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SUBMODEL OF BYPASS FLOW IN CRACKING SOILS. PART 2- EXPERIMENTAL VALIDATION

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Abstract. The experimental validation of bypass flow submodel was done using data gathered at two sites Grabów and Czes³awice. Measured and calculated moisture content show better agreement when the bypass flow is taken into account. This is especally important for deeper layers of the soil where the Richard's equation modeling shows too small water content. The bypass flow mechanism allows more water to flow down immediately to deep layers bypassing the top layers of soil profile.

Keywords: bypass flow, numerical validation, experimental validation

INTRODUCTION

In this study we present the validation of the bypass flow submodel. We have decided to validate the model in two ways. First to check model behaviour with hypothetical data; initial water content, crack geometry and relative area and the second for verification and calibration of the model on the basis of the field experiment data.

METHODS AND EQUIPMENT

Numerical test of crack submodel

The testing input data consists four rainy days with an average rainfall 3 cm/day. Assumed rainfall looks cumulated in time but it gives rather low average rainfall intensity due to ACCESS-II assumption of constant rainfall intensity during each day. Bypass flow depends highly on the rainfall distribution and is most important for high momees of the rainfall. Mean daily intensity of the rainfall taken into account in the ACCESS-II model is always much lower than the momentary intensities observed in reality. It suggests that in real conditions bypass flow will start for lower daily rainfall intensities than used for model testing. Van Lenen *et. al.* [7] shows evidence of bypass flow for daily rainfall as low as 0.7 cm.

The soil profile of the depth 160 cm is assumed to be homogeneous with respect to hydraulic properties and crack development parameters. The data set characterizes the silty soil with the shrinking swelling properties leading to the maximal relative crack area 0.5 %.

We assumed three variants of initial water content:

1. Initially there are cracks reaching the bottom of the soil profile.
2. Initial cracks reach the depth 80 cm.
3. The soil is wet enough and cracks are not present.

For these three initial water contents the ACCESS-II was run for 10 days elapsing time twice: first with CRACK subroutine and the second without activation of CRACK subroutine for the by pass flow).

Results of simulation are presented on 6 figures. Figure 1a shows the first case without crack influence, and Fig. 1b with crack influence on the bypass flow. The presence of bypass flow causes an additional water amount to flow to the bottom of the soil profile and water content in this region to raise.

Figure 2a shows th water transport to the depth about 80 cm and then redistribution of the water into the soil profile.

When the initial water content in the soil profile is high, cracks are closed and in this case no difference can be observed when running ACCESS- II with and without procedure CRACKS. This situation is presented on the Figs 3a and b.

Experimental field localization and characteristics

The research area Grabów [5]

The research area Grabów is located in the southern part of the Mazovian Plain, constituting a part of the greater physiographic subprovince called Middle Polish Lowlands. The entire area is situated within the mid-Polish glaciation and thus, all the surface formations consist of boulder materials in the form of loam and sands. The landscape is relatively monotonous and the relief is typical for flat rolling areas of ground moraine. The elevation ranges from 158 to 166 m asl, with relative denivelation up to 8 m.

Climate of this region is moderate, with average annual temperature 7.3 °C and average annual precipitation 576 mm. The experimental site is located in the Agricultural Experimental Station at Grabow. Mosaic soil cover consists of uniform or non-uniform sandy and/or loamy podzolic and leached brown soils and black earth, part of them being boggy in shallow depressions with visible signs of intensive gleying in lower horizons. The prevailing mechanical composition of these soils is medium loam, and weakly loamy or loamy sands. Calcium carbonate appears at a depth of 80 - 100 cm, rarely at 150 cm. Thickness of arable layer is about 20-30 cm. The most often depth of the lower boundary of eluvial horizon reaches 40-45 cm. Soil pH ranges from 5.1 to 6.0, available P_2O_5 4-9 mg, and K_2O 8-17 mg/100 g of soil.

The soil material is mostly leached, with high percentage of sand. Because of low permeability of deeper horizons a great part of these soils undergo gleying processes and therefore, occasionally they are water-logged. The arable layer shows weak soil structure. These soils can be utilized both as arable or grassland field. The typical crop rotation system on this soil can be grain crops and potatoes.

Fertilization: NPK - above average in Poland, FYM - occasionally for root crops.Tillage: fully mechanized field operations: winter ploughing 20-30 cm, one or two cultivations connected with harrowing (8-10 cm). The experiments were performed on podzolic soil derived from sandy loam. During the growing season 1993 and 1994 the moisture content, temperature and additionally electrical bulk conductivity were measured at seven soil depths in the field under winter wheat and five depths in black fallow.

The experimental field is located close to the agrometeorological station, where the following climatic data are collected: precipitation, max/min temperature, wind velocity and direction, total and net radiation, and cloudiness.

The research area Czesławice [1]

The research area Czesławice is located in the south-eastern part of Poland within the Nałęczów Plateau, about 215 m asl. The Nałęczów Plateau consists the western part of a greater physiographic unit, called Lublin Upland, laying on the loessial belt. Climate of this region is moderate, with average annual temperature +7.6 °C and precipitation about 511 mm. The experimental site is located on the Experimental Station Czesławice of the University of Agriculture in Lublin (20 km west of Lublin). The soil cover is derived from a typical loess and is classified as soil lessivé (*Orthic Luvisols*). The landscape shows a typical rolling configuration for the loessial belt and the differentiation in profile depth due to erosion processes. The experimental site

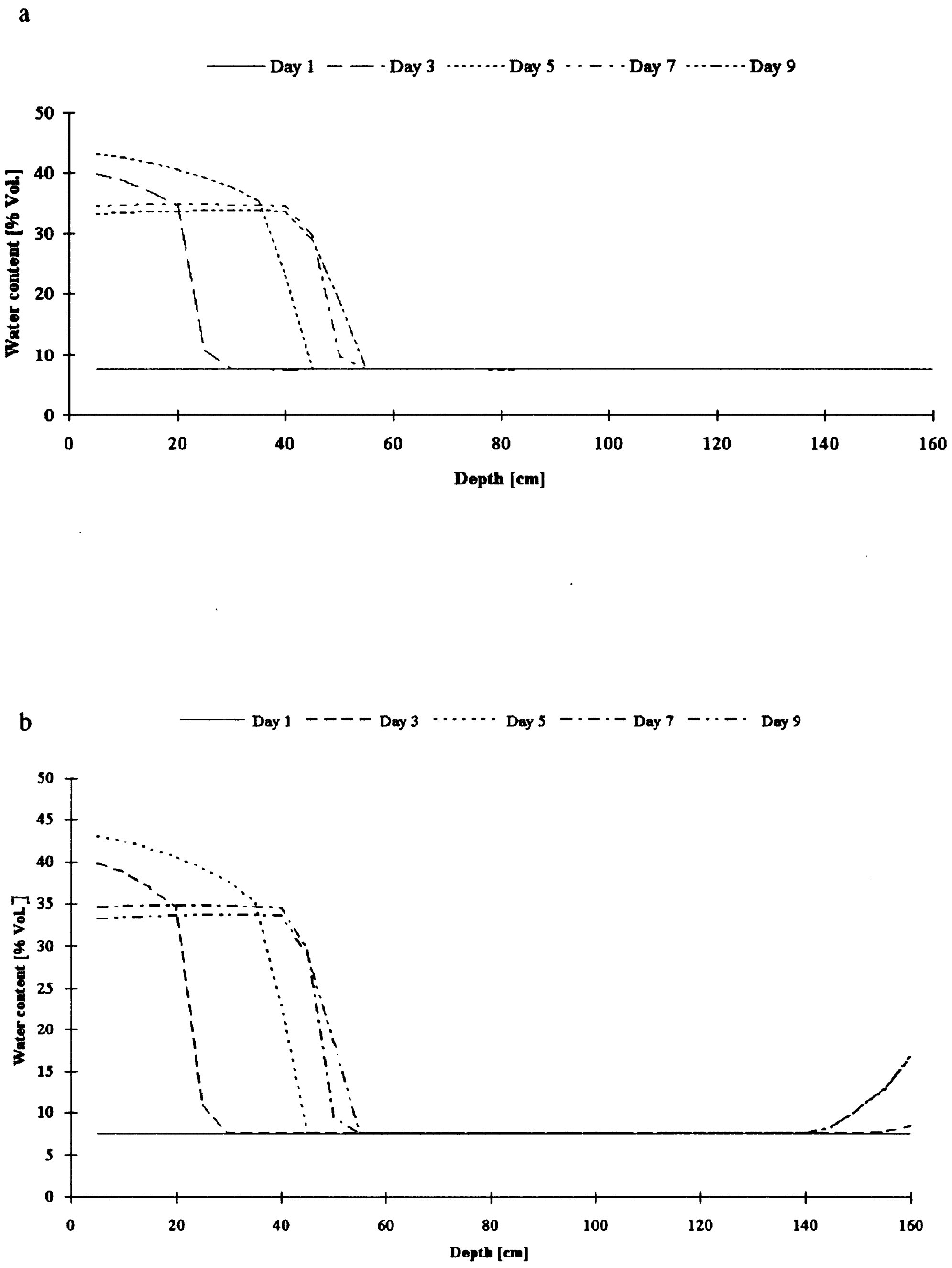

Fig. 1. Numerical test of the crack submodel without cracks (a), and with crack influence on the bypass flow (b) for first variant of initial water content.

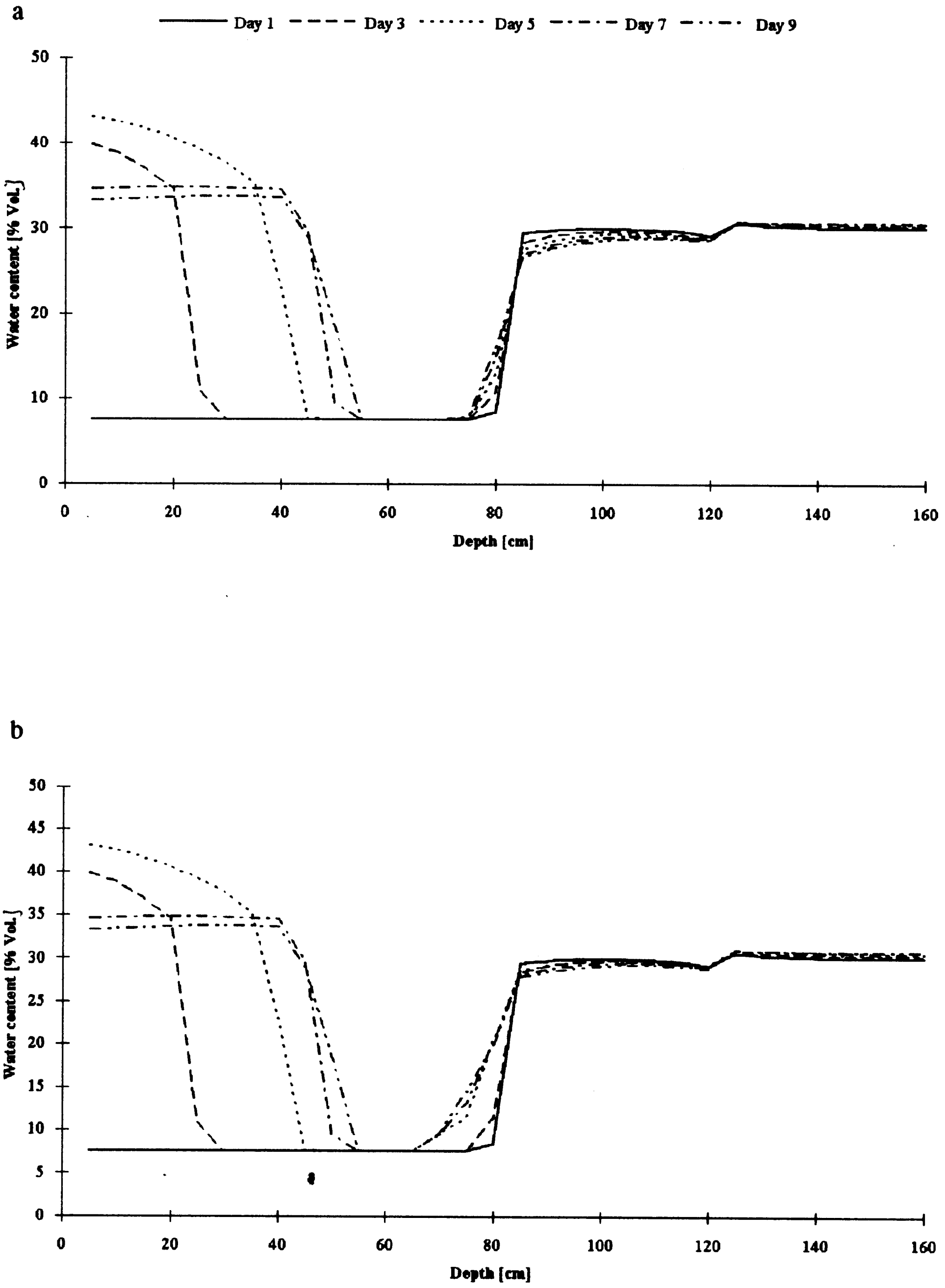

Fig. 2. Numerical test of the crack submodel without cracks (a), and with crack influence on the bypass flow (b) for second variant of initial water content.

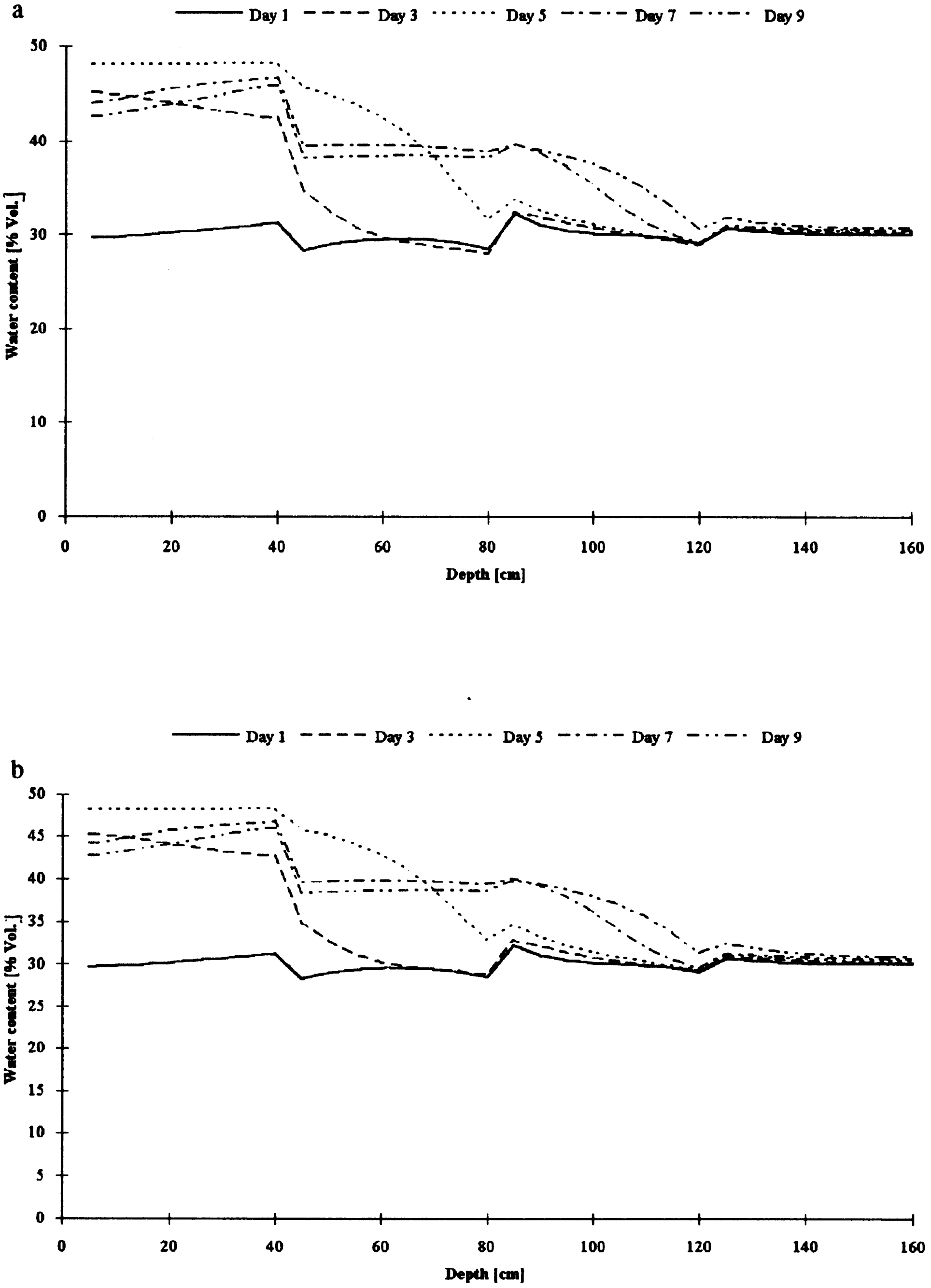

Fig. 3. Numerical test of the crack submodel without cracks (a), and with crack influence on the bypass flow (b) for third variant of initial water content.

is located on hill tops, where the soil cover is uniform with a typical horizons Ap, Ap-E, E, Bt1, Bt2, Bc till 145 cm. The mechanical composition of the soil is silt, pH in KCl of the Ap horizon is 5.5, P_2O_5 content 16.1 mg/100 g, K_2O 28.3 mg/100 g, and Mg 8.2 mg/100 g soil, CEC 196 me/100 g. The field is under intensive agricultural farming system. Crop rotation system typical for this soil: Potato - spring barley - winter maize - (lucerne with grasses as intermediate crop every 3 years) - winter wheat.

Fertilization: NPK - above average in Poland. For example for winter wheat: N - 50, P_2O_5 - 90, K_2O - 120 kg/ha. FYM - occasionally for root crops.

Tillage: Fully mechanized field work, i.e., only tractor operations: winter ploughing (25-30 cm), one or two-time cultivation connected with harrowing (8-10 cm). In dry spring or autumn, before or after sowing a roller is used.

RESULTS

The TDR equipment of soil moisture, salinity and temperature dynamics measurement in these two experimental sites was used [2-4,6,8].

Grabów experiment

The meteorological data collected for the whole 1993-1994 years were used for modeling. The water content, salinity and temperature dynamics in the soil profile was measured on 1 June - 2 Aug 1993 (182-214 day) and on 30 Apr - 2 Aug 1993 (120-214 day) everyday at 2 PM. There are two measurements for winter wheat and bare soil.

These measurement are compared with the calculated by ACCESS-II model water content. Calculations were performed in two versions: first using only RICHARD'S procedure and the second including CRACK sub-model with RICHARD'S. The CRACK subroutine accounts for the bypass flow in the soil profile.

Figure 4 shows the water content changes on 5, 15, 25, 55, 85 and 135 cm: measured and two calculated curves with and without bypass flow accounting for. The water content calculated and measured for four top levels shows good agreement for both cases (with and without bypass flow).

For the bottom levels the inclusion of bypass flow significantly improves an agreement of measured and calculated water content profiles. The relative crack cover was fit to the data in order to minimize the difference to measured water content. The best fit gives the value $\sigma = 1.0$ % for the relative crack cover. We checked the values between 0.0 % and 20.0 % which cover the whole range of variability of this parameter. The Richard's model without bypass flow is not able to reach such a good agreement to the experimental data. The agreement reached due to account for the bypass flow may be an evidence of preferential flow in the soil profile which can not be modeled by Richard's equation.

Figures 5a, 5b and 5c show the measurement and modeled values on 5, 85 and 135 cm for 1994 season. The surface layer water content changes very dynamically. Modeled values of water content follow measured very closely, the good agreement has been found also at layers till 85 cm depth. The deeper layers are not properly modeled due to saturation of the soil caused by high ground water level. Measured ground water level reached 150 cm at this time. The Richard's model is not able to deal with such a situation due to assumed different bottom boundary condition. The discrepancy remains high in both cases with and without bypass flow.

Czeslawice experiment

The meteorological data collected for the whole 1994 year were used for modeling. The water content dynamics in the soil profile was measured betwen 30 May and 2 July 1994 (143-202 day) everyday at 2 PM. There are two measurements for winter barley and bare soil. The experimental results and modeled water content are presented on Figs 6a, 6b and 6c for depths 5 cm, 85 cm and 135 cm, respectively. All results show a good agreement with and without bypass flow. The loess soil in this site shows much less cracking ability than the

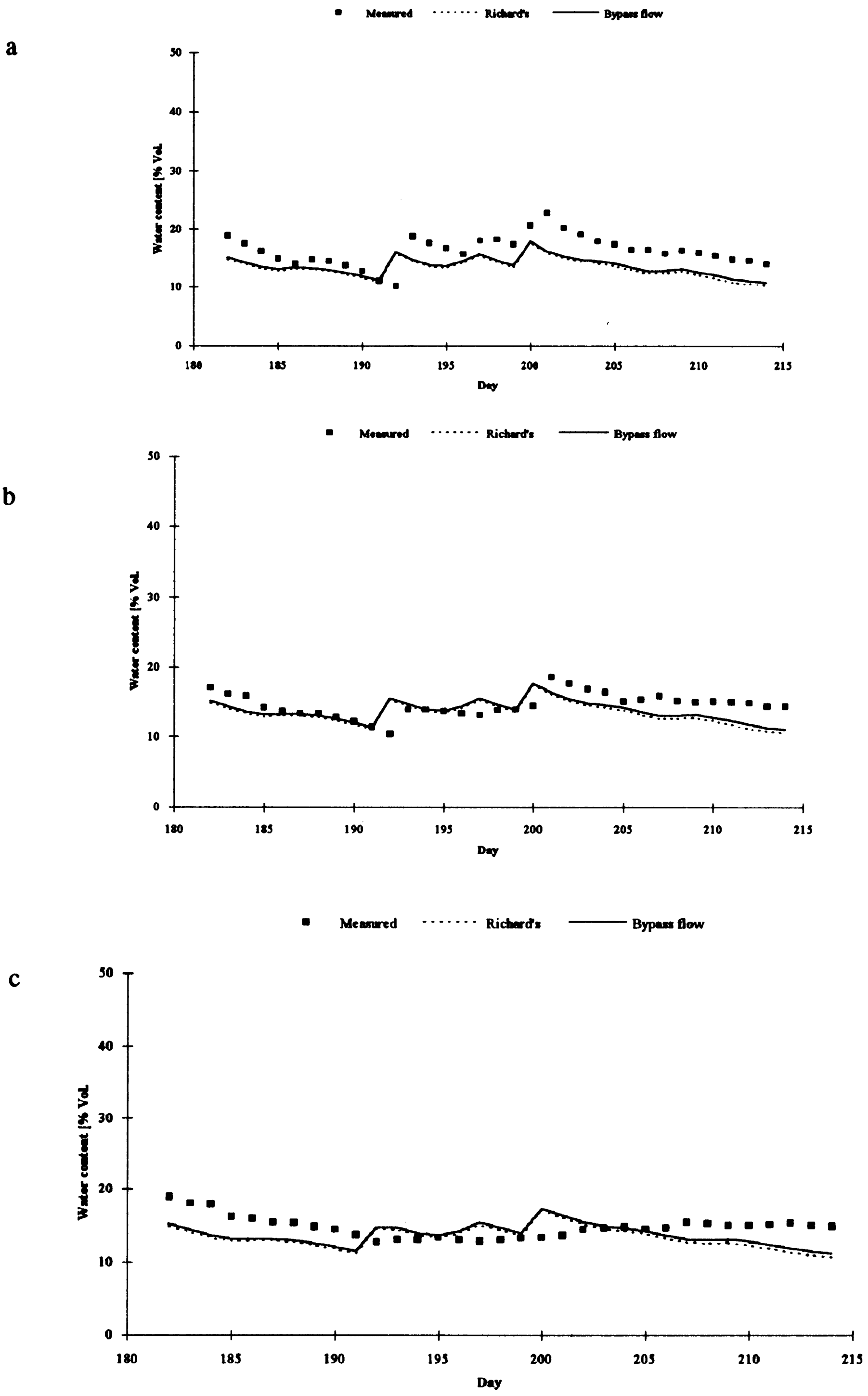

Fig. 4. Experimental field validation. Grabów - winter wheat 1993, layers: a) 5 cm, b) 15, c) 25 cm, d) 55 cm, e) 85 cm, f) 135 cm.

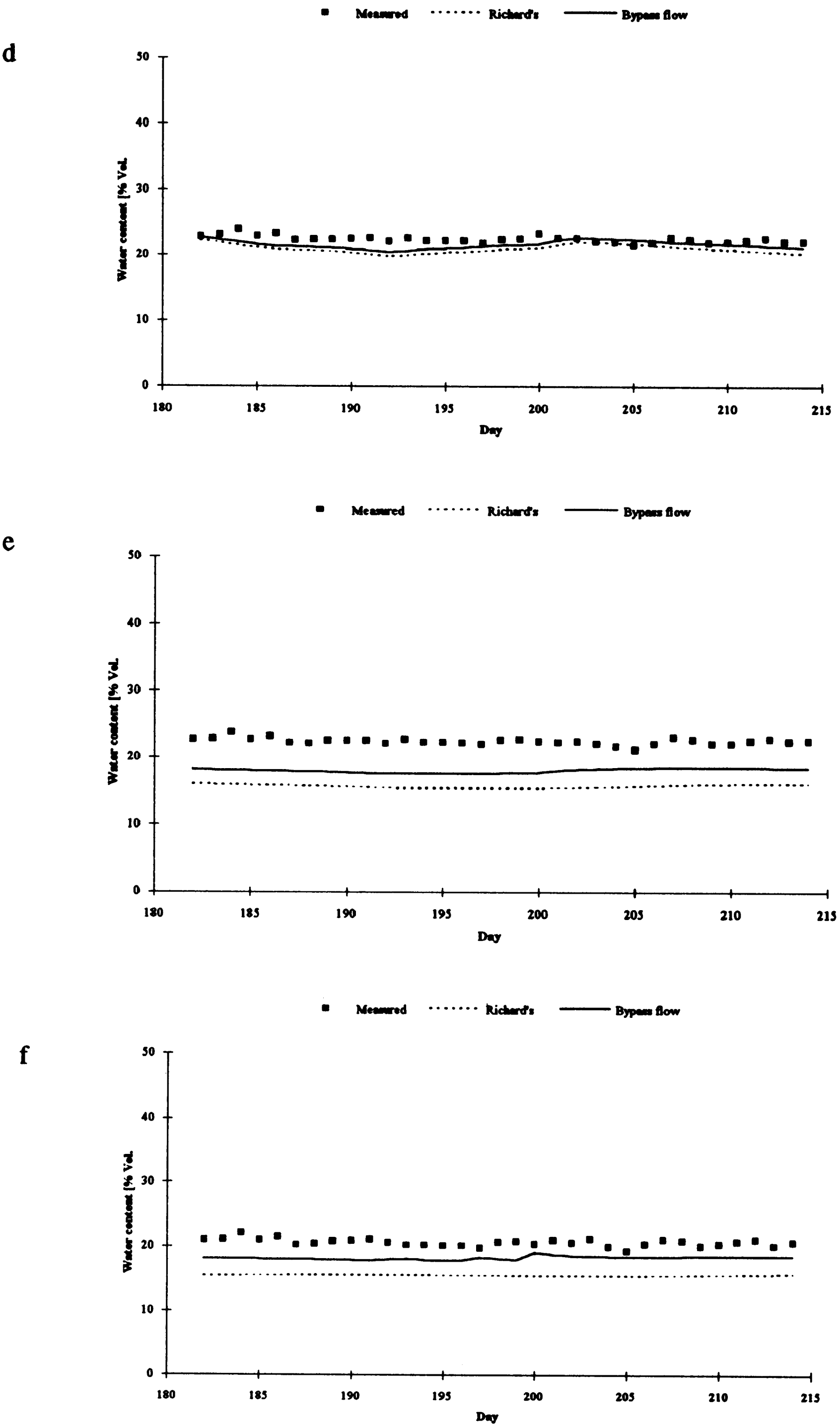

Fig. 4. Continuation.

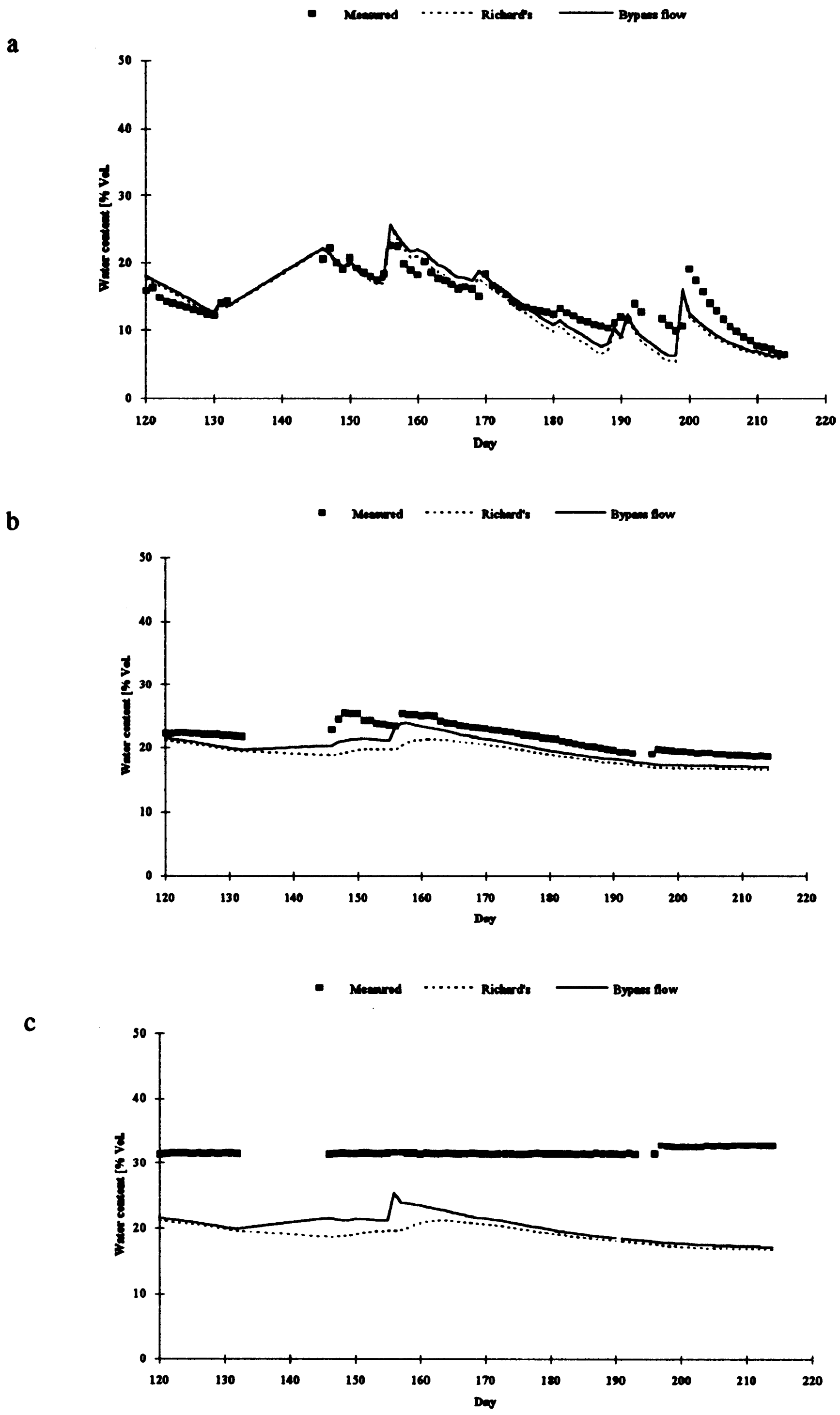

Fig. 5. Experimental field validation. Grabów - winter wheat 1994, layers: a) 5 cm, b) 85 cm, and c) 135 cm.

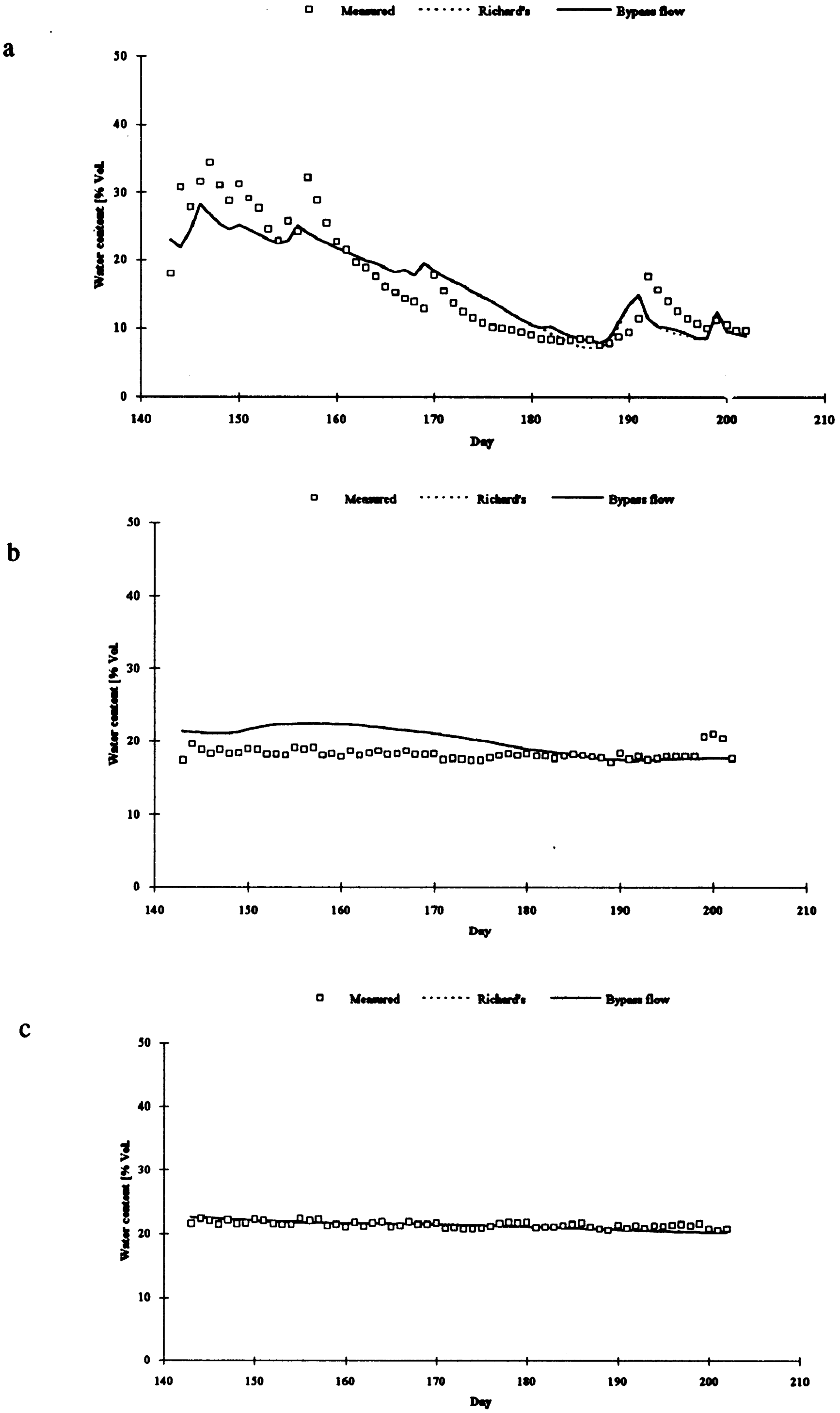

Fig. 6. Experimental field validation. Czesławice - winter wheat 1994, layers: a) 5 cm, b) 85 and c) 135 cm.

soil in Grabów. The water content range observed in the profile was above the crack development limit. The top layer of the soil reached the range of crack occurrence, cracks effect on the water flow is not important at the top of the profile.

CONCLUSIONS

Proposed model of bypass flow description was verified numerically and compared to the experimental data. The experimental data show evidence of bypass flow, the CRACK submodel improves the agreement of the ACCESS model with measured data for water content. The bypass flow importance depends on the water content and the soil type. We can expect that for soils much heavier than that we validated model, the bypass flow will be much more important. We expect that for such cases the bypass flow is an indispensable factor of water transport. In order to use the bypass flow submodel in multipoint model one should supply it with data concerning soil cracking, or widely speaking, concerning soil bypass flow ability. It can be done by a soil classification with respect to bypass flow vulnerability. Ones such a classification exists, the soil maps (or other thematic maps) can be used to supply data for specific sites or for the network of sites.

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