4	100 x 100	9	2 5 10		
BAR7	100 x 100	9	5 10 25		

Table 3 Surface moisture content measurements Barrax

II.3 Soil water suction

In dry soil (suction > 800 cm) it is impossible to measure water suction with tensiometry. Since suctions in Tomelloso were lower than that, the water suction was only successfully measured in Barrax (Appendix 4). The original setup to measure soil water suction by tensiometry failed as many sensors leaked. This was detected, only after installation. The result is limited suction data from the 'Wageningen' group in Barrax for the first half of June. Working sensors became available in the second half of June. Fortunately, also the 'Grenoble' group collected suction data in Barrax for the full period. The tensiometers were installed vertically with a ceramic cup of 5 cm length. Readings were taken with the, so called 'Wieringa' system (Marthaler, 1983).

II.4 Near-saturated conductivity by disc permeameter

Near-saturated conductivity values intended to be measured by the disc permeameter, by which water is infiltrating into the soil under negative pressure. In principle the sorptivity and the steady state flow can be determined while measuring time and inflow. Plotting outflow versus square root of the time yields the sorptivity estimated by the slope at the early infiltration times. From this sorptivity value combined with the steady state infiltration rate and the initial and final moisture content values, the unsaturated conductivity can be calculated:

$$K=q-\frac{4bS^2}{\pi r(\theta_f-\theta_i)} \qquad (3)$$

where K is conductivity [cm hr^{-1}], q is steady state infiltration rate [cm hr^{-1}], S is sorptivity [cm $hr^{-½}$], r is disc radius [cm], θ_f = final moisture content [cm^3cm^{-3}], θ_i = initial moisture content [cm^3cm^{-3}] and b is a constant (0.55).

However, sorptivity measurements using this methodology may lead to serious errors. Alternatively suction infiltration can be measured with two different disk sizes at two nearby locations. After steady state infiltration of these two measurements the unsaturated conductivity can then be obtained by elimination of the sorptivity:

$$K=q_1-\frac{4bS^2}{\pi r_1(\theta_{f,1}-\theta_{i,1})} \qquad (4)$$

$$K=q_2-\frac{4bS^2}{\pi r_2(\theta_{f,2}-\theta_{i,2})} \qquad (5)$$

which leads to:

$$S=\sqrt{\frac{\pi}{4b}(q_1-q_2)\left(\frac{r_1\theta_1 r_2\theta_2}{r_2\theta_2-r_1\theta_1}\right)} \qquad (6)$$

$$K=q_1-(q_1-q_2)\left(\frac{r_2\theta_2}{r_2\theta_2-r_1\theta_1}\right) \qquad (7)$$

The limitation of this approach is, that it assumed that differences in steady state infiltration rate is dependent only on the disk size and not influenced by soil heterogeneity between the two spots. Measurements were carried out in Tomelloso and Barrax (see Appendix 4).

II.4 Saturated hydraulic conductivity by Guelph permeameter

Field saturated hydraulic conductivity was planned to be determined by a Guelph permeameter, in a 6-cm diameter cylindrical well hole. Which maintaining a constant head, steady state intake rate in the unsaturated soil was measured. Under the assumptions that the soil is homogeneous, isotropic and rigid, Reynolds et al. (1983) derived a solution for Q by the following analytical expression:

$$Q=\frac{2\pi H^2}{C}K_{fs}+\pi R^2 K_{fs}+\frac{2\pi H}{C}\Phi_m \tag{8}$$

where Q is steady state flow [cm^3min^{-1}], H is well height [cm], K_{fs} is field saturated conductivity [cm min^{-1}], ϕ_m is matric flux potential [cm^2 min^{-1}] R is well radius [cm], and C is a constant dependent on the H/R ratio. The three terms in the right hand side represent the three forces on the intake rate: hydraulic push, gravitational pull and capillary pull respectively.

The two unknowns in this equation are: the field saturated conductivity and the matric flux potential. At least two measurements with different well heights (or different radius) are necessary to solve this equation. The solution is called the Richards analysis:

$$K_{fs}=G_2Q_2-G_1Q_1 \tag{9}$$

where,

$$G_2=\frac{H_1C_2}{\pi\left[2H_1H_2(H_2-H_1)+R^2(H_1C_2-H_2C_1)\right]} \tag{10}$$

and where,

$$G_1=G_2\frac{H_2C_1}{H_1C_2} \tag{11}$$

If the capillary term, with ϕ_m is ignored, the Laplace analysis can be used:

$$K_{fs}=\frac{CQ}{2\pi H^2+C\pi R^2} \tag{12}$$

The Gardner analysis is based only on the capillary forces and thus gives only the matric flux potential:

$$\Phi_m=\frac{CQ}{2\pi H} \tag{13}$$

The advantage of the Laplace and Gardner analysis is that only one measurement is required.

16 Guelph permeameter measurements in a grid of 40 meter have been completed in Barrax (BAR2). In every plot two measurements with different well heights were completed. The well radius was 6 cm, well heights were 5 and 10 cm, and their respective C values were 0.53 and 0.85.

II.6 Soil hydraulic properties

In contrast with the former measurements which were carried out in the field, the multi-step outflow method for estimation of the soil hydraulic properties is a laboratory method. Undisturbed samples of 100, 250 and 600 cm^3 were collected in the field. In the laboratory, each sample was placed in a Tempe pressure cell on top of a ceramic plate. After saturating the sample from below the plate, a small suction is applied (10-30 cm) until equilibrium was reached. Then, the pneumatic pressure on top of the sample was increased, inducing unsaturated flow in the soil sample whit the ceramic plate saturated. This combined system of soil and ceramic plate has the following initial and boundary conditions (Van Dam et al, 1992):

$$h=h_0(x) \qquad t=0 \qquad 0 \le x \le L$$

$$\frac{\partial h}{\partial x}=1 \qquad t>0 \qquad x=0$$

$$h=h_L-h_a \qquad t>0 \qquad x=L$$

where x=0 is top of soil core [cm], L is the height of sample including the ceramic plate [cm], h_L is initial water potential below ceramic plate [cm] and h_a is applied pneumatic pressure [cm].

Within a 2-week period, the pressure on top of the sample is increased stepwise until a final pressure of 1 bar is reached. During the experiment, starting after the sample has been saturated, time and outflow are recorded. Upon completion of the outflow experiment, the saturated moisture content θ_s is measured by re-saturating and oven-drying the sample. The conductivity of the ceramic plate has measured independently using a positive pressure of 50 cm.

Assuming one-dimensional unsaturated flow, hydraulic properties can be estimated by inverse modelling, thereby matching simulated with observed time-outflow data. This inverse method is based on the principle that the flow-process is repeatingly simulated with adjusted soil hydraulic properties until the simulated outflow is close to the observed outflow. One has to use analytical functions to describe these properties. In this experiment the Mualem-Van Genuchten (MVG) model is used (Van Genuchten, 1980):

$$\Theta = [1 + |\alpha h|^{n}]^{-m} \tag{14}$$

$$K = K_s \Theta^{L} \left[1 - \left(1 - \Theta^{\frac{1}{m}}\right)^{m}\right]^{2} \tag{15}$$

where

$$\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r} \tag{16}$$

$$m = 1 - \frac{1}{n} \tag{17}$$

where α [cm^{-1}], n [-] and L [-] are empirical parameters, θ_r is residual water content [$cm^3\ cm^{-3}$], θ_s saturated water content [$cm^3\ cm^{-3}$] and K_s is saturated hydraulic conductivity [$cm\ hr^{-1}$].

II.7 Particle size distribution

Disturbed samples for the particle size analysis were taken in Tomelloso in every field and in Barrax near every plot at intervals of 10 cm depth (Appendix 20). Particle size distribution is determined by sieving the grain fraction > 0.053 mm and by sedimentation experiments based on Stokes' law for the fraction < 0.053 mm. In this method a pre-treatment has to be done first to remove cementing components (Fe- and Al-oxides, $CaCo_3$, organic matter). Samples of about 20 g are taken and the fraction < 0.053 mm is mixed with water in a one litre reservoir. After 15 min the fraction < 0.016 mm is sampled at a prescribed depth and after 16 hours the fraction of < 0.002 mm. A full description of the method is given in Klute (1986).

III DESCRIPTION OF COLLECTED DATA AND DATAFILES

III.1 Energy balance

A full description of the results of the energy balance measurements is given in Moors (1993) and will not be described here.

III.2 moisture content

In principle TDR calibration is not necessary. However, for dry soils, soils with a high iron contents or soils with bound water (clay), calibration becomes inevitable. First, the three TDR instruments, the cable tester (CT) and two Polish systems (MDP and ZDP), were compared with each other (Figure 1 till 3). Figure 1 shows that the deviation between the two Polish systems in the dry range can be 5 volume percent. From Figure 2 it is clear the deviation between CT and ZDP is high. Also other measurements showed that the ZDP was insensitive to volumetric soil moisture contents changes in the 8 and 15 % range. Therefore the ZDP was rarely used. Comparison of volumetric water content as determined with the three TDR instruments with gravimetric water content is presented in Figure 4. Correlation between TDR and gravimetric samples is very low due to several circumstances. First, samples were taken from several fields to obtain a broad range of moisture contents. Consequently, the variability in soil composition influenced the TDR measurements. Second, due to the presence of stones in the soil and the hardness of the dry soil, we had difficulties in the collecting of undisturbed samples.

The regular moisture content measurements by TDR are presented graphically in Appendix 7 and are stored in the file TDR.DAT with indication of the applied TDR system. In Tomelloso, a steadily decrease of water content can be observed, except for plot T13. This plot was irrigated on June 25 to establish also wet conditions. In Barrax, water contents strongly fluctuated by irrigation for several plots. The results of the spatial variability measurement as determined by TDR on field TOM2 are given in Appendix 8 and in file SPATIAL.DAT.

The results of the extensive moisture content measurements on the 19th of June are stored in the file FLY.DAT and given in Appendix 9.

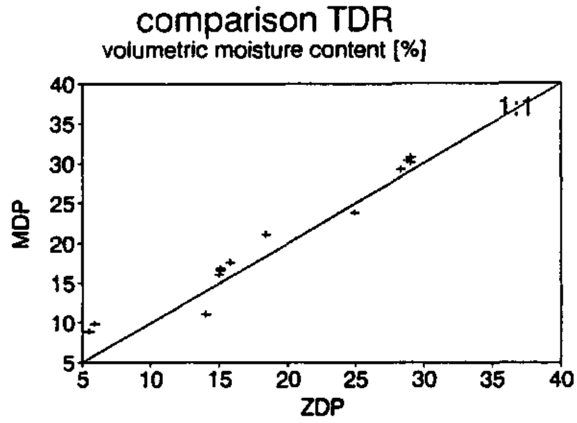

Figure 1 Comparison Polish TDR systems.

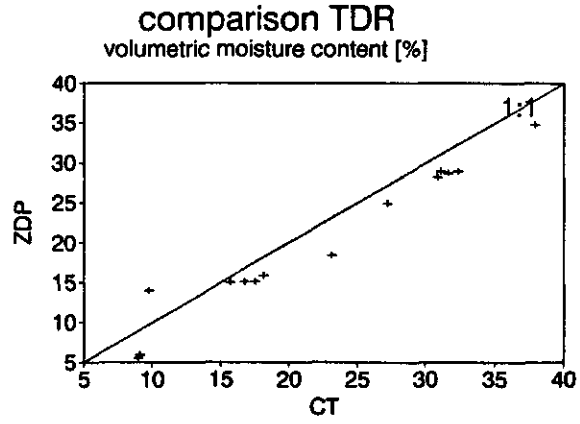

Figure 2 Comparison CT versus ZDP.

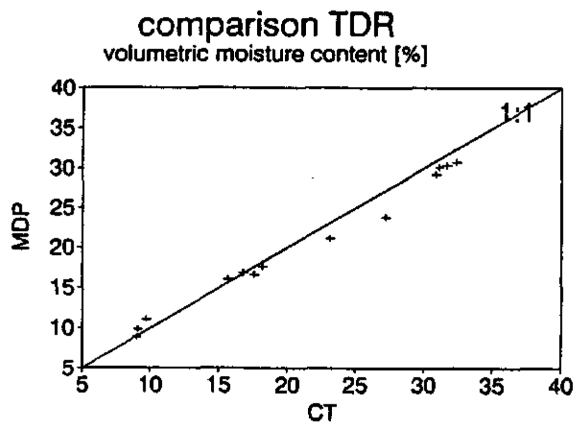

Figure 3 Comparison CT versus MDP.

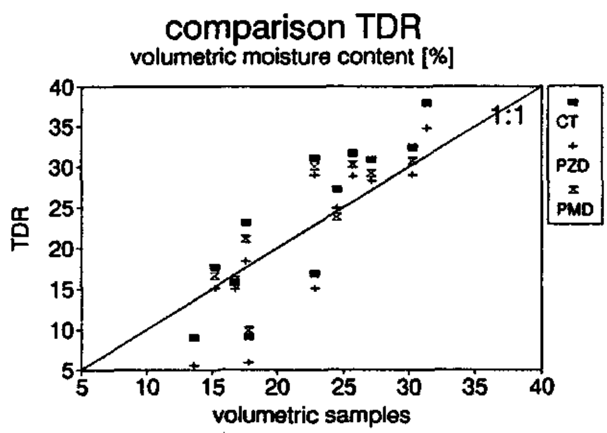

Figure 4 Comparison TDR versus samples.

The neutron probe data at Tomelloso sites are stored in the file NEUTRON.DAT. Relative count rates are tabulated (count rate at a particular depth divided by the standard count rate). The standard count rate is registrated just before starting a series of measurements at each plot. Calibration of the neutron probe was carried out by using the TDR measurements of the CT. In table 4 results of this calibration for several combinations of depths and plots are listed. Only TDR and neutron probe measurements taken at the same day were included in this calibration.

fields	depths	number of points	a	b	R^2
all	all	87	0.0128	0.1217	0.702
all	20 cm	26	0.0197	0.0999	0.504
all	≥ 30 cm	61	0.0491	0.0894	0.459
TOM1	all	14	-0.0019	0.1319	0.848
TOM2	all	18	-0.0273	0.1595	0.837
TOM3	all	16	0.0035	0.1495	0.518
TOM5	all	24	0.0272	0.1089	0.608
TOM6	all	15	-0.0156	0.1491	0.801
TOM3+5	all	40	0.0310	0.1075	0.595

Table 4 Neutron probe calibration versus TDR.

From these results the combined the calibration curve for all depths and all plots was used:

$$\theta=0.0128+0.1217n \tag{18}$$

where n is the relative count rate. This calibration was based on 87 points with an R^2 value of 0.702. A plot of this calibration curve is shown in Figure 5. The calculated moisture contents using eq. (18) are plotted in Appendix 10 and in the file NEUTRON2.DAT.

The bulk density and porosity obtained by gamma probe are listed in Appendix 11 and in the file GAMMA.DAT.

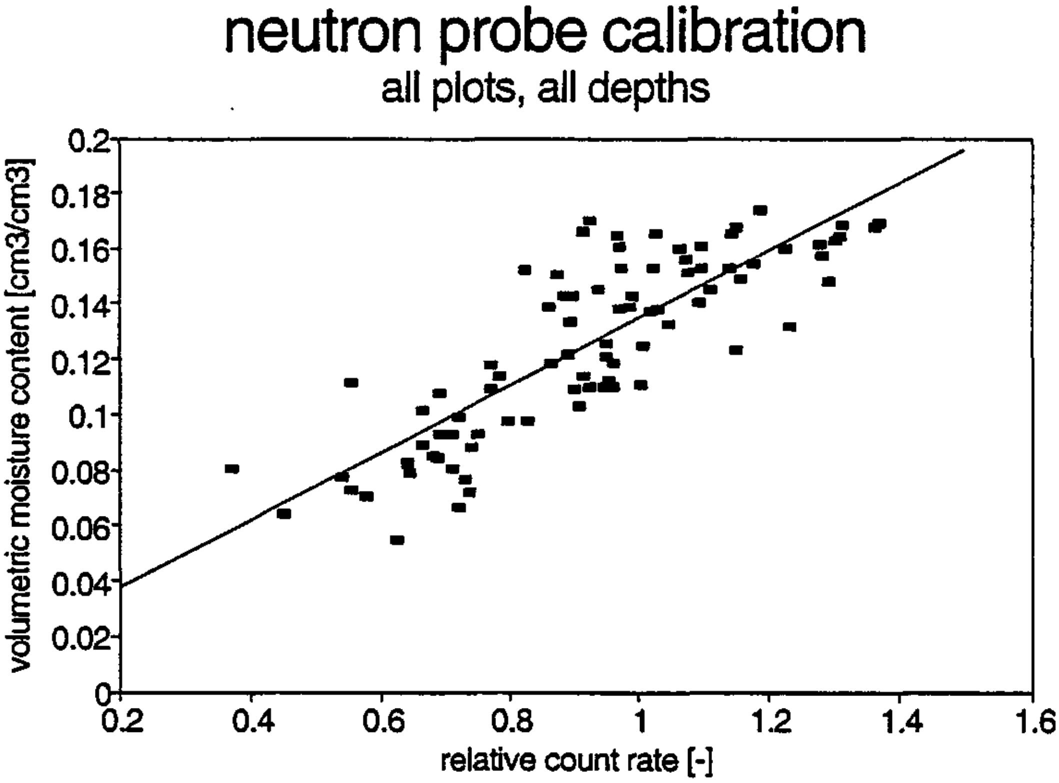

Figure 5 Neutron probe calibration.

III.3 Soil water suction

After failure of the first set of installed tensiometers, the improved tensiometers were installed at the 20th of June. So only data of the last part of the month are available. The results are shown in Appendix 12 and in the file TENS.DAT.

III.4 near-saturated conductivity by disc permeameter

The measured data are stored in the file DISC.DAT. Basic information, initial and final moisture content are reviewed in Appendix 13. Analysis of the measurements must reveal how valuable these data are. The experimental conditions for the method were not ideal due to strong winds affecting the stability of the disc permeameter, the stony soil and the soil variability at very short distances.

III.5 Saturated hydraulic conductivity by Guelph permeameter

The Guelph permeameter measurements were carried out only in field BAR2 (bare soil) in a 40 x 40 m grid at 16 points. Two pressures of 5 and 10 cm were applied; the well radius was 6 cm. The saturated conductivity and the matrix flux potential were calculated using the three methods as described in section I.5. The results are tabulated in Appendix 14. Construction of a good well hole was not always possible because of the dry soil. Also, during the experiment some disturbances of the well hole occurred. The results must be interpreted in context with these disturbances. It may partly explain some of the negative saturated conductivities values in Appendix 14. However, also soil heterogeneity also can cause unrealistic results.

III.6 Soil hydraulic properties

The multi-step outflow measurements were done in series of 20 (100 cm^3) or 10 (250 or 600 cm^3) samples. In total 120 samples were measured from fields in Barrax, and 37 samples from fields in Tomelloso (Appendix 15).

The applied pressure steps are 15 (suction), 30, 50, 100, 350 and 1000 cm. At several steps, especially at 15 and 1000 cm pressure, outflow was recorded until equilibrium, before increasing the pneumatic pressure for the next step (Appendix 16). These equilibrium points can be used in the optimization program as fixed points of the retention curve.

The simulation of time-outflow data and optimization of the MVG-parameters were carried out by the program MULSTP (Van Dam et al, 1990). In the optimization only 5 parameters were left variable: α, n, θ_r, K_s and L. The saturated water content θ_s was fixed at the value measured after the outflow experiment; in case a sample was lost when removing it from the pressure cell, an average θ_s was used.

The range of possible values for the parameters n, K_s and L was restricted in the inputfile of the program (table 5). Values of $n<1$ would cause an unrealistic shape of the retention curve, whereas n-values larger than 5 causes problems during the optimization. The optimized values of K_s and L were well correlated; not restricting their possible ranges can cause unrealistic values for one or both parameters. Example input- and outputfile of the program are given in Appendix 17.

parameter	minimum	maximum
α	---	---
n	1.1	5.0
θ_r	---	---
K_s	0	10.0
L	-2.0	2.5

table 5 Constraints of MVG-parameters in the optimization process

The first step of the outflow-experiment (h=0 to 15 cm) often showed an irregular cumulative outflow. This was probably caused by air entrapment (Van Dam et al, 1990) and contribution of macro-pores to the flow-process. In order to avoid problems in simulating this irregular behaviour, the optimization of the experiment was started at an initial equilibrium suction of 15 cm. The time-outflow data were optimized in different ways (table 6); depending on whether retention points were included or not.

optimization	initial pressure (cm)	fixed retention points
fit 1	0	none
fit 2	15	none
fit 3	0	h=-15 and h=-1000 cm
fit 4	15	h=-15 and h=-1000 cm

table 6 Optimization of parameters for hydraulic functions for different conditions

The results of fit 1 to 4 are given for 5 100 cm^3 samples, from different fields in Tomelloso (table 7) there can be considered to be representative for all experiments. Rösslerová (1991) gave a similar comparison for a series of samples taken in Barrax.

sample	field	plot	depth (cm)
C3	TOM3	T7	30-35
CT144	TOM2		50-55
CT24	TOM2		12-17
H42	TOM2	T3	50-55
CT59	TOM3	T9	30-35

table 7 Illustrative examples for different optimizations

Figure 6 shows measured and simulated cumulative outflow. For most samples the simulated outflow represents the measured outflow very well and there appears to be little difference between the 4 optimizations. Only for sample CT24 (Figure 6 e+f), with no outflow during several steps and a sudden increase at t=79.5 hr (pressure increased to 100 cm), the simulated outflow for all fits exceeds the measured outflow during the first steps. Total outflow at the end of the experiment showed a good agreement between measured and simulated outflow.

Although sample CT59 (Figure 6 i+j) also has almost no outflow during several steps of the experiment, the simulated outflow for this sample agree well with the measured outflow. This is probably due to the fact that outflow starts as pressure increases to 50 cm and the total amount of outflow of sample CT59 is much less than of sample CT24.

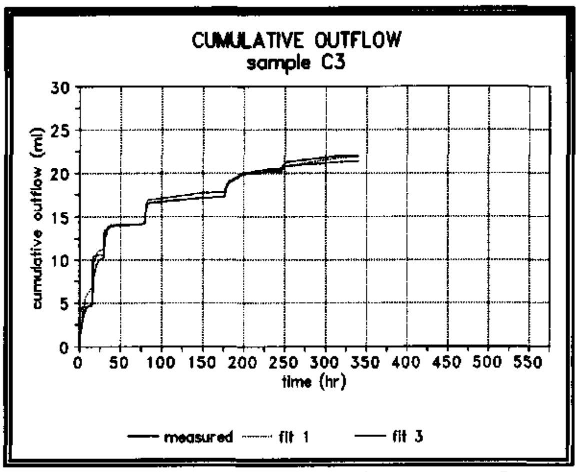

fig. 6a: outflow fit 1 and 3 sample C3

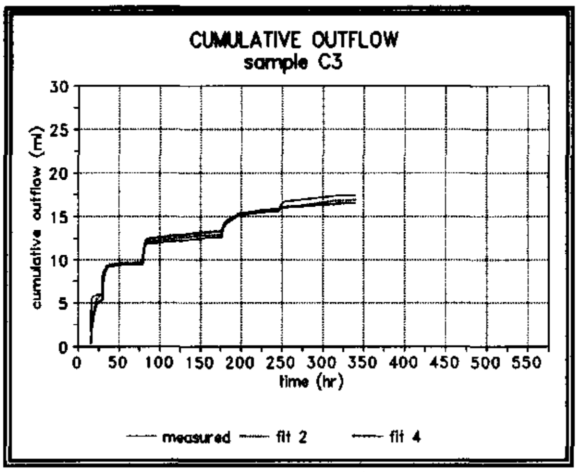

fig. 6b: outflow fit 2 and 4 sample C3

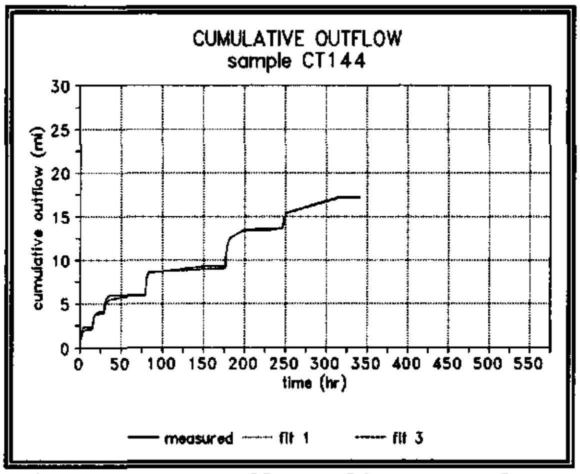

fig. 6c: outflow fit 1 and 3 sample CT144

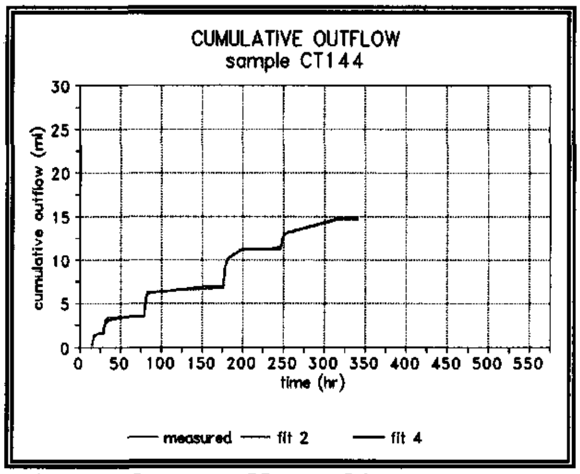

fig. 6d: outflow fit 2 and 4 sample CT144

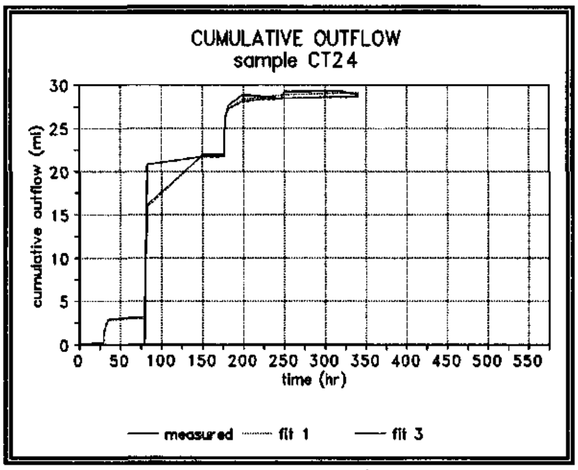

fig. 6e: outflow fit 1 and 3 sample CT24

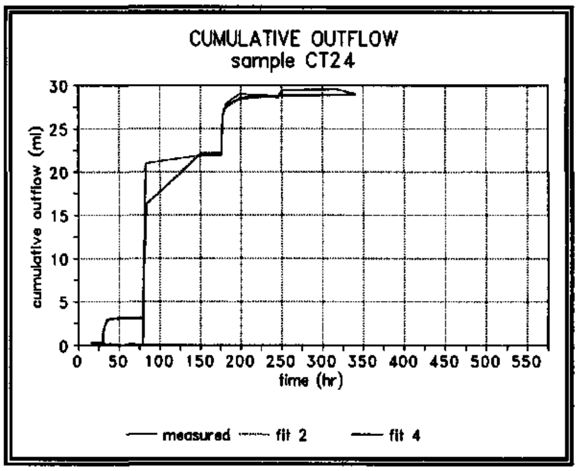

fig. 6f: outflow fit 2 and 4 sample CT24

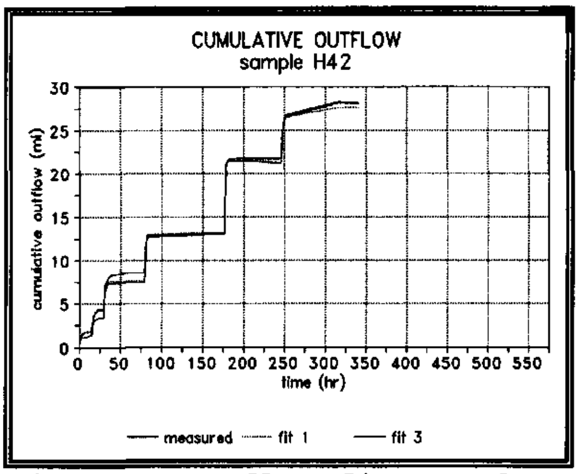

fig. 6g: outflow fit 1 and 3 sample H42

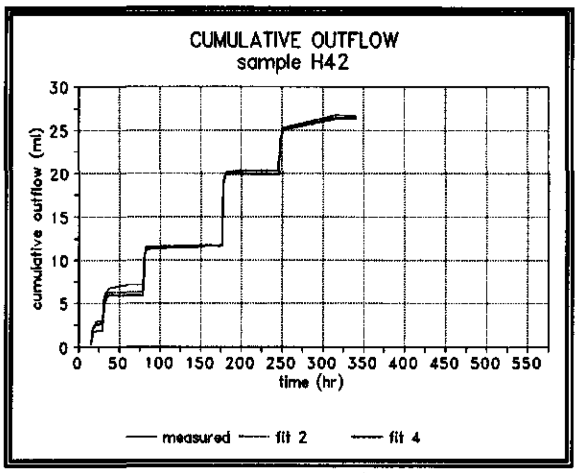

fig. 6h: outflow fit 2 and 4 sample H42

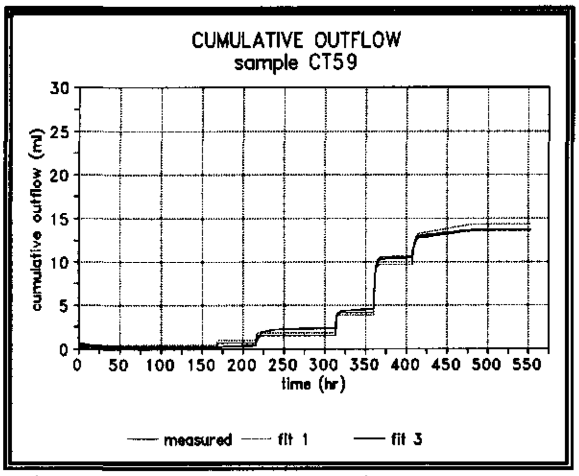

fig. 6i: outflow fit 1 and 3 sample CT59

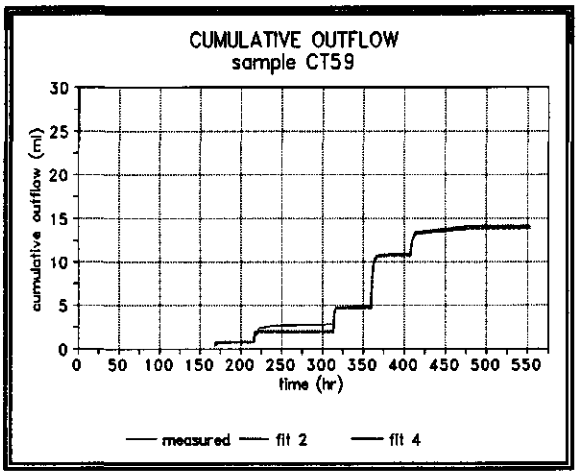

fig. 6j: outflow fit 2 and 4 sample CT59

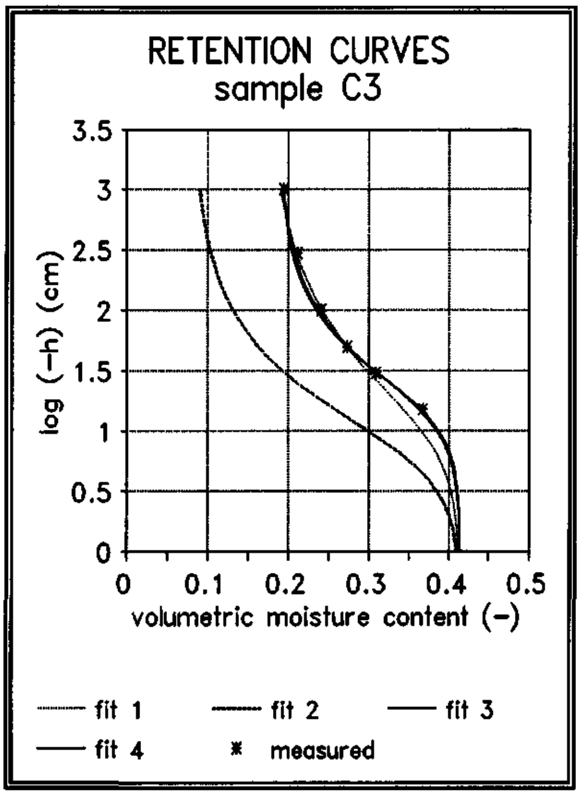

fig. 7a: retention curve sample C3

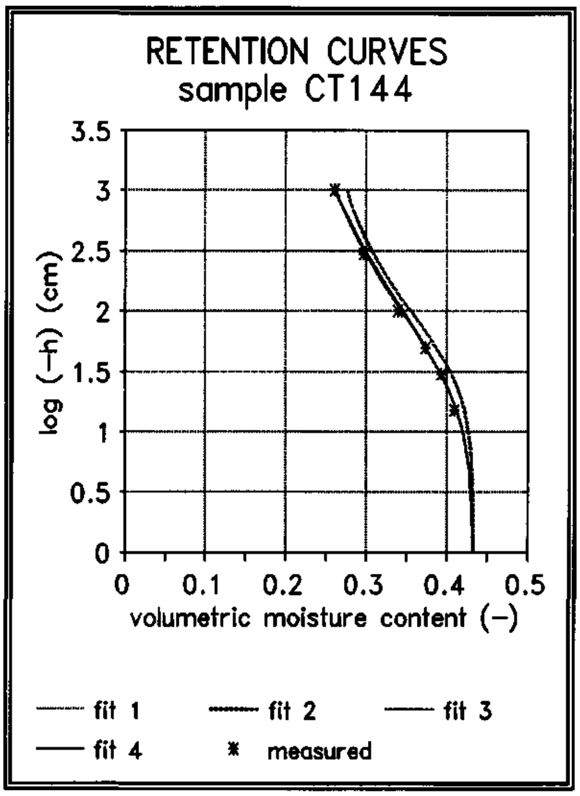

fig. 7b: retention curve sample CT144

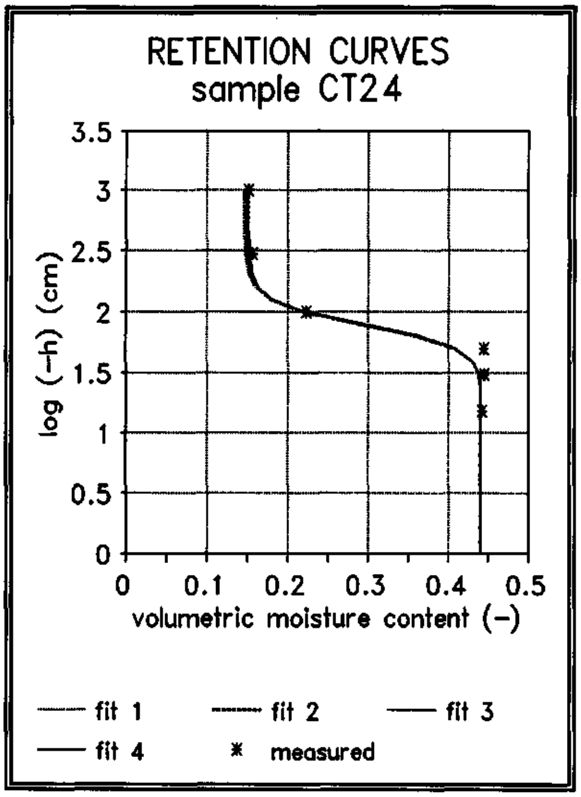

fig. 7c: retention curves
sample CT24

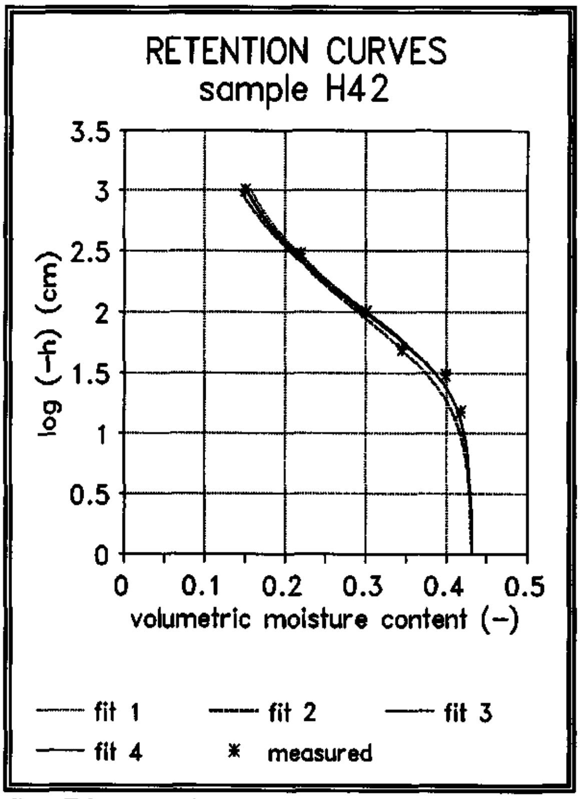

fig. 7d: retention curve
sample H42

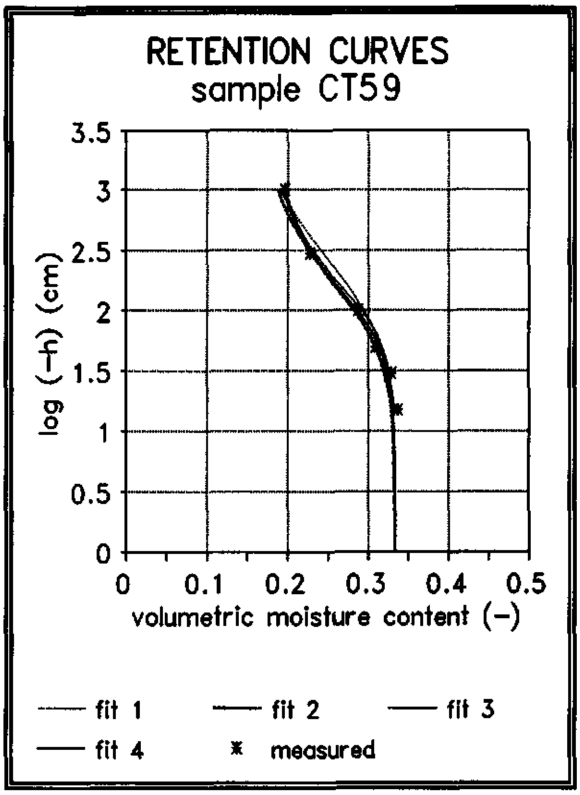

fig. 7e: retention curve
sample CT59

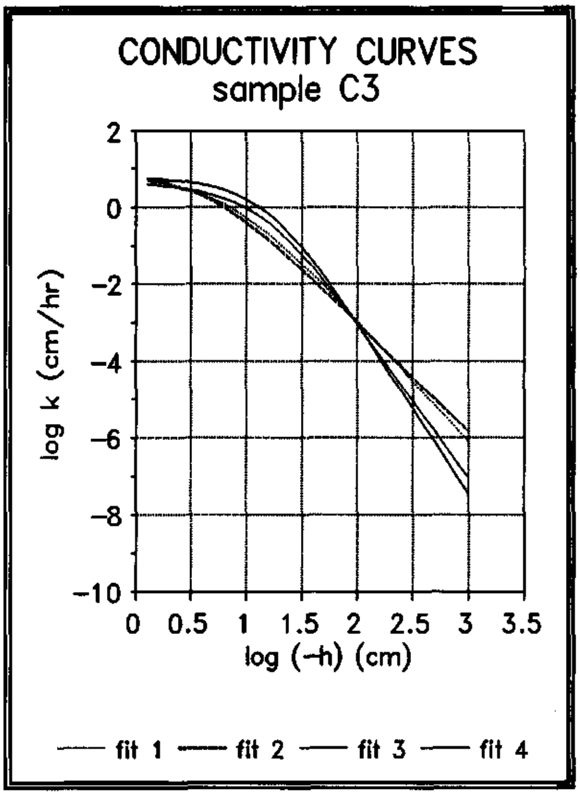

fig. 8a: conductivity curve
sample C3

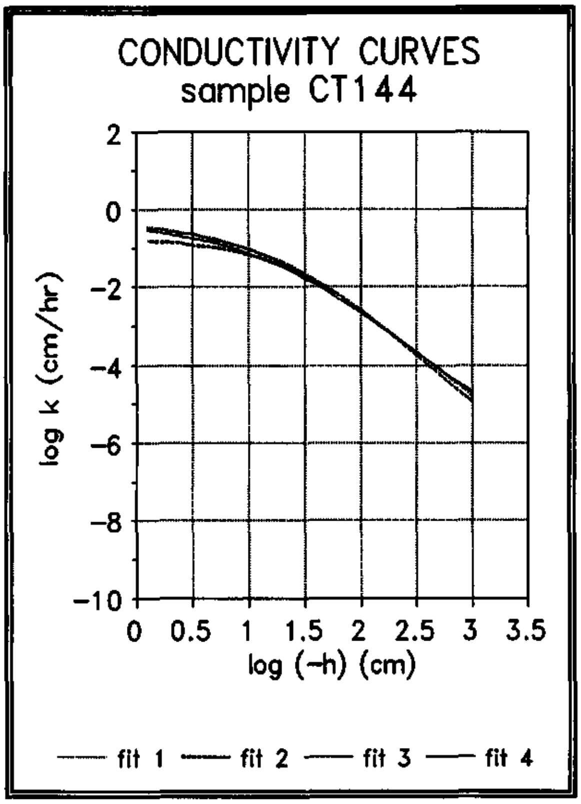

fig. 8b: conductivity curve
sample CT144

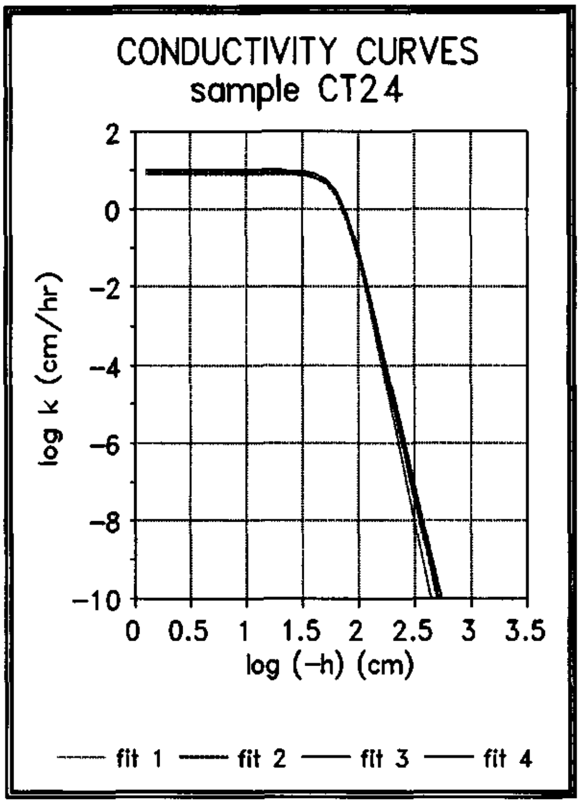

fig. 8c: conductivity curve
sample CT24

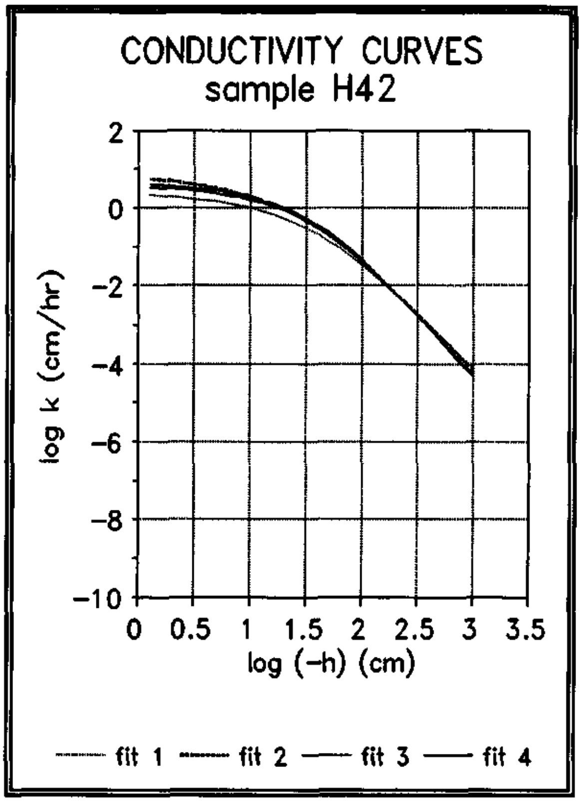

fig. 8d: conductivity curve
sample H42

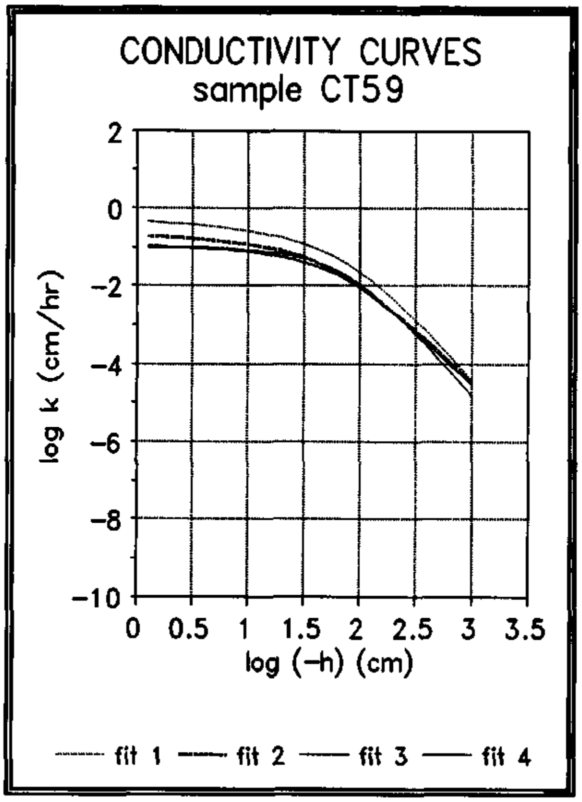

fig. 8e: conductivity curve
sample CT59

The resulting retention and conductivity curves are shown in Figure 7 and 8. The moisture content calculated from measured outflow at the end of each pressure step are also indicated in these figures (measured points). For samples CT144, H42 and CT59 (Figure 7/8 b,c,d), the optimized curves agree well with measured points. For sample C3, the optimization starting at an initial pressure of 15 cm with no fixed retention points (fit 2) shows a significant deviation from the other retention curves and from the measured retention data (Figure 7a).
Deviations between fitted and measured points occur for CT24 (Figure 7c) in the wet part of the curve. Rösslerova found similar results for samples taken in Barrax, that had no outflow during several steps. Possible, the shape of the retention curve for samples with a high air entry value is not adequately expressed by the MVG model.

After comparison of the results for the different fits, a final choice had to be made for the further calculations. Fit 2 did not appear to be adequate but, fits 1, 3 and 4 gave almost the same results. To avoid problems with the optimization of the first irregular part of the flow-process, fit 4 was chosen to be the best, except for those samples that had a relatively high air entry value. These samples cannot be optimized correctly using the model given by equation (14) and (15).
Final results for all measured samples (including final results of Rösslerová) are given in Appendix 18 and 19. Appendix 16 gives the exact pressure steps and equilibrium points of each series of measurements. For some series there is no equilibrium point at 15 cm pressure. In these cases the initial pressure of the optimization is h=0 cm and there is only one fixed retention point at h=-1000 cm. For samples where there is no outflow measured till the pressure is increased to 100 cm (Appendix 16, negative or nearly zero values for first three steps), there are no MVG-parameters listed in Appendix 19.

As indicated in Appendix 13 and mentioned by Rösslerova, some series had been resaturated in a stepwise fashion after completion of the outflow experiment and cumulative inflow is measured. Results of optimization of the inflow experiments are not given in Appendix 15 and 16, because problems appeared in the optimization with the program MULSTP.

The input- and outputfiles of the program MULSTP are available for each series of measurements, including the inflow-experiments. In general the inputfile is named <SERIES>_4.mul, the outputfiles are <SERIES>_4.res (complete results) and <SERIES>_4.par (MVG-parameters only). For some series, additional optimizations were made; these are all condensed in a file <SERIES>.zip and can be extracted again by the program PKUNZIP.

III.7 Particle size distribution

Results of the particle size distribution are presented in Appendix 20 and are stored in the file PARTICLE.DAT. The samples not specified by a plot number represent a whole field. In total 86 samples were sieved to a fraction smaller than 0.053 mm for the sedimentation experiment and bigger than 0.053 mm for sand fraction determination. Due to measurement errors, some negative values were determined for the sedimentation experiment in Appendix 20. For the sand fraction determination some of the 86 samples bigger than 0.053 mm were put together, resulting in 31 samples. Although these 31 samples were already separated to a fraction bigger than 0.053 mm still some particles smaller than 0.053 mm were left in the samples (see Appendix 20).

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Van Genuchten, M.Th., 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J., 44, 892-898.

APPENDIX 1 data files on diskette.

DISC.DAT
disc permeameter measurements
column 1 = samplename, number of observations
column 2 = diskdiameter [cm], reservoirdiameter [cm], watercontent initial, water content end
column 3 = time [hr], reading [cm]

FLY.DAT
moisture contents by TDR on June 19
see appendix 6 for layout

GAMMA.DAT
bulk density and porosity by gamma probe
see appendix 11

MULPAR.DAT
Mualem-VanGenuchten parameters from multi-step outflow
see appendix 19

NEUTRON.DAT
neutron probe measurements (only Tomelloso)
line 1 = plot number
line 2 = depths [cm]
line 3 = day of June 1991, relative count rate [-]

NEUTRON2.DAT
neutron probe measurements (only Tomelloso)
line 1 = plot number
line 2 = depths [cm]
line 3 = day of June 1991, water content [cm3/cm3]

PARTICLE.DAT
particle size distribution
see appendix 20

SPATIAL.DAT
spatial variability of water contents by TDR TOM2
line 1 = profile number (see appendix 5)
line 2 = depth [cm], water content [cm3/cm3]

TDR.DAT
water contents measured by TDR
line 1 = plot number, nr of days, nr of depths
line 2 = depths [cm]
line 3 = day and decimal time of June 1991, water [cm3/cm3]

TENS.DAT
tensiometer measurements (only Barrax)
line 1 = plot number
line 2 = depths [cm]
line 3 = day and decimal time of June 1991, soil water suction (absolute value) [cm]

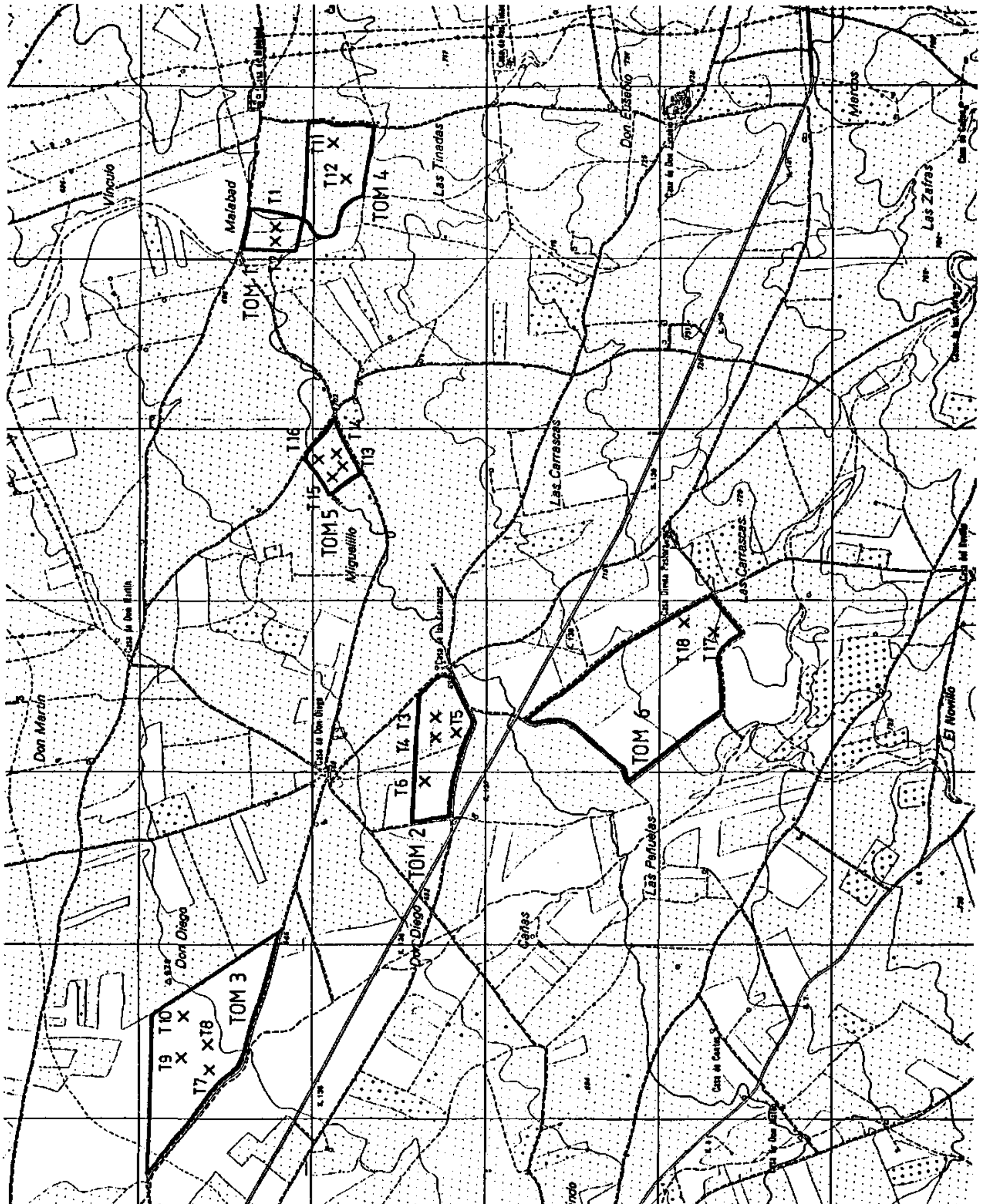
<SERIES>_4.MUL
inputfiles for program Mulstp
see appendix 17

<SERIES>_4.RES
resultfiles from program Mulstp
see appendix 17

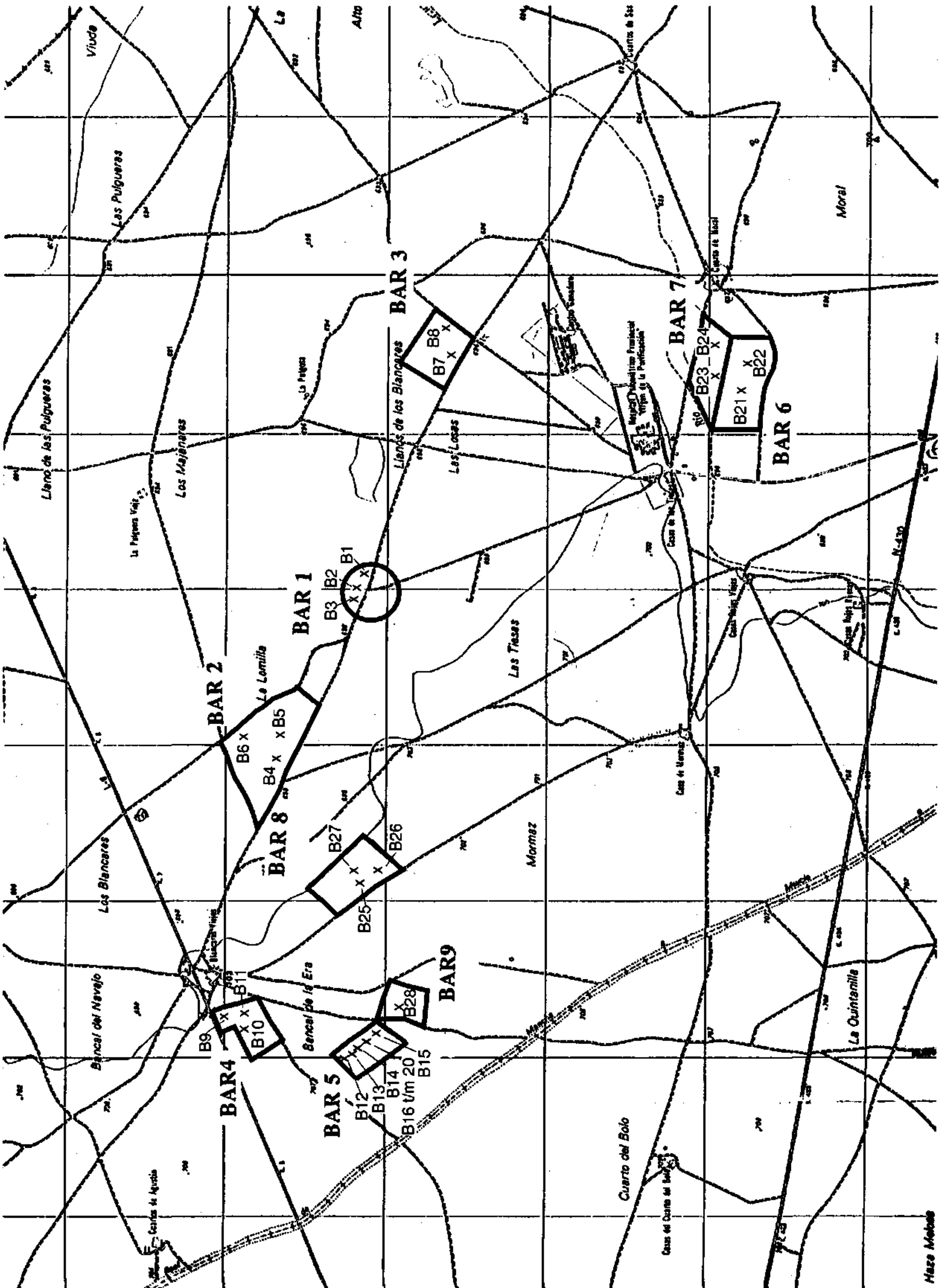
<SERIES>_4.MUL
Mualem-VanGenuchten parameters
see appendix 18

<SERIES>.ZIP
compressed file with additional optimizations
use PKUNZIP to extract

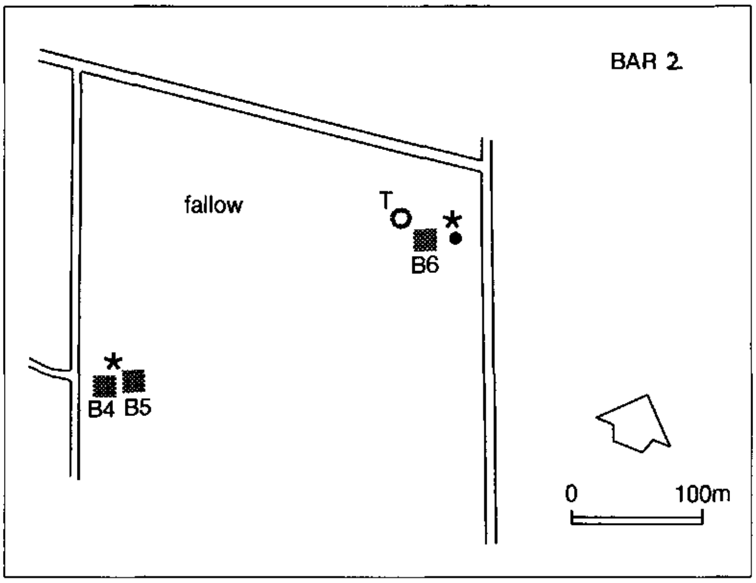
APPENDIX 2a Map of Tomelloso site.

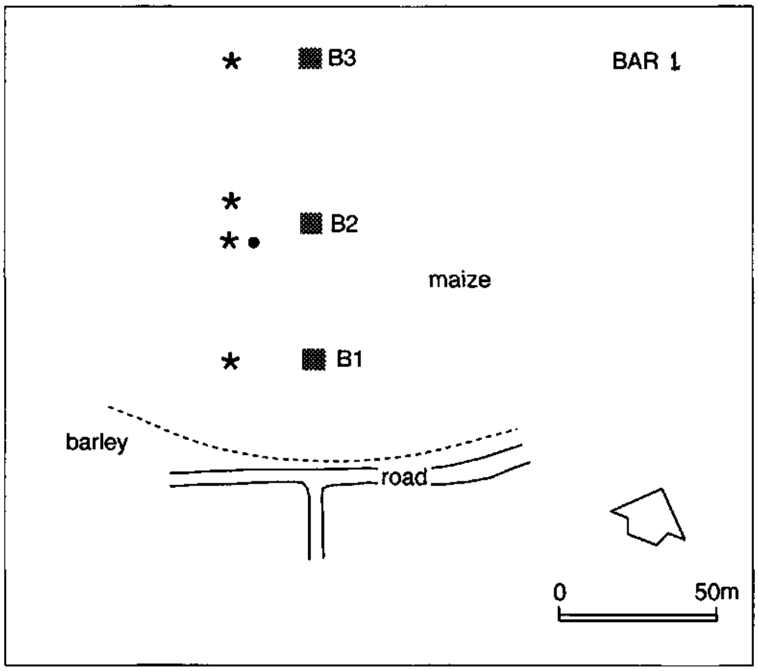


APPENDIX 2b Map of Barrax site.



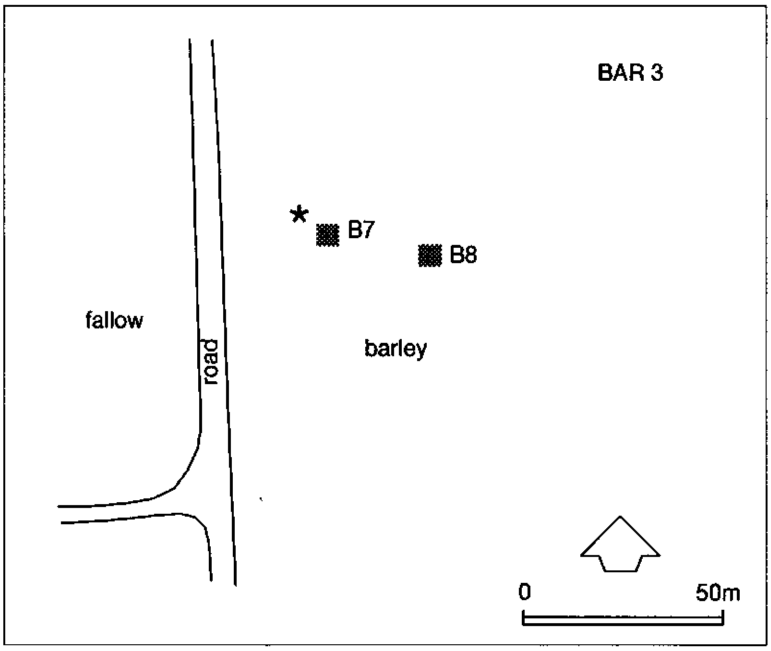
APPENDIX 3 Layout of some fields for Barrax.

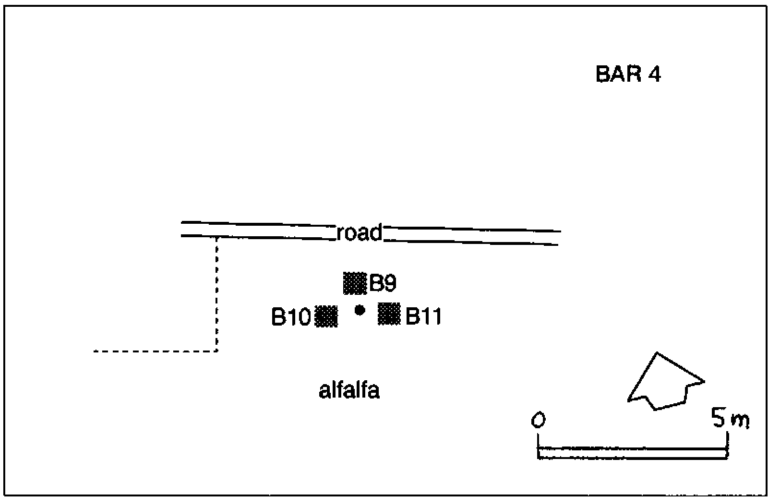




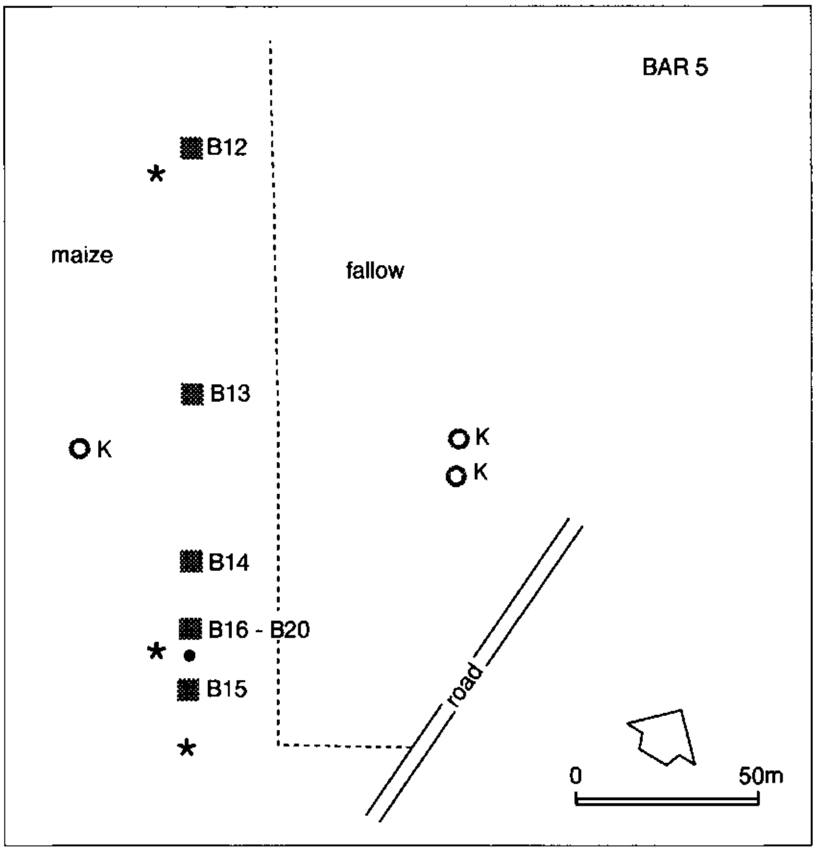
Legend:

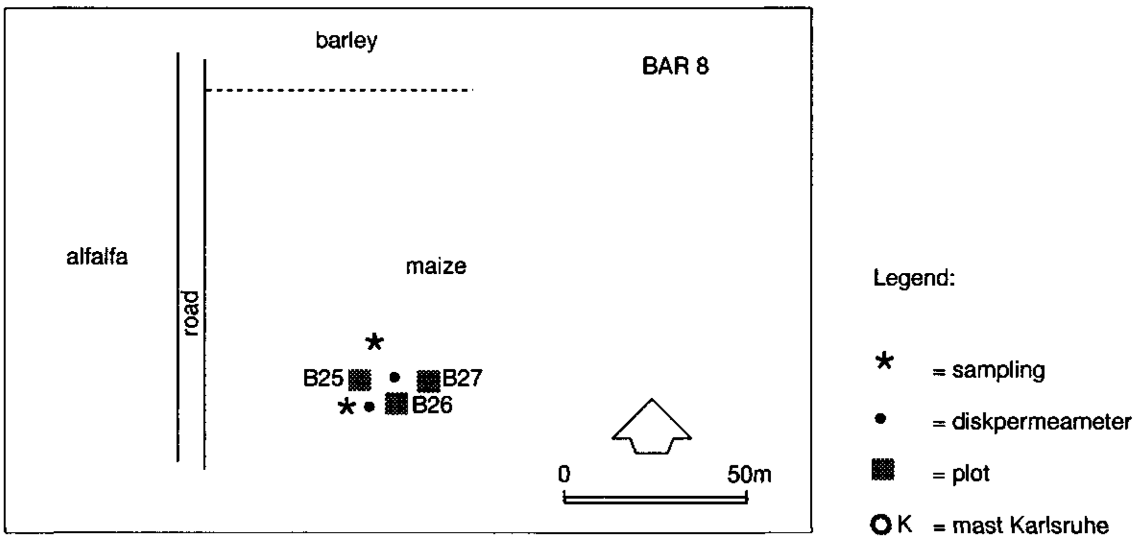
* = sampling
• = diskpermeameter
■ = plot
O = mast Toulouse





Legend:
* = sampling
• = diskpermeameter
■ = plot


BAR 5
B12
maize
fallow
B13
K
K
K
B14
B16 - B20
B15
road
0
50m


barley
BAR 8
alfalfa
road
maize
B25
B27
B26
0
50m
Legend:
* = sampling
• = diskpermeameter
= plot
K = mast Karlsruhe

APPENDIX 4 layout soil measurements.

field BAR1 (irrigated maize)

---

plot B1
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm
50 cm

---

plot B2
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
33 cm

---

plot B3
tensio 20 cm (18-6-91)
28 cm (18-6-91)
tdr 10 cm
20 cm
33 cm

---

undisturbed samples
10-15 cm ==> 3 (100 cc)
25-30 cm ==> 3 (100 cc)
10-15 cm ==> 1 (300 cc)
10-20 cm ==> 1 (600 cc)
15-25 cm ==> 1 (600 cc)

---

disturbed samples
0-10 cm ==> 3
10-20 cm ==> 3
20-30 cm ==> 3
30-40 cm ==> 3

---

disc permeameter
depth 2 cm, suction 3 cm ==> 3 disks
depth 2 cm, suction 10 cm ==> 2 disks
depth 25 cm, suction 3 cm ==> 3 disks
depth 25 cm, suction 10 cm ==> 1 disk

****

field BAR2 (fallow land)

---

plot B4
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 5 cm
10 cm
20 cm
30 cm
37 cm

---

plot B5
tensio 21 cm (18-6-91)
28 cm (18-6-91)
tdr 10 cm
20 cm
33 cm

---

plot B6 (15-6-91)
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm
40 cm

---

undisturbed samples
15-20 cm ==> 3 (100 cc)
25-30 cm ==> 6 (100 cc)
20-25 cm ==> 1 (300 cc)
25-30 cm ==> 1 (300 cc)
20-30 cm ==> 2 (600 cc)

---

disturbed samples
0-10 cm ==> 2
10-20 cm ==> 2
20-30 cm ==> 2

---

disc permeameter
depth 5 cm, suction 3 cm ==> 3 disks
depth 5 cm, suction 10 cm ==> 3 disks
depth 25 cm, suction 3 cm ==> 3 disks
depth 25 cm, suction 10 cm ==> 2 disks

---

guelph permeameter
depth 30 cm, pressure 5 and 10 cm ==> 16

---

aircraft day 19-6-91
29 points moisture content (TDR) at
depth 5, 10 and 30 cm

****

field BAR3 (dry barley)

---

plot B7
tdr 10 cm
20 cm
30 cm
40 cm

---

plot B8
tdr 5 cm
10 cm
20 cm
35 cm

---

undisturbed samples
10-15 cm ==> 6 (100 cc)

---

disturbed samples
0-10 cm ==> 2
10-20 cm ==> 2
20-30 cm ==> 2

---

disc permeameter
depth 5 cm, suction 3 cm ==> 1 disk
depth 5 cm, suction 10 cm ==> 1 disk
depth 20 cm, suction 3 cm ==> 1 disk

****

field BAR4 (irrigated alfalfa)

---

plot B9
tensio 18 cm (20-6-91)
tdr 3 cm

7 cm
18 cm

---

plot B10
tensio 21 cm (20-6-91)
tdr 5 cm
21 cm

---

plot B11
tensio 15 cm (20-6-91)
25 cm (20-6-91)
tdr 15 cm
25 cm

---

undisturbed samples
10-15 cm ==> 3 (100 cc)
20-25 cm ==> 3 (100 cc)
10-15 cm ==> 1 (300 cc)
10-20 cm ==> 1 (600 cc)

---

disturbed samples
0-10 cm ==> 1
10-20 cm ==> 1

---

disc permeameter
depth 0 cm, suction 3 cm ==> 1 disk
depth 0 cm, suction 10 cm ==> 1 disk
depth 20 cm, suction 3 cm ==> 1 disk
depth 20 cm, suction 10 cm ==> 1 disk

---

aircraft day 19-6-91
7 points moisture content (TDR) at
depth 2, 5 and 10 cm

****

field BAR5 (irrigated maize)

---

plot B12
tensio 10 cm (20-6-91)
20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm
40 cm

---

plot B13
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm

---

plot B14
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm
50 cm

---

plot B15
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm
50 cm

---

plot B16, B17, B18, B19, B20
tensio 10 cm (20-6-91)
20 cm (18-6-91)
30 cm (18-6-91)
tdr 5 cm (5 sensors)
10 cm (5 sensors)
20 cm (5 sensors)
30 cm (5 sensors)

---

undisturbed samples
5-10 cm ==> 3 (100 cc)
10-15 cm ==> 24 (100 cc)
20-25 cm ==> 22 (100 cc)
25-30 cm ==> 3 (100 cc)
10-15 cm ==> 2 (300 cc)
20-25 cm ==> 1 (300 cc)
25-30 cm ==> 1 (300 cc)
5-15 cm ==> 1 (600 cc)
10-20 cm ==> 2 (600 cc)
15-25 cm ==> 1 (600 cc)

---

disturbed samples
0-10 cm ==> 2
10-20 cm ==> 2
20-30 cm ==> 2
30-40 cm ==> 2

---

disc permeameter
depth 2 cm, suction 3 cm ==> 1 disk
depth 2 cm, suction 10 cm ==> 1 disk
depth 30 cm, suction 3 cm ==> 1 disk
depth 30 cm, suction 10 cm ==> 1 disk

---

aircraft day 19-6-91
25 points moisture content (TDR) at
depth 2, 5 and 10 cm

****

field BAR6 (irrigated barley)

---

plot B21
tdr 10 cm
20 cm
26 cm

---

plot B22
tdr 10 cm
15 cm
23 cm

---

undisturbed samples
10-15 cm ==> 3 (100 cc)
20-25 cm ==> 3 (100 cc)
10-15 cm ==> 1 (300 cc)
20-25 cm ==> 1 (300 cc)
10-20 cm ==> 1 (600 cc)

---

disturbed samples
0-10 cm ==> 2
10-20 cm ==> 2

****

field BAR7 (dry barley)

---

plot B23
tdr 10 cm
20 cm
25 cm

---

plot B24
tdr 10 cm
20 cm
25 cm

---

disturbed samples
0-10 cm ==> 2
10-20 cm ==> 2

---

aircraft day 19-6-91
9 points moisture content (TDR) at
depth 5, 10 and 25 cm

****

field BAR8 (irrigated maize)

---

plot B25
tensio 20 cm (18-6-91)
30 cm (18-6-91)
tdr 10 cm
20 cm
30 cm
50 cm

---

plot B26
tensio 20 cm
30 cm
tdr 10 cm
20 cm
30 cm
50 cm

---

plot B27 (till 15-6-91)
tdr 10 cm
20 cm
40 cm
50 cm

---

undisturbed samples
10-15 cm ==> 6 (100 cc)
25-30 cm ==> 6 (100 cc)
10-15 cm ==> 1 (100 cc)
10-20 cm ==> 1 (600 cc)
15-25 cm ==> 2 (600 cc)

---

disturbed samples
0-10 cm ==> 2
10-20 cm ==> 2
20-30 cm ==> 2
30-40 cm ==> 2

---

disc permeameter
depth 0 cm, suction 3 cm ==> 1 disk
depth 0 cm, suction 10 cm ==> 1 disk
depth 30 cm, suction 3 cm ==> 3 disks
depth 30 cm, suction 10 cm ==> 1 disk

****

field BAR9 (fallow land)

---

plot B28
tdr 5 cm
12 cm
20 cm
31 cm

---

undisturbed samples
20-25 cm ==> 2 (100 cc)
30-35 cm ==> 2 (100 cc)
10-20 cm ==> 1 (600 cc)

---

disturbed samples
0-10 cm ==> 1
10-20 cm ==> 1
20-30 cm ==> 1
30-40 cm ==> 1

****

field TOM1 (fallow land)

---

plot T1
tdr 10 cm
20 cm
30 cm
40 cm
50 cm
neutron 20 cm
30 cm
40 cm
50 cm

---

plot T2
tdr 10 cm
20 cm
30 cm
50 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm

---

undisturbed samples
35-40 cm ==> 1 (100 cc)
40-45 cm ==> 1 (100 cc)

---

disturbed samples
5-15 cm ==> 1
15-25 cm ==> 1
25-35 cm ==> 1
35-45 cm ==> 1

---

disc permeameter
depth 0 cm, suction 9 cm ==> 2 disk
depth 35 cm, suction 9 cm ==> 2 disk

****

field TOM2 (vineyard)

---

plot T3
tdr 10 cm
20 cm
30 cm
40 cm
60 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm
70 cm
80 cm

---

plot T4
tdr 10 cm
20 cm

30 cm
40 cm
50 cm
neutron 20 cm
30 cm
40 cm

---

plot T5
tdr 10 cm
20 cm
30 cm
50 cm
60 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm
70 cm

---

plot T6
tdr 10 cm
15 cm
25 cm
65 cm
neutron 20 cm
30 cm
40 cm
50 cm

---

undisturbed samples
10-15 cm ==> 1 (100 cc)
20-25 cm ==> 2 (100 cc)
25-30 cm ==> 1 (100 cc)
30-35 cm ==> 2 (100 cc)
50-55 cm ==> 4 (100 cc)
25-35 cm ==> 1 (600 cc)
40-50 cm ==> 1 (600 cc)

---

disturbed samples
5-15 cm ==> 1
15-25 cm ==> 1
25-35 cm ==> 1
35-45 cm ==> 1

---

disc permeameter
depth 0 cm, suction 9 cm ==> 8 disk
depth 20 cm, suction 9 cm ==> 1 disk
depth 25 cm, suction 9 cm ==> 2 disk

****

field TOM3 (vetch)

---

plot T7
tdr 10 cm
17 cm
26 cm
39 cm
48 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm

---

plot T8
tdr 10 cm
20 cm
30 cm
40 cm
50 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm
70 cm

---

plot T9
tdr 11 cm
20 cm
27 cm
37 cm
49 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm

---

plot T10
tdr 10 cm
20 cm
30 cm
40 cm
50 cm
neutron 20 cm
30 cm
40 cm

---

undisturbed samples
5-10 cm ==> 2 (100 cc)
10-15 cm ==> 3 (100 cc)
15-20 cm ==> 2 (100 cc)
20-25 cm ==> 4 (100 cc)
25-30 cm ==> 2 (100 cc)
30-35 cm ==> 5 (100 cc)

---

disturbed samples
5-15 cm ==> 1
15-25 cm ==> 1
25-35 cm ==> 1
35-45 cm ==> 1

---

disc permeameter
depth 0 cm, suction 6 cm ==> 5 disk
depth 20 cm, suction 6 cm ==> 1 disk
depth 30 cm, suction 6 cm ==> 3 disk

****

field TOM4 (vineyard)

---

plot T11
tdr 13 cm
23 cm
48 cm
72 cm

---

plot T12
tdr 10 cm
20 cm
30 cm
40 cm
55 cm

---

disturbed samples
5-15 cm ==> 1
15-25 cm ==> 1
25-35 cm ==> 1
35-45 cm ==> 1

****

field TOM5 (vineyard)

---

plot T13
tdr 10 cm
20 cm
30 cm
40 cm
55 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm
70 cm
80 cm

---

plot T14
tdr 8 cm
25 cm
40 cm
50 cm
65 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm
70 cm
80 cm

---

plot T15
tdr 10 cm
20 cm
30 cm
40 cm
50 cm
neutron 20 cm
30 cm
40 cm

---

plot T16
tdr 10 cm
15 cm
33 cm
48 cm
80 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm

---

undisturbed samples
15-20 cm ==> 1 (100 cc)
20-25 cm ==> 3 (100 cc)
25-30 cm ==> 1 (100 cc)
30-35 cm ==> 3 (100 cc)
35-40 cm ==> 2 (100 cc)
45-50 cm ==> 2 (100 cc)
50-55 cm ==> 1 (100 cc)
55-60 cm ==> 2 (100 cc)
70-75 cm ==> 1 (100 cc)
cm ==> 2 (600 cc)

---

disturbed samples
5-15 cm ==> 1
15-25 cm ==> 1
25-35 cm ==> 1
35-45 cm ==> 1

---

disc permeameter
depth 0 cm, suction 10 cm ==> 4 disk
depth 30 cm, suction 10 cm ==> 2 disk
depth 35 cm, suction 10 cm ==> 2 disk

****

field TOM6 (vineyard)

---

plot T17
tdr 10 cm
20 cm
30 cm
40 cm
55 cm
neutron 20 cm
30 cm
40 cm
50 cm
60 cm
70 cm

---

plot T18
tdr 9 cm
19 cm
38 cm
51 cm
66 cm
neutron 20 cm
30 cm
40 cm

---

undisturbed samples
20-25 cm ==> 1 (100 cc)
25-30 cm ==> 1 (100 cc)
30-35 cm ==> 1 (100 cc)
40-45 cm ==> 4 (100 cc)
45-50 cm ==> 1 (100 cc)
55-60 cm ==> 1 (100 cc)

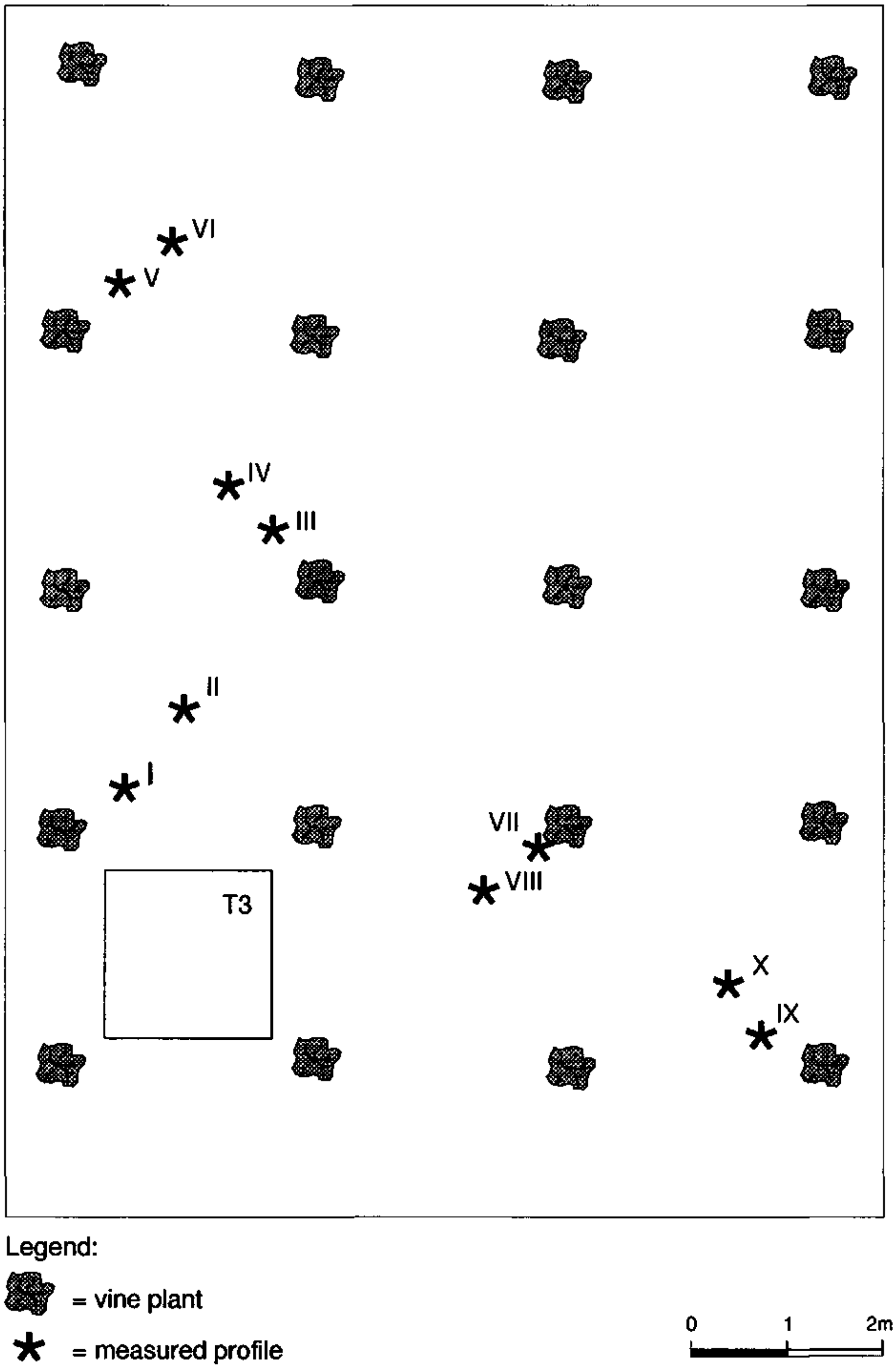
---

disturbed samples
5-15 cm ==> 1
15-25 cm ==> 1
25-35 cm ==> 1
35-45 cm ==> 1
****
****

TOTAL

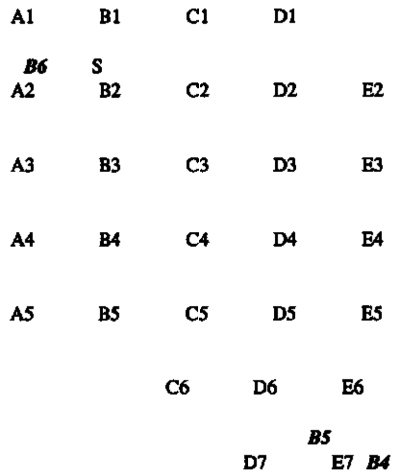
activity	Barrax	Tomelloso	total	category
tensiometers	32	0	32	sensors
tdr	100	91	191	sensors
neutron probe	0	79	79	points
undisturbed samples	102	56	158	100 cc rings
	10	0	10	300 cc rings
	14	5	19	600 cc rings
disc permeameter	37	32	69	measurements
guelphpermeameter	16	0	16	measurements

APPENDIX 5 Layout spatial variability TOM2.



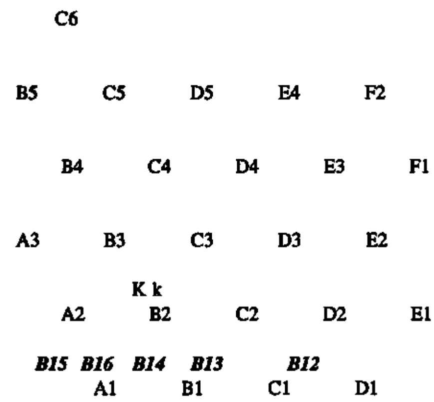
APPENDIX 6 Layout grids surface moisture content measurements at June 19.

Field BAR2



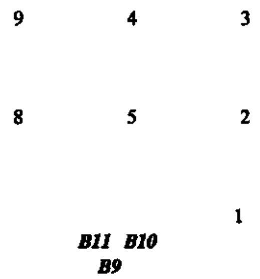
Grid distance = 40 m
A1 - E7 = moisture content measurement at 5, 10 and 30 cm
B4* - *B6 = regularly monitoring plots
S = Samer station

Field BAR5



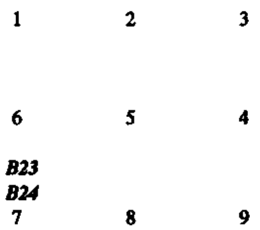
Grid distance = 40 m
A1 - F2 = moisture content measurement at 2, 5 and 10 cm
B12* - *B16 = regularly monitoring plots
K = main mast Karlsruhe
k = small mast Karlsruhe

Field BAR4



Grid distance = 100 m
1 - 9 = moisture content measurement at 2, 5 and 10 cm
B9* - *B11 = regularly monitoring plots

Field BAR7



Grid distance = 100 m
1 - 9 = moisture content measurement at 5, 10 and 20 or 25 cm
B23 - B24 = regularly monitoring plots

Field TOM1

S s

T2 *T1*

W

1	4	5	6
2	9	8	7
3	10	11	12
16	15	14	13

Grid distance = 60 m
1 - 16 = moisture content measurement at 5, 10 and 30 cm
T1* - *T2 = regularly monitoring plots
W = 'Wallingford' mast
S = Radiation mast 'Wageningen'
s = Temperature mast 'Wageningen'

Field TOM2

	1	16	17	32	33
	2	15	18	31	34
	3	14	19	30	35
	4	13	20	29	36
A					
	5	12	21	28	37
	6	11	22	27	38
	7	10	23	26	39
	8	9	24	25	40

Grid distance = horizontal 41.25 m
vertical 44 m
1 - 40 = moisture content measurement at 5, 15 and 25 cm
A = 'University of Amsterdam' mast

Field TOM3

T7
1 14 15

2 13 16
T8

3 12 17

T9
4 11 18

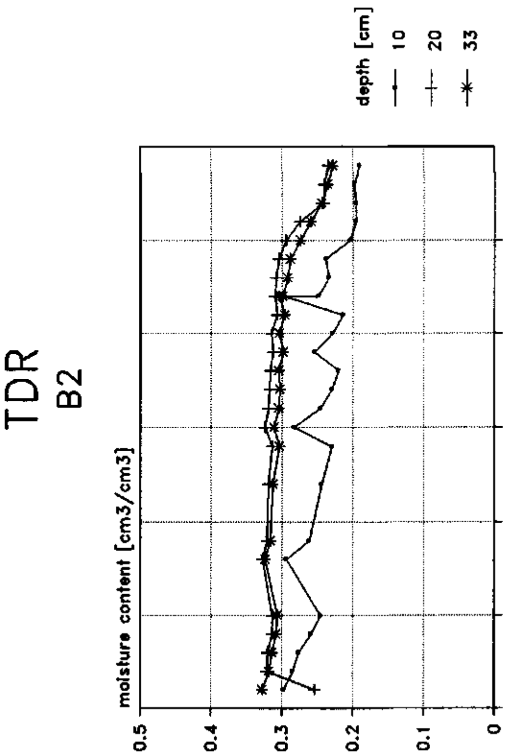
5 10 19
T10

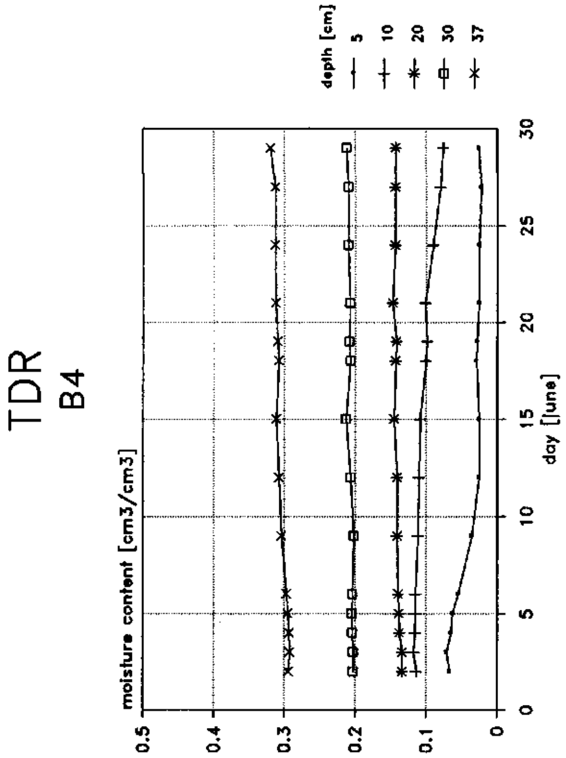
6 9 20

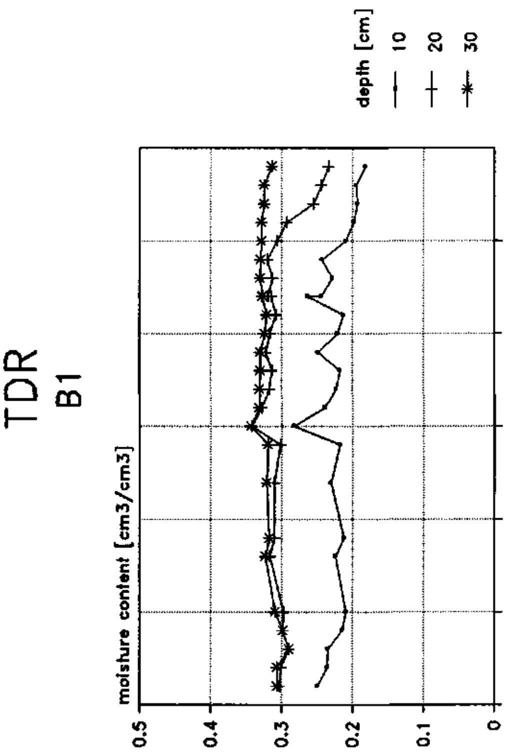
7 8 21

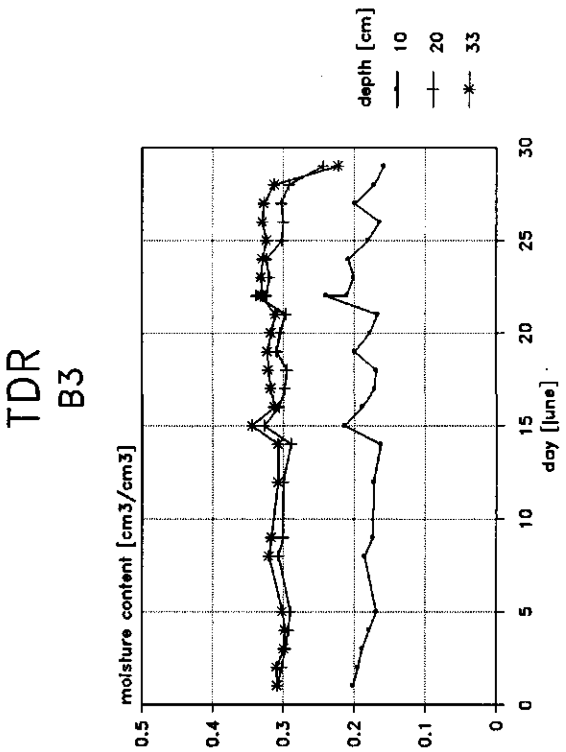
Grid distance = 50 m
1 - 21 = moisture content measurement at 5, 15 and 25 cm
T7* - *T10 = regularly monitoring plots

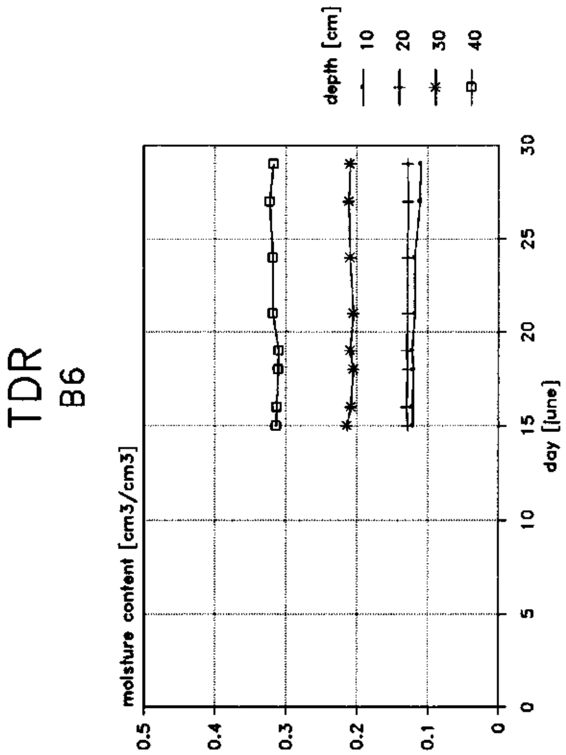
APPENDIX 7 Soil moisture profiles by TDR.

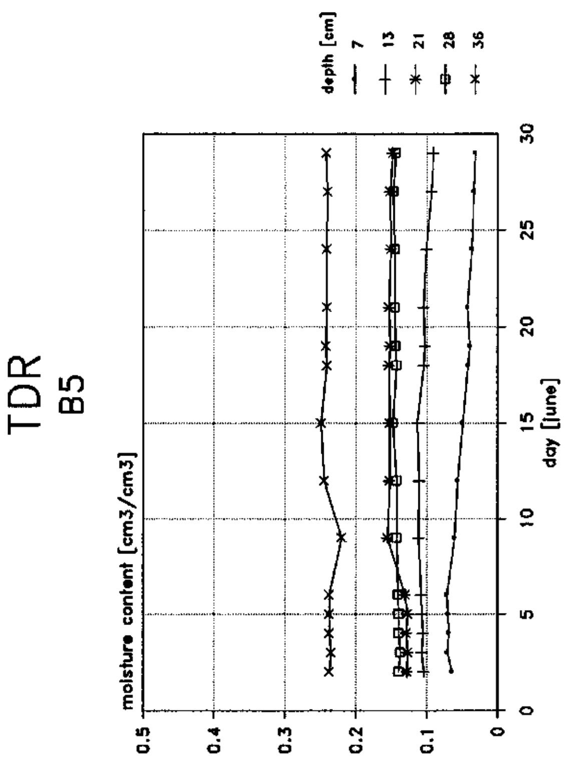


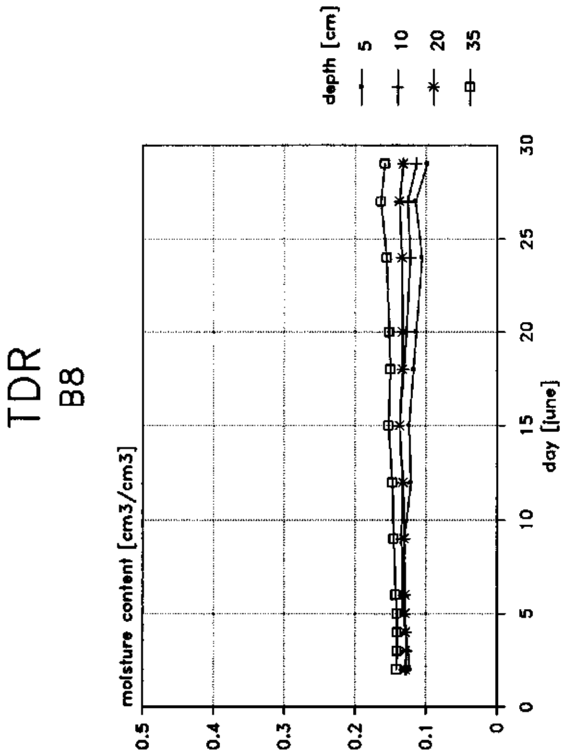


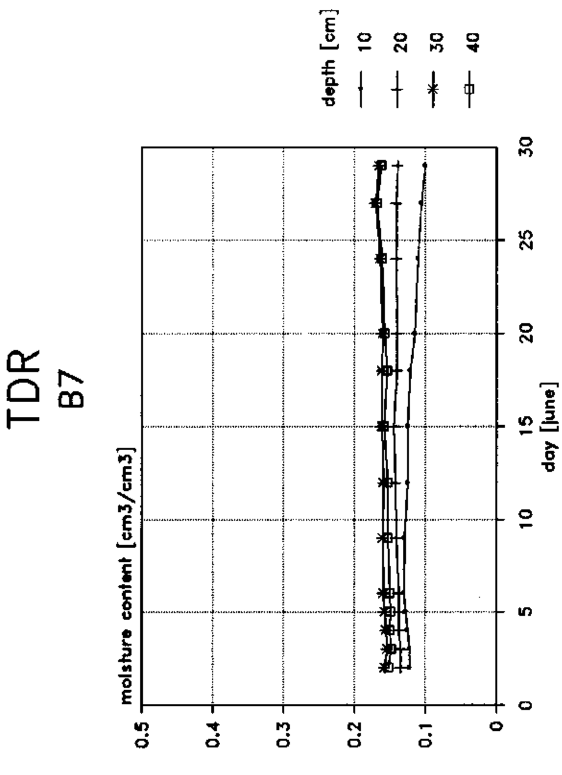


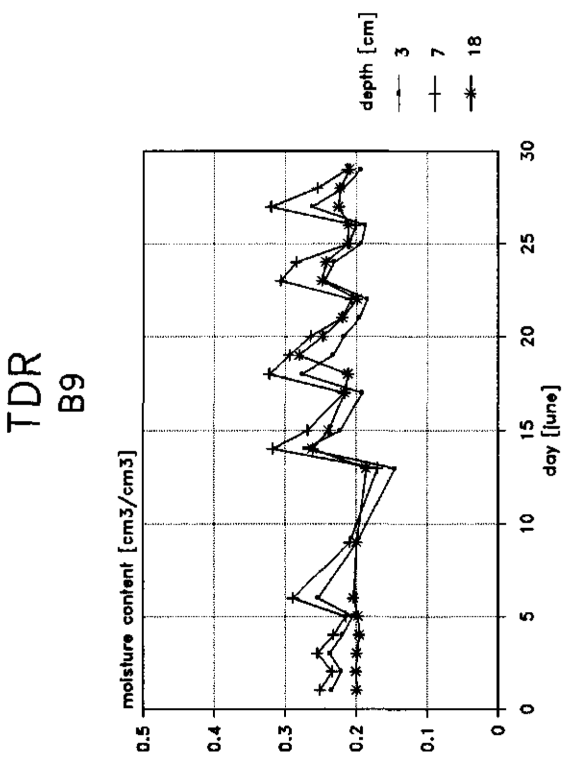


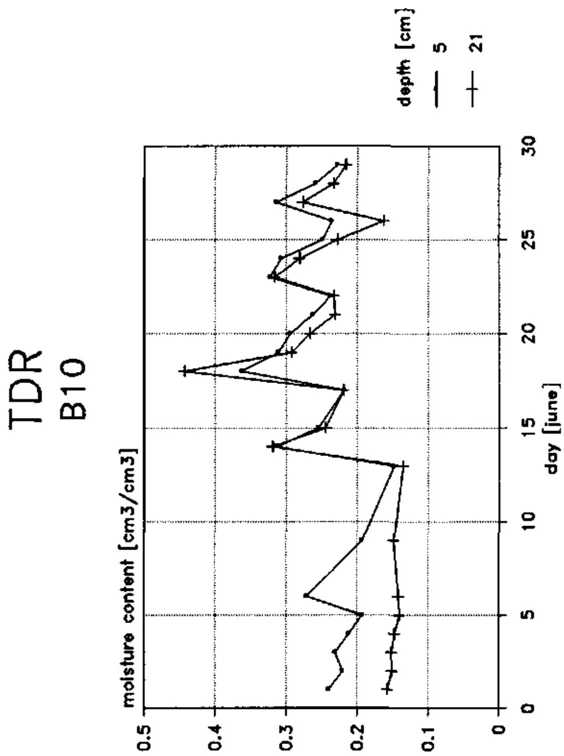

TDR
B6
moisture content [cm3/cm3]
day [june]
depth [cm]
10
20
30
40

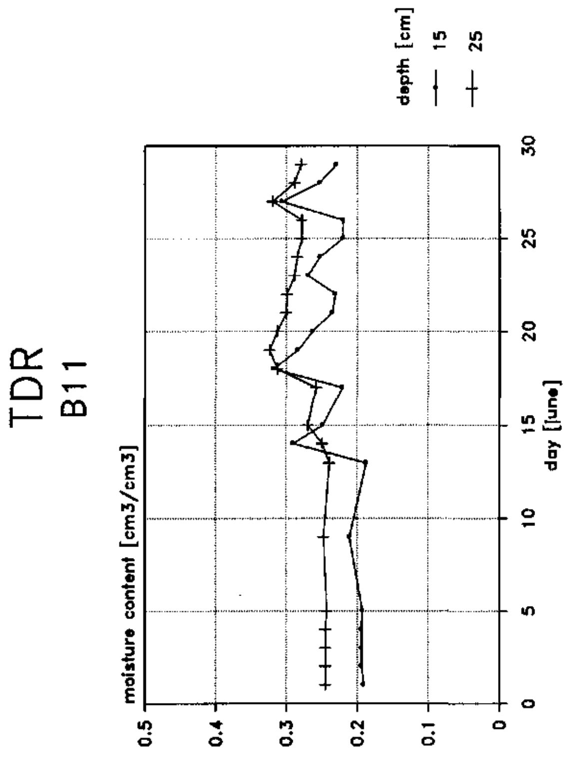

TDR
B5
moisture content [cm3/cm3]
day [june]
depth [cm]
7
13
21
28
36

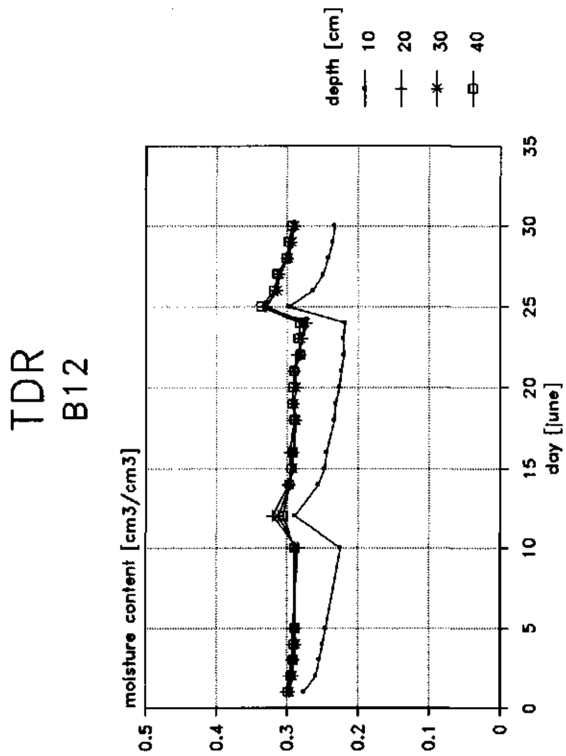

TDR
B8
moisture content [cm3/cm3]
day [june]
depth [cm]
5
10
20
35


TDR
B7
moisture content [cm3/cm3]
day [june]
depth [cm]
10
20
30
40

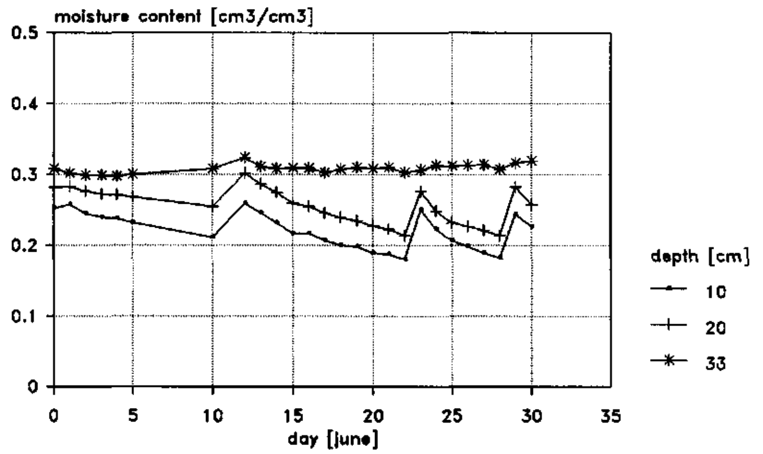

TDR
B9
moisture content [cm3/cm3]
day [june]
depth [cm]
3
7
18


TDR
B10
moisture content [cm3/cm3]
day [june]
depth [cm]
5
21

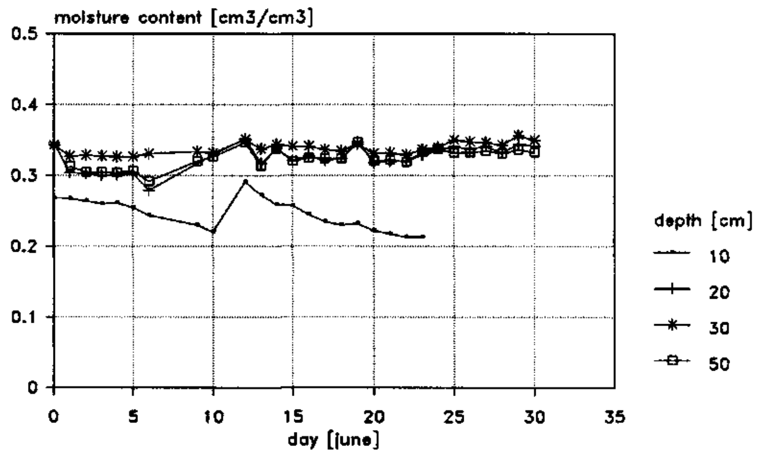

TDR
B11
moisture content [cm3/cm3]
day [june]
depth [cm]
15
25


TDR
B12
moisture content [cm3/cm3]
day [june]
depth [cm]
10
20
30
40

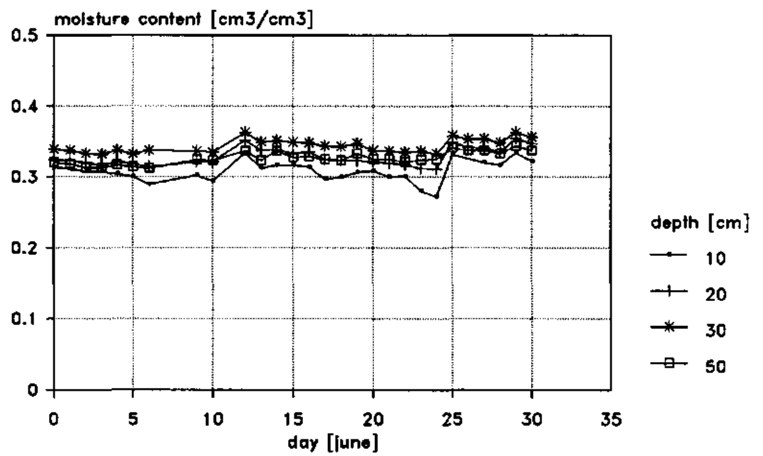
TDR
B13



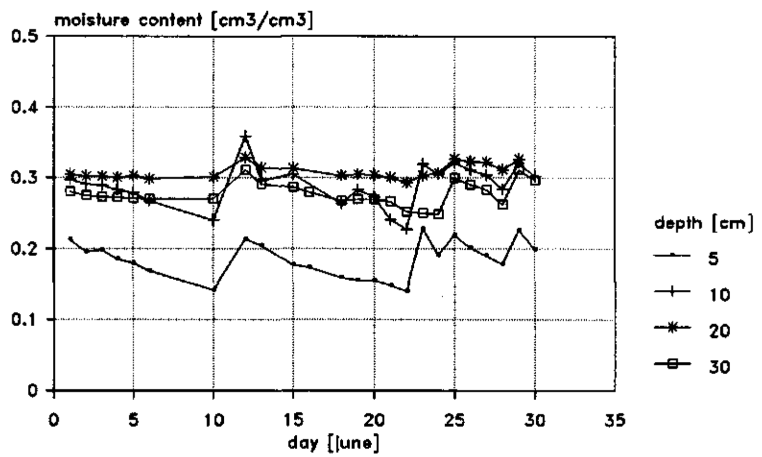
TDR
B14



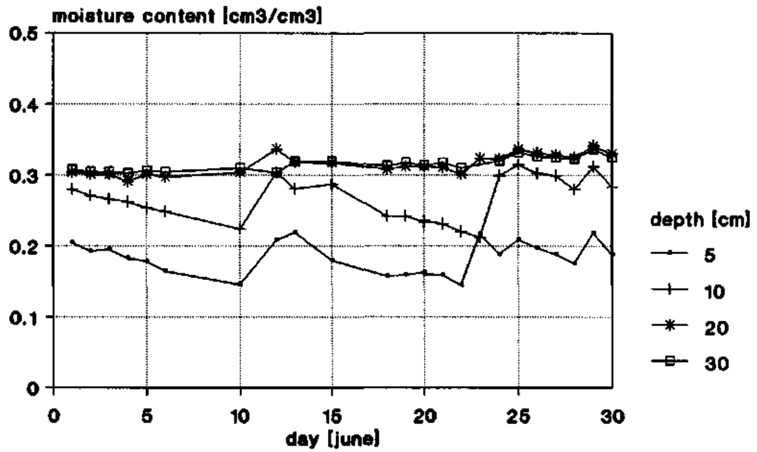
TDR
B15



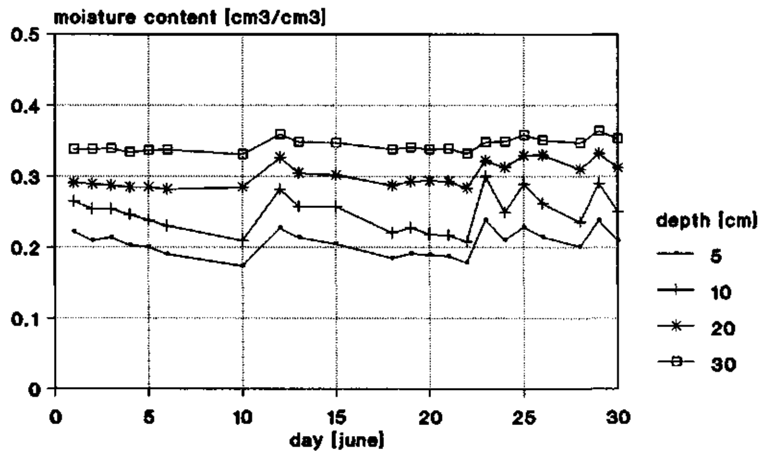
TDR
B16



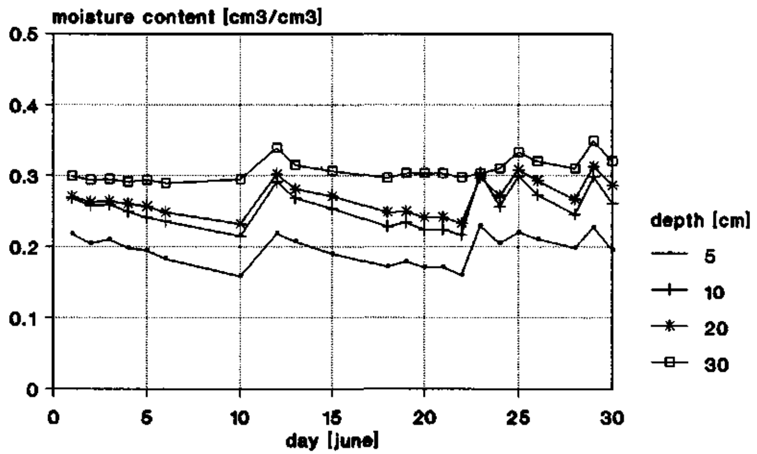
TDR
B17



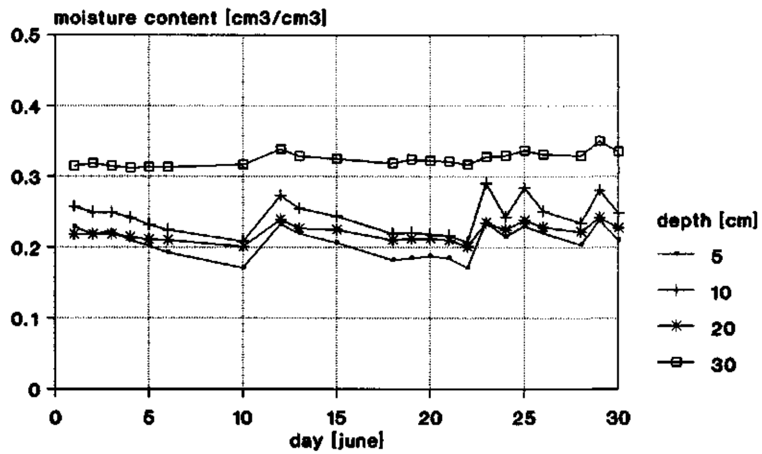
TDR
B18



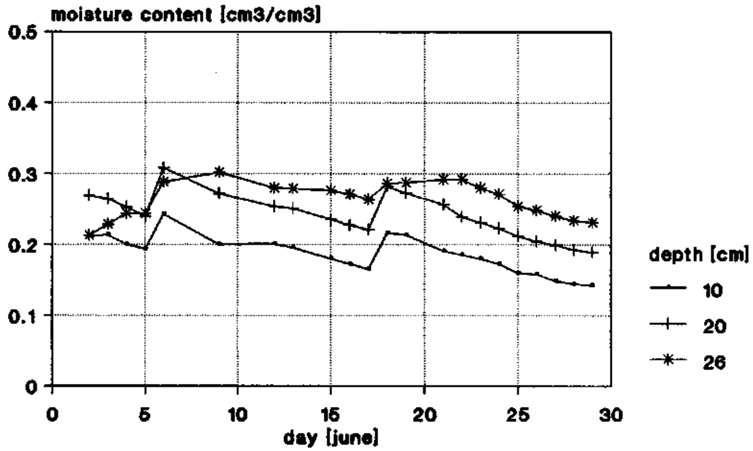
TDR
B19



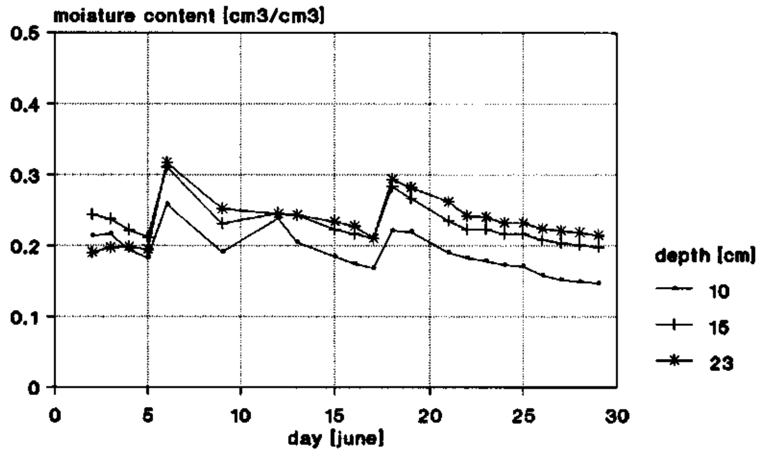
TDR
B20



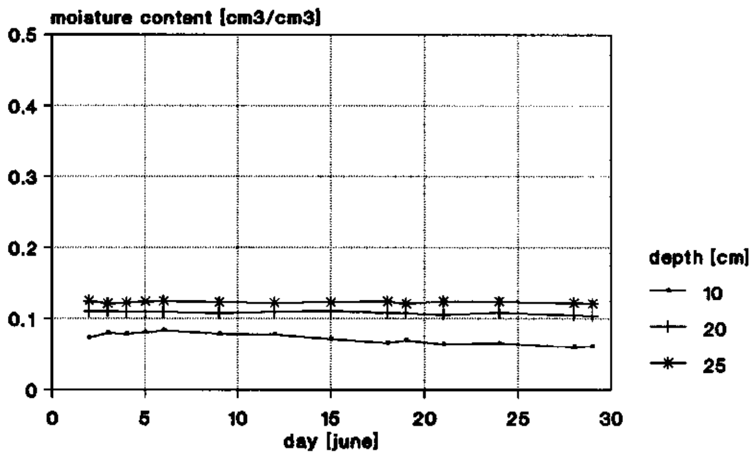
TDR
B21



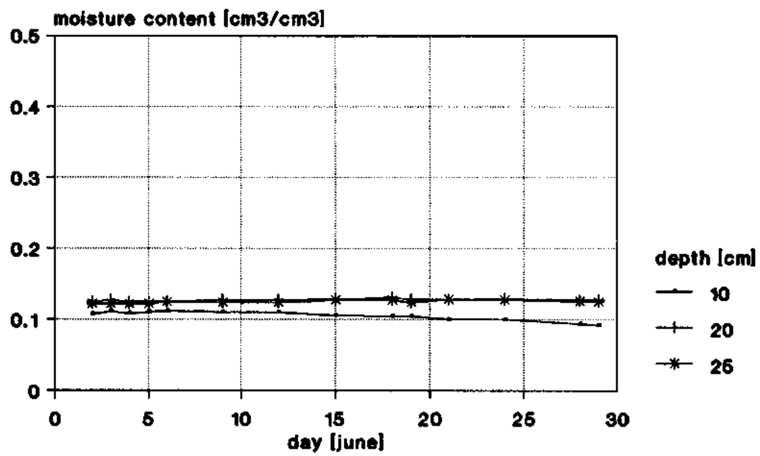
TDR
B22



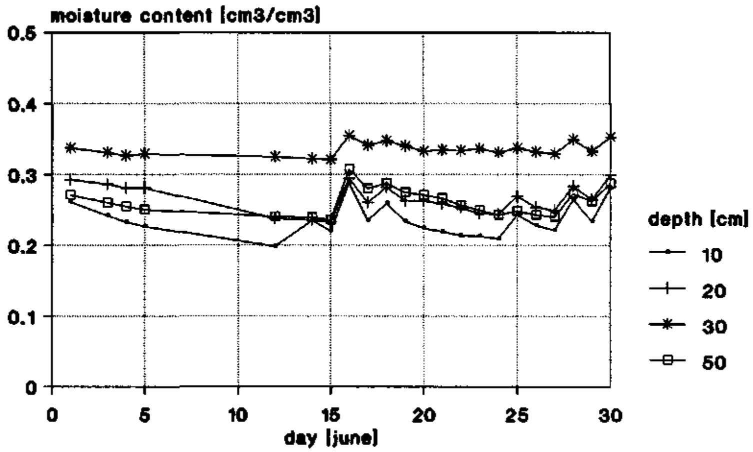
TDR
B23



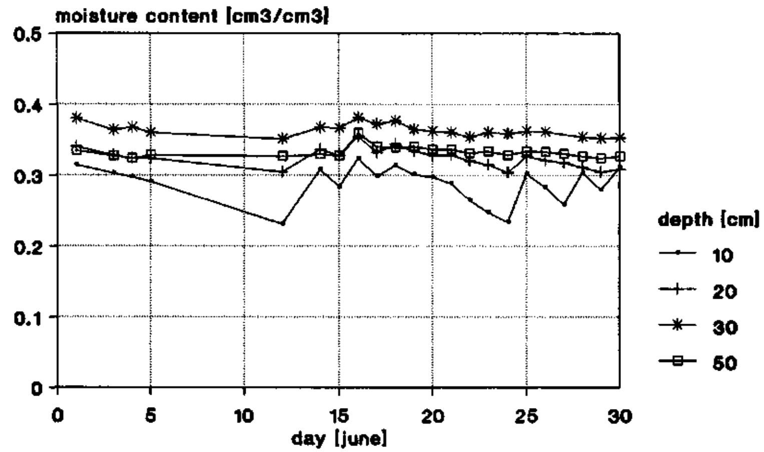
TDR
B24



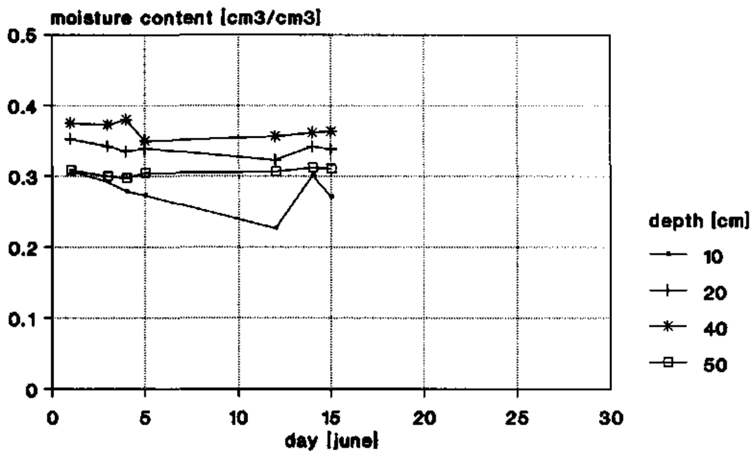
TDR
B25



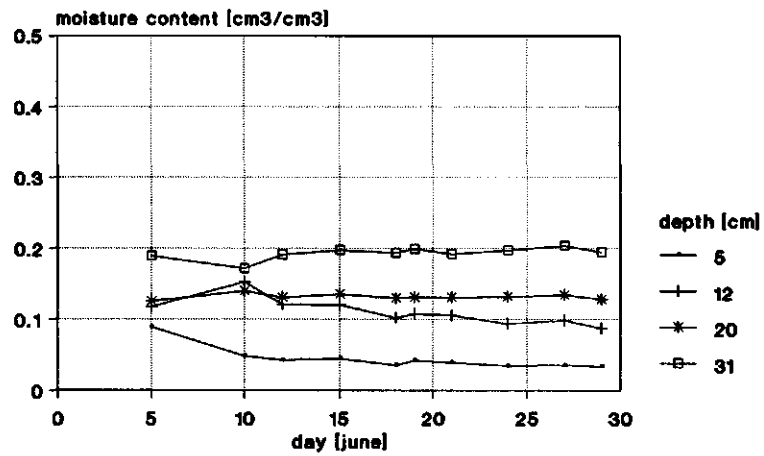
TDR
B26



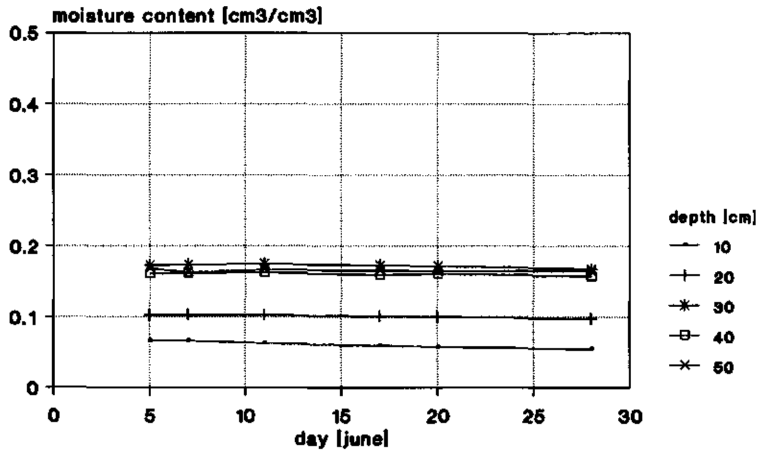
TDR
B27



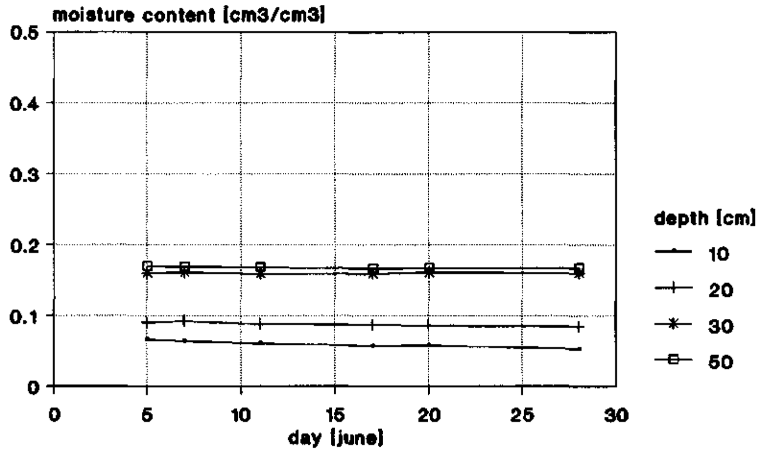
TDR
B28



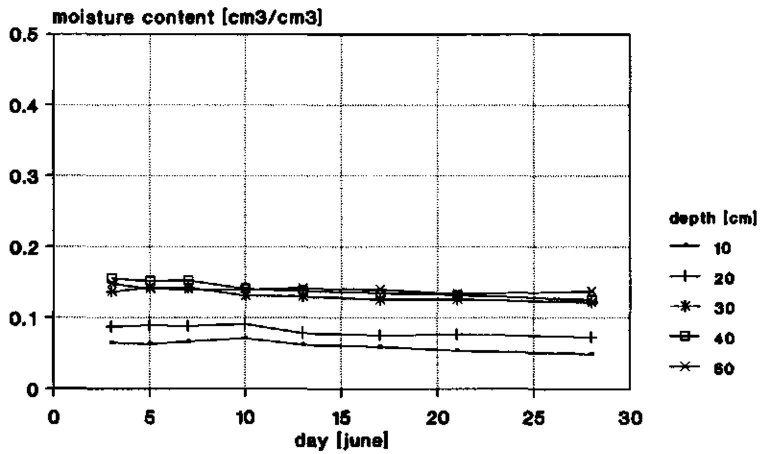
TDR
T1



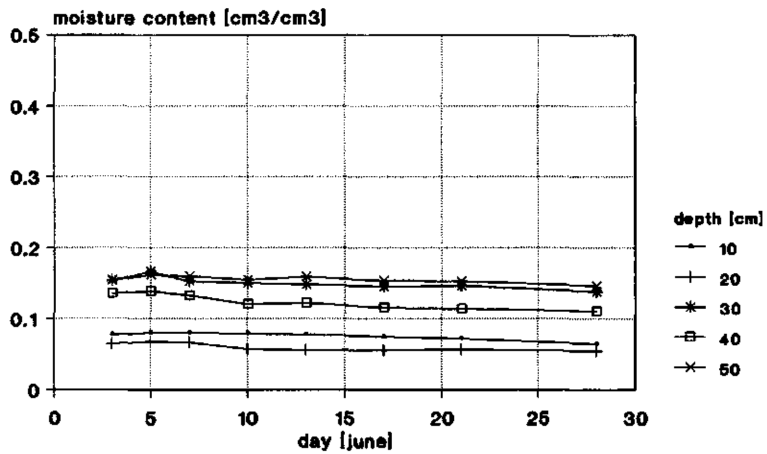
TDR
T2

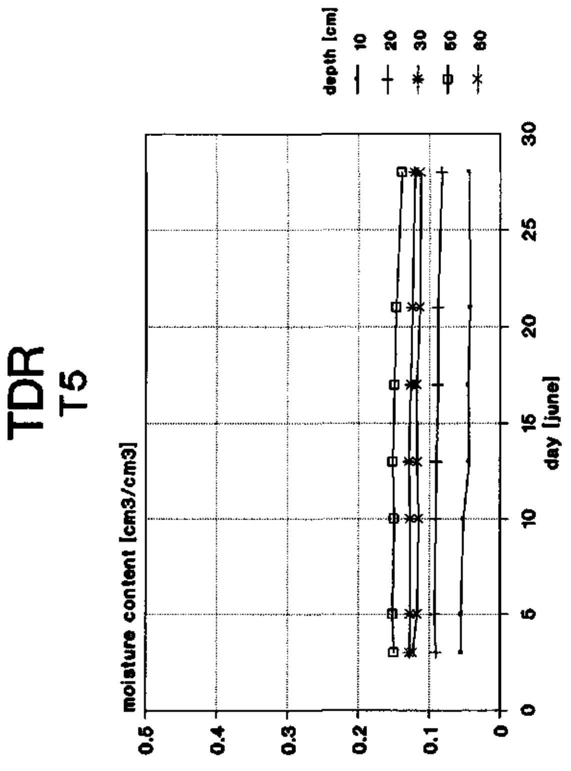


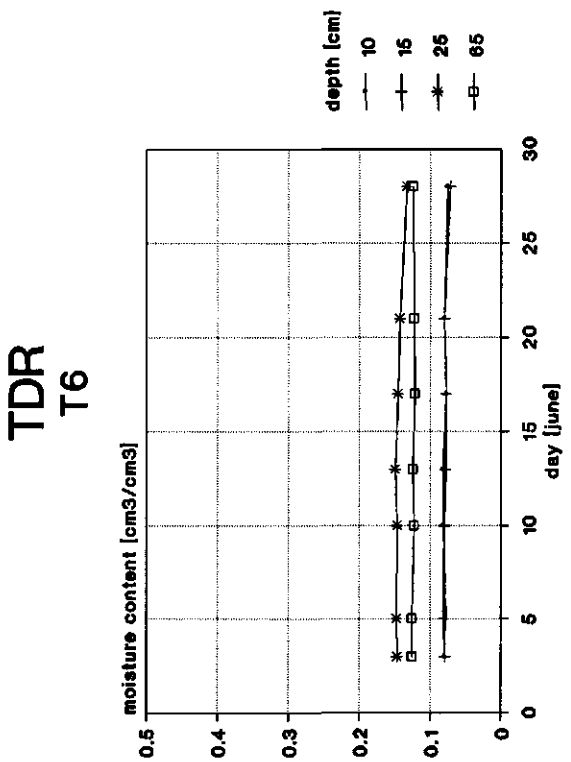
TDR
T3

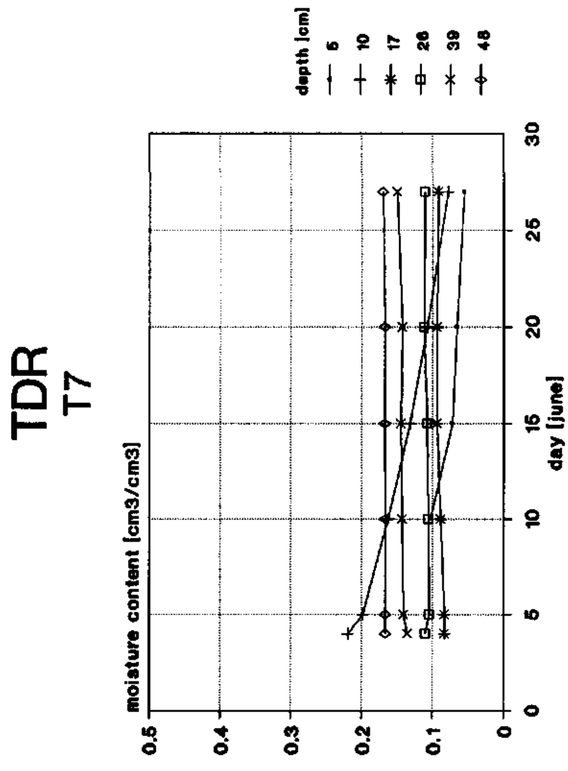


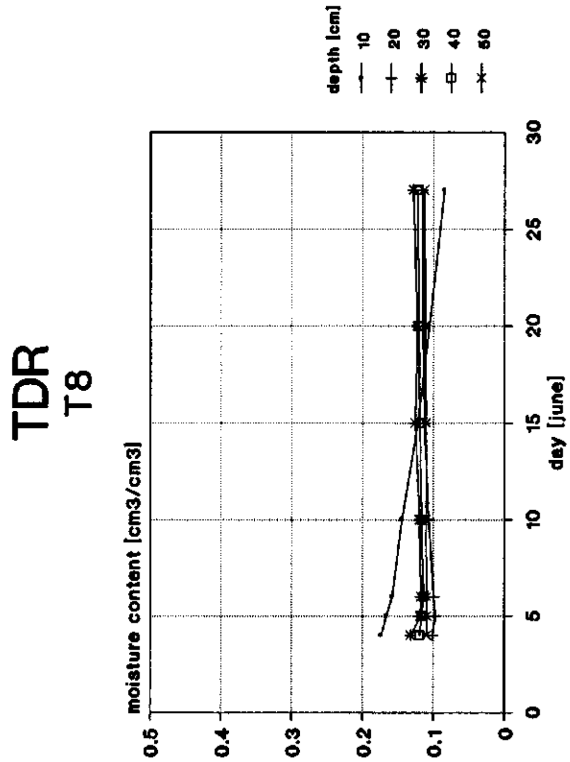
TDR
T4



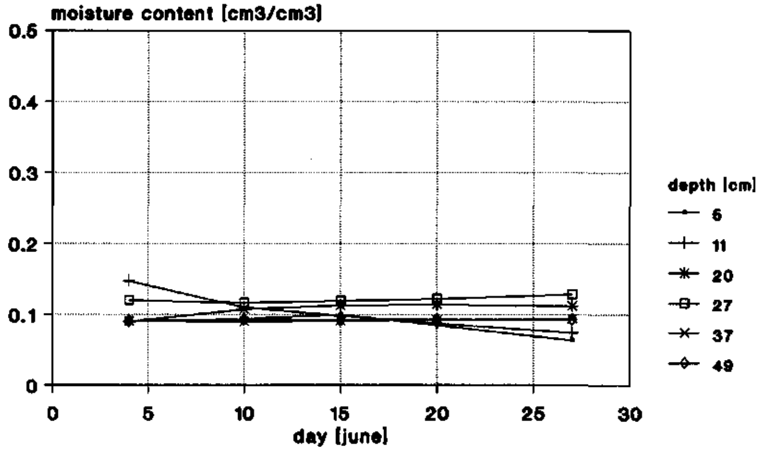

TDR
T5
moisture content [cm3/cm3]
day [june]
depth [cm]
10
20
30
50
60


TDR
T6
moisture content [cm3/cm3]
day [june]
depth [cm]
10
15
25
65

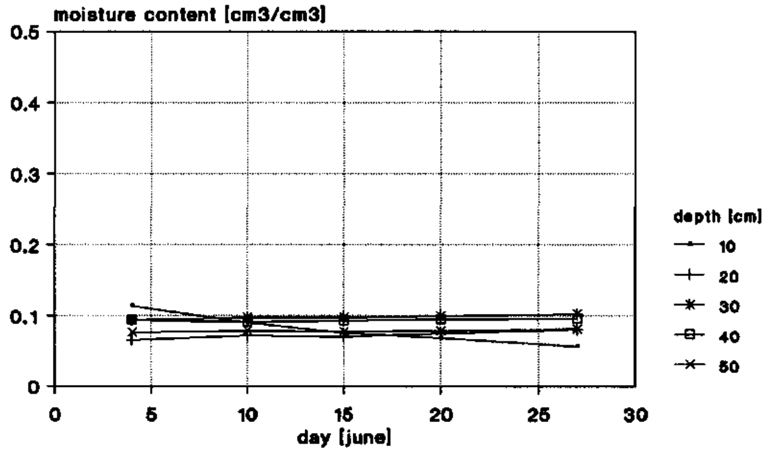

TDR
T7
moisture content [cm3/cm3]
day [june]
depth [cm]
5
10
17
28
39
48


TDR
T8
moisture content [cm3/cm3]
day [june]
depth [cm]
10
20
30
40
50

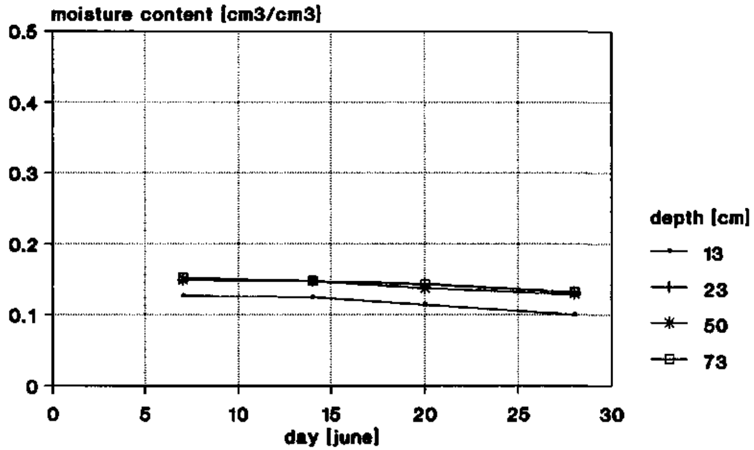
TDR
T9



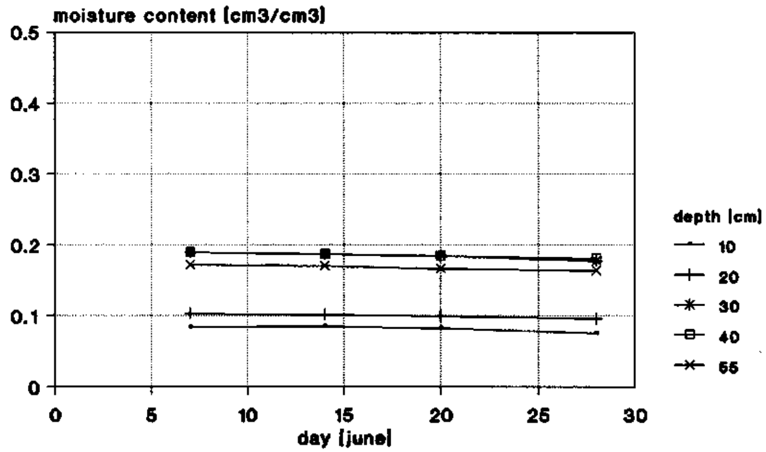
TDR
T10



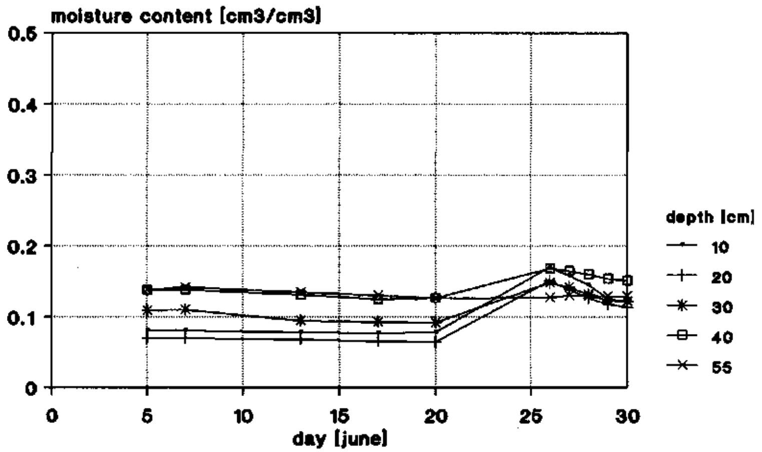
TDR
T11



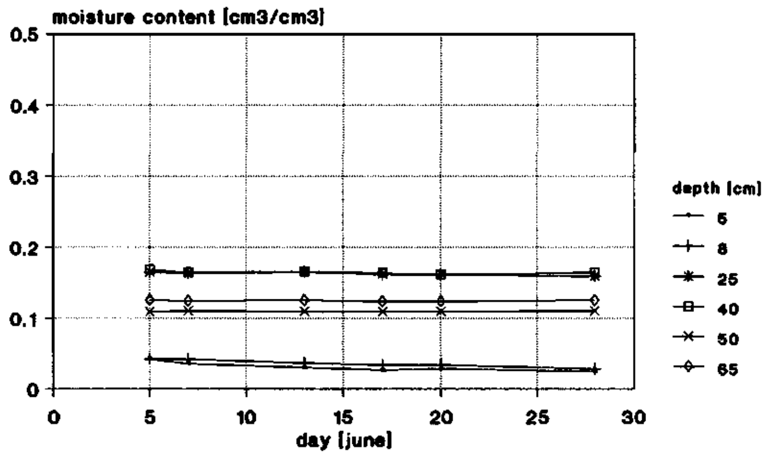
TDR
T12



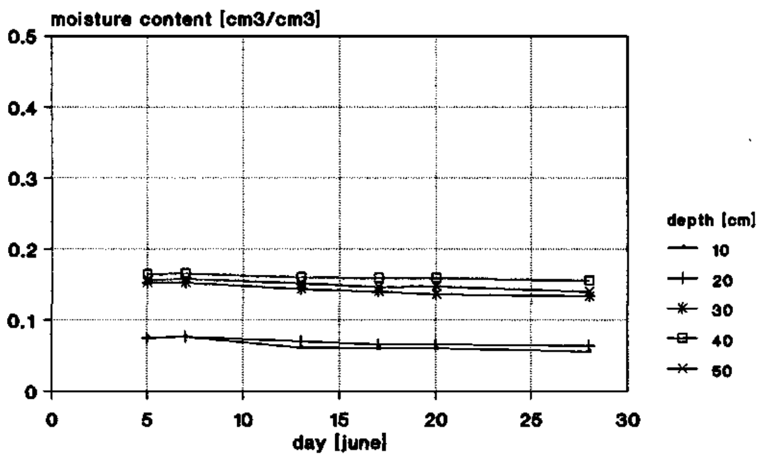
TDR
T13



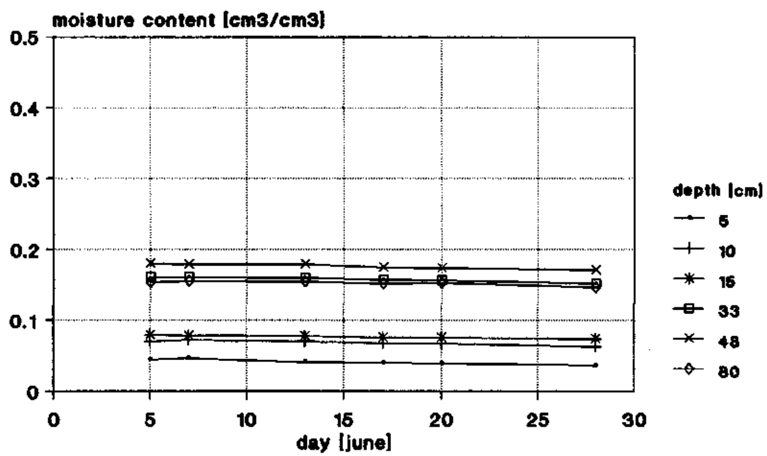
TDR
T14



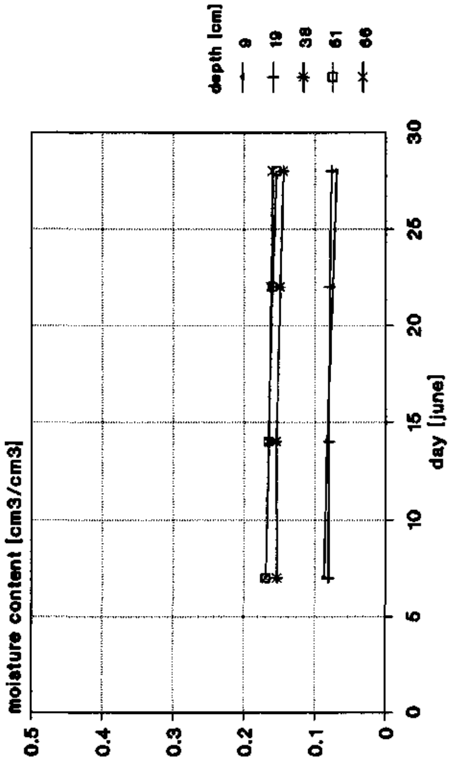
TDR
T15



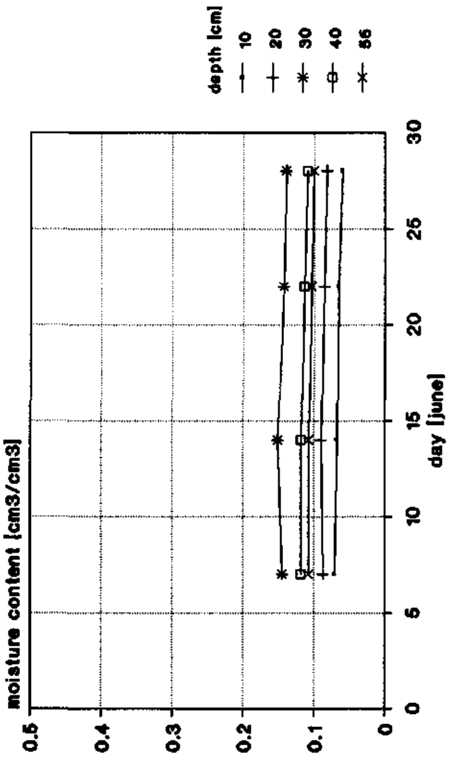
TDR
T16



TDR
T18



TDR
T17



APPENDIX 8 Results spatial variability TOM2.

volumetric moisture contents in %

depth	I	II
60	15.4	14.9
50	11.8	14.3
40	16.5	16.0
30	16.9	12.8
20	9.5	7.3
10	6.7	5.6
5	3.8	3.8
2	2.7	1.2
	III	IV
60	12.3	12.8
50	15.9	13.0
40	15.0	12.5
30	16.0	10.3
20	11.0	7.6
10	5.6	3.6
5	4.2	2.8
2	1.7	1.7
	V	VI
60	13.3	13.0
50	13.9	15.6
40	12.0	16.4
30	13.4	15.7
20	6.5	7.9
10	5.3	5.1
5	2.9	4.0
2	1.4	1.9
	VII	VIII
60	13.9	14.6
50	15.9	13.4
40	13.4	13.4
30	12.2	15.1
20	10.3	7.0
10	6.7	5.4
5	3.7	4.2
2	2.0	1.3
	IX	X
60	12.3	10.0
50	15.8	15.5
40	12.7	15.2
30	12.0	16.6
20	7.8	7.2
10	5.2	6.0
5	2.9	4.3
2	2.1	2.3

APPENDIX 9 Results moisture contents on June 19.

volumetric moisture contents in %

BAR2 8:20-10:35 h

point	TDR 5cm	TDR 10cm	TDR 30cm	crust	vol 0-5cm	vol 5-10cm
A1	3.0	6.5	20.7	3.5	4.4	15.4
A2	4.3	6.8	10.2	3.0	3.6	10.4
A3	4.5	6.0	16.6	2.3	4.8	9.4
A4	3.7	7.9	22.5	3.4	4.7	12.0
A5	3.9	9.0	12.3	4.2	5.7	10.7
B1	2.3	5.5	16.6	4.2	4.2	10.0
B2	2.9	7.0	20.2	2.9	3.7	10.2
B3	2.7	7.0	18.8	3.0	4.8	11.7
B4	4.4	6.4	15.6	2.8	4.5	7.8
B5	4.1	7.1	16.1	3.8	5.8	11.9
C1	3.1	6.4	14.1	3.5	3.8	9.6
C2	5.5	9.3	14.2	3.7	4.3	10.9
C3	2.2	7.6	16.7	2.5	4.3	7.7
C4	3.8	5.6	14.5	4.0	4.9	12.2
C5	2.4	7.4	17.1	3.4	6.6	9.8
C6	3.5	7.7	13.6	0.0	5.5	8.9
D1	3.7	6.2	22.1	2.2	3.2	9.6
D2	2.4	7.1	18.4	3.1	4.3	10.1
D3	3.9	9.1	20.7	3.3	4.5	13.0
D4	3.5	6.0	18.3	3.8	5.3	12.5
D5	3.6	8.9	12.9	4.3	5.4	10.2
D6	3.3	5.6	12.1	3.0	4.5	12.3
D7	2.6	6.7	11.6	0.0	3.9	10.4
E2	3.2	7.5	14.3	3.1	4.7	12.0
E3	5.3	8.5	10.5	2.8	7.0	14.5
E4	3.7	5.4	13.1	4.0	5.3	10.3
E5	3.6	7.0	11.7	2.6	5.8	12.5
E6	3.0	6.7	16.8	0.0	5.2	10.0
E7	2.6	10.1	20.7	2.0	6.9	10.7

BAR4 15:30-16:20 h

point	2cm	5cm	10cm
1	14.7	27.9	31.2
2	29.2	31.8	34.6
3	31.1	29.7	32.1
4	26.5	32.3	33.9
5	19.5	33.1	32.4
6	==	==	==
7	==	==	==
8	17.5	28.7	28.6
9	23.9	31.3	33.1

BAR5 12:30-14:15 h

point	TDR 2cm	TDR 5cm	TDR 10cm	crust	vol 0-5cm	vol 5-10cm
A1	11.2	17.5	24.1	4.9	13.0	20.1
A2	10.3	15.6	19.0	5.6	15.2	23.0
A3	11.8	20.7	29.7	5.9	15.0	20.2

B1	11.9	13.7	27.3	4.7	11.0	18.2	
B2	0.0	0.0	19.8	3.9	14.5	20.8	
B3	10.7	14.5	16.2	3.6	13.2	21.9	
B4	8.2	16.1	28.6	3.6	12.6	22.0	
B5	11.9	15.2	22.1	4.9	12.4	17.7	
C1	14.2	19.5	28.8	0.0	16.4	21.5	irrigated
C2	8.6	12.3	19.8	2.7	12.7	19.3	
C3	10.3	13.9	21.1	4.0	13.1	20.4	
C4	13.6	20.3	29.7	3.7	14.0	22.8	
C5	10.6	17.1	30.1	4.5	15.2	21.3	
C6	10.7	12.3	23.8	4.9	13.1	18.7	
D1	18.7	23.1	30.0	0.0	21.0	23.8	irrigated
D2	18.3	23.5	28.2	0.0	15.1	21.7	irrigated
D3	10.2	19.7	28.3	0.0	17.7	24.8	irrigated
D4	14.3	21.7	25.2	3.5	10.6	20.7	
D5	13.7	18.8	24.2	5.8	12.1	22.3	
E1	14.1	18.1	32.5	0.0	16.2	21.8	irrigated
E2	13.0	15.2	23.9	0.0	18.6	20.3	irrigated
E3	12.8	21.6	31.4	0.0	20.2	29.4	irrigated
E4	16.4	30.7	32.1	0.0	26.0	26.6	irrigated
F1	25.5	28.5	32.3	0.0	20.1	24.8	irrigated
F2	13.1	17.7	25.9	0.0	19.8	24.5	irrigated

BAR7 6:15-7:00 h

point	5cm	10cm	20cm	25cm
1	5.4	8.4	9.6	==
2	5.5	9.5	==	14.8
3	6.0	9.1	==	14.9
4	7.4	9.7	==	==
5	5.1	10.9	==	==
6	5.7	10.0	14.9	==
7	4.8	10.5	==	12.4
8	4.0	9.3	==	==
9	4.8	11.2	==	==

TOM1

point	5cm	15cm	25cm
1	4.8	7.0	7.5
2	4.3	6.9	11.3
3	4.9	6.6	16.3
4	4.1	6.6	15.7
5	4.1	8.2	15.8
6	4.4	7.9	11.5
7	4.4	8.9	14.8
8	4.2	7.4	15.4
9	4.8	7.0	16.6
10	4.8	9.5	16.7
11	5.3	7.1	11.7
12	4.2	7.2	17.0
13	6.2	7.7	13.2
14	4.2	7.3	13.5
15	4.3	7.1	18.3
16	5.3	7.3	14.8

TOM2

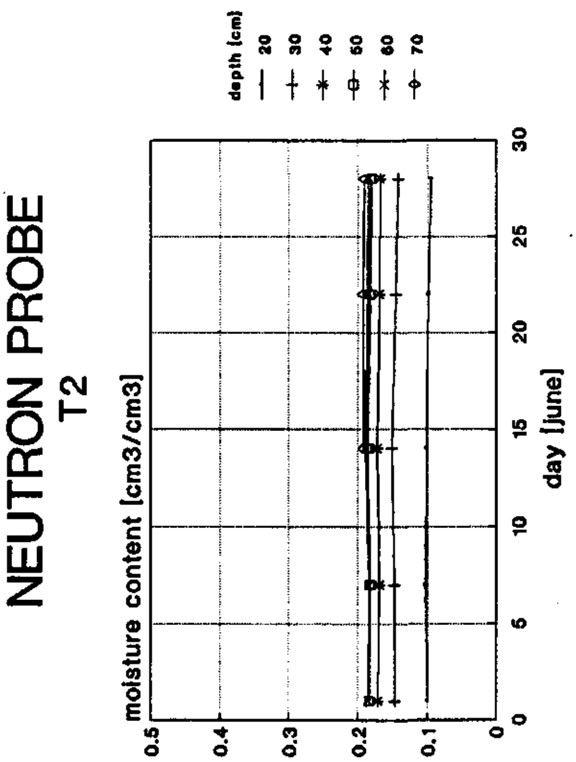
point	5cm	15cm	25cm
1	8.1	13.7	16.5
2	3.9	6.7	13.7
3	5.5	8.3	13.7

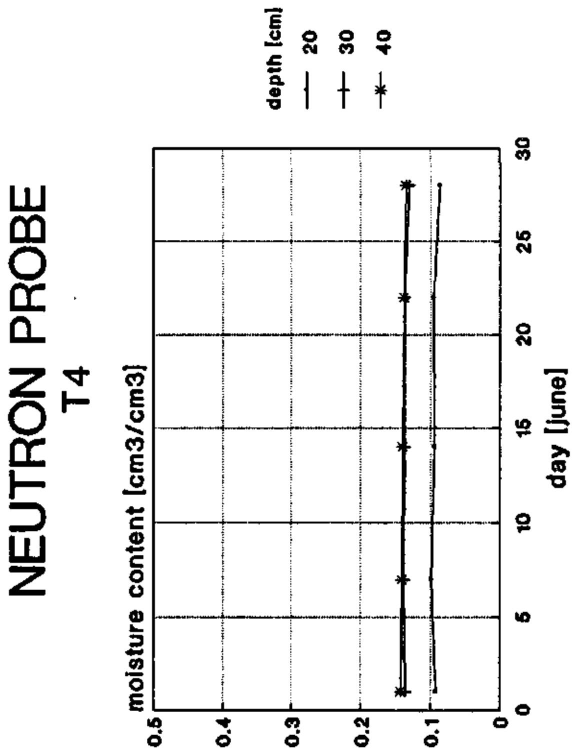
4	4.0	7.4	15.3
5	1.7	6.9	14.3
6	3.9	6.7	15.5
7	3.7	6.6	12.3
8	2.6	6.6	9.8
9	4.4	6.5	14.5
10	5.7	10.8	16.5
11	5.3	7.3	15.0
12	4.5	8.5	13.4
13	5.3	7.1	13.6
14	3.8	7.0	13.9
15	5.0	6.1	15.3
16	6.4	12.8	15.9
17	4.2	6.5	16.7
18	4.3	7.3	12.5
19	3.0	6.9	14.2
20	5.0	6.4	14.3
21	4.8	6.8	13.1
22	4.0	6.7	12.5
23	5.3	8.6	17.8
24	5.2	7.5	13.6
25	3.8	7.1	10.8
26	4.3	6.8	12.4
27	4.3	6.5	16.2
28	4.9	5.7	16.9
29	4.9	6.1	15.0
30	4.1	5.8	9.4
31	4.5	6.4	11.0
32	3.6	5.9	17.0
33	5.6	8.0	21.7
34	3.0	5.4	18.7
35	3.7	5.9	19.3
36	4.5	6.0	9.8
37	4.3	5.7	14.8
38	3.9	5.9	15.4
39	4.8	6.4	10.9
40	5.0	5.8	13.8

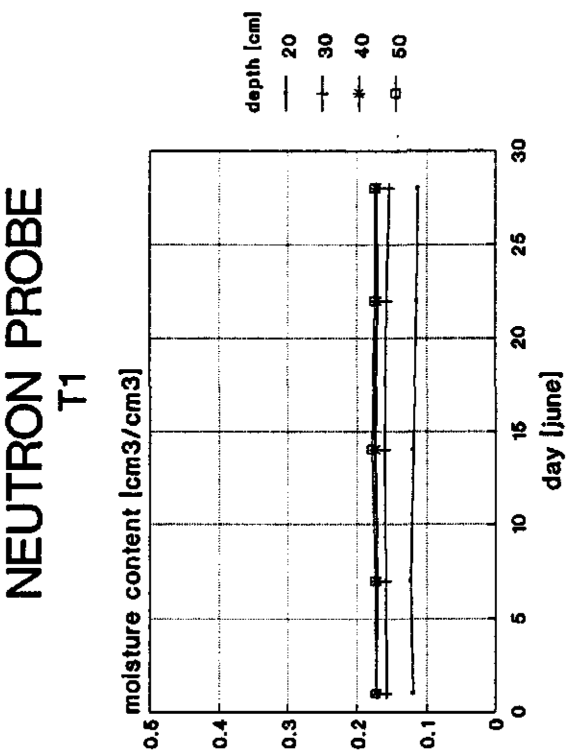
TOM3

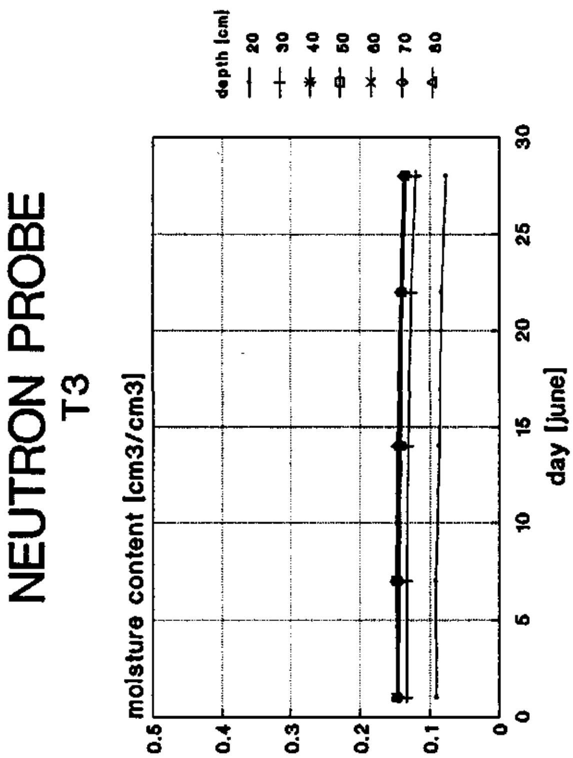
point	5cm	15cm	25cm
1	4.0	6.8	8.9
2	4.2	7.4	9.2
3	5.3	7.0	9.2
4	3.6	7.2	10.7
5	5.5	7.4	7.9
6	4.6	6.3	10.9
7	4.9	5.9	8.9
8	4.9	7.5	9.5
9	3.3	7.8	10.3
10	3.2	7.0	12.8
11	3.9	8.7	11.6
12	6.3	12.9	12.5
13	5.6	9.2	10.4
14	5.8	9.8	12.0
15	5.3	8.7	15.5
16	5.9	12.6	13.7
17	4.7	7.0	12.7
18	4.1	8.7	13.4
19	6.2	11.3	11.4
20	4.2	8.6	9.0
21	7.3	7.5	13.6

APPENDIX 10 Soil moisture profiles by neutron probe for Tomelloso.

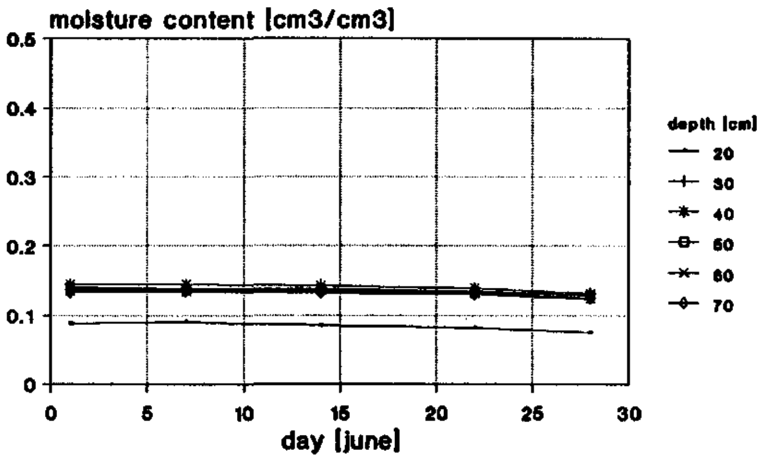




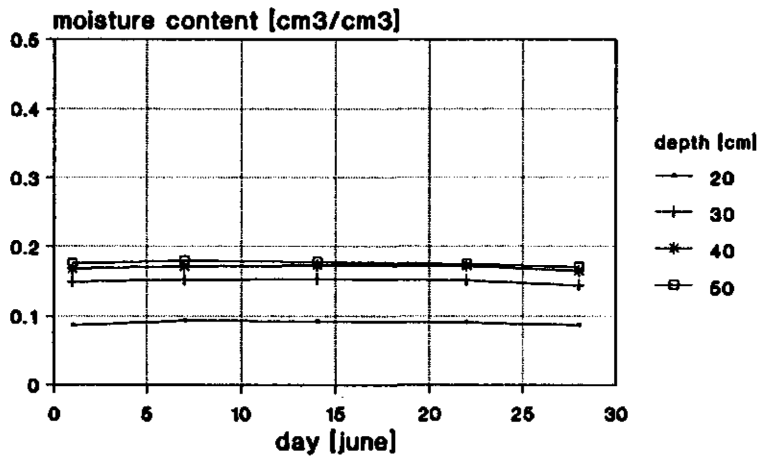




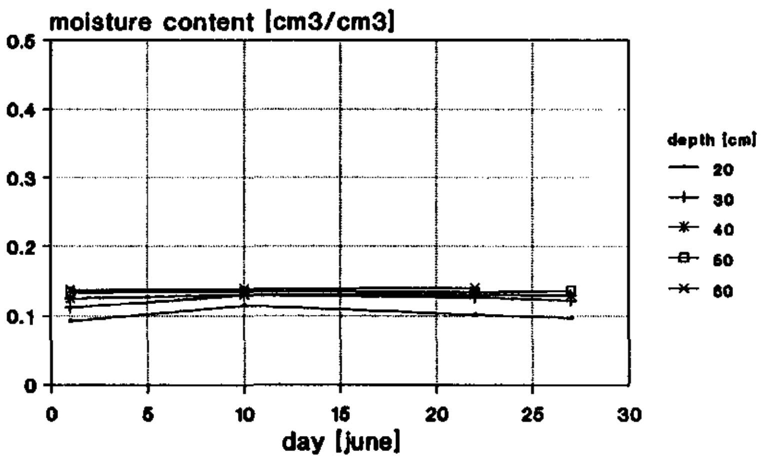
NEUTRON PROBE
T5



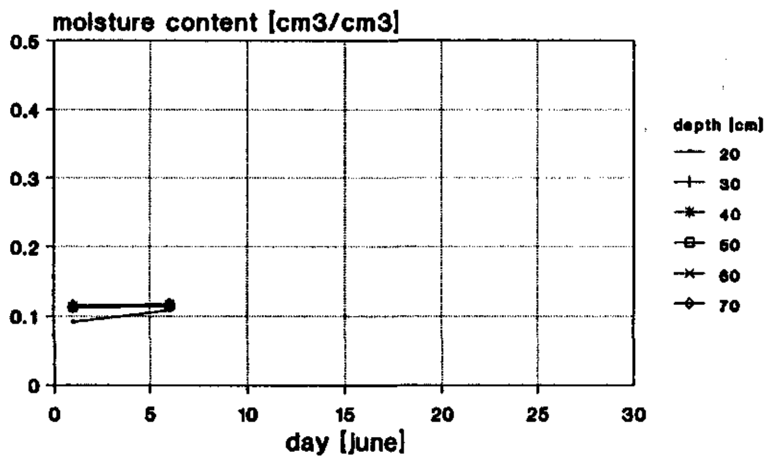
NEUTRON PROBE
T6



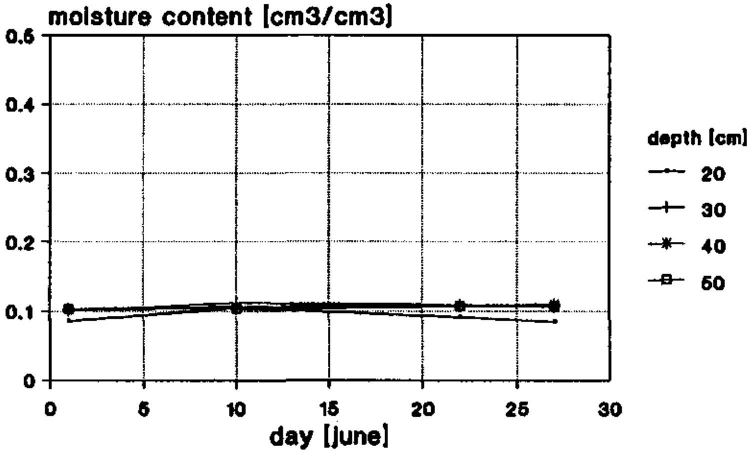
NEUTRON PROBE
T7



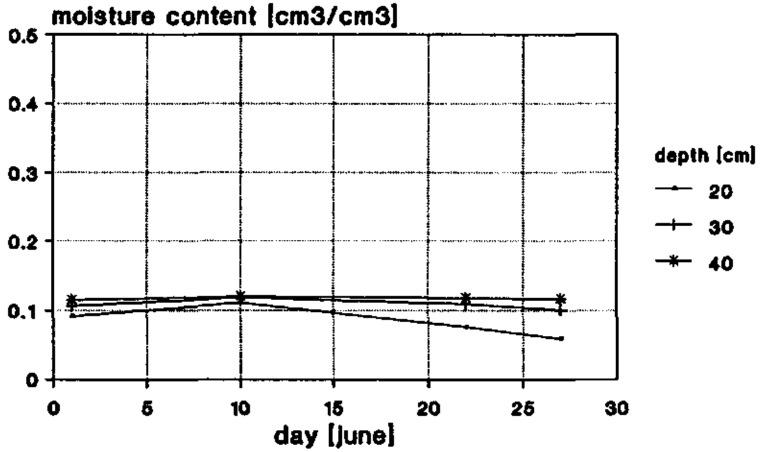
NEUTRON PROBE
T8



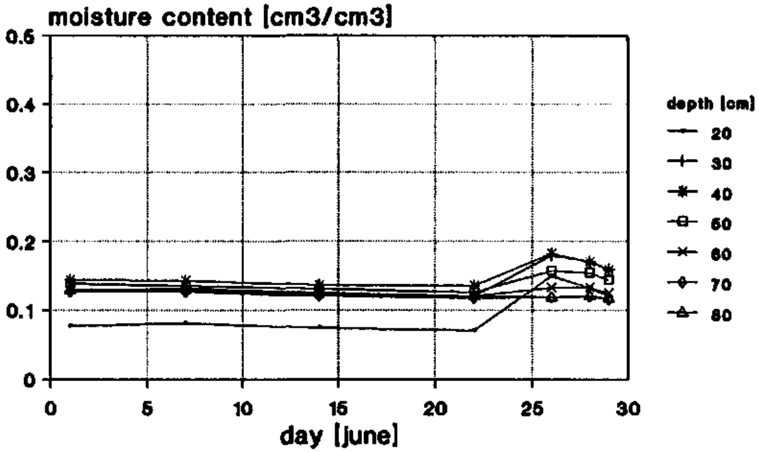
NEUTRON PROBE
T9



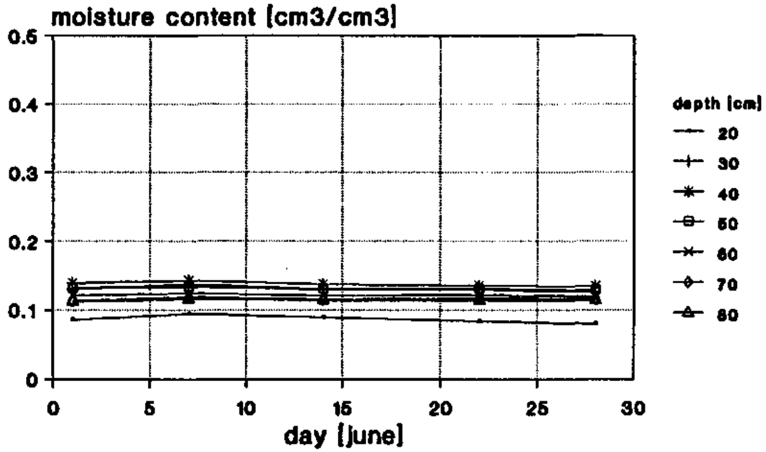
NEUTRON PROBE
T10



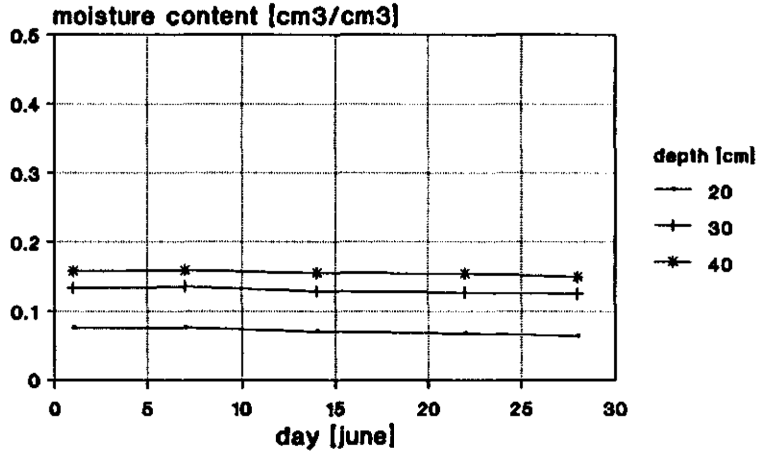
NEUTRON PROBE
T13



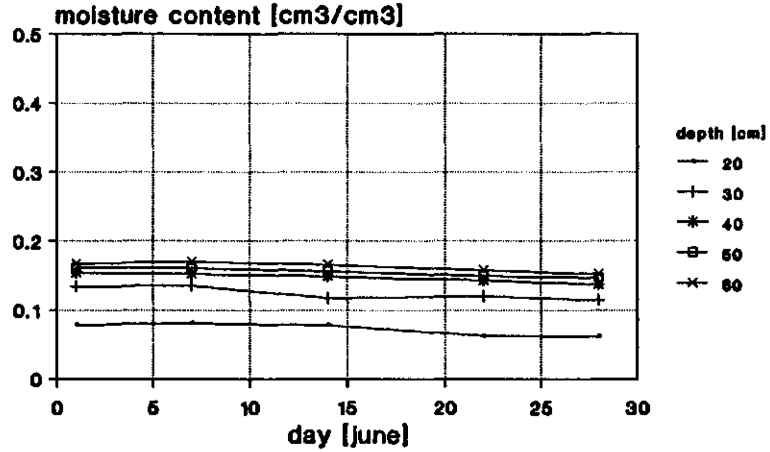
NEUTRON PROBE
T14



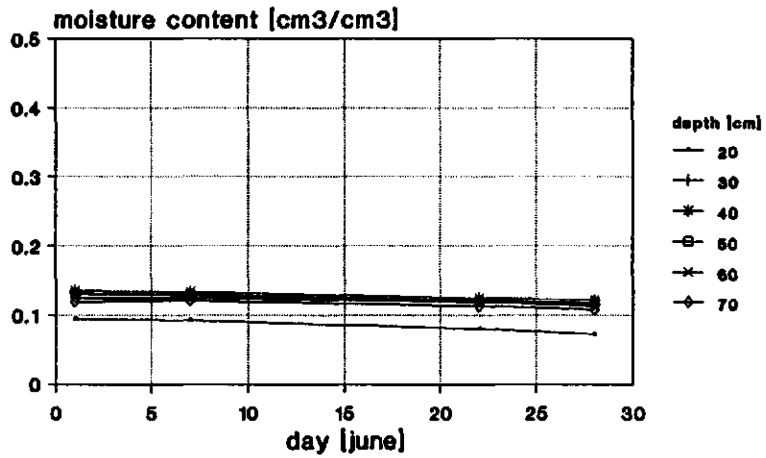
NEUTRON PROBE
T15



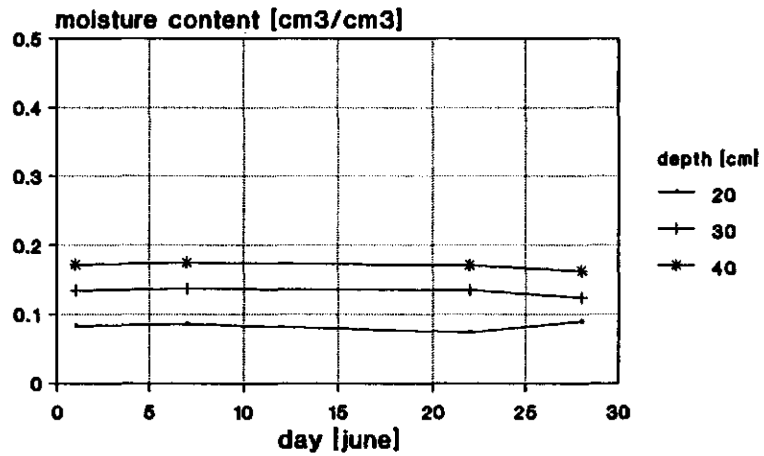
NEUTRON PROBE
T16



NEUTRON PROBE
T17



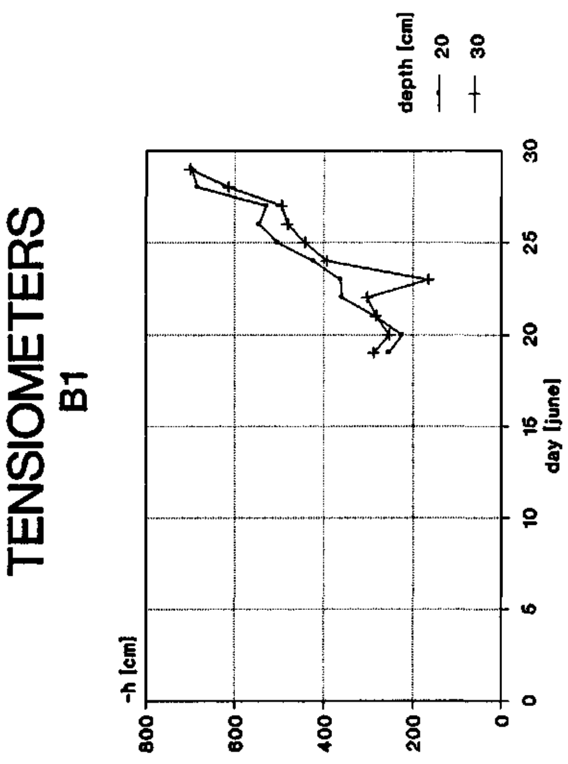
NEUTRON PROBE
T18

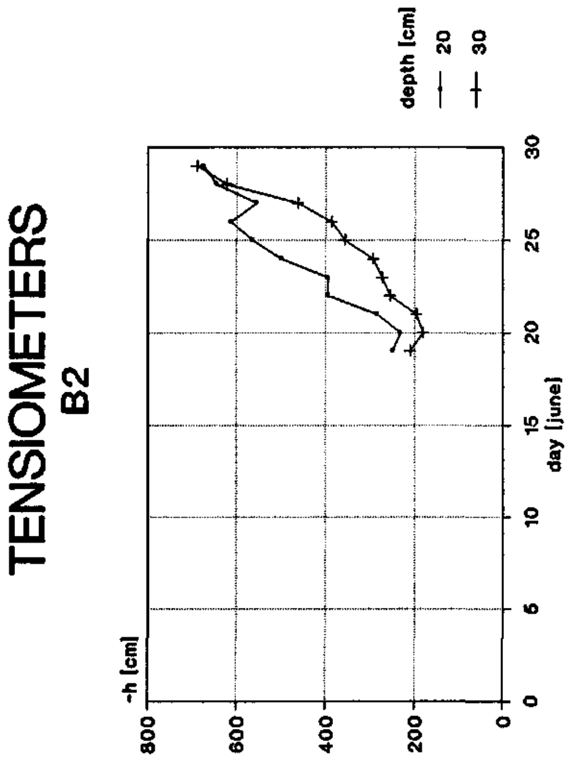


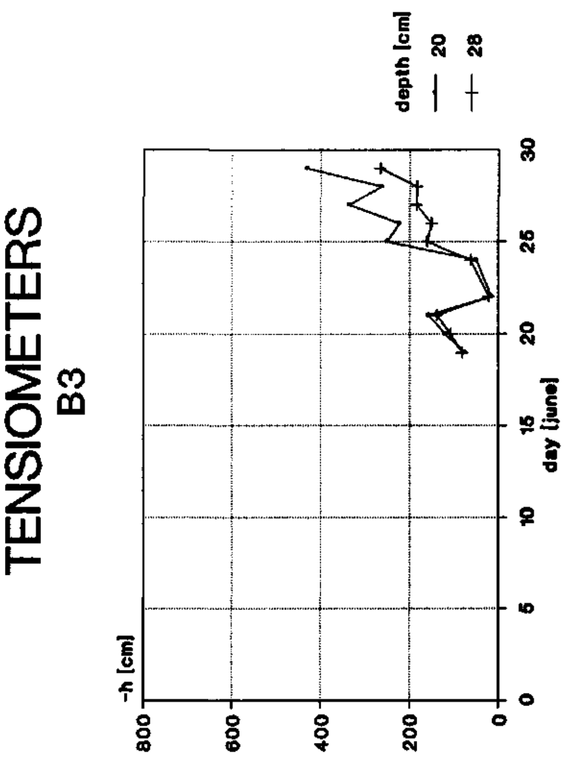
APPENDIX 11 Bulk density and porosity by gamma probe for Tomelloso.

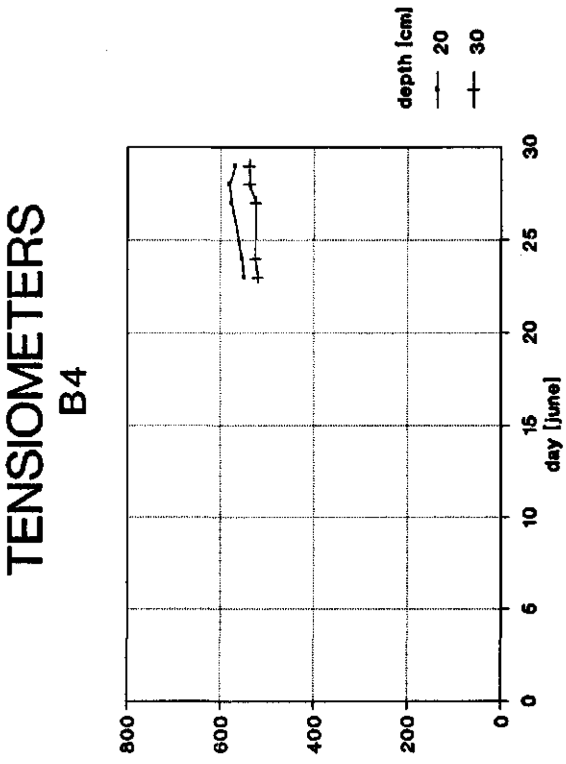
plot	depth [cm]	bulkdensity [g/cm³]	porosity [cm³/cm³]
T1	-10	1.2764	0.5183
	-20	1.2194	0.5399
	-30	1.2634	0.5232
	-40	1.2078	0.5442
T2	-10	1.3357	0.4960
	-20	1.1511	0.5656
	-30	1.2372	0.5331
	-40	1.1940	0.5494
	-50	1.1887	0.5514
T3	-10	1.2990	0.5098
	-20	1.1185	0.5779
	-30	1.2640	0.5230
	-40	1.2268	0.5370
	-50	1.1881	0.5517
T4	-10	1.4115	0.4674
	-20	1.2581	0.5252
	-30	1.2584	0.5251
T5	-10	1.3257	0.4997
	-20	1.2571	0.5256
T6	-10	1.3903	0.4753
	-20	1.2177	0.5405
	-30	1.1854	0.5527
	-40	1.2024	0.5463
T7	-10	1.2829	0.5159
	-20	1.1383	0.5705
T8	-10	1.2948	0.5114
	-20	1.1967	0.5484
	-30	1.2476	0.5292
	-40	1.1975	0.5481
	-50	1.1329	0.5725
T13	-10	1.4218	0.4635
	-20	1.1896	0.5511
	-30	1.1766	0.5560
	-40	1.1178	0.5782
	-50	1.1699	0.5585
	-60	1.1883	0.5516
	-70	1.1842	0.5531
T14	-10	1.3241	0.5003
	-20	1.1285	0.5741
	-30	1.1929	0.5498
	-40	1.1958	0.5488
	-50	1.1971	0.5483
	-60	1.1625	0.5613
	-70	1.1825	0.5538
T15	-10	1.3715	0.4825
	-20	1.2080	0.5442
	-30	1.2286	0.5364
T16	-10	1.4431	0.4554
	-20	1.1930	0.5498
	-30	1.2161	0.5411
	-40	1.1216	0.5767

APPENDIX 12 Soil water suction by tensiometry for Barrax.

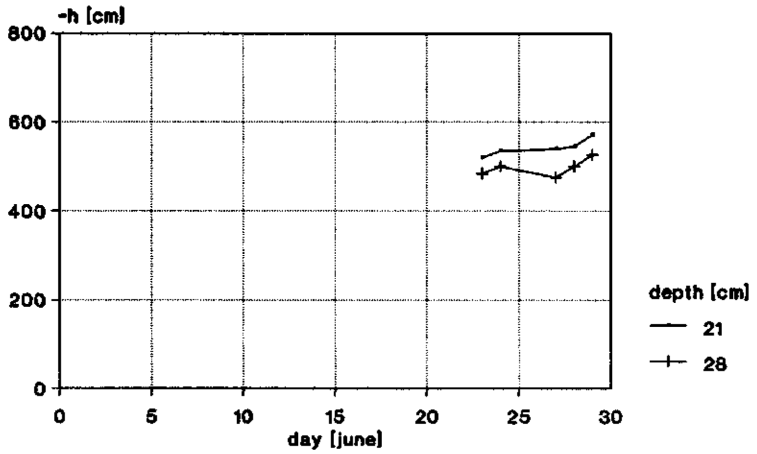




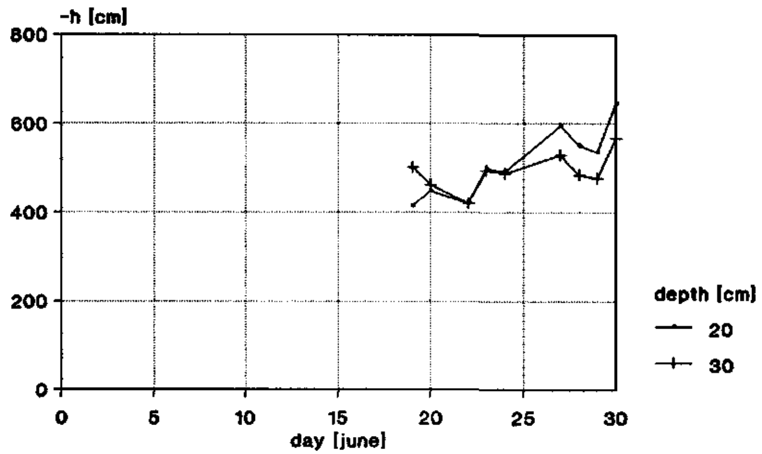




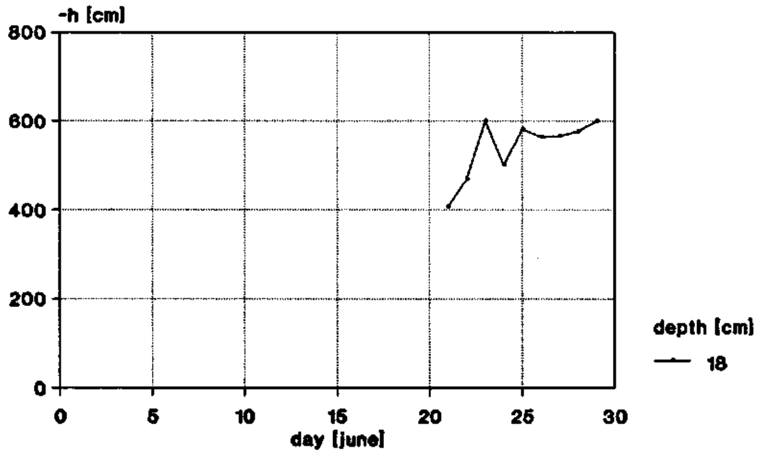
TENSIOMETERS B5



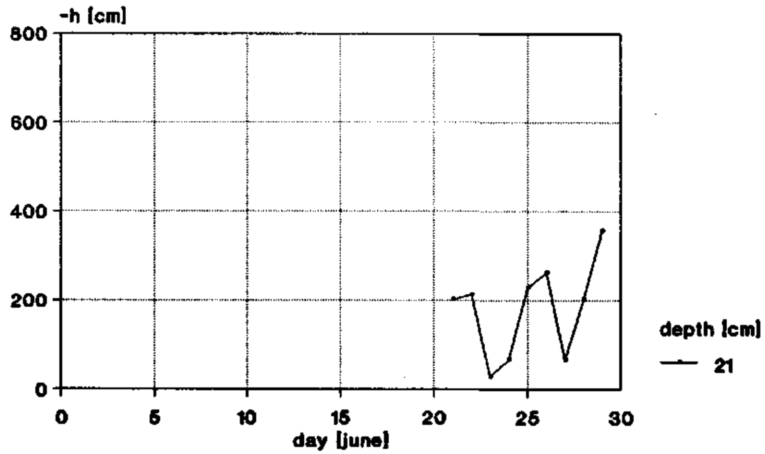
TENSIOMETERS B6



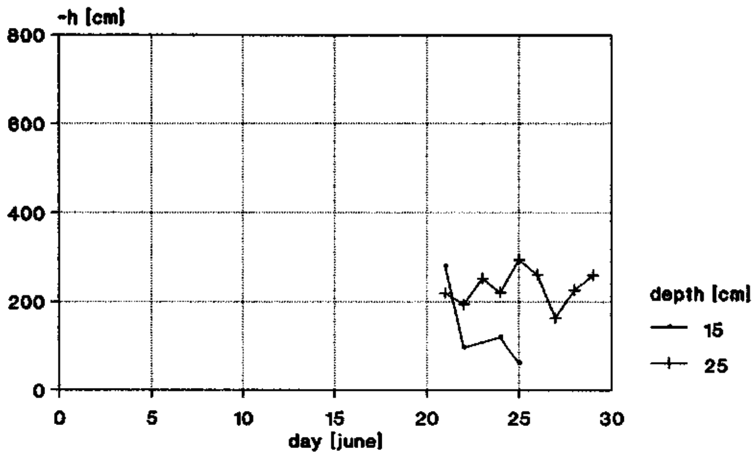
TENSIOMETERS B9



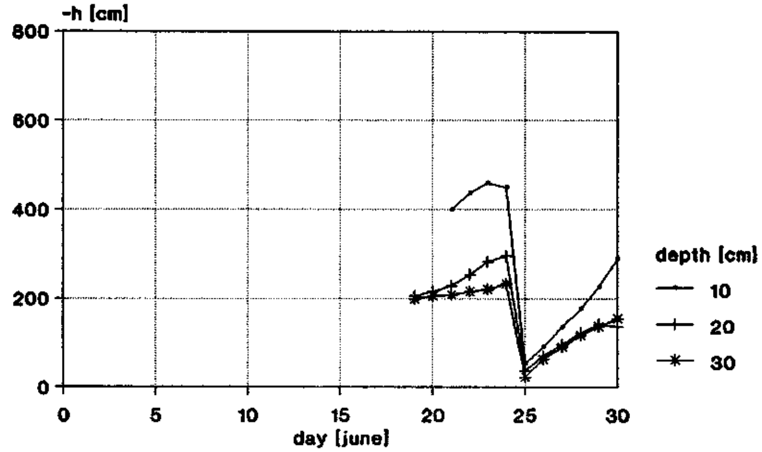
TENSIOMETERS B10



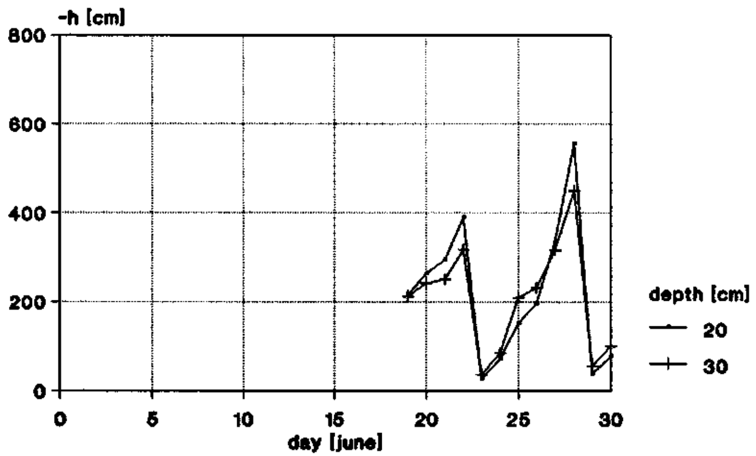
TENSIOMETERS
B11



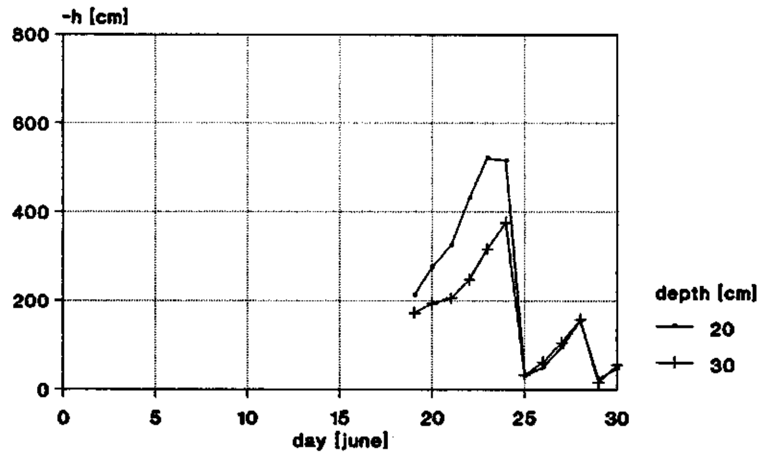
TENSIOMETERS
B12



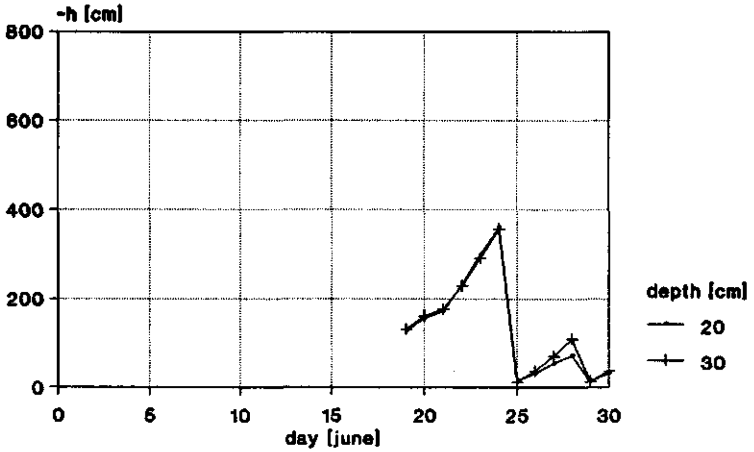
TENSIOMETERS
B13



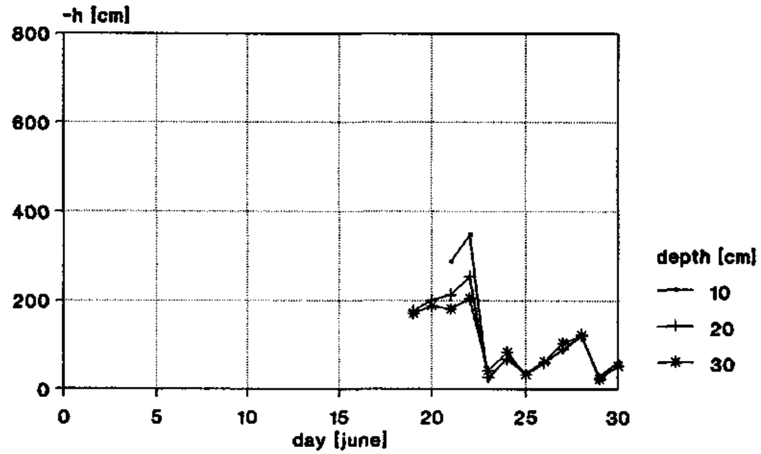
TENSIOMETERS
B14



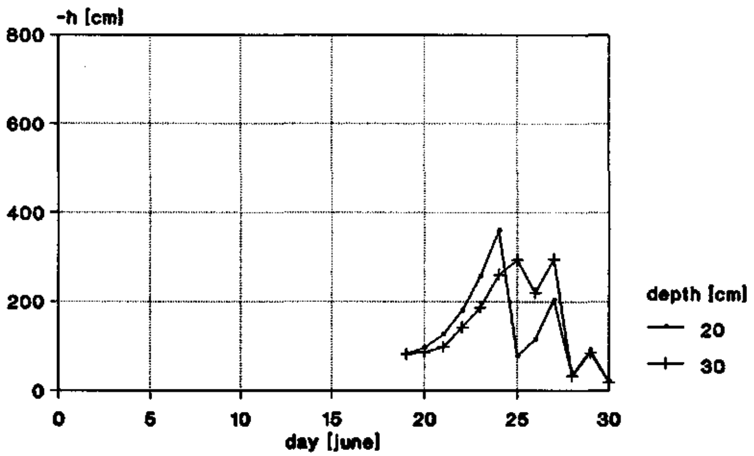
TENSIOMETERS
B15



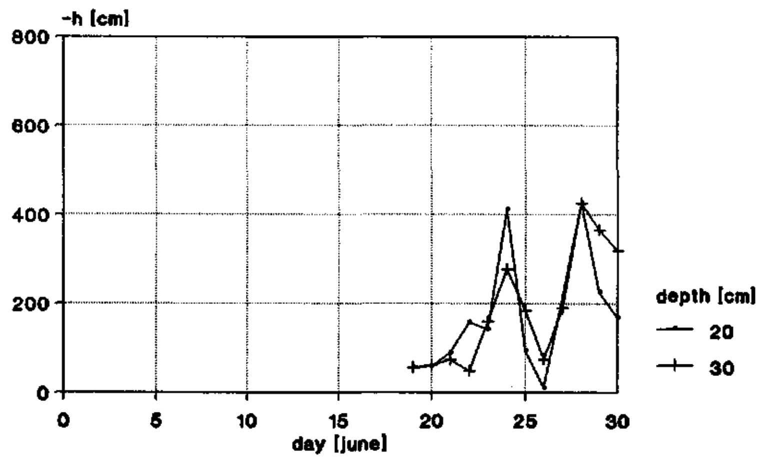
TENSIOMETERS
B16



TENSIOMETERS
B25



TENSIOMETERS
B26



APPENDIX 13 Basic information of disc-permeameter measurements.

name	plot	depth cm	diam cm	suction cm	wc init cm3/cm3	wc wet cm3/cm3
T1-1	T1	0	20	8.9	0.0450	0.5165
T1-2	T1	0	11	8.9	0.0545	0.5587
T1-4	T1	35	20	8.9	0.1750	0.5853
T1-3	T1	35	11	8.9	0.1750	0.6214
T4-1	T4	0	20	9.3	0.1289	0.4000
T4-3	T4	0	11	9.3	0.0445	0.4968
T4-2	T4	25	20	9.3	0.1568	0.4236
T4-4	T4	25	11	9.3	0.0800	0.4464
T5-1	T5	0	20	8.7	0.0377	0.4111
T5-2	T5	0	11	8.7	0.0302	0.4619
T5-3	T5	0	20	8.7	0.0306	0.4353
T5-4	T5	0	11	8.7	0.0290	0.4520
T5-6	T5	0	20	8.7	0.0236	0.4655
T5-5	T5	0	11	8.7	0.0275	0.4743
T5-7	T5	20	20	10.2	0.1330	0.4382
T7-2	T7	0	20	5.7	0.0422	0.4521
T7-3	T7	0	11	5.7	0.0458	0.4804
T7-4	T7	23	20	5.7	0.1390	0.4490
T7-5	T7	30	11	5.8	0.1424	0.4302
T9-1	T9	0	20	5.5	0.0423	0.3920
T9-2	T9	0	11	5.5	0.0460	0.4961
T9-3	T9	30	20	5.5	0.1162	0.4391
T9-4	T9	30	11	5.5	0.1026	0.3603
T9-5	T9	0	11	5.5	0.0603	0.4457
T13-1	T13	0	20	9.7	0.0355	0.4942
T13-2	T13	0	11	9.7	0.0465	0.4925
T13-3	T13	35	20	9.7	0.1805	0.4330
T13-4	T13	35	11	9.7	0.1805	0.4700
T14-1	T14	0	20	10	0.0410	0.4598
T14-2	T14	0	11	10	0.0260	0.4136
T14-3	T14	30	20	10	0.1708	0.4369
T14-4	T14	30	11	10	0.1708	0.5604
B8L0300	B26	0	20	3	0.15	0.44
B8L1000	B26	0	20	10	0.15	0.44
B8L0330	B26	30	20	3	0.29	0.33
B8L1030	B26	30	20	10	0.29	0.33
B8S0330	B26	30	4	3	0.30	0.32
B8L0331	B26	30	20	3	0.30	0.33
B1S0302	B2	2	4	3	0.17	0.30
B1L0302	B2	2	20	3	0.17	0.27
B1M0302	B2	2	12.5	3	0.17	0.27
B1L1002	B2	2	20	10	0.20	0.35
B1M1002	B2	2	12.5	10	0.20	0.39
B1S0325	B2	25	4	3	0.30	0.28
B1M0325	B2	25	12.5	3	0.30	0.29
B1S1025	B2	25	4	10	0.31	0.32
B1L0325	B2	25	20	3	0.30	0.38
B2S0325	B5	25	4	3	0.20	0.38
B2L0305	B5	5	20	3	0.15	0.38
B2S0305	B5	5	4	3	0.15	0.31
B2L1005	B5	5	20	10	0.15	0.36
B2M0305	B5	5	12.5	3	0.15	0.39
B2M1005	B5	5	12.5	10	0.15	0.36
B2S1005	B5	5	4	10	0.15	0.36
B2M0325	B5	25	12.5	3	0.20	0.43
B2L0325	B5	25	20	3	0.20	0.42
B2L1025	B5	25	20	10	0.19	0.36
B2M1025	B5	25	12.5	10	0.19	0.41
B2LA	B6	25	20	3	0.18	0.35
B2LB	B6	25	20	3	0.18	0.35
B2LC	B6	25	20	3	0.18	0.34
B2LD	B6	25	20	3	0.18	0.35
B2LE	B6	25	20	3	0.18	0.34
B2LF	B6	25	20	3	0.18	0.35
B2LG	B6	25	20	3	0.18	0.39
B3L0305	B7	5	20	3	0.00	0.00
B3L1005	B7	5	20	10	0.00	0.00
B3L0320	B7	20	20	3	0.00	0.00

APPENDIX 14 Results Guelph permeameter.

DATA GUELPH PERMEAMETER BAR2

point	-- pressure -- 5 cm steady state flow cm/min	10 cm steady state flow cm/min	reservoir constant cm^2	5 cm Laplace K cm/min	10 cm Laplace K cm/min	5 cm Gardner Φ_m cm^2/min	10 cm Gardner Φ_m cm^2/min	Richard K cm/min	Richard Φ_m cm^2/min
C1	0.8	1.05	35.45	0.0874	0.0485	0.4784	1.0071	0.0054	0.4409
C2	0.65	1.7	35.45	0.0710	0.0785	0.3887	1.6306	0.0923	-0.2488
C3	0.6	1.4	35.45	0.0655	0.0647	0.3588	1.3428	0.0676	-0.1083
D1	0.5	1.7	35.45	0.0546	0.0785	0.2990	1.6306	0.1117	-0.4725
D2	0.7	1.6	35.45	0.0764	0.0739	0.4186	1.5346	0.0754	-0.1025
D3	0.7	1.3	35.45	0.0764	0.0600	0.4186	1.2469	0.0443	0.1125
D4	0.5	0.8	35.45	0.0546	0.0370	0.2990	0.7673	0.0183	0.1725
D5	0.5	1.3	35.45	0.0546	0.0600	0.2990	1.2469	0.0702	-0.1858
D6	0.25	0.8	35.45	0.0273	0.0370	0.1495	0.7673	0.0507	-0.2004
D7	0.6	0.5	35.45	0.0655	0.0231	0.3588	0.4796	-0.0258	0.5368
E2	0.9	1.4	35.45	0.0983	0.0647	0.5383	1.3428	0.0288	0.3392
E3	0.3	1.1	35.45	0.0328	0.0508	0.1794	1.0551	0.0753	-0.3409
E4	0.4	1.2	35.45	0.0437	0.0554	0.2392	1.1510	0.0728	-0.2634
E5	0.6	2	35.45	0.0655	0.0924	0.3588	1.9183	0.1299	-0.5384
E6	0.9	1.1	35.45	0.0983	0.0508	0.5383	1.0551	-0.0023	0.5543
E7	1.4	6.5	2.16	0.0093	0.0183	0.0510	0.3799	0.0301	-0.1566

APPENDIX 15 Description of samples applied on multi-step outflow.

sample	cell	name in inputfile	serie multi-step	volume cm^3	field	plot *	grid **	depth cm
C2	4	BX240	BXF	100	BAR1	B1-B3		10-15
A15	5	BX250	BXF	100	BAR1	B1-B3		10-15
A5	2	BX220	BXF	100	BAR1	B1-B3		10-15
A14	3	BX230	BXF	100	BAR1	B1-B3		10-15
C7	9	BX290	BXF	100	BAR1	B1-B3		10-15
A1	10	BX300	BXF	100	BAR1	B1-B3		10-15
A13	6	BX260	BXF	100	BAR1	B1-B3		10-15
C16	18	BX580	BXG	100	BAR1	B1-B3		10-15
A9	19	BX390	BXF	100	BAR1	B1-B3		10-15
A7	13	BX330	BXF	100	BAR1	B1-B3		10-15
A17	1	BX210	BXF	100	BAR1	B1-B3		10-15
CT09	4	BX14B	BXBBIG	250	BAR1	B1-B3		10-15
8	8	BX18	BXABIG	250	BAR1	B1-B3		10-15
CT10	5	BX15	BXABIG	250	BAR1	B1-B3		10-15
27	2	BIG2	BIG3	600	BAR1	B1-B3		10-22
12	6	B6	BIG1	600	BAR1	B1-B3		10-22
11	3	BX53B	BIG2	600	BAR1	B1-B3		15-27
A2	12	BX320	BXF	100	BAR1	B1-B3		20-25
A4	15	BX350	BXF	100	BAR1	B1-B3		20-25
A3	14	BX340	BXF	100	BAR1	B1-B3		20-25
C10	20	BX400	BXF	100	BAR1	B1-B3		25-30
C5	8	BX280	BXF	100	BAR1	B1-B3		25-30
C20	17	BX370	BXF	100	BAR1	B1-B3		25-30
D12	6	BX460	BXG	100	BAR2	B4-B5		15-20
14	8	BX58B	BIG2	600	BAR2	B4-B5		20-32
18	7	BX57B	BIG2	600	BAR2	B4-B5		20-32
D14	5	BX450	BXG	100	BAR2	B4-B5		25-30
D15	3	BX430	BXG	100	BAR2	B4-B5		25-30
D17	7	BX470	BXG	100	BAR2	B4-B5		25-30
B24	16	BX560	BXG	100	BAR2	B6		25-20
B5	4	BX440	BXG	100	BAR2	B6		25-30
7	7	BX17	BXABIG	250	BAR2	B6		25-30
CT89	3	BT630	BTH	100	BAR3	B7-B8		10-15
A23	16	BX360	BXF	100	BAR3	B7-B8		10-15
B19	1	BT610	BTH	100	BAR3	B7-B8		10-15
A24	5	BT650	BTH	100	BAR3	B7-B8		10-15
A12	4	BT640	BTH	100	BAR4	B9-B11		10-15
CT05	3	BX13	BXABIG	250	BAR4	B9-B11		10-15
23	2	B2	BIG1	600	BAR4	B9-B11		10-22
A18	8	BT680	BTH	100	BAR4	B9-B11		20-25
A11	6	BT660	BTH	100	BAR4	B9-B11		20-25
A20	1	BX410	BXG	100	BAR4	B9-B11		20-25

sample	cell	name in inputfile	serie multi-step	volume cm^3	field	plot *	grid **	depth cm
4	9	BIG9	BIG3	250	BAR5			10-15
13	3	BIG3	BIG3	600	BAR5			10-22
CT92	2	BAR2	BARRAX1	100	BAR5		A1	10-15
CT75	11	BAR11	BARRAX1	100	BAR5		A1	10-15
CT83	12	BAR12	BARRAX1	100	BAR5		A1	20-25
CT87	15	B15	BAR2OUT	100	BAR5		A1	20-25
CT93	3	B3	BAR2OUT	100	BAR5		A2	10-15
CT85	13	B13	BAR2OUT	100	BAR5		A2	10-15
CT76	14	B14	BAR2OUT	100	BAR5		A2	20-25
CT88	1	B1	BAR2OUT	100	BAR5		A3	10-15
CT96	4	B4	BAR2OUT	100	BAR5		A3	10-15
CT79	19	B19	BAR2OUT	100	BAR5		A3	20-25
CT80	4	BX04O	BXE	100	BAR5		A3	20-25
CT91	18	B18	BAR2OUT	100	BAR5		B2	10-15
B6	9	B9	BAR2OUT	100	BAR5		B2	10-15
B15	10	B10	BAR2OUT	100	BAR5		B3	10-15
B14	12	B12	BAR2OUT	100	BAR5		B3	10-15
B16	5	BX05O	BXE	100	BAR5		B3	20-25
A10	8	BX08O	BXE	100	BAR5		B3	20-25
CT94	2	B2	BAR2OUT	100	BAR5		B4	10-15
CT95	8	B8	BAR2OUT	100	BAR5		B4	10-15
B8	7	BX07O	BXE	100	BAR5		B4	20-25
CT86	10	BX10O	BXE	100	BAR5		B4	20-25
CT82	5	B5	BAR2OUT	100	BAR5		C3	10-15
B9	1	BX01O	BXE	100	BAR5		C3	20-25
CT74	2	BX02O	BXE	100	BAR5		C3	20-25
A19	16	B16	BAR2OUT	100	BAR5		C4	10-15
A22	11	B11	BAR2OUT	100	BAR5		C4	10-15
B13	3	BX03O	BXE	100	BAR5		C4	20-25
B20	6	BX06O	BXE	100	BAR5		C4	20-25
B12	7	B7	BAR2OUT	100	BAR5		C5	10-15
B18	6	B6	BAR2OUT	100	BAR5		C5	10-15
B10	9	BX09O	BXE	100	BAR5		C5	20-25
C13	11	BX11O	BXE	100	BAR5		C5	20-25
D21	3	BAR3	BARRAX1	100	BAR5	B12		10-15
D23	5	BAR5	BARRAX1	100	BAR5	B12		10-15
D20	13	BAR13	BARRAX1	100	BAR5	B12		10-15
D18	1	BAR1	BARRAX1	100	BAR5	B12		20-25
D19	7	BAR7	BARRAX1	100	BAR5	B12		20-25
17	6	BX56B	BIG2	600	BAR5	B12		10-22
D16	18	BAR18	BARRAX1	100	BAR5	B15		10-15
D24	19	BAR19	BARRAX1	100	BAR5	B15		10-15
B4	10	BAR10	BARRAX1	100	BAR5	B15		25-30
B2	14	BAR14	BARRAX1	100	BAR5	B15		25-30
D6	15	BAR15	BARRAX1	100	BAR5	B16-B20		5-10

sample	cell	name in inputfile	serie multi-step	volume cm^3	field	plot *	grid **	depth cm
D5	16	BAR16	BARRAX1	100	BAR5	B16-B20		5-10
D8	4	BAR4	BARRAX1	100	BAR5	B16-B20		20-25
D10	17	BAR17	BARRAX1	100	BAR5	B16-B20		20-25
15	4	BX54B	BIG2	600	BAR5	B16-B20		5-17
19	10	B10	BIG1	600	BAR5	B16-B20		15-27
2	7	BIG7	BIG3	250	BAR5	B16-B20		20-25
C11	20	BX600	BXG	100	BAR6	B21-B22		10-15
C23	11	BX510	BXG	100	BAR6	B21-B22		10-15
C15	15	BX550	BXG	100	BAR6	B21-B22		10-15
26	8	B8	BIG1	600	BAR6	B21-B22		10-22
C14	8	BX480	BXG	100	BAR6	B21-B22		20-25
C21	2	BX420	BXG	100	BAR6	B21-B22		20-25
B17	9	BX490	BXG	100	BAR6	B21-B22		20-25
10	10	BX20	BXABIG	250	BAR6	B21-B22		20-25
5	10	BIG10	BIG3	250	BAR6	B21-B22		20-25
C6	13	BX130	BXE	100	BAR8	B25-B27		10-15
C18	14	BX140	BXE	100	BAR8	B25-B27		10-15
B11	19	BX190	BXE	100	BAR8	B25-B27		10-15
C24	16	BX160	BXE	100	BAR8	B25-B27		10-15
C19	12	BX120	BXE	100	BAR8	B25-B27		10-15
21	4	B4	BIG1	600	BAR8	B25-B27		10-22
16	9	B9	BIG1	600	BAR8	B25-B27		15-27
22	7	B7	BIG1	600	BAR8	B25-B27		15-27
B23	11	BX310	BXF	100	BAR8	B25-B27		25-30
C8	15	BX150	BXE	100	BAR8	B25-B27		25-30
C1	17	BX170	BXE	100	BAR8	B25-B27		25-30
B7	20	BX200	BXE	100	BAR8	B25-B27		25-30
C4	18	BX180	BXE	100	BAR8	B25-B27		25-30
20	2	BX52B	BIG2	600	BAR9	B28		10-22
D2	12	BX520	BXG	100	BAR9	B28		20-25
D1	19	BX590	BXG	100	BAR9	B28		20-25
D4	13	BX530	BXG	100	BAR9	B28		30-35
D3	17	BX570	BXG	100	BAR9	B28		30-35
H47	1	TM010	TMA_O	100	TOM1	T1-T2		35-40
CT20	2	TM020	TMA_O	100	TOM1	T1-T2		40-45
CT144	11	TM110	TMA_O	100	TOM2			50-55
CT24	7	TM070	TMA_O	100	TOM2			12-17
CT1	4	TM040	TMA_O	100	TOM2			18-23
CT9	5	TM050	TMA_O	100	TOM2			18-23
CT132	6	TM060	TMA_O	100	TOM2			25-30
H33	13	TM130	TMA_O	100	TOM2	T3		30-35
H43	12	TM120	TMA_O	100	TOM2	T3		30-35
CT6	3	TM030	TMA_O	100	TOM2			48-53
H42	9	TM090	TMA_O	100	TOM2	T3		50-55
H44	10	TM100	TMA_O	100	TOM2	T3		50-55

sample	cell	name in inputfile	serie multi-step	volume cm^3	field	plot *	grid **	depth cm
H41	8	TM080	TMA_O	100	TOM2	T3		50-55
9(T2)	10	BX60B	BIG2	600	TOM2	T3		
10(T5)	6	BIG6	BIG3	600	TOM2	T5		25-37
8(T1)	9	BX59B	BIG2	600	TOM2	T5		40-52
CT49	12	BT720	BTH	100	TOM3	T9		7-12
CT71	14	BT740	BTH	100	TOM3	T9		7-12
CT51	20	TM200	TMA_O	100	TOM3	T9		10-15
H30	17	BT770	BTH	100	TOM3	T9		20-25
CT11	18	BT780	BTH	100	TOM3			20-25
H40	9	BT690	BTH	100	TOM3	T9		24-29
CT63	11	BT710	BTH	100	TOM3	T9		30-35
H46	15	BT750	BTH	100	TOM3	T9		30-35
CT59	13	BT730	BTH	100	TOM3	T9		30-35
H45	16	TM160	TMA_O	100	TOM3	T7		10-15
H27	17	TM170	TMA_O	100	TOM3	T7		10-15
CT7	19	TM190	TMA_O	100	TOM3	T7		15-20
CT13	14	TM140	TMA_O	100	TOM3	T7		20-25
H26	15	TM150	TMA_O	100	TOM3	T7		20-25
H38	10	BT700	BTH	100	TOM3	T7		30-35
C3	18	TM180	TMA_O	100	TOM3	T7		30-35
CT12	16	BT760	BTH	100	TOM5			40-45
6(T3)	4	BIG4	BIG3	600	TOM5			
7(T4)	5	BIG5	BIG3	600	TOM5			
CT72	20	BT800	BTH	100	TOM5	T13		30-35
CT70	19	BT790	BTH	100	TOM5	T13		55-60

*: several plots indicated means that samples are taken among plots
**: see lay-out grid remote-sensing

APPENDIX 16 Multi-step series and equilibrium points.

serie	BARRAX1(see internal report Rösslerova)
date	18-07-91
in/outflow	outflow
pressure steps	15 50 80 150 350 1000
equilibrium	15 80 150 350 1000
fixed points	15 50
initial pressure	15

serie	BIG1
date	16-09-91
in/outflow	outflow
pressure steps	50 150 420 1000
equilibrium	150 1000
fixed points	1000
initial pressure	0

serie	BAR2OUT
date	15-10-91
in/outflow	outflow
pressure steps	30 50 100 350 1000
equilibrium	100 1000
fixed points	1000
initial pressure	0

serie	BIG2
date	16-10-91
in/outflow	outflow
pressure steps	15 30 70 150 350 1000
equilibrium	15 70 1000
fixed points	15 1000
initial pressure	15

serie	BIG3
date	25-11-91
in/outflow	outflow
pressure steps	15 30 50 100 350 1000
equilibrium	15 30 50 100 350 1000
fixed points	15 1000
initial pressure	15

serie	BXABIG
date	03-02-92
in/outflow	outflow
pressure steps	15 30 50 100 350 1000
equilibrium	15 30 50 350 1000
fixed points	15 1000
initial pressure	15

serie	TMA_O
date	24-02-92
in/outflow	outflow
pressure steps	15 30 50 100 300 1000
equilibrium	15 100 300 1000
fixed points	15 1000
initial pressure	15

serie	BXBBIG
date	13-04-92
in/outflow	outflow
pressure steps	15 30 50 100 350 1000
equilibrium	15 30 50 100 1000
fixed points	15 1000
initial pressure	15

serie	BXE
date	06-05-92
in/outflow	outflow
pressure steps	15 30 100 350 1000
equilibrium	15 1000
fixed points	15 1000
initial pressure	15
serie	BXF
date	05-06-92
in/outflow	outflow
pressure steps	15 30 50 100 350 1000
equilibrium	15 50 1000
fixed points	15 1000
initial pressure	15
serie	BXG
date	10-07-92
in/outflow	outflow
pressure steps	15 30 50 100 350 1000
equilibrium	15 50 1000
fixed points	15 1000
initial pressure	15
serie	BTH
date	17-11-92
in/outflow	outflow
pressure steps	15 30 50 100 350 1000
equilibrium	15 1000
fixed points	15 1000
initial pressure	15
serie	BARRAX1(see internal report Rösslerova)
date	07-08-91
in/outflow	inflow
pressure steps	1000 350 150 110 70 30 15
equilibrium	350
fixed points	15 50
final pressure	15
serie	BAR2IN
date	28-10-91
in/outflow	inflow
pressure steps	1000 350 100 50 30 8 0
equilibrium	50
fixed points	1000
final pressure	8
serie	TMB_I
date	10-03-92
in/outflow	inflow
pressure steps	1000 300 100 50 30 15 0
equilibrium	300 100
fixed points	15 1000
final pressure	15

APPENDIX 17 Example input and outputfile multi-step.

Variables inputfile MULSTP

```
            10          20          30          40          50          60
1 NCASE NPR NOUT KHAL NRES
2       DESCRIPTION OF THE SIMULATION OR OPTIMIZATION
3                       SAMPL
4
5     NN LNS        DNUL       DUMMY        AIRP        EPS1        EPS2
6          SLL         PLL        DIAM        CPLT NOBB MDAT MODE  MIT
7
8       B(1)        B(2)        B(3)        B(4)        B(5)        B(6)
9   INDEX(1)    INDEX(2)    INDEX(3)    INDEX(4)    INDEX(5)    INDEX(6)
10   BMIN(1)     BMIN(2)     BMIN(3)     BMIN(4)     BMIN(5)     BMIN(6)
11   BMAX(1)     BMAX(2)     BMAX(3)     BMAX(4)     BMAX(5)     BMAX(6)
--        AT          RT        WCRT        WCST
--        ZX
--     HO(I)       FO(I) ITYP     WT(I)                           (NOBB times)
--    TPRESS      PRESSU                                          (-AIRP times)
--    TPRINT                                                      (NPR times)
```

VARIABLE	PLACE	DESCRIPTION
NCASE	1- 5	Number of cases considered
NPR	6-10	Number of times on which h(z) and θ(z) are printed in DISTP.DAT
NOUT	11-15	Observations:
		0 = printing in outputfile
		1 = no printing in outputfile
KHALL	16-20	Option to fix the retention curve and optimize α, n, K_s and/or 1 of the conductivity function:
		0 = simultaneous optimization of θ(h) and k(h)
		1 = θ(h) is fixed, k(h) is optimized
NRES	21-25	1 = print the simulated data in OBSERV.DAT
SAMPL	16-20	Code for sample
NN	1- 5	Number of nodes
LNS	6-10	Number of nodes in soil
DNUL	11-20	Initial time step
DUMMY	21-30	No significance
AIRP	31-40	Positive: One step method --> pneumatic head
		Negative: Multi step method --> number of pressure steps
EPS1	41-50	Temporal weighing coefficient
EPS2	51-60	Iteration weighing coefficient
SLL	1-10	Length of soil core
PLL	11-20	Thickness of porous plate
DIAM	21-30	Diameter of soil core
CPLT	31-40	Conductivity of porous plate
NOBB	41-45	Number of observations
MDAT	46-50	Mode for observation data:
		1 = transient flow data only
		2 = last Q(t) entry represents equilibrium outflow
MODE	51-55	Mode for type of calculation:
		0 = flow equation is solved for initial parameter values
		1 = optimization process continues until parameter values converge or the number of iterations reaches MIT;
		all intermediate parameter values are printed
		2 = as MODE=1 except parameter values are only printed at the end of every iteration
		3 = as MODE=2 but θ(h) and k(h) according to final parameter values are also printed
		With negative sign --> the program continues with two other sets of initial parameters
MIT	55-60	Maximum number of iterations in optimization routine
B(1)	1-10	Initial value of α
B(2)	11-20	Initial value of n
B(3)	21-30	Initial value of θ_r
B(4)	31-40	Initial value of θ_s
B(5)	41-50	Initial value of K_s
B(6)	51-60	Initial value of 1
INDEX(I)		Index indicating fixed or loose parameters:
		0 = parameter B(I) is known and is kept constant
		1 = parameter B(I) is not known and will be optimized
BMIN(I)		Minimum permissible parameter values
BMAX(I)		Maximum permissible parameter values
AT	1-10	Fixed α of θh) (This line only if KHALL=1)
NT	11-20	Fixed n of θ(h)
WCRT	21-30	Fixed θ_r of θ(h)
WCST	31-40	Fixed θ_s of θ(h)
ZX	1-10	Initial pressure head at the center of the sample
HO(I)	1-10	Time (ITYPE=0) or pressure head (ITYPE=1 or 2)
FO(I)	11-20	Outflow (ITYPE=0), moisture content (ITYPE=1) or unsaturated conductivity (ITYPE=2)
ITYPE(I)	21-25	Data type:
		0 = Q(t)
		1 = θ(h)
		2 = k(h)
WT(I)	25-35	Array containing weights assigned to every observation
TPRESS	1-10	Time on which pressure is increased
PRESSU	11-20	Applied pneumatic pressure
TPRINT	free	Times on which h and θ against depth are printed in DISTP.DAT

Example inputfile

```
   3    0    1    0
    OPTIMALISATIE TOMELLOSO outflow 24-02-92
monster :        H42

  46   41     0.00001          0       -5.0       1.00       1.00
     5.10        0.57       5.00     0.0027     50    1     2   25

   0.0204      1.5121     0.0792     0.4324     1.0458     0.2480
        1           1          1          0          1          1
   0.0000      1.1000     0.0000     0.4124     0.0000    -2.0000
   0.0000      5.0000     0.0000     0.4524    10.0000     2.5000
   -15.00
     0.20        0.30
     0.61        0.75
     1.53        1.40
     2.58        1.65
     5.41        1.80
     8.40        1.90
    14.13        1.90
    14.30        2.30
    14.60        3.10
    15.01        4.20
    15.98        5.80
    20.13        6.40
    22.53        6.80
    39.25        7.10
    46.53        7.15
    64.01        7.15
    64.11        7.40
    64.18        7.70
    64.36        8.40
    64.90        9.50
    65.35       10.10
    65.96       10.60
    67.36       11.10
    68.23       11.25
   135.60       11.55
   140.13       11.60
   161.35       11.60
   161.45       12.60
   161.50       13.30
   161.56       14.20
   162.66       18.90
   163.18       19.35
   164.40       19.80
   165.90       19.95
   166.90       20.00
   183.63       20.00
   206.98       19.90
   215.31       19.85
   231.31       19.80
   231.46       20.25
   231.56       20.70
   232.78       23.20
   233.75       24.10
   234.58       24.60
   235.75       25.10
   236.33       25.30
   301.73       26.80
   325.46       26.60
     -15.       .4180     1   10.
   -1000.       .1520     1   10.
     0.00       30.00
    14.13       50.00
    64.01      100.00
   161.35      298.00
   231.31     1000.00
    OPTIMALISATIE TOMELLOSO outflow 24-02-92
monster :        CT144

  46   41     0.00001          0       -5.0       1.00       1.00
     5.10        0.57       5.00     0.0027     50    1     2   25

   0.0360      1.3351     0.1870     0.4329     1.0458     0.2480
        1           1          1          0          1          1
   0.0000      1.1000     0.0000     0.4129     0.0000    -2.0000
   0.0000      5.0000     0.0000     0.4529    10.0000     2.5000
   -15.00
     0.21        0.25
     0.63        0.65
     1.55        1.15
     2.60        1.35
     5.43        1.50
     8.41        1.55
    14.15        1.60
    14.31        1.80
    14.61        2.15
    15.03        2.35
    16.00        2.65
    20.15        3.00
    22.55        3.15
    39.26        3.45
    46.55        3.50
    64.03        3.55
    64.13        3.70
    64.20        3.95
    64.38        4.45
    64.91        5.05
    65.36        5.45
    65.98        5.65
    67.38        6.00
    68.25        6.15
   135.61        6.90
   140.15        6.95
   161.36        7.00
   161.46        7.50
   161.51        7.65
   161.58        7.80
```

```
  162.68       8.80
  163.20       9.05
  164.41       9.55
  165.91      10.00
  166.91      10.15
  183.65      11.15
  207.00      11.25
  215.33      11.25
  231.33      11.20
  231.48      11.35
  231.58      11.45
  232.80      12.05
  233.76      12.40
  234.60      12.65
  235.76      12.95
  236.35      13.05
  301.75      14.85
  325.48      14.85
    -15.      .4090    1   10.
  -1000.      .2610    1   10.
    0.00      30.00
   14.13      50.00
   64.01     100.00
  161.35     298.00
  231.31    1000.00
   OPTIMALISATIE TOMELLOSO outflow 24-02-92
monster :       C3

 46   41    0.00001          0        -5.0       1.00       1.00
    5.10       0.57       5.00     0.0027    50    1     2   25

  0.0552     1.9380     0.1929     0.4140     1.0458     0.2480
       1          1          1          0          1          1
  0.0000     1.1000     0.0000     0.3940     0.0000    -2.0000
  0.0000     5.0000     0.0000     0.4340    10.0000     2.5000
  -15.00
    0.21       1.65
    0.63       4.00
    1.55       5.65
    2.60       5.75
    5.43       5.90
    8.41       5.95
   14.15       5.90
   14.31       7.05
   14.61       8.05
   15.03       8.45
   16.00       8.80
   20.15       8.95
   22.55       9.25
   39.26       9.35
   46.55       9.45
   64.03       9.45
   64.13       9.95
   64.20      10.15
   64.38      10.45
   64.91      10.90
   65.36      11.15
   65.98      11.35
   67.38      11.65
   68.25      11.85
  135.61      12.50
  140.15      12.55
  161.36      12.60
  161.46      12.75
  161.51      12.90
  161.58      12.90
  162.68      13.40
  163.20      13.55
  164.41      13.80
  165.91      14.05
  166.91      14.15
  183.65      15.25
  207.00      15.40
  215.33      15.55
  231.33      15.55
  231.48      15.65
  231.58      15.70
  232.80      16.15
  233.76      16.25
  234.60      16.45
  235.76      16.60
  236.35      16.65
  301.75      17.35
  325.48      17.35
    -15.      .3680    1   10.
  -1000.      .1940    1   10.
    0.00      30.00
   14.13      50.00
   64.01     100.00
  161.35     298.00
  231.31    1000.00
```

Example outputfile

```
1         ***************************************************************
          *                                                             *
          *                                                             *
          *    OPTIMALISATIE TOMELLOSO outflow 24-02-92                 *
          *                   MONSTER H42                               *
          *                                                             *
          ***************************************************************


          PROGRAM PARAMETERS
          ==================
          NUMBER OF NODES.....................(NN)................ 46
          NODE AT SOIL-PLATE BOUNDARY.........(LNS)............... 41
          INITIAL TIME STEP...................(DNUL)............  .10E-04
          PNEUMATIC PRESSURE..................(AIRP)............  -5.000
          TEMPORAL WEIGHTING COEFF............(EPS1)............   1.00
          ITERATION WEIGHTING COEFF...........(EPS2)............   1.00
          MAX. ITERATIONS.....................(MIT)............... 25
          DATA MODE...........................(MDATA)..............  1
          NO. OF OBSERVATIONS.................(NOBB).............. 50


          SOIL AND PLATE PROPERTIES
          =========================
          SOIL COLUMN LENGTH..................(SLL).............   5.100
          COLUMN DIAMETER.....................(DIAM)............   5.000
          THICKNESS OF PLATE..................(PLL).............    .570
          PLATE CONDUCTIVITY..................(CONDS(2))......  .2700E-02
          SATURATED MOISTURE CONTENT..........(WCS).............    .432
          RESIDUAL MOISTURE CONTENT...........(WCR).............    .079
          FIRST COEFFICIENT...................(ALPHA)...........    .020
          SECOND COEFFICIENT..................(N)...............   1.512
          SATURATED CONDUCTIVITY SOIL.........(CONDS(1)).....   .1046E+01
          EXPONENT L MUALEM-GENUCHTEN.........(EXPL)............    .248

          INITIAL PRESSURE AT CENTER SAMPLE :    -15.0


              5 STEPS IN PNEUMATIC PRESSURE   :
              TIME  PRESSURE

               .00      30.0
             14.13      50.0
             64.01     100.0
            161.35     298.0
            231.31    1000.0


ITERATION NO        SSQ            ALPHA        N          WCR        CONDS       EXPL
     0          .1379D+01          .0204     1.5121      .0792      1.0458      .2480
     1          .6282D+00          .0209     1.5406      .0867      1.5930     -.9624
     2          .6143D+00          .0207     1.5448      .0865      2.3955     -.4800
     3          .6089D+00          .0206     1.5428      .0858      3.0919     -.3166
     4          .6084D+00          .0206     1.5355      .0839      4.6452      .0475
     5          .6069D+00          .0206     1.5326      .0829      5.8772      .1920
     6          .6065D+00          .0206     1.5368      .0840      4.6768      .0093
     7          .6064D+00          .0206     1.5390      .0847      4.5130     -.0310
     8          .6064D+00          .0206     1.5377      .0844      4.6142     -.0197
     9          .6063D+00          .0206     1.5377      .0844      4.6076     -.0215

          MASS BALANCE ERROR IN FE SOLUTION DURING FINAL RUN WAS    .5540 %

          RSQUARE FOR REGRESSION OF PREDICTED VS OBSERVED = .99465

          CORRELATION MATRIX
          ==================
                1            2            3            4            5
           1  1.0000
           2  -.5765       1.0000
           3  -.3411        .9427       1.0000
           4   .0525       -.4605       -.4757       1.0000
           5  -.1182       -.3127       -.3845        .9568       1.0000

          NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
          ================================================
                                                      95% CONFIDENCE LIMITS
          VARIABLE         VALUE        S.E.COEFF.    LOWER        UPPER
            ALPHA         .02059          .0008        .0190        .0221
            N            1.53774          .0279       1.4816       1.5939
            WCR           .08436          .0070        .0703        .0984
            CONDS        4.60762         3.9182      -3.2846      12.4998
            EXPL         -.02152          .6809      -1.3929       1.3499


         --------OBSERVED & FITTED OUTFLOW --------
                                              RESI-
         NO   TIME (HR)     OBS     FITTED    DUAL
          1      .200      .300      .294     .006
          2      .610      .750      .786    -.036
          3     1.530     1.400     1.519    -.119
          4     2.580     1.650     1.991    -.341
          5     5.410     1.800     2.493    -.693
          6     8.400     1.900     2.613    -.713
          7    14.130     1.900     2.644    -.744
          8    14.300     2.300     2.977    -.677
          9    14.600     3.100     3.482    -.382
         10    15.010     4.200     4.027     .173
         11    15.980     5.800     4.865     .935
         12    20.130     6.400     5.839     .561
         13    22.530     6.800     5.912     .888
         14    39.250     7.100     5.937    1.163
         15    46.530     7.150     5.937    1.213
         16    64.010     7.150     5.938    1.212
```

17	64.110	7.400	6.425	.975
18	64.180	7.700	6.740	.960
19	64.360	8.400	7.469	.931
20	64.900	9.500	9.074	.426
21	65.350	10.100	9.915	.185
22	65.960	10.600	10.622	-.022
23	67.360	11.100	11.354	-.254
24	68.230	11.250	11.532	-.282
25	135.600	11.550	11.705	-.155
26	140.130	11.600	11.705	-.105
27	161.350	11.600	11.705	-.105
28	161.450	12.600	13.226	-.626
29	161.500	13.300	13.797	-.497
30	161.560	14.200	14.382	-.182
31	162.660	18.900	18.523	.377
32	163.180	19.350	19.137	.213
33	164.400	19.800	19.797	.003
34	165.900	19.950	20.100	-.150
35	166.900	20.000	20.183	-.183
36	183.630	20.000	20.274	-.274
37	206.980	19.900	20.274	-.374
38	215.310	19.850	20.274	-.424
39	231.310	19.800	20.274	-.474
40	231.460	20.250	21.343	-1.093
41	231.560	20.700	21.624	-.924
42	232.780	23.200	23.335	-.135
43	233.750	24.100	24.033	.067
44	234.580	24.600	24.452	.148
45	235.750	25.100	24.872	.228
46	236.330	25.300	25.034	.266
47	301.730	26.800	26.341	.459
48	325.460	26.600	26.341	.259
49	-15.000	.418	.414	.004
50	-1000.000	.152	.153	-.001

1

```
******************************************************************
*                                                                *
*                                                                *
*     OPTIMALISATIE TOMELLOSO outflow 24-02-92                   *
*                   MONSTER CT144                                *
*                                                                *
******************************************************************
```

PROGRAM PARAMETERS

```
NUMBER OF NODES.....................(NN)................ 46
NODE AT SOIL-PLATE BOUNDARY.........(LNS)............... 41
INITIAL TIME STEP...................(DNUL)............ .10E-04
PNEUMATIC PRESSURE..................(AIRP)............ -5.000
TEMPORAL WEIGHTING COEFF............(EPS1)............  1.00
ITERATION WEIGHTING COEFF...........(EPS2)............  1.00
MAX. ITERATIONS.....................(MIT)............... 25
DATA MODE...........................(MDATA).............  1
NO. OF OBSERVATIONS.................(NOBB).............. 50
```

SOIL AND PLATE PROPERTIES

```
SOIL COLUMN LENGTH..................(SLL).............   5.100
COLUMN DIAMETER.....................(DIAM)............   5.000
THICKNESS OF PLATE..................(PLL).............    .570
PLATE CONDUCTIVITY..................(CONDS(2))......  .2700E-02
SATURATED MOISTURE CONTENT..........(WCS).............    .433
RESIDUAL MOISTURE CONTENT...........(WCR).............    .187
FIRST COEFFICIENT...................(ALPHA)...........    .036
SECOND COEFFICIENT..................(N)...............   1.335
SATURATED CONDUCTIVITY SOIL.........(CONDS(1))......  .1046E+01
EXPONENT L MUALEM-GENUCHTEN.........(EXPL)............    .248
```

INITIAL PRESSURE AT CENTER SAMPLE : -15.0

5 STEPS IN PNEUMATIC PRESSURE :

TIME	PRESSURE
.00	30.0
14.13	50.0
64.01	100.0
161.35	298.0
231.31	1000.0

ITERATION NO	SSQ	ALPHA	N	WCR	CONDS	EXPL
0	.4292D+00	.0360	1.3351	.1870	1.0458	.2480
1	.4024D+00	.0344	1.2721	.1638	.8970	-.7412
2	.2783D+00	.0360	1.2495	.1456	.9450	-1.5628
3	.2710D+00	.0362	1.2479	.1427	.9723	-1.5776
4	.2710D+00	.0362	1.2479	.1427	.9723	-1.5783

MASS BALANCE ERROR IN FE SOLUTION DURING FINAL RUN WAS .5775 %

RSQUARE FOR REGRESSION OF PREDICTED VS OBSERVED = .99609

CORRELATION MATRIX

	1	2	3	4	5
1	1.0000				
2	-.5315	1.0000			
3	-.3671	.9769	1.0000		
4	.0850	-.6494	-.6854	1.0000	
5	-.4434	-.0916	-.2096	.7627	1.0000

NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS

VARIABLE	VALUE	S.E.COEFF.	95% CONFIDENCE LIMITS LOWER	UPPER

ALPHA	.03619	.0021	.0319	.0405
N	1.24789	.0202	1.2073	1.2885
WCR	.14269	.0143	.1139	.1714
CONDS	.97229	.4305	.1051	1.8395
EXPL	-1.57835	.6736	-2.9351	-.2216

--------OBSERVED & FITTED OUTFLOW --------

NO	TIME (HR)	OBS	FITTED	RESI-DUAL
1	.210	.250	.264	-.014
2	.630	.650	.656	-.006
3	1.550	1.150	1.185	-.035
4	2.600	1.350	1.498	-.148
5	5.430	1.500	1.801	-.301
6	8.410	1.550	1.866	-.316
7	14.150	1.600	1.918	-.318
8	14.310	1.800	2.138	-.338
9	14.610	2.150	2.436	-.286
10	15.030	2.350	2.738	-.388
11	16.000	2.650	3.165	-.515
12	20.150	3.000	3.669	-.669
13	22.550	3.150	3.715	-.565
14	39.260	3.450	3.734	-.284
15	46.550	3.500	3.734	-.234
16	64.030	3.550	3.814	-.264
17	64.130	3.700	4.078	-.378
18	64.200	3.950	4.214	-.264
19	64.380	4.450	4.485	-.035
20	64.910	5.050	5.024	.026
21	65.360	5.450	5.337	.113
22	65.980	5.650	5.647	.003
23	67.380	6.000	6.074	-.074
24	68.250	6.150	6.231	-.081
25	135.610	6.900	6.593	.307
26	140.150	6.950	6.593	.357
27	161.360	7.000	6.721	.279
28	161.460	7.500	7.149	.351
29	161.510	7.650	7.268	.382
30	161.580	7.800	7.404	.396
31	162.680	8.800	8.530	.270
32	163.200	9.050	8.858	.192
33	164.410	9.550	9.416	.134
34	165.910	10.000	9.879	.121
35	166.910	10.150	10.100	.050
36	183.650	11.150	10.990	.160
37	207.000	11.250	11.030	.220
38	215.330	11.250	11.030	.220
39	231.330	11.200	11.243	-.043
40	231.480	11.350	11.488	-.138
41	231.580	11.450	11.586	-.136
42	232.800	12.050	12.229	-.179
43	233.760	12.400	12.545	-.145
44	234.600	12.650	12.772	-.122
45	235.760	12.950	13.034	-.084
46	236.350	13.050	13.151	-.101
47	301.750	14.850	15.076	-.226
48	325.480	14.850	15.091	-.241
49	-15.000	.409	.412	-.003
50	-1000.000	.261	.262	-.001

1

```
*****************************************************************
*                                                               *
*                                                               *
*     OPTIMALISATIE TOMELLOSO outflow                           *
*                         MONSTER C3                            *
*                                                               *
*****************************************************************
```

PROGRAM PARAMETERS
==================

```
NUMBER OF NODES....................(NN)............... 46
NODE AT SOIL-PLATE BOUNDARY........(LNS).............. 41
INITIAL TIME STEP..................(DNUL)............ .10E-04
PNEUMATIC PRESSURE.................(AIRP)............ -5.000
TEMPORAL WEIGHTING COEFF...........(EPS1)............  1.00
ITERATION WEIGHTING COEFF..........(EPS2)............  1.00
MAX. ITERATIONS....................(MIT).............. 25
DATA MODE..........................(MDATA)............  1
NO. OF OBSERVATIONS................(NOBB)............. 50
```

SOIL AND PLATE PROPERTIES
=========================

```
SOIL COLUMN LENGTH.................(SLL).............   5.100
COLUMN DIAMETER....................(DIAM)............   5.000
THICKNESS OF PLATE.................(PLL).............    .570
PLATE CONDUCTIVITY.................(CONDS(2))...... .2700E-02
SATURATED MOISTURE CONTENT.........(WCS).............    .414
RESIDUAL MOISTURE CONTENT..........(WCR).............    .193
FIRST COEFFICIENT..................(ALPHA)...........    .055
SECOND COEFFICIENT.................(N)...............   1.938
SATURATED CONDUCTIVITY SOIL........(CONDS(1))..... .1046E+01
EXPONENT L MUALEM-GENUCHTEN........(EXPL)............    .248
```

INITIAL PRESSURE AT CENTER SAMPLE : -15.0

5 STEPS IN PNEUMATIC PRESSURE :

TIME	PRESSURE
.00	30.0
14.13	50.0
64.01	100.0
161.35	298.0
231.31	1000.0

ITERATION NO	SSQ	ALPHA	N	WCR	CONDS	EXPL
0	.1347D+01	.0552	1.9380	.1929	1.0458	.2480

1	.1240D+01	.0533	1.8945	.1888	4.5587	1.1693
2	.1049D+01	.0532	1.9304	.1893	10.0000	.9841
3	.1034D+01	.0531	1.9458	.1895	6.1312	.5664
4	.1034D+01	.0530	1.9480	.1894	6.3571	.5584
5	.1034D+01	.0530	1.9482	.1895	6.3733	.5623

MASS BALANCE ERROR IN FE SOLUTION DURING FINAL RUN WAS .6208 %

RSQUARE FOR REGRESSION OF PREDICTED VS OBSERVED = .94433

CORRELATION MATRIX

	1	2	3	4	5
1	1.0000				
2	-.0956	1.0000			
3	.0861	.6887	1.0000		
4	-.0969	-.5606	-.4036	1.0000	
5	-.3518	-.4559	-.4867	.9203	1.0000

NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS

VARIABLE	VALUE	S.E.COEFF.	95% CONFIDENCE LIMITS LOWER	UPPER
ALPHA	.05302	.0021	.0487	.0573
N	1.94820	.0637	1.8198	2.0766
WCR	.18945	.0034	.1826	.1963
CONDS	6.37329	11.6966	-17.1863	29.9328
EXPL	.56234	1.0060	-1.4640	2.5886

--------OBSERVED & FITTED OUTFLOW --------

NO	TIME (HR)	OBS	FITTED	RESI-DUAL
1	.210	1.650	.323	1.327
2	.630	4.000	.910	3.090
3	1.550	5.650	1.977	3.673
4	2.600	5.750	2.897	2.853
5	5.430	5.900	4.365	1.535
6	8.410	5.950	5.013	.937
7	14.150	5.900	5.400	.500
8	14.310	7.050	5.707	1.343
9	14.610	8.050	6.215	1.835
10	15.030	8.450	6.811	1.639
11	16.000	8.800	7.775	1.025
12	20.150	8.950	9.140	-.190
13	22.550	9.250	9.300	-.050
14	39.260	9.350	9.387	-.037
15	46.550	9.450	9.387	.063
16	64.030	9.450	9.477	-.027
17	64.130	9.950	9.810	.140
18	64.200	10.150	9.985	.165
19	64.380	10.450	10.329	.121
20	64.910	10.900	10.982	-.082
21	65.360	11.150	11.347	-.197
22	65.980	11.350	11.710	-.360
23	67.380	11.650	12.224	-.574
24	68.250	11.850	12.429	-.579
25	135.610	12.500	13.207	-.707
26	140.150	12.550	13.207	-.657
27	161.360	12.600	13.309	-.709
28	161.460	12.750	13.454	-.704
29	161.510	12.900	13.490	-.590
30	161.580	12.900	13.530	-.630
31	162.680	13.400	13.869	-.469
32	163.200	13.550	13.973	-.423
33	164.410	13.800	14.166	-.366
34	165.910	14.050	14.352	-.302
35	166.910	14.150	14.455	-.305
36	183.650	15.250	15.283	-.033
37	207.000	15.400	15.667	-.267
38	215.330	15.550	15.742	-.192
39	231.330	15.550	15.887	-.337
40	231.480	15.650	15.902	-.252
41	231.580	15.700	15.907	-.207
42	232.800	16.150	15.946	.204
43	233.760	16.250	15.966	.284
44	234.600	16.450	15.981	.469
45	235.760	16.600	15.999	.601
46	236.350	16.650	16.007	.643
47	301.750	17.350	16.431	.919
48	325.480	17.350	16.511	.839
49	-15.000	.368	.366	.002
50	-1000.000	.194	.195	-.001

APPENDIX 18 Measured outflow by multi-step.

sample	volume cm³	pressure-step 1	pressure-step 2	pressure-step 3	pressure-step 4	pressure-step 5	pressure-step 6
C2	100	4.9	10.65	14.6	18.15	22.45	25.05
A15	100	3.55	7.25	10.35	13.55	17.25	18.5
A5	100	12.7	18	20.95	23.8	27.45	29.25
A14	100	7.65	9.35	11.85	14.05	17.1	19.45
C7	100	6.15	10.6	14.8	22.2	26.55	28.55
A1	100	10.45	14	16.85	19.3	22.3	24.1
A13	100	8.8	14.1	17.55	20.25	23.35	25.15
C16	100	10.25	13.2	15.35	17.85	22	25.75
A9	100	1.1	1.75	2.85	6.55	10.45	12.85
A7	100	1.25	2	4.8	7.75	11.05	13.15
A17	100	0.6	0.9	2.0	6.45	10.1	12.1
CT09	250	21	25	29	34	42	43
8	250	3	20	34	45	56	65
CT10	250	19	28	34	40	46	50
27	600	39	54	62	73	84	100
12	600	41	71	82	99		
11	600	12	19	36	55	72	85
A2	100	0.3	0.4	0.75	4.2	6.6	8.4
A4	100	0.9	1.8	2.8	5.75	8.2	9.9
A3	100	0.4	0.75	3.75	4.9	6.9	8.8
C10	100	1.05	2.45	6.75	9.15	13.0	15.3
C5	100	1	2.15	3.75	8.8	12.7	14.6
C20	100	2.65	6	8	10.65	14.7	16.8
D12	100	17.85	22.75	26.95	31.0	36.95	39.25
14	600	54	84	120	145	166	180
18	600	28	46	81	110	131	149
D14	100	12.9	20.25	25.9	29.95	36.1	38.3
D15	100	14.4	20.0	24.0	27.8	33.0	36.05
D17	100	10.9	15.75	20.3	25.7	30.6	32.0
B24	100	5.8	9.9	15.7	20.9	26.9	30.85
B5	100	7.0	13.35	20.3	25.7	31.9	35.6
7	250	21	32	42	52	64	71
CT89	100	1.55	7.75	16.45	22.45	29.8	32.9
A23	100	0	-0.3	-0.6	12.55	20.6	24.1
B19	100	1.3	6.2	13	19.35	27.1	30.15
A24	100	-0.4	0.65	6	12.8	21.25	24.7
A12	100	0.35	1.1	2.85	5.25	6.8	8.35
CT05	250	5	9	15	18	22	30
23	600	17	33	38	51		
A18	100	1.5	2.95	5.3	6.1	7.7	8.7
A11	100	0.9	6.1	7.35	8.25	9.7	10.9
A20	100	1.7	9.1	10.6	11.55	13	14.6
4	250	31	48	58	65	72	78

sample	volume cm^3	pressure-step 1	pressure-step 2	pressure-step 3	pressure-step 4	pressure-step 5	pressure-step 6
13	600	24	40	49	60	70	86
CT92	100	3.4	11.2	13.0	15.1	16.9	19.1
CT75	100	0.1	0.0	5.3	7.6	9.9	12.3
CT83	100	1.7	7.7	9.65	11.65	13.15	15.5
CT87	100	5.85	9.0	11.15	14.85	17.25	
CT93	100	2.65	6.7	8.6	11.6	13.8	
CT85	100	6.15	10.1	12.1	15.25	17.65	
CT76	100	0.25	2.15	3.7	5.85	7.75	
CT88	100	4.75	8.0	9.6	12.25	14.2	
CT96	100	4.8	6.8	9.2	11.4	13.3	
CT79	100	6.3	7.75	8.85	10.8	12.8	
CT80	100	1.85	4.95	7.7	10.1	12.1	
CT91	100	7.8	11.05	13.3	17.25	20.4	
B6	100	4.8	10.7	13.2	17.15	19.4	
B15	100	8.7	12.15	14.45	17.7	19.7	
B14	100	10.3	14.45	17.05	20.35	22.55	
B16	100	5.65	8.55	13.25	16.35	17.45	
A10	100	2.2	3.5	7.85	11.25	13.75	
CT94	100	8.95	12.3	14.3	17.25	19.95	
CT95	100	6.5	10.65	13.1	16.55	19.4	
B8	100	0.45	2	7.2	9.6	11.4	
CT86	100	4	8.2	13.2	15.9	19.4	
CT82	100	4.0	7.1	9.05	12.1	13.95	
B9	100	1.6	2.8	7.2	10.2	12.2	
CT74	100	2.45	5.65	11.6	14.65	17.35	
A19	100	1.3	2.3	4.9	8.05	9.85	
A22	100	3.75	7.65	10.25	13.8	16.05	
B13	100	0.45	1.55	5.9	9.45	12.15	
B20	100	0.6	2.05	6.1	9.2	12.3	
B12	100	7.35	13.05	15.35	18.4	18.85	
B18	100	2.3	6.95	9.65	13.05	14.95	
B10	100	-0.2	-0.25	10.15	13.8	15.4	
C13	100	0.4	0.45	6.8	9.8	12.1	
D21	100	0.3	1.6	2.7	5.1	7.5	10.6
D23	100	1.7	5.1	6.9	9.5	12.2	15.3
D20	100	0.2	1.8	4.1	6.9	9.35	11.7
D18	100	0.5	2.3	4.0	6.6	8.3	11.4
D19	100	0.6	6.2	7.4	9.85	11.85	13.25
17	600	18	24	41	57	76	94
D16	100	7.0	12.35	14.1	16.0	17.1	19.0
D24	100	0.3	0.2	11.05	13.3	15.45	17.3
B4	100	0.4	4.0	5.5	6.9	8.1	10.0
B2	100	0.2	2.9	5.6	7.3	8.35	9.9
D6	100	-0.3	0.7	1.9	3.9	4.8	6.3
D5	100	0.1	-0.2	-0.45	-0.35	5.3	8.4

sample	volume cm^3	pressure-step 1	pressure-step 2	pressure-step 3	pressure-step 4	pressure-step 5	pressure-step 6
D8	100	1.3	2.6	3.2	4.6	5.8	8.45
D10	100	1.1	4.3	5.8	7.4	8.95	11.0
15	600	20	29	48	72	91	107
19	600	5	46	52	63		
2	250	5	12	18	24	30	36
C11	100	1.15	3.25	5.15	9.95	15.85	19.75
C23	100	2.7	3.9	4	12	17.7	20.7
C15	100	-0.05	9.2	11.1	14.4	19.35	23.85
26	600	26	65	82	99		
C14	100	1.5	6.15	11.2	15.25	20.7	23.6
C21	100	1.2	3.3	8.8	14.85	21.85	26.15
B17	100	0.2	2.1	7.9	11.3	16.5	19.1
10	250	7	11	20	32	46	55
5	250	10	17	25	34	44	51
C6	100	12.1	17.2	22.85	26.6	28.9	
C18	100	0.5	3.45	9.65	13.7	16.9	
B11	100	0.4	1.4	10.25	13.3	16.1	
C24	100	1.1	0.7	7.1	10.1	13.05	
C19	100	11.7	17.35	23.3	25.7	28.5	
21	600	3	26	32	48		
16	600	34	64	73	89		
22	600	9	24	31	44		
B23	100	0	-0.15	0.3	3.55	6.85	8.45
C8	100	8.95	11.85	15.8	18.45	21.1	
C1	100	1	3.2	6.8	10.2	12.6	
B7	100	0.05	1.55	4.35	7.25	9.4	
C4	100	-0.45	1.4	5.2	8.3	10.4	
20	600	13	23	43	64	84	102
D2	100	-0.9	0.7	0.6	3.2	7.45	10.3
D1	100	1.1	7.25	11.15	14.7	20.4	24.5
D4	100	1.05	2.25	2.3	10.1	15.25	18.1
D3	100	0.25	0	-0.1	10.1	15.1	18.95
H47	100	2.1	4.0	7.1	11.95	18.1	22.65
CT20	100	3.55	7.05	11.4	16.85	24.45	29.35
CT144	100	2.35	3.95	5.9	9.35	13.55	17.2
CT24	100	-0.2	-0.4	-0.2	21.7	28.35	28.8
CT1	100	1.9	3.45	6.2	10.6	17	21
CT9	100	1.35	2.4	4.5	8.5	14.3	17.5
CT132	100	1.95	3.2	5.15	8.35	15	18.9
H33	100	2.05	4.2	9.5	17.35	23.7	26.3
H43	100	-0.6	3.3	8.2	13.9	20.5	23.75
CT6	100	1.45	2.8	5.4	9.8	18.2	24.3
H42	100	1.45	3.35	8.6	13.05	21.25	28.05
H44	100	2.25	4.55	7.8	13.6	23.4	29.7
H41	100	2.35	3.95	5.9	9.35	13.55	17.2

sample	volume cm^3	pressure-step 1	pressure-step 2	pressure-step 3	pressure-step 4	pressure-step 5	pressure-step 6
9(T2)	600	16	31	57	99	148	194
10(T5)	600	24	43	69	114	172	196
8(T1)	600	8	20	56	110	149	179
CT49	100	-2.2	-0.95	2.15	9.05	16.5	19.65
CT71	100	0.3	0.15	6.45	14.6	21.9	25.2
CT51	100	2.1	5.2	8.6	12.5	17.6	20.95
H30	100	-0.05	-0.2	4.05	7.45	13.1	16.25
CT11	100	-0.3	-0.45	14.45	18.3	23.9	26.9
H40	100	1.25	4	9.6	14.8	22.25	24.85
CT63	100	-0.85	-1.05	-1.4	3.65	8.8	11.3
H46	100	3.7	10.05	14.2	18.75	24.8	27.65
CT59	100	-0.4	0.4	2.4	4.6	10.5	13.65
H45	100	2.25	5.3	10.2	15.1	20.9	24.5
H27	100	1.55	5.05	9.75	14.2	19.75	23.6
CT7	100	1.6	5.2	9.15	13.15	18.65	22
CT13	100	2.8	6.55	10.75	15.45	20.6	24.35
H26	100	2.4	5.7	10.1	15.1	20.7	24.6
CT13	100	3.2	7.8	11.3	13.2	15.8	25.4
H38	100	2.25	3.9	5.6	8	12.55	15.95
C3	100	4.65	10.55	14.1	17.25	20.2	22
CT12	100	2.45	5.1	8.6	17.15	28.65	32.75
6(T3)	600	19	33	48	83	148	181
7(T4)	600	18	38	51	81	150	194
CT72	100	-0.5	0.25	3.15	6.7	15.05	19.65
CT70	100	1.55	2.9	5.15	9.2	21.9	29.35

APPENDIX 19 Mualem-VanGenuchten parameters from multi-step outflow.

sample	volume cm^3	α	n	k_s	exp 1	θ_r	θ_s	ssq	mbal
C2	100	0.0517	1.712	0.777	-0.596	0.151	0.417	0.418	0.56
A15	100	0.0503	1.711	0.228	-1.438	0.181	0.379	0.207	0.55
A5	100	0.1521	1.523	10.000	-0.808	0.073	0.388 A	0.278	0.72
A14	100	0.0966	1.650	0.012	-2.000	0.141	0.352	0.848	0.87
C7	100	0.0570	1.584	9.689	-0.155	0.105	0.422	0.793	0.59
A1	100	0.1759	1.436	10.000	-0.761	0.155	0.424	0.448	0.66
A13	100	0.0946	1.646	10.000	0.089	0.171	0.437	0.361	0.71
C16	100	0.1630	1.388	0.497	-2.000	0.073	0.370	0.757	0.65
A9	100	0.0149	1.617	0.137	0.303	0.215	0.372	0.347	0.34
A7	100	0.0274	1.598	0.029	-1.879	0.238	0.390	0.232	0.41
A17	100	0.0120	2.582	0.043	0.400	0.258	0.383	0.338	0.20
CT09	250	0.3012	1.115	10.000	-2.000	0.069	0.416	1.465	0.74
8	250	0.0844	1.647	1.839	-0.992	0.057	0.438	1.297	0.45
CT10	250	0.1766	1.477	10.000	-0.528	0.177	0.423	0.509	0.44
27	600	0.0597	2.335	10.000	2.500	0.135	0.368	11.171	0.29
12	600	0.0544	1.284	2.240	-1.111	0.126	0.370	1.599	0.18
11	600	0.0357	1.289	0.402	-2.000	0.152	0.372	1.386	0.25
A4	100	0.0209	1.618	0.050	-1.141	0.265	0.380	0.287	0.38
A3	100	0.0353	1.657	0.062	-0.989	0.268	0.367	0.482	0.47
C10	100	0.0279	1.972	0.008	-2.000	0.212	0.371	0.585	0.44
C5	100	0.0171	1.917	0.281	0.506	0.204	0.362	0.424	0.40
C20	100	0.0455	1.495	1.455	-0.354	0.186	0.385	0.434	0.58
D12	100	0.1156	1.823	0.123	-2.000	0.000	0.398 A	1.314	0.77
14	600	0.0943	1.446	8.281	-1.008	0.054	0.398 A	1.875	0.13
18	600	0.0548	1.403	0.940	-2.000	0.089	0.398 A	2.619	0.20
D14	100	0.0851	1.732	0.293	-2.000	0.000	0.398 A	0.400	0.74
D15	100	0.1428	1.472	2.566	-1.811	0.000	0.398 A	0.350	0.69
D17	100	0.0885	1.679	0.379	-2.000	0.046	0.383	0.920	0.71
B24	100	0.0530	1.476	10.000	0.421	0.036	0.398 A	0.704	0.61
B5	100	0.0507	1.744	0.498	-1.265	0.022	0.398 A	0.543	0.59
7	250	0.0741	1.506	1.708	-1.398	0.120	0.421	0.735	0.43
CT89	100	0.0258	2.357	0.979	-0.076	0.120	0.452	0.831	0.39
B19	100	0.0237	2.148	6.289	0.696	0.143	0.453	0.660	0.46
A24	100	0.0143	2.370	0.335	-0.319	0.199	0.452	0.710	0.27
A12	100	0.0157	2.281	0.099	1.377	0.293	0.381	0.254	0.18
CT05	250	0.3799	1.191	10.000	-0.384	0.120	0.392	0.983	0.84
23	600	0.0395	1.187	0.457	-1.084	0.235	0.408	1.167	0.23
A18	100	0.0472	1.666	0.632	0.180	0.260	0.355	0.297	0.60
A11	100	0.0419	2.952	0.352	0.475	0.257	0.366	0.687	0.50
A20	100	0.0431	2.990	2.076	0.941	0.252	0.398 A	0.939	0.46
4	250	0.0576	3.256	10.000	1.696	0.002	0.438	7.079	0.54
13	600	0.0535	2.130	10.000	1.746	0.199	0.384	6.352	0.14
CT92	100	0.0499	1.739	0.268	-1.440	0.198	0.400	0.411	0.72

sample	volume cm^3	α	n	k_s	exp l	θ_r	θ_s	ssq	mbal
CT83	100	0.0367	1.829	0.046	-1.083	0.231	0.390	0.309	0.69
CT87	100	0.0506	1.473	0.336	-2.000	0.168	0.372	0.326	0.57
CT93	100	0.0499	1.410	0.045	-2.000	0.243	0.421	0.592	0.49
CT85	100	0.0590	1.550	0.081	-1.827	0.216	0.413	0.330	0.47
CT76	100	0.0195	1.335	0.007	-2.000	0.246	0.388	0.473	0.40
CT88	100	0.0699	1.450	0.090	-2.000	0.232	0.399	0.320	0.51
CT96	100	0.0570	1.491	0.450	-0.719	0.254	0.408	0.245	0.52
CT79	100	0.2641	1.200	2.784	-2.000	0.204	0.394	0.327	0.65
CT80	100	0.0505	1.572	0.386	-0.632	0.253	0.389	0.540	0.62
CT91	100	0.1015	1.260	2.373	-1.500	0.110	0.402	0.353	0.59
B6	100	0.0526	1.545	0.049	-2.000	0.173	0.394	0.899	0.50
B15	100	0.0762	1.528	1.360	-0.733	0.177	0.396	0.311	0.68
B14	100	0.0718	1.633	1.311	-0.618	0.171	0.412	0.448	0.68
B16	100	0.1050	1.427	2.093	-2.000	0.194	0.397	0.229	0.70
A10	100	0.0476	1.214	2.550	-0.639	0.150	0.393	0.271	0.58
CT94	100	0.1161	1.375	1.099	-1.496	0.182	0.421	0.407	0.71
CT95	100	0.0544	1.523	0.276	-1.169	0.203	0.424	0.397	0.49
B8	100	0.0212	2.008	1.413	1.145	0.272	0.392	0.432	0.35
CT86	100	0.0599	1.502	1.646	0.157	0.196	0.419	0.468	0.62
CT82	100	0.0447	1.561	0.104	-1.336	0.215	0.373	0.281	0.44
B9	100	0.0333	1.401	1.256	0.727	0.193	0.355	0.203	0.51
CT74	100	0.0409	1.573	6.833	1.323	0.180	0.378	0.399	0.51
A19	100	0.0197	1.393	0.019	-2.000	0.225	0.377	0.574	0.37
A22	100	0.0335	1.777	0.051	-1.205	0.226	0.397	0.426	0.38
B13	100	0.0197	1.612	0.204	-0.037	0.235	0.381	0.226	0.43
B20	100	0.0242	1.464	0.944	1.278	0.228	0.389	0.315	0.42
B12	100	0.1044	1.620	0.082	-2.000	0.205	0.407	0.919	0.57
B18	100	0.0277	1.957	0.361	0.077	0.246	0.401	0.564	0.47
D21	100	0.0120	1.313	0.036	-1.722	0.172	0.370	0.162	0.50
D23	100	0.0325	1.261	0.116	-2.000	0.118	0.380	0.150	0.64
D20	100	0.0133	1.681	0.008	-2.000	0.255	0.400	0.293	0.37
D18	100	0.0157	1.517	0.049	-1.291	0.233	0.380	0.259	0.48
D19	100	0.0292	1.932	0.074	-1.448	0.218	0.360	0.490	0.60
17	600	0.0390	1.276	0.175	-2.000	0.115	0.357	3.316	0.35
D16	100	0.2124	1.178	52.980	2.500	0.018	0.370	0.489	0.76
B4	100	0.0301	1.713	0.041	-1.807	0.266	0.380	0.334	0.57
B2	100	0.0220	1.890	0.018	-0.850	0.263	0.380	0.464	0.60
D6	100	0.0077	1.533	0.001	2.461	0.226	0.410	0.241	0.53
D8	100	0.0158	1.173	0.023	-2.000	0.180	0.390	0.208	0.65
D10	100	0.0339	1.452	0.201	-1.441	0.231	0.370	0.189	0.58
15	600	0.0485	1.236	0.456	-2.000	0.071	0.372	4.722	0.33
2	250	0.0406	1.939	0.592	0.128	0.228	0.396	1.514	0.50
C11	100	0.0179	1.591	0.536	-0.086	0.165	0.404	0.388	0.41
C23	100	0.0190	1.255	7.603	2.500	0.025	0.407	1.333	0.40
C15	100	0.0269	2.881	0.650	1.074	0.144	0.384	2.460	0.24

sample	volume cm^3	α	n	k_s	exp l	θ_r	θ_s	ssq	mbal
26	600	0.0316	1.327	0.205	-2.000	0.144	0.390	3.670	0.26
C14	100	0.0277	2.131	0.246	-0.713	0.172	0.414	0.517	0.44
C21	100	0.0194	1.888	2.812	1.106	0.134	0.415	0.496	0.36
B17	100	0.0229	2.791	0.004	-1.938	0.216	0.408	0.578	0.46
10	250	0.0202	1.800	0.128	-0.714	0.180	0.395	0.988	0.56
5	250	0.045	1.844	5.306	0.674	0.160	0.413	2.195	0.34
C6	100	0.1423	1.525	10.000	-0.636	0.137	0.449	0.418	0.74
C18	100	0.0243	1.854	0.546	0.249	0.205	0.387	0.646	0.40
B11	100	0.0154	2.576	0.618	1.494	0.217	0.381	0.398	0.18
C19	100	0.1228	1.618	10.000	-0.177	0.163	0.463	0.512	0.71
21	600	0.0088	1.269	0.011	-2.000	0.141	0.338	3.321	0.37
16	600	0.0450	1.390	0.623	-1.099	0.201	0.393	1.320	0.17
22	600	0.0133	1.230	0.041	-2.000	0.196	0.369	1.326	0.31
C8	100	0.2222	1.326	10.000	-1.001	0.157	0.410	0.390	0.64
C1	100	0.0308	1.525	0.177	-0.993	0.235	0.388	0.389	0.51
B7	100	0.0244	1.486	0.248	-0.281	0.263	0.388	0.387	0.45
C4	100	0.0216	1.773	0.200	-0.367	0.257	0.377	0.492	0.41
20	600	0.0298	1.326	0.284	-2.000	0.145	0.398 A	1.842	0.28
D1	100	0.0262	2.158	0.387	-0.334	0.154	0.405	1.128	0.40
D4	100	0.0114	1.830	0.337	-0.154	0.212	0.416	0.942	0.26
H47	100	0.0247	1.428	2.108	-0.221	0.129	0.432	0.274	0.49
CT20	100	0.0353	1.476	10.000	0.430	0.068	0.428	0.464	0.57
CT144	100	0.0362	1.248	0.972	-1.578	0.143	0.433 A	0.271	0.58
CT1	100	0.0205	1.488	10.000	2.447	0.177	0.449	0.308	0.59
CT9	100	0.0144	1.721	0.640	-0.176	0.208	0.411	0.404	0.36
CT132	100	0.0209	1.294	5.076	2.500	0.080	0.400	0.406	0.50
H33	100	0.0228	1.884	10.000	1.541	0.143	0.425	0.676	0.25
H43	100	0.0224	2.397	3.485	0.499	0.163	0.404	1.462	0.26
CT6	100	0.0140	1.491	2.144	0.327	0.128	0.461	0.347	0.40
H42	100	0.0206	1.538	4.608	-0.022	0.084	0.432	0.606	0.55
H44	100	0.0210	1.450	10.000	1.958	0.051	0.449	0.430	0.66
H41	100	0.0362	1.255	0.854	-1.652	0.148	0.433 A	0.272	0.58
10(T5)	600	0.0327	1.698	10.000	-0.309	0.048	0.450	6.179	0.08
8(T1)	600	0.0128	1.827	9.222	1.540	0.154	0.493	4.476	1.39
CT49	100	0.0132	3.062	0.152	-0.730	0.215	0.415	0.574	0.15
CT71	100	0.0125	3.423	0.797	0.987	0.152	0.405	0.755	0.39
CT51	100	0.0333	1.632	2.985	-0.113	0.159	0.393	0.455	0.49
H30	100	0.0136	1.978	0.198	-0.319	0.201	0.376	0.627	0.20
CT11	100	0.0215	5.000	1.157	1.771	0.141	0.411	1.723	0.34
H40	100	0.0212	1.976	0.298	-1.375	0.142	0.403	0.469	0.43
H46	100	0.0385	1.742	2.745	-0.429	0.113	0.408	0.413	0.57
CT59	100	0.0110	1.807	0.105	-1.071	0.172	0.333	0.296	0.27
H45	100	0.0295	1.703	0.898	-1.042	0.192	0.461	0.323	0.53
H27	100	0.0288	1.822	0.883	-0.735	0.195	0.446	0.752	0.50
CT7	100	0.0302	1.785	4.340	0.351	0.198	0.433 A	0.611	0.51

sample	volume cm^3	α	n	k_s	exp 1	θ_r	θ_s	ssq	mbal
CT13	100	0.0359	1.667	3.219	-0.272	0.189	0.456	0.524	0.55
H26	100	0.0318	1.709	1.845	-0.911	0.191	0.460	0.538	0.53
H38	100	0.0315	1.170	1.194	-2.000	0.045	0.398	0.306	0.50
C3	100	0.0530	1.948	6.373	0.562	0.189	0.414	1.034	0.62
CT12	100	0.0176	1.606	10.000	0.460	0.070	0.467	1.039	0.70
6(T3)	600	0.0286	1.448	10.000	-0.221	0.014	0.442	5.298	0.11
7(T4)	600	0.0268	1.409	7.672	-0.863	0.000	0.476	6.886	0.10
CT72	100	0.0120	1.794	0.242	-0.630	0.184	0.415	0.408	0.31
CT70	100	0.0092	1.535	10.000	2.500	0.040	0.458	0.618	1.89

A: average θ_s

APPENDIX 20 Results particle size distribution.

sedimentation

field	plot	depth [cm]	### ---- FRACTION 10-3 CM ---- ###			
			0-2	2-16	16-50	>50
BAR1	B1	0-10	0.08	0.18	0.47	0.28
BAR1	B1	10-20	0.02	0.18	0.55	0.24
BAR1	B1	20-30	0.09	0.15	0.53	0.24
BAR1	B1	30-40	0.11	0.12	0.59	0.18
BAR1	B2	0-10	0.08	0.12	0.53	0.27
BAR1	B2	10-20	0.08	0.07	0.55	0.30
BAR1	B2	20-30	0.09	0.06	0.54	0.31
BAR1	B2	30-40	0.11	0.07	0.54	0.27
BAR1	B3	0-10	0.09	0.13	0.43	0.36
BAR1	B3	10-20	0.10	0.11	0.46	0.33
BAR1	B3	20-30	0.09	0.09	0.40	0.42
BAR1	B3	30-40	0.10	0.09	0.44	0.37
BAR2	B4/B5	0-10	0.07	0.27	0.47	0.19
BAR2	B4/B5	10-20	0.04	0.27	0.51	0.17
BAR2	B4/B5	20-30	0.04	0.27	0.50	0.18
BAR2	B4/B5	30-40	0.05	0.27	0.52	0.16
BAR2	B6	0-10	0.15	0.17	0.49	0.19
BAR2	B6	10-20	0.11	0.14	0.55	0.20
BAR2	B6	20-30	0.08	0.18	0.54	0.19
BAR2	B6	30-40	0.10	0.19	0.53	0.18
BAR3	B7	0-10	0.11	0.21	0.43	0.26
BAR3	B7	10-20	0.12	0.22	0.42	0.25
BAR3	B7	20-30	0.12	0.21	0.44	0.23
BAR3	B8	0-10	0.14	0.23	0.42	0.21
BAR3	B8	10-20	0.13	0.25	0.43	0.20
BAR3	B8	20-30	0.02	0.12	0.67	0.19
BAR4		0-10	0.01	0.14	0.35	0.49
BAR4		10-20	-0.02	0.17	0.43	0.42
BAR5	B13	0-10	0.09	0.19	0.43	0.30
BAR5	B13	10-20	0.10	0.18	0.44	0.28
BAR5	B13	20-30	0.11	0.20	0.46	0.24
BAR5	B14/B15	0-10	0.10	0.11	0.60	0.19
BAR5	B14/B15	10-20	0.12	0.12	0.58	0.18
BAR5	B14/B15	20-30	0.15	0.08	0.57	0.20
BAR5	B14/B15	30-40	0.11	0.10	0.57	0.22
BAR5	B16/B20	0-10	0.18	0.20	0.43	0.19
BAR5	B16/B20	10-20	0.06	0.27	0.51	0.16
BAR5	B16/B20	20-30	0.09	0.24	0.44	0.23
BAR6	B21	0-10	0.08	0.16	0.45	0.31
BAR6	B21	10-20	0.05	0.16	0.52	0.27
BAR6	B22	0-10	0.06	0.22	0.48	0.24
BAR6	B22	10-20	0.08	0.03	0.67	0.22
BAR7	B23	0-10	0.09	0.17	0.39	0.35
BAR7	B23	10-20	0.09	0.16	0.38	0.37
BAR7	B24	0-10	0.09	0.18	0.36	0.37
BAR7	B24	10-20	0.10	0.19	0.37	0.33
BAR8	B25	0-10	0.02	0.19	0.54	0.24
BAR8	B25	10-20	0.06	0.18	0.49	0.26
BAR8	B25	20-30	0.03	0.18	0.53	0.26
BAR8	B25	30-40	0.12	0.20	0.46	0.21
BAR8	B25	40-50	0.05	0.16	0.45	0.34
BAR8	B25	50-60	0.06	0.17	0.50	0.27
BAR8	B26	0-10	0.09	0.24	0.44	0.22
BAR8	B26	10-20	0.11	0.21	0.48	0.20
BAR8	B26	20-30	0.15	0.21	0.45	0.19
BAR8	B26	20-30	0.07	0.13	0.42	0.38
BAR9	B28	0-10	0.12	0.24	0.46	0.19
BAR9	B28	10-20	0.14	0.23	0.44	0.20
BAR9	B28	20-30	0.09	0.27	0.46	0.18

BAR9	B28	30-40	0.12	0.26	0.45	0.17
TOM1		15-25	0.05	-0.03	0.39	0.60
TOM1		25-35	0.04	0.02	0.38	0.57
TOM1		35-45	0.03	0.00	0.38	0.58
TOM1		5-15	0.06	0.06	0.27	0.61
TOM1		5-15	0.05	0.01	0.42	0.52
TOM1		5-15	0.02	-0.05	0.41	0.61
TOM2		15-25	0.08	0.12	0.27	0.54
TOM2		25-35	0.06	0.12	0.60	0.22
TOM2		35-45	0.11	0.06	0.33	0.51
TOM2		5-15	0.07	0.13	0.25	0.55
TOM3		15-25	0.12	0.21	0.44	0.23
TOM3		25-35	0.15	0.16	0.46	0.23
TOM3		35-45	0.15	0.17	0.43	0.25
TOM3		5-15	0.11	0.22	0.40	0.27
TOM4		15-25	0.05	0.12	0.33	0.50
TOM4		25-35	0.08	0.05	0.32	0.55
TOM4		5-15	0.06	0.02	0.36	0.56
TOM5		25-35	0.02	0.16	0.24	0.58
TOM5		35-45	-0.03	0.18	0.25	0.61
TOM5		45-55	-0.03	0.17	0.29	0.57
TOM5		55-65	0.04	0.16	0.29	0.51
TOM5		65-75	0.07	0.12	0.34	0.47
TOM6		15-25	-0.02	0.18	0.28	0.57
TOM6		25-35	0.05	0.15	0.31	0.49
TOM6		35-45	0.03	0.17	0.36	0.45
TOM6		5-15	0.02	0.13	0.28	0.57

sieving

			### ---------- FRACTION 10-3 CM ---------- ###					
field	plot	depth [cm]	<0.053	0.053-0.106	0.106-0.212	0.212-0.425	0.425-2.000	>2.000
BAR1	B1/B2	0-10	0.10	0.55	0.13	0.06	0.13	0.04
BAR1	B1/B2	10-20	0.07	0.52	0.10	0.06	0.14	0.11
BAR1	B1/B2	20-40	0.04	0.53	0.10	0.05	0.13	0.14
BAR1	B3	0-20	0.01	0.32	0.07	0.05	0.14	0.40
BAR1	B3	20-40	0.02	0.25	0.09	0.07	0.19	0.39
BAR2		0-10	0.04	0.60	0.12	0.06	0.13	0.05
BAR2		10-20	0.06	0.53	0.11	0.06	0.14	0.10
BAR2		20-30	0.07	0.52	0.11	0.05	0.12	0.13
BAR3		0-10	0.03	0.61	0.11	0.05	0.10	0.10
BAR3		10-30	0.05	0.67	0.12	0.05	0.09	0.02
BAR4		0-20	0.03	0.28	0.09	0.06	0.15	0.39
BAR5	B13	10-30	0.07	0.53	0.12	0.04	0.10	0.14
BAR5	B14/B20	0-10	0.05	0.67	0.10	0.05	0.09	0.03
BAR5	B14/B20	10-20	0.03	0.60	0.13	0.06	0.11	0.07
BAR5	B14/B20	20-40	0.08	0.55	0.12	0.05	0.09	0.10
BAR6		0-10	0.02	0.41	0.14	0.09	0.12	0.22
BAR6		10-20	0.03	0.43	0.16	0.10	0.14	0.13
BAR7		0-10	0.02	0.39	0.15	0.10	0.15	0.19
BAR7		10-20	0.03	0.36	0.15	0.10	0.16	0.20
BAR8	B25/B26	0-10	0.02	0.48	0.14	0.09	0.19	0.08
BAR8	B25/B26	20-30	0.03	0.47	0.14	0.08	0.18	0.11
BAR8	B25/B26	40-60	0.01	0.24	0.10	0.07	0.13	0.45
BAR9	B28	0-40	0.04	0.59	0.12	0.05	0.14	0.05
TOM1		15-45	0.01	0.15	0.13	0.10	0.26	0.36
TOM1		5-15	0.01	0.16	0.14	0.09	0.21	0.38
TOM2		5-45	0.01	0.22	0.17	0.10	0.18	0.31
TOM3		5-45	0.02	0.54	0.13	0.08	0.15	0.08
TOM4		5-35	0.01	0.23	0.18	0.09	0.16	0.32
TOM5		25-75	0.02	0.24	0.23	0.15	0.21	0.16
TOM6		25-45	0.03	0.32	0.23	0.10	0.15	0.17
TOM6		5-25	0.01	0.20	0.15	0.08	0.17	0.38

APPENDIX 21 Doelstellingen en voorbereiding.

HAPEX - SPANJE

26-3-'91

HBH bodem/meteorologie groep

1. Doelstellingen
2. Methoden en technieken
3. Instrumentatie
4. Lay-out en meetprogramma's
5. Organisatie en menskracht
6. Werkplan
7. Financiën

ad 1

a. Bepaling van de energiebalans boven een aërodynamisch homogeen terrein (stoppel/gerst).
b. Bepaling van bodemfysische karakteristieken en de ruimtelijke variabiliteit ervan.
c. Toepassing bodemfysische informatie in agrohydrologische en geparameteriseerde modellen. Validatie van de modellen m.b.v. de flux metingen van andere groepen.
d. Monitoring van lokale waterbalansen op diverse plaatsen binnen de invloedssferen van de diverse masten gedurende de gehele meetcampagne.
e. Monitoring van het bodemvocht in de toplaag, incidenteel en intensief, ter ondersteuning van remote sensing activiteiten en ten behoeve van geo-statistisch onderzoek.

ad 2

a. Bepaling van de energiebalans m.b.v. meetmastje. Per 10 minuten wordt de sensibele warmtestroom geschat met de profielmethode en de fluctuatiemethode. De verdamping wordt indirect bepaald uit de energiebalans vergelijking. De Bowenratio-methode zal worden toegepast voor een deel van de meetperiode;
b. Voor het bepalen van de bodemfysische karakteristieken zal de multi-step methode worden toegepast (met eventueel enige additionele pF punten in het droge stuk). Verder kan de disk-permeameter (te leen van I.B. Haren en/of Winand Staring Centrum) toegepast worden. In-situ bepaling van pf-curve kan worden gedaan met behulp van vochtmeting en bodemvochtspanning tot ca. -800 mb.

c. Diverse agrohydrologische modellen staan ter beschikking; van sterk fysisch georienteerd tot geparameteriseerde modellen. Technieken ter beschikking zijn o.a. scaling, inverse modellering en stochastische benaderingen.
d. Monitoring van lokale waterbalansen kan geschieden door de bodemvochtinhoud per profiel en de percolatie uit het profiel regelmatig te bepalen. Percolatie zal naar verwachting geen rol van betekenis meer spelen gedurende het veldexperiment in juni. Bodemvocht kan worden bepaald met de TDR-methode, de neutronensonde-methode en gravimetrische metingen. Voor bodemvochtspanningen wordt tensiometrie toegepast.
e. Het bodemvocht in de toplaag wordt bepaald m.b.v. TDR. De meetwijze is 'priksgewijs' en moet statistisch verantwoord worden uitgevoerd (sampling theorie).

ad 3

a. Energiebalans instrumentatie en accessoires:

- 2x2 nivo's: droge bol temp./ natte bol temp. voelers,
- netto stralingsmeters,
- kortgolvige in- en uitgaande stralingsmeter,
- bodemwarmtefluxplaatje(s),
- zonneschijnduur meter,
- windrichtingsmeter,
- windsnelheidsmeters,
- regenmeter (type tipping bucket),
- snel thermo-koppel voor fluctuaties,
- 2 datalogger systemen + geheugenkaarten,
- zonnepanelen, accu's en kisten,
- draagbare P.C. + harde schijf en floppy's (3½ inch),
- reserve onderdelen voor kwetsbare componenten.

b,d,e. Bepaling bodemfysische karakteristieken en monitoring:
- multi-step installaties in lab. Nieuwlanden (100 cc en 600 cc),
- 100 cc en 600 cc ringen voor bemonstering,
- weerstandsmeter (penetrometer),
- disk permeameter (bij voorkeur 2),
- droogstoof,
- aggregaat voor energie,
- vochtdoosjes,
- 3 TDR opstellingen (1 x cable tester, 2 x Poolse opzet),
- groot aantal TDR sensoren,

- tensiometers, uitleesunits en accessoires,
- ontluchtingsapparatuur voor water,
- neutronensonde en buizen,
- draagbare P.C. + harde schijf en floppy's (3½ inch),
- volumetrische dichtheidsbepalingen (kan evt. later in lab)
- balans voor gravimetrische bepaling,
- conserveermiddel voor ongestoorde monsters,
- piketten + lint voor afzetten + labels.

ad 4

a. De micro-meteorologische bepalingen met de meetmast worden gedaan in een voldoende groot gerst- of stoppelveld in Tomelloso. De metingen moeten plaatsvinden binnen een zgn aangepaste grenslaag.

c. Deze activiteit vindt plaats in Wageningen.

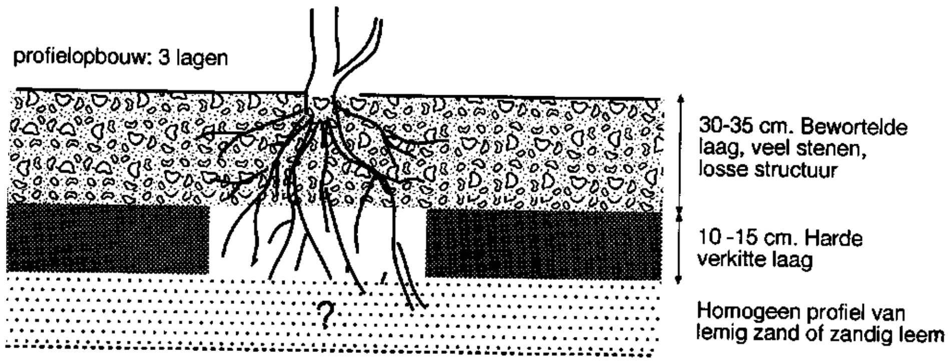
b,d,e. De lay-out voor de bepaling van de bodemfysische grootheden en voor de monitoring van de waterbalansen ligt veel moeilijker. Uiteindelijk gaat het erom dat steeds weer de metingen met kleine ruimtelijke schaal geïntegreerd moeten worden met metingen met een grotere ruimtelijke schaal (meteorologische metingen). Een belangrijke rol in de keuze van de lay-out speelt de indeling in representatieve subgebiedjes (grondgebruik en grondsoort) en binnen elk subgebied speelt het probleem van de ruimtelijke variabiliteit (sampling strategie). De keuze van de lay-out wordt uiteraard ook bepaald door de beschikbare instrumentatie en mankracht.

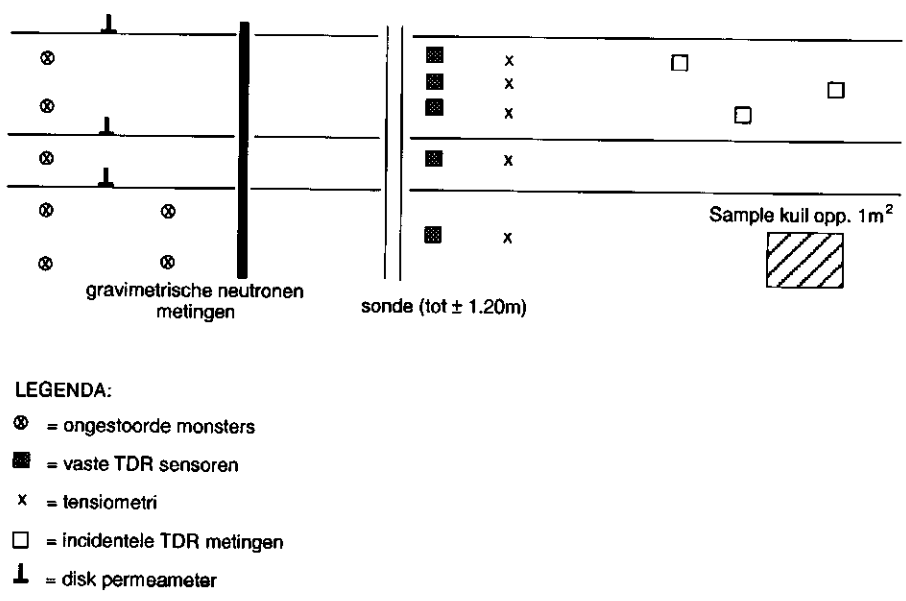
TOMELLOSO

Landgebruik:
- stoppel/gerst,
- wijngaard:
  - oud (volledige rozetbeworteling),
  - jong (onvolledige rozetbeworteling in horizontale vlak).

Randvoorwaarden en veronderstellingen:
- wijnstruiken in carré van ca. 2x2 m,
- vochtontrekking als gevolg van transpiratie en evaporatie,

- er worden 3 typen landgebruik onderscheiden met de volgende kenmerken:
    - stoppel/gerst: gelijkmatige vochtontrekking per oppervlakte eenheid,
    - wijngaard 'oud': gelijkmatige vochtontrekking in eerste laag a.g.v voll. doorworteling,
    - wijngaard 'jong': ongelijkmatige vochtontrekking in eerste laag a.g.v. niet voll. doorworteling,
- er wordt gewerkt met een zgn basisconfiguratie voor de monitoring gedurende de volledige meetperiode,
- er vinden op lokale schaal incidenteel intensieve meetcampagnes plaats,
- het meetprogramma wordt afgestemd op de bijdrage van andere partners (Staring Centrum, **Wallingford**).





Uitgegaan wordt van: - 8 basisconfiguraties in oude wijngaard,
- 8 basisconfiguraties in jonge wijngaard,
- 5 basisconfiguraties in stoppel/gerst.

De keuze van de lokaties gebeurt select m.b.t. de percelen waarbij uitgegaan wordt van zoveel mogelijk spreiding binnen het proefgebied (binnen fetch-afstand centrale masten) en aselect binnen de percelen.

De inrichting van de meetplek dient zodanig te geschieden dat verstoring van de meetplek wordt vermeden of beperkt.

De meetfrequentie is afhankelijk van de weersomstandigheden; bij voortdurend droog weer ≈ 1 keer/1 of 2 dagen; na neerslag moet zoveel mogelijk gemeten worden.

De informatie welke verkregen wordt m.b.v. de basisconfiguraties is:
- waterbalansen over korte tijdsintervallen,
- veranderingen θ en h per laag,
- bodemfysische karakterisering,
- variabiliteit tussen lokatie m.b.t. θ, h en bodemfysische karakteristieken,
- uitdroging van de toplaag,
- mogelijk vochttransport over tweede laag, vochtonttrekking aan eerste laag
- enige informatie over de bijdrage van transpiratie en evaporatie aan totale onttrekking van vocht via vergelijk oude en jonge aanplant.

Incidentele monitoring is nodig op de volgende punten:
- t.b.v. remote sensing: bodemvocht toplaag, 1 of 2 dagen met TDR,
- bodemvocht-bemonstering op korte afstand (grid) t.b.v. geo-statistische analyse,
- evt. aantal ongestoorde bodemmonsters t.b.v. α-verdeling schaalfactoren,
- wortelverspreiding in oude- en jonge aanplant, horizontaal,
- wortelpenetratie in laag 3 t.b.v. juiste modellering,
- aparte monitoring voor bijdrage transpiratie (sapstroommetingen) en evaporatie (evt. micro-lysimeters).

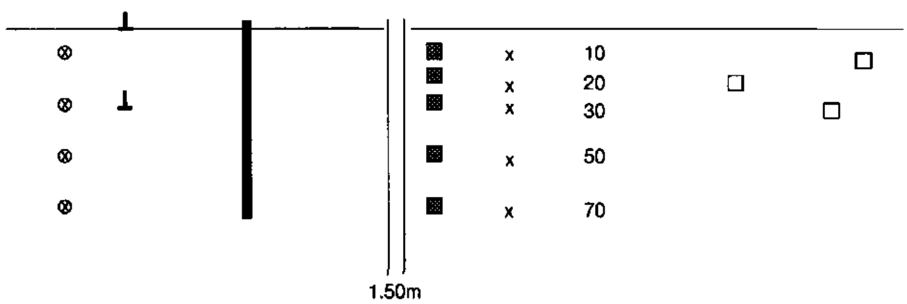
BARRAX

Landgebruik: - geïrrigeerde landbouw, vooral maïs,
- niet geïrrigeerde landbouw, wintergerst/stoppel, alfalfa

Profielopbouw: profiel is te beschouwen als één laag en overwegend een zware zavelachtige grond. Met name de geirigeerde gronden zijn steenvrij gemaakt en van een zeer goede kwaliteit. Opbouw profiel is homogeen, maar met de diepte neemt de compactheid toe, met op 80 cm begin van verkitting.

Randvoorwaarden en veronderstellingen:

- maïs is een rij-gewas en dus moet daarmee rekening worden gehouden bij de metingen,
- vochtonttrekking vooral door transpiratie in de geirigeerde percelen,
- er worden 3 typen landgebruik bemeten:
  - geirigeerde maïs,
  - niet geirigeerde alfalfa,
  - niet geirigeerde wintergerst/stoppel,
- ook hier wordt gewerkt met zgn. basisconifiguraties, echter kleiner in aantal, en iets anders van opzet.
- extra informatie van de hydraulische karakteristieken buiten de informatie van de vaste lokaties. Dit is noodzakelijk om de variabiliteit (α-factoren) voldoende te kunnen beschrijven, statistiek,
- ook hier zal op lokale schaal en incidenteel intensief gemeten worden remote sensing, geo-statistische informatie),
- meetprogramma afstemmen op bijdragen van andere deelnemers (Grenoble, derden).



Uitgegaan wordt van - 6 lokaties in de maïs,
- 6 lokaties in de alfalfa,
- 4 lokaties in wintergerst/stoppel.

De keuze ook hier weer select m.b.t. percelen en aselect in het perceel. Lokaties weer binnen de fetch van de centrale mast(en).

Meetfrequentie: - voor geïrrigeerd 1 keer/dag,
- voor niet geïrrigeerd 1 keer/2 dagen.

Informatie: in grote lijnen overeenkomend met Tomelloso.
Incidentele monitoring: Nodig t.a.v de volgende punten:

- remote sensing: 1 à 2 dagen bodemvocht bemonstering met TDR, bodemvocht bemonstering op korte afstand (grid) t.b.v. geo-statistische analyse,
- bewortelings-diepten.

Onzekerheden en zwakke punten in meetprogramma:

- nog geen zekerheid omtrent gebruik neutronensonde in Spanje: papieren zijn naar Spanje ter goedkeuring,
- tensiometers meten tot ca. -800 mb minimaal,
- bovenlaag in Tomelloso zeer verstoord door stenen. Wat wordt er precies gemeten. Vooraf in Wageningen nog een testprogramma uitvoeren voor gesimuleerde omstandigheden van Tomelloso,
- het is niet zeker of de disk-permeameter op alle nivo's in Tomelloso werkt. Voor 2e en 3e laag lijkt het goed, hetzelfde geldt voor Barrax,
- het nemen van ongestoorde grondmonsters is zeer arbeidsintensief en zal niet altijd lukken in Tomelloso.
- de gravimetrische bemonstering lijkt niet eenvoudig. Wellicht met een gutsboor.

ad 5

- Uitgaande van de basisconfiguraties gaat het om 21 lokaties in Tomelloso en 14 in Barrax. In principe komen de activiteiten rond de basisconfiguraties voor verantwoordelijkheid van de HBH groep. Bepaalde activiteiten rond de bemonstering van de bodem t.b.v de hydraulische karakteristieken zal in samenwerking gebeuren met het Winand Staring Centrum, aangezien ook monsters worden genomen ten behoeve van de verdampingsmethode.
- Van de incidentele metingen zal in Tomelloso nauw worden samengewerkt met het Staring Centrum en in Barrax met Grenoble. Ten aanzien van de remote sensing is

Van de Griend (VU Amsterdam) de hoofdverantwoordelijke van de lay-out en het programma.

- De beschikbare mankracht voor Spanje omvat 6 personen, te weten: Gijs van de Abeele, Peter Droogers, Tom Bakkum, Radka Rösslerová, René Kim en Han Stricker. Kole zal in principe de neutronensonde metingen verrichten, in ieder geval in Tomelloso en eventueel in Barrax. Het laatste hangt af van de beschikbaarheid van een 2e meetapparaat (Grenoble, Spaanse deelname). Van de Abeele zal in ieder geval in Tomelloso werken i.v.m. de meetmast e.d. Hij is echter ook inzetbaar voor incidentele metingen. Twee personen zullen moeten werken aan de verzameling van monsters en in situ bodemfysische informatie (1 in Barrax, 1 in Tomelloso), d.w.z. ongestoorde monsters en de disk-permeameter. Overleg moet plaatsvinden met het Staring Centrum (Tomelloso) en Grenoble (Barrax) over inzetbaarheid van ook elk 1 persoon zodat in principe in groepjes van 2 kan worden gewerkt. Voor de metingen van TDR en tensiometers en gravimetrische bepalingen bij de vaste lokaties is in Tomelloso en in Barrax 1 persoon verantwoordelijk (gezien de levertijd van de Poolse TDR aan Grenoble behoort een kleine herverdeling van het werk in Barrax, in overleg met Grenoble, tot de mogelijkheden. De Franse TDR metingen zouden dan door LUW-HBH gedaan kunnen worden). De resterende persoon is wisselend inzetbaar.
- De groep heeft de beschikking over de meetauto van de vakgroep en 1 personenauto.
- De verblijfplaats van de groep ligt nog niet vast voor zowel Tomelloso als Barrax. Hier wordt aan gewerkt. In Barrax zullen in ieder geval twee personen werkzaam zijn van de HBH-groep en evt. Kole afwisselend.
- In verband met de benodigde voorbereidingen in het veld (1 week) en de reis en de grens moeilijkheden in het weekend, wordt de vertrekdatum 22 mei. Verwacht wordt dat we terugkeren in Wageningen 6 juli.
- Aandacht moet worden besteed hoe het leven tijdens de campagne goed te organiseren (maaltijden, vrijaf, eten e.d.).

ad 6

Aan de hand van de werkzaamheden zal er een gedetailleerd draaiboek moeten komen op korte termijn. Dit draaiboek moet omvatten:

- de voorbereidingen:
  - instrumentatie (incl. reserve onderdelen),
  - papieren,
  - vervoer,
  - huisvesting en verblijf,
  - financiën.
- reis heen en terug: kosten, tijden, overnachtingen,

- de meetcampagne:
    - werkplan in het veld,
    - organisatie en mankracht,
    - vervoer en logistiek,
    - verantwoordelijkheden,
    - data-opslag, verwerking,
    - sociale organisatie, recreatie,
    - financiële beheer,
    - kleding.

ad 7

De kosten van het EFEDA-project worden gedekt door E.G. gelden. Werkelijke kosten. Geen overdaad!

N.a.b.:

- De bodemactiviteiten van het S.C. zijn bekend en doorgesproken door Han Stricker en Pavel Kabat op 19-3-'91 . Met Grenoble (Vauclin) is dat gebeurd op 25-3-'91 op de bijeenkomst van de Tomelloso groep in Wageningen.
- Eerstvolgende bezoek aan Tomelloso/Barrax door Stricker, de Bruin en Kabat op 11-14 april t.b.v. exacte meetplaatsen, huisvesting, uitproberen enige installatie- en meet-technieken e.d. Madrid meeting 6-7 mei: plenaire vergadering.