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THE METHOD OF RAINFALL INTENSITY ESTIMATION FOR RUNOFF PREDICTION*

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A b s t r a c t. In the hydrological models, for correct water movement description in the soil profile and within soil-plant-atmosphere system it is necessery to know intensity of precipitation because in total water balance equation runoff componenet is included.

In this work the analysis of pluviographic data from meteorological station of the University of Maria Curie-Skłodowska on the period 1979-1991 was made. The aim of the study is to determine the precipitation intensity distribution on the base of typical data from meteorological station (daily precipitation for fixed place and time).

It results from the analysis carried out that, the intensity of precipitation can be estimated by lognormal distribution. Using distribution parameters of precipitation intensity, it is possible to estimate intensity distribution from daily precipitation data, which are conventionally collected on meteorological stations. On the ground of these considerations one can determine runoff, as very important water balance component.

K e y w o r d s: intensity of precipitation, runoff, lognormal distribution

INTRODUCTION

Runoff, as one of the components of the water balance in the system of soil-plant-atmosphere, must be taken into consideration while modelling the flow processes in it. The value of the runoff depends on the actual soil moisture conditions as well as on the intensity of the rainfall. The aim of this paper is to propose a method, which will provide an estimate of the intensity of rainfall for a particular time and place, on the basis of standard meteorological data (the amount of daily rainfall). At the standard agroclimatic stations, only a daily value of rainfall is measured, not its intensity. For the precise estimation of the rainfall intensity as well as the intensity of the runoff, the value and the duration period of the rainfall are necessary. To measure the value of the rainfall in shorter periods of time it is necessary to increase the accuracy of the estimation of momentum intensity of the rainfall.

In literature one can find a description of a method, which provides an estimate for the intensity of rainfall on the basis of standard data. The methods of estimating the intensity of the rainfall, shown in the paper of Dębski [1], describe the relation between the duration period and the intensity, and this relation is different for particular climatic zones.

Modelling the runoff using the SCS (Soil Conservation Service) method has been shown in the paper of Shalk *et al.* [4]. In this method, the value of the runoff is determined by the value of the rainfall as well as by the initial moisture present in the upper 150 mm layer of soil. Using the equations proposed by Schmidt and Schultze [5], the daily value of rainfall and the value of hydrophysical parameters describing the soil (saturation, point of permanent wilting), we can calculate the runoff.

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In the SWAP (Soil Water Partitioning Model) model, runoff is estimated by describing the rainfall, using the triangle with the area equal to the rainfall value r (Fig. 1). T on the y-axis is the rainfall duration period. Knowing the infiltration rate into the soil matrix, I_m, and the flow though macro-pores, IM, we can calculate the runoff as the amount of water equal to the part of the triangle's area lying above these values.

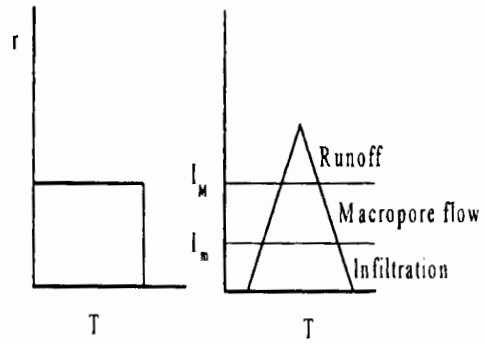

Fig. 1. Partition of rainfall into soil water components.

METHOD

The method of statistic analysis of the pluviographic data has been proposed with the following condition: rainfall value and its duration period are specific for the particular place and time of the year, which shows the possibility of predicting the intensity of the rainfall.

From the pluviographic data from the UMCS climatic station in Lublin, a data base for the years of 1979-1991, was created. Six months: May, June, July, August, September, and October were analyzed. There was no problem of snow or water freezing in the soil profile and in the pluviograph during these months. Six data files containing the values of rainfall intensity, which appeared during the particular month in all analyzed years, were created. The values of rainfall intensity were calculated individually for each period of rainfall with the accuracy of 0.01 mm/min.

The data prepared in such a way were statistically analyzed in order to estimate the function approximating the statistical distribution of the rainfall intensity in the analyzed month.

RESULTS AND DISCUSSION

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 h rainfall sums, and the aerosol concentrations in the atmosphere.

The smallest possible value of rainfall intensity, considered in the statistic analysis is 0.01 mm/min. In the analyzed 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 analyzed months are displayed in Table 1.

Expected values and standard deviations for the summer months (June, July, August) have similar values. Similar values of these parameters are also in May and September (Fig. 2), which means that the real distributions of rainfall intensity in June, July, and August had the same progress. Similar progress

Table 1. Parameters of the lognormal distribution approximating the distribution of rainfall intensity for analyzed months

Month	Expetation (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

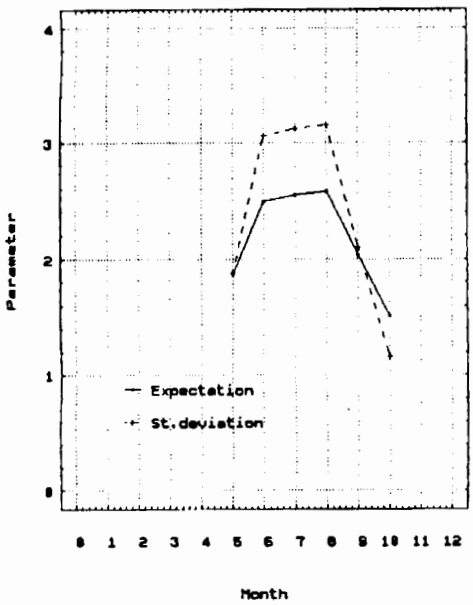

Fig. 2. The lognormal distribution parameters for analyzed month.

of the real distributions of rainfall intensivity are also in May and September.

Figures 3 and 4 show the real and approximated distributions of rainfall intensities in May and July, as representative for these two separated groups. Figure 5 shows the real and approximated distribution of rainfall intensity in October. Figure 6 shows the real and approximated distribution of rainfall intensity on July 18th 1984.

In order to calculate the runoff, besides the rainfall intensity, which can be calculated if we know the parameters of the approximating distribution, we also need to know the coefficient of water infiltration into the soil profile. Estimated final coefficient of infiltration for chosen soils is shown in Table 2 [2].

Figure 7 shows the algorithm of calculating the runoff and infiltration.

Symbols used in the algorithm are as follow:

P - daily rainfall,

P_c - daily rainfall calculated from the lognormal distribution,

I - amount of infiltrating water,

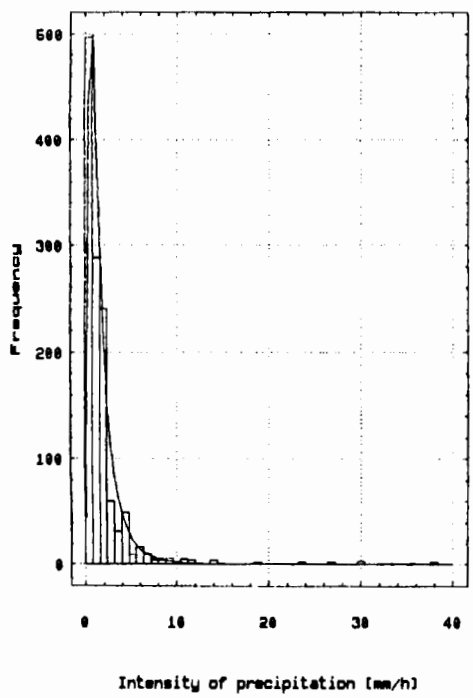

Fig. 3. Frequency histogram of intensity of precipitation May 1979-1991.

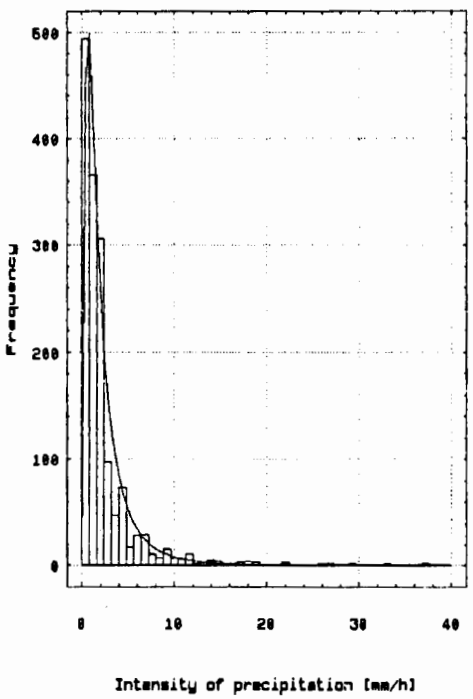

Fig. 4. Frequency histogram of intensity of precipitation July 1979-1991.

Table 2. Estimated final coefficient of infiltration for chosen soils

Soil	Infiltration (mm/h)
Sands	> 20
Sandy and silty soils	10 - 20
Loams	5 - 10
Clayey soils	1 - 5
Sodic clayey soils	< 1

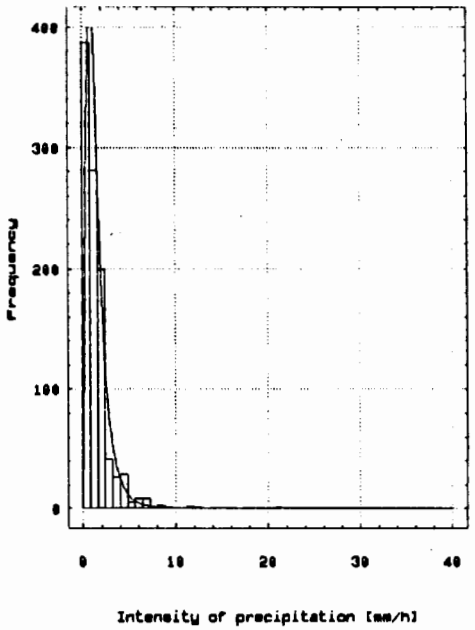

Fig. 5. Frequency histogram of intensity of precipitation October 1979-1991.

μ - expected value,

σ - standard deviation,

A_1 - amount of rainfall with smaller intensity then infiltration,

A_2 - amount of rainfall with greater intensity than infiltration,

R_{off} - runoff,

I_r - infiltration amount,

F - distribution function.

The example of the calculations has been carried out for August. Daily value of the rainfall and the value of the infiltration coefficient have been put into the model as the basic data:

$$P = 12 \text{ mm}$$

$$I_r = 2 \text{ mm/h}.$$

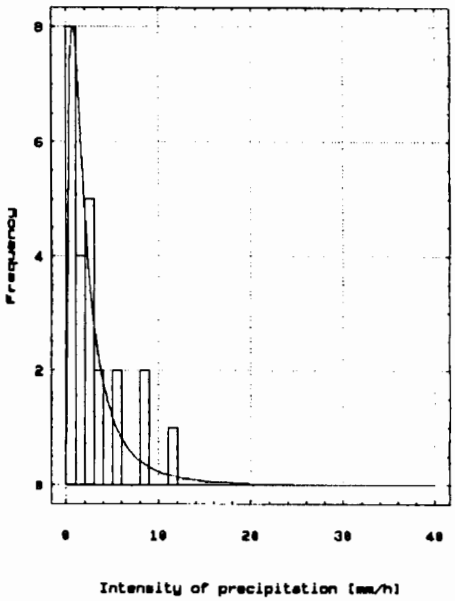

Fig. 6. Frequency histogram of intensity of precipitation 18th of July 1984.

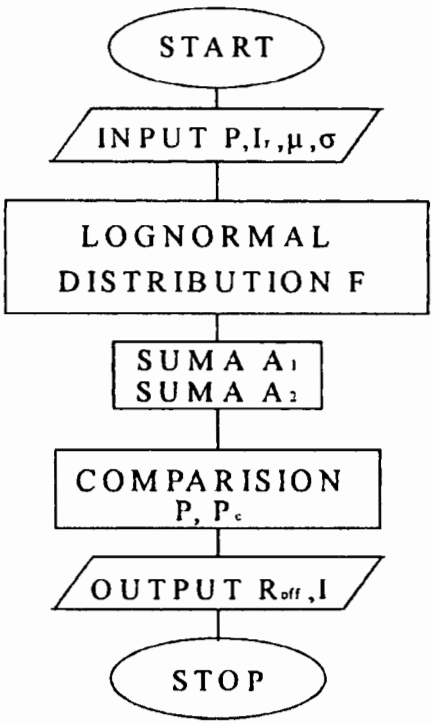

Fig. 7. Algorythm of calculation.

The value of cumulative infiltration and the value of the runoff are results of the model:

$$P_c = 11.85 \text{ mm}$$

$$I = 9.87 \text{ mm}$$

$$R_{off} = 1.97 \text{ mm}.$$

From the practical point of view we can estimate the distribution parameters using data from meteorological stations, at which pluviographs are installed, and then interpolate it to the chosen place. Such interpolation is used, for example, by the Geographic Information System.

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PRZEWIDYWANIE SPŁYWU POWIERZCHNIOWEGO NA PODSTAWIE OSZACOWANIA INTENSYWNOŚCI OPADU

W modelach hydrologicznych do poprawnego opisu transportu wody w glebie oraz w systemie gleba-roślina-atmosfera potrzebna jest znajomość intensywności opadu, ponieważ w ogólnym bilansie wody w tym systemie niezbędna jest znajomość spływu powierzchniowego.

W standardowych stacjach agroklimatycznych rejestrowana jest wielkość opadu. W pracy dokonano analizy danych pluwiograficznych z lat 1979-1991 ze stacji klimatycznej w Lublinie. Analiza ta wykazała, że częstość występowania poszczególnych intensywności w analizowanym opadzie może być aproksymowana rozkładem lognormalnym.

Na podstawie znajomości parametrów tego rozkładu oraz współczynnika infiltracji można, dla danego miejsca i czasu, określić przy danym opadzie ilość wody infiltrującej w głąb profilu glebowego oraz wielkość spływu powierzchniowego.

S ł o w a k l u c z o w e: intensywność opadu, spływ powierzchniowy, rozkład lognormalny.