Scientific registration n° : 1108
Symposium n° : 3
Presentation : poster

Importance of precipitation distribution approximation in water dynamic modelling in soil profile
Importance de l'estimation de la distribution des intensités de précipitation sur la simulation du régime hydrique du profil de sol

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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 and having the influence on changes of soil water content profile and runoff. Intensity of precipitation determines the amount of water accumulated in soil layers and amount of runoff water. At the standard agroclimatic stations, only cumulative daily value of precipitation is collected as climatic and agroclimatic information set.

Precipitation intensity in theoretical physical-mathematical studies of water status in soil profile was discussed for homogeneous soil profile as well as soil profile with macropores of biological and physical (created in the swelling-shrinking processes) origin. The influence of precipitation of intensities different comparing with infiltration rate considering its constant and changing values in time on the amount of water accumulated in profile and runoff water was investigated [2].

The aim of the paper is to show the importance of consideration of precipitation distribution approximation in water dynamics modelling in soil profile taking into account preferential water flow. It was assumed to realise this aim in the following stages:

1. choosing a hydrological model considering the simulation of water dynamics in soil profile and its modification to include the simulation of bypass flow process
2. elaboration of the method of rainfall intensity estimation on the base of data from standard agroclimatical station;
3. experimental verification of dynamic model in natural conditions for three chosen variants:
   a. soil profile is composed of homogeneous layers; rainfall intensity is approximated as daily average value;
   b. soil profile is composed of homogeneous layers with vertical macropores; intensity is approximated as daily average value;

c. 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 year.

In the frame of EURO-ACCESS (AgroClimatic Change and European Soil Suitability) project [1, 5, 6, 7, 8] (Fig. 1.) the model of crop growth and yield prediction was elaborated. Hydrological part of this model is based on one-dimensional Richard's equation. For the purpose of heterogeneity of the soil profile, in the Institute of Agrophysics PAS, the model of bypass flow was elaborated and included into the hydrological part of EURO-ACCESS model.

Main assumptions of bypass flow submodel:

- Heterogeneous soil profile is devided into homogeneous compartments.
- Vertical water flow in soil matrix is described by Richard's equation (one-dimensional flow model).
- Part of water is flowing directly in macropores (proportionally to relative cracks area).
- Part of water which can not vertically infiltrate in soil profile (runoff) is flowing into the macropores.
- Water fills crack (Fig. 1.), giving the hydrostatic pressure distribution at the crack wall which is used as the boundary condition for the water infiltration into the soil.
- Initial moisture for each time step of horizontal infiltration is assumed to be constant in space.
- The Green-Ampt approach is use for the horizontal infiltration description.

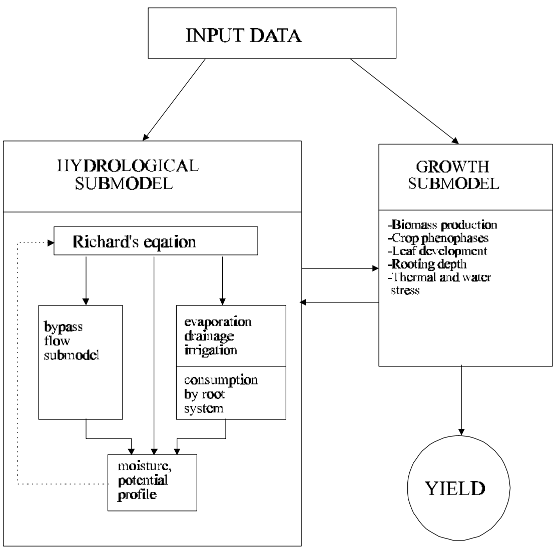


Fig. 1. Scheme of EURO-ACCESS-II model [8].

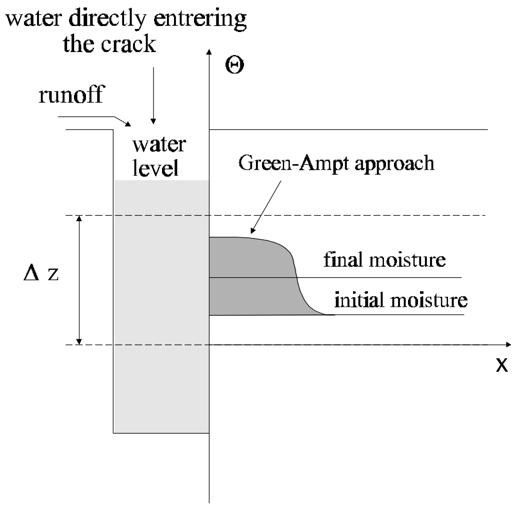


Fig. 2. Scheme of macropore [8].

One of the method of runoff estimation is triangular method (Fig.3). Runoff estimated by describing the rainfall, using the triangle with the area equal to the rainfall value. Knowing the infiltration rate into the soil matrix I_m, and the flow through micropores I_M, it is possible to calculate the runoff as amount of water equal to the part of the triangle's area lying above these values. For utilisation of this method in hydrological models of water flow is necessary to know the period of rainfall duration.

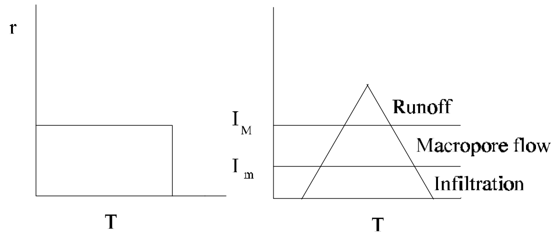


Fig. 3. Partition of rainfall into soil water components [3].

From the pluviographic data from the University of Maria Curie-**Sk³odowska climatic** station in Lublin, a data base for the years 1979-1991, was created. Six month: May, June, July, August, September and October were analysed [2]. There no problem of snow and 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 approximating the statistical distribution of the rainfall intensity in the analysed month.
On the basis of standard meteorological data (the amount of daily rainfall) it was find that the distribution of rainfall intensity is asymmetric. Lognormal distribution is asymmetric and it is often used for describing natural environmental processes. Lognormal distribution is also characteristic for such meteorological values related to rainfall as: monthly, seasonal and annual sums of atmospheric rainfall, the size of rain drops in clouds, maximum 24-hour rainfall sums, and the aerosol concentrations in the atmosphere.
Figures 4 and 5 show the real and approximated distributions of rainfall intensities in May and July, as representative for these two separated groups. Figure 6 shows the real and approximated distribution of rainfall intensity in October. The smallest possible value of rainfall intensity, considered in the statistical analysis is 0.01 [mm/min]. In the analysed files there is no data for an intensity smaller than 0.01 [mm/min]. Such a value, according to the statistical analysis, is the most expected.
The lack of this value means that there is no left side of the distribution in the data files. This fact makes it impossible to identify the distribution using the classic methods of statistics. That is why the lognormal distribution was used as a distribution approximating the measured data. Expected values and standard deviations of the lognormal distribution approximating the intensity distribution of rainfall for the analysed months are displayed in Table 1 and Fig. 7.

Table 1. Parameters of the lognormal distribution approximating the distribution of rainfall intensity for analysed month [4].

Month	Expectation [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

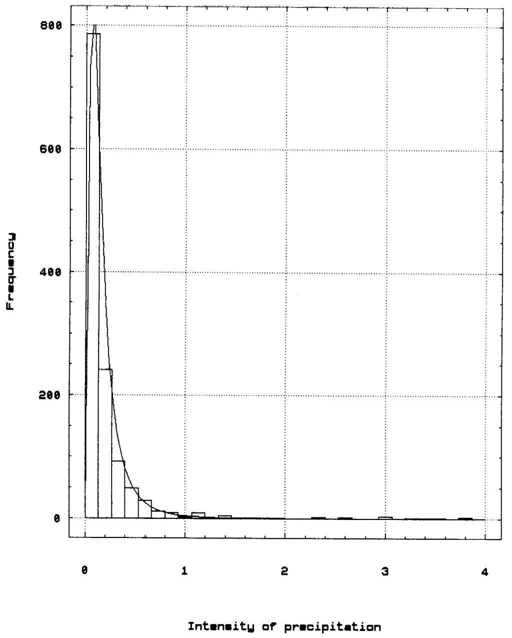


Fig. 4. Frequency histogram of intensity of precipitation (May 1979-1991) [4].

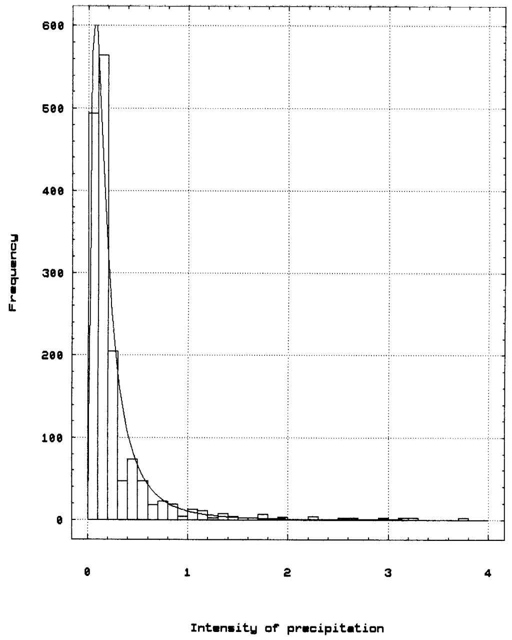


Fig. 5. Frequency histogram of intensity of precipitation (July 1979-1991) [4]

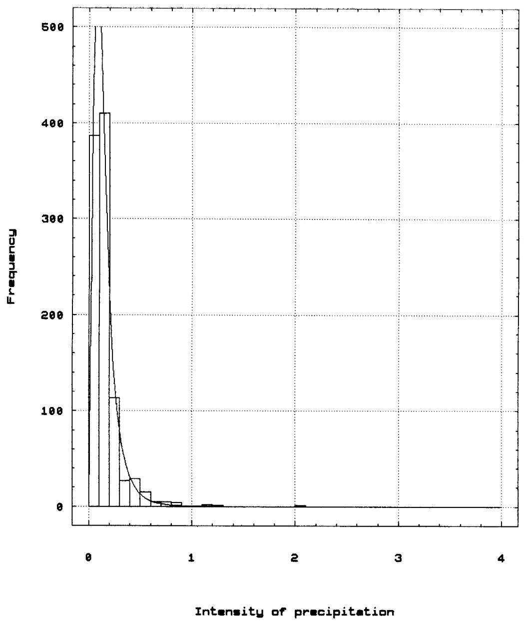


Fig. 6. Frequency histogram of intensity of precipitation (October 1979-1991) [4]

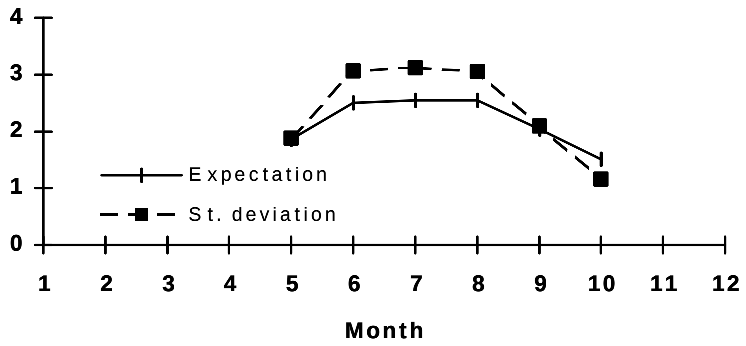


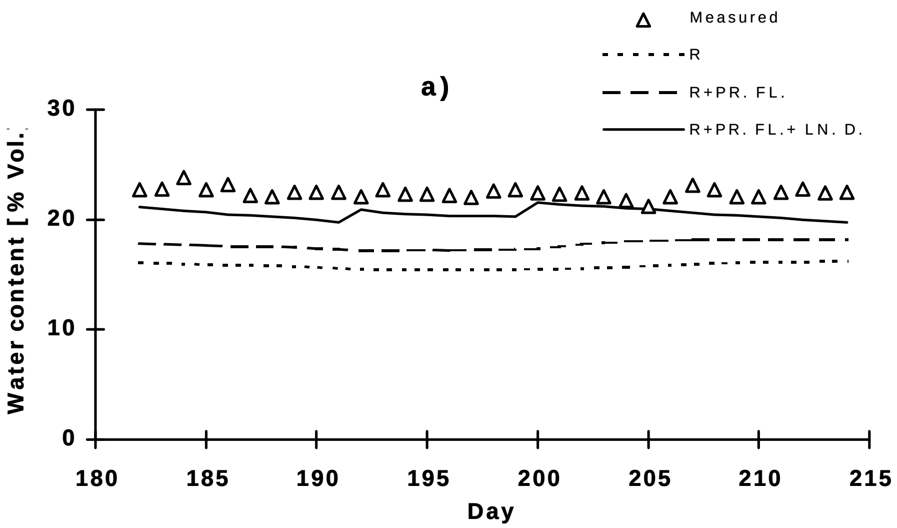
Fig. 7. The lognormal distribution parameters for analysed month [4].

Expected values and standard deviation for the summer months (June, July, August) have similar values. Similar values of these parameters are also in May and September (Fig.7), which means that the real distributions of rainfall intensity in June, July, and August had the same progress. Similar progress of the real distributions of rainfall intensity are also in May and September.

The experimental validation of the model was done using data gathered at Grabów site. 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 soil is classified as Stagnogleic Luvisols. The profile is at a site characterized by intensive farming and belongs to a state-run farm - Agricultural Experimental Station of the Institute of Soil Sciences and Plant Cultivation.

The experimental field is located about 100 meters far from 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 collected meteorological data were used for modeling. The water content dynamics in the soil profile was measured using TDR equipment [9, 10] everyday on 2 PM. There was measurements for winter wheat.

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 σ=1.0% for the relative crack area. We checked the values between 0.0% and 20.0% which cover the whole range of variability of this parameter.



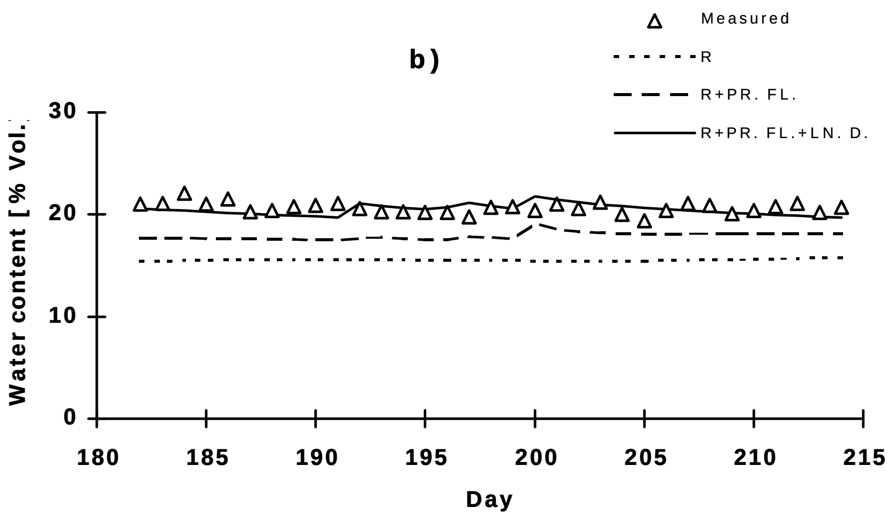


Fig. 9. Results of experimental verification (Grabów-Poland) of importance of precipitation intensity in dynamic modelling of exampled profiles compartments (a - 85 cm, b - 135 cm) for three versions:
R. - soil profile is composed of homogeneous layers; rainfall intensity is approximated as daily average value;
R.+PR. FL. - soil profile is composed of homogeneous layers with vertical macropores; intensity is approximated as daily average value;
R.+PR. FL.+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 year.

The experimental verification showed that for a good description of soil water profile in case of the existence of vertical macropores (even if they take 1% of the soil surface only) it is necessary to use simultaneously:
-hydrological submodels with preferential flow procedures
-estimation of rainfall intensity using a procedure giving more precise distribution for its description than daily average value, e.g. log-normal distribution, characteristic for a given place and period of the year.

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Keywords: water flow modelling, boundary conditions, rainfall intensity, preferential flow, modelling of soil water profile, runoff
Mots clés : modélisation des flus d'eau, conditions aux limites, intensité de pluie, écoulement préférentiel, modélisation de profils hydriques du sol, ruissellement