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A BYPASS FLOW MODEL WITH A PROCEDURE TO APPROXIMATE PRECIPITATION INTENSITY

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A b s t r a c t. Precipitation and intensity of precipitation are the most important parameters of soil profile water balance. Precipitation values give the information about amount of water reaching the soil surface. Intensity of the precipitation determines the amount of water accumulated in a soil profile and the amount of runoff water.

The aim of the paper was to show the importance of consideration of precipitation distribution approximation in water dynamics modelling in soil profile taking into account preferential water flow.

K e y w o r d s: preferential water flow, intensity of precipitation, lognormal distribution.

INTRODUCTION

As part of EURO-ACCESS (AgroClimatic Change and European Soil Suitability) project [1,5-8] (Fig. 1), a model of crop growth and yield prediction was elaborated. Hydrological part of this model is based on one-dimensional Richards equation. To achieve heterogeneity of the soil profile, a model of bypass flow was elaborated in the Institute of Agrophysics PAS and included into the hydrological part of the EURO-ACCESS model.

The main assumptions of the bypass flow submodel are as follows:

- A heterogeneous soil profile is divided into homogeneous compartments.
- A vertical water flow in the soil matrix is described by the Richards equation (one-dimensional flow model).
- Part of water is flowing directly in the macropores (proportionally to the relative crack area).
- Part of water which cannot infiltrate the soil profile vertically (runoff) is flowing into the macropores.

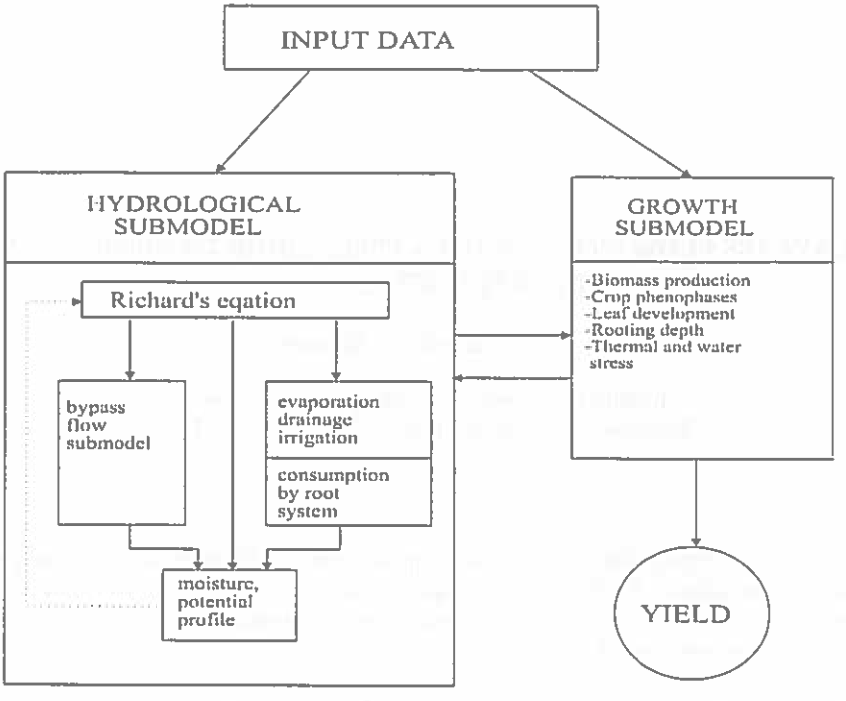

Fig. 1. Scheme of EURO-ACCESS-II model [8].

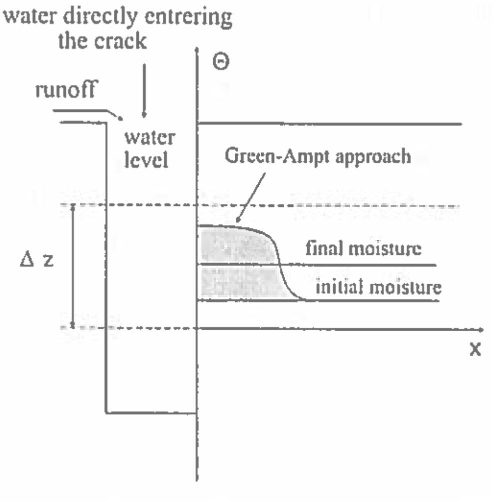

Fig. 2. Scheme of macropore [8].

- Water fills the crack (Fig. 2), creating hydrostatic pressure distribution at the crack wall which is used as a boundary condition for the water infiltration into the soil.

- Initial moisture for each time-step of the horizontal infiltration is assumed to be constant in space.

- The Green-Ampt (Fig. 2) approach is used for the description of horizontal infiltration.

METHODS

Precipitation and its intensity are the most important parameters of water balance in the soil profile. Precipitation values provide information on the amount of water reaching the soil surface that influences changes in the water content of the soil profile and runoff. Precipitation intensity determines the amount of water accumulated in the soil layers and amount of runoff water. At standard agroclimatic stations, only cumulative daily precipitation is collected as part of climatic and agroclimatic information set.

Precipitation intensity in theoretical physical-mathematical studies of the water status in the soil profile was discussed for a homogeneous soil profile as well as a soil profile with macropores of biological and physical origin (created in swelling-shrinking processes). The influence of precipitation intensity levels at different infiltration rates both for the values that are constant and changing in time, on the amount of water accumulated in the profile and runoff water was investigated [2].

One of the methods for the runoff estimation is a triangular method (Fig. 3). Runoff is then estimated by describing rainfall, using a triangle with the surface area equal to the rainfall value. With a known infiltration rate into the soil matrix I_m, and the flow through macropores I_M, it is possible to calculate the runoff as the amount of water equal to the part of the triangles area lying above these values. To apply this method in the hydrological models of water flow is necessary to know rainfall duration.

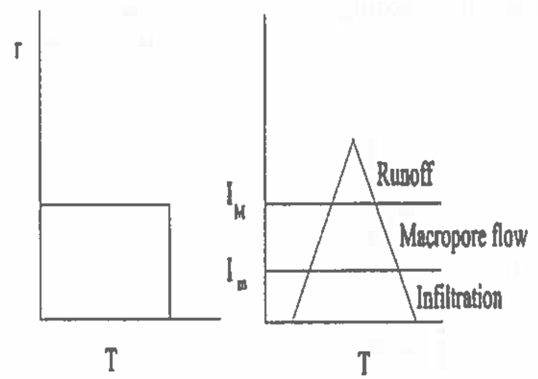

Fig. 3. Partition of rainfall into the soil water components.

The aim of the present paper was to show the importance of considering approximation of precipitation distribution in modelling water dynamics in the soil profile taking into account bypass flow.

Pluviographic data obtained from the climatic station of the Maria Curie-Skłodowska University in Lublin were used to create a data base for the period 1979-1991. Six months: May, June, July, August, September and October were analysed [2]. There were no problems with snow or water freezing in the soil profile and in the pluviograph during these month.

This data base was statistically analysed in order to estimate the function of approximating statistical distribution of rainfall intensity in the analysed month.

On the basis of standard meteorological data (the amount of daily rainfall), it was found out that the distribution of rainfall intensity is asymmetric. The lognormal distribution is asymmetric and it is often used for describing natural environmental processes. The lognormal distribution is also characteristic for such meteorological values related to rainfall as: monthly, seasonal and annual sums of atmospheric rainfall, size of rain drops in clouds, the maximum sum of the 24-hour rainfall, and aerosol concentration levels in the atmosphere.

RESULTS

Figures 4 and 5 show real and approximated distributions of rainfall intensity values in May and July, as representative for these two separated groups. Figure 6 shows real and approximated distribution of rainfall intensity in October. The lowest possible value of rainfall intensity considered in the statistical analysis, is 0.01 mm/min. In the analysed files there is no data for the intensity lower than 0.01 mm/min. The above value is most expected according to the statistical analysis.

Lack of the above value means that there is no left side of the distribution in the

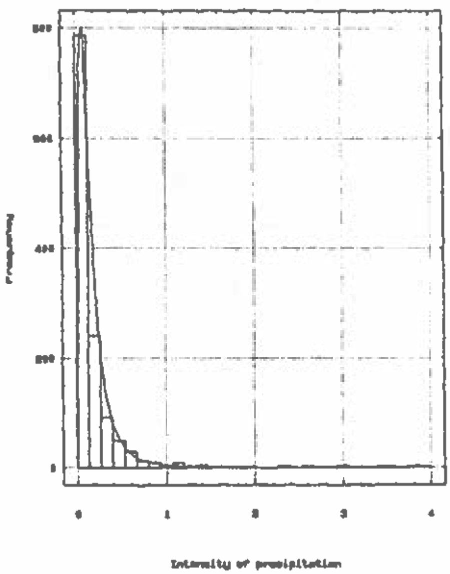

Fig. 4. Frequency histogram of precipitation intensity (May 1979-1991) [4].

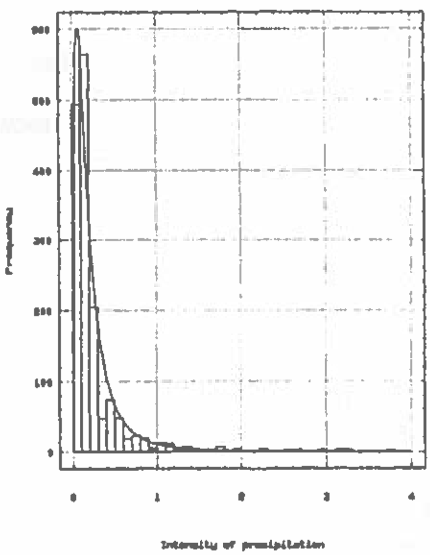

Fig. 5. Frequency histogram of precipitation intensity (July 1979-1991) [4].

data files. That is why it is impossible to identify distribution using classic statistical methods. Such a lognormal distribution was then used as a distribution approximating the measured data. The expected values and standard deviations of the lognormal distribution approximating the intensity distribution of rainfall in the analysed months are shown in Table 1 and Fig. 7.

The expected values and standard deviation for the summer months (June, July, August) had similar values. Similar values of these parameters were also observed in May and September (Fig. 7), which means that the real distributions of rainfall intensity in June, July, and August had the same course. A similar course of the real distribution of rainfall intensity was also found in May and September.

Experimental validation of the model was done using data gathered at the Grabów site. The Grabów research area is located in the southern part of the Mazovian Plain and constitutes part

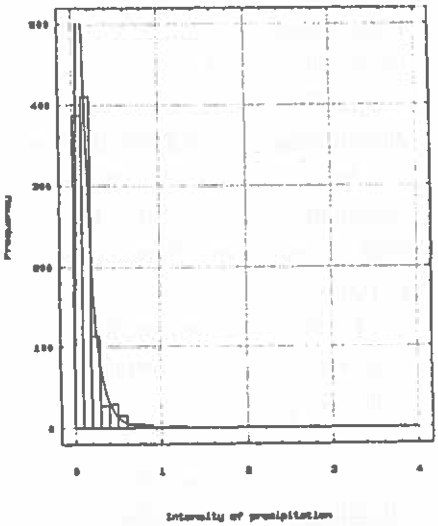

Fig. 6. Frequency histogram of precipitation intensity (October 1979-1991) [4].

Fig. 7. Lognormal distribution parameters for the analysed months [4].

Table 1. Parameters of the lognormal distribution approximating distribution of rainfall intensity in the analysed months [4]

Month	Expected (mm/h)	Standard deviation
May	1.86	1.88
June	2.50	3.06
July	2.55	3.12
August	2.55	3.05
September	2.04	2.10
October	1.51	1.16

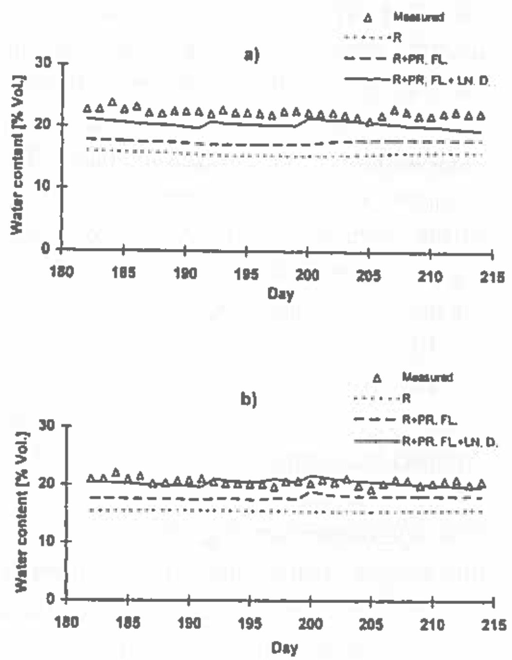

Fig. 8. Results of experimental verification (Grabów-Poland) of importance of precipitation intenstiy in dynamic modelling of exampled profile compartments (a - 85 cm, b - 135 cm) for three versions:
R - soil profile is composed of homogeneous layers; rainfall intensity is approximated as daily average value;
R + PR FL - soil profile is composed of homogeneous layers with vertical macropores; intensity is approximated as daily average value;
R + PR F + LN D - soil profile is composed of homogeneous layers with vertical macropores; rainfall intensity is approximated by distribution estimated from pluviographic data collected for a given place and period of the year.

of a greater physiographic subprovince called the Middle Polish Lowlands. The soil there is classified as Stagnogleic Luvisols. The profile is characterised by intensive farming and belongs to the Agricultural Experimental Station of the Institute of Soil Sciences and Plant Cultivation in Puławy.

In this agrometeorological station, the following climatic data are collected: precipitation, max/min temperature, wind velocity and direction, total and net radiation, and cloudiness. The collected meteorological data were used for modelling. Dynamics of water content in the soil profile was measured using a TDR equipment [9,10] each day at 2:00 p.m. The measurements were carried out on winter wheat.

The relative crack cover was fit to the data in order to minimise the difference for the measured water content. The best fit gives the value =1.0% for the relative crack area. We checked the values between 0.0 and 20.0% which cover the whole range of variability in this parameter.

CONCLUSIONS

The experimental verification showed that for a good description of soil water profile if there are vertical macropores (even if they take 1% of the soil surface only) it is necessary to use simultaneously:

- hydrological submodels with preferential flow procedures (Fig. 8),
- estimation of rainfall intensity using a procedure with a more precise distribution

for its description than a daily average value, e.g. a lognormal distribution, characteristic for a given place and period of the year (Fig. 8).

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