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INFLUENCE OF SELECTED SOIL PHYSICAL PARAMETER (TWO MEASUREMENT METHODS) ON SOIL MOISTURE SIMULATION

Igaz Dušan, Jana Domanová, Andrej Tárnik

Department of Biometeorology and Hydrology, Slovak Agricultural University in Nitra,

Hospodárska 7, 949 01 Nitra, Slovakia

Abstract

The hydraulic conductivity is important hydraulic parameter for flow and transport-related phenomena in soil profile, but the results are affected by the method that was used for determination and also by measurements in different conditions. The aim of this study was to evaluate the effect of soil hydraulic conductivity measured at the laboratory or in the field on the daily course of simulated soil moisture. Research study was undertaken at experimental site of Slovak University of Agriculture in Nitra (locality Kolíňany – near town Nitra). Saturated soil hydraulic conductivity was measured using double ring infiltrometer in field conditions. For laboratory experiment was used falling head method. The values of $K_{(DRI)}$, $K_{(FHM)}$ and other hydro-physical characteristics were used as input for the model GLOBAL, which is mathematical model of water movement in the soil. The correlation coefficient between measured and simulated values with used K (DRI) was 0.68. Simulation which used K (FHM) had sufficiently good supply behavior of measured soil moisture values. The correlation coefficient was 0.90.

Key words: *soil moisture, hydraulic conductivity*

1. INTRODUCTION

Unsaturated soil zone also called zone of soil aeration is a part of soil profile between soil surface and ground water level. This zone, which accumulates and then supplies water to the total water cycle in the nature, is systematically studied by experts from various scientific disciplines. This increased interest is mainly due to anthropogenic activities of human beings, but also due to activities of natural processes influencing the dynamics and amount of water in this water resource. Studying the water movement processes in the aeration zone, description and quantification is linked with the use of mathematical models, which enable to reach the multispectral requirements of scientific disciplines as e.g. hydrology, ecology, meteorology, climatology, forestry, agriculture and so on (Liang, 1996, Lipiec, 2003, Eitzinger, 2004; Park, 2009). The problem of using the models is the lack of soil data, high spatial variability of soil properties and different methods of obtaining them. The basic inputs parameters are retention curve (*pF*) and saturated soil hydraulic conductivity (*K*). Soil hydraulic conductivity (*K*) expresses the soil ability to conduct water and is function of soil permeability (K_p), fluidity of moving liquid in the soil (*f*) and function of soil moisture (Antal, 1999). Soil as a porous medium allows water to flow. The zone in which water can move is limited and is equivalent to pore volume. If the water fills all the pores during flow (i.e. soil is saturated by water; $\theta = P$), this flow is called saturated flow. If the soil is only partly saturated with water (i.e. soil moisture is lower then porosity; $\theta < P$), this flow is called unsaturated flow. Driving force of this process is in both cases the gradient of total soil water potential. Hydraulic conductivity is mathematically expressed by well known Darcy's equation for saturated flow, published for example in this form (Antal, 1999):

$$v = -K\frac{dH}{dz} \qquad (1)$$

where:

v - is a speed of flow in saturated soil ($m.s^{-1}$), K – is a coefficient of saturated hydraulic conductivity ($m.s^{-1}$), H – is a total soil water potential or total hydraulic height of soil water (m) and z – is a length at direction of soil water movement (m).

The coefficient of hydraulic conductivity is mostly estimated by experimental methods or calculated using empirical equations. Determination of the coefficient of hydraulic conductivity value using experimental methods gives more representative and reliable results compared to value calculated by empirical equations. The coefficient of hydraulic conductivity can by experimentally determined at the laboratory or by field methods. Except these most frequently used direct experimental methods, we can determinate the coefficient of hydraulic conductivity using indirect methods. However, obtained results are inaccurate, and if we want to use them, they must be compared with direct measurement (Kutílek, 1978; Dirksen, 1991, Ankeny, 1991, Bohne, 1992, Price, 2008). All listed methods are described in scientific literature. Methods based on using regression or neural network give better results. Pachepsky et al., 1996; Wösten 2001, Štekauerová et al., 2002; Štekauerová and Šútor, 2004; Schaap, 2006 and others published these indirect methods of *K* determination and other soil hydrophysical characteristic as so called PTFs (Pedotransfer functions). Results of *K* obtained using pedotransfer functions may for certain soil types (e.g. soils with high soil organic mater content) give unsatisfactory results compared to results of measured *K* (Balland et al., 2008).

Generally, the reduction of soil porosity and increase of soil bulk density decrease hydraulic conductivity (e.g., by mechanical compaction of soil). However, Kutílek and Niesen (1994) published that aggregates compaction may significantly decrease the value of *K* also by nearly unchanged porosity. The value of hydraulic conductivity is strongly influenced by presence of preferred pathways in the soil. The water flows faster through these pathways than through the soil matrix. To get a correct mathematical simulation, it is necessary to distinguish whether the measured *K* values express the conductivity of soil matrix, or the values of soil with preferred pathways (Štekauerová, 1998; Mikulec a Štekauerová, 2003).

The main objective of this study was to evaluate the influence of soil hydraulic conductivity obtained either at the laboratory or measured in the field on the daily course of simulated soil moisture.

2. MATERIAL AND METHODS

2.1 Experimental site

Research study was undertaken at experimental site of Slovak University of Agriculture in Nitra (locality Kolíňany – near town Nitra) located in the south-east of Slovakia. From the point of regional-geological view it is located on geological dividing line of Mesozoic massif of Tribeč and Žitavská upland. The plot has a south-east slope with altitude ranging from 160 up to 180 m a.s.l.

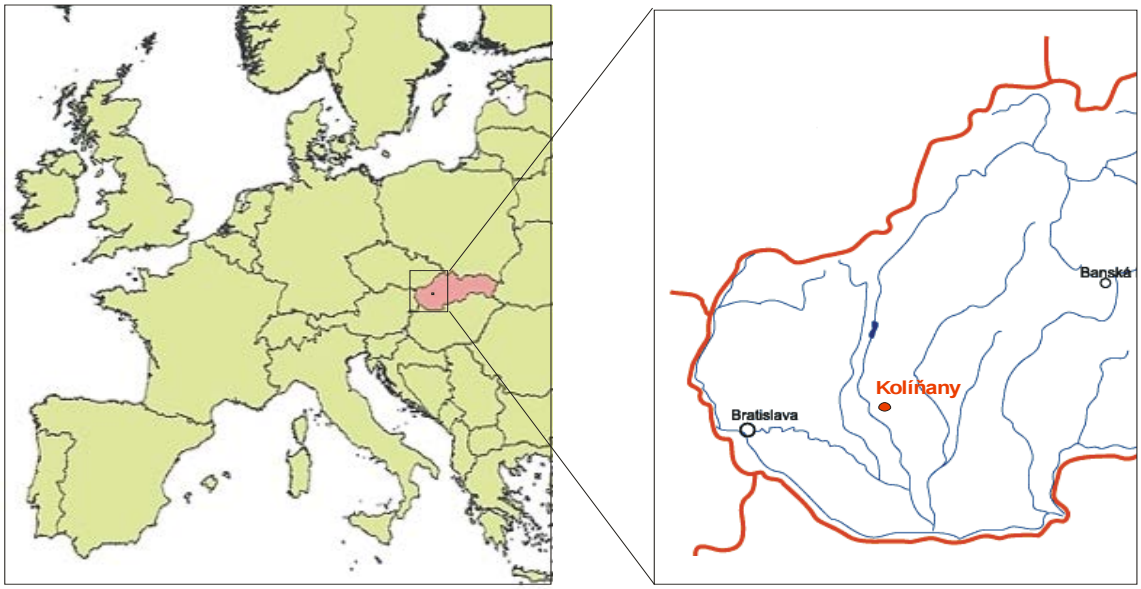

Fig. 1. Location of experimental site (Slovakia - Kolíňany)

The soil is brown soil closer specified as subtype Haplic Luvisols (HMa). In humus horizon (Akp cultisol horizon) it was sandy loam (content of particles < 0.01 mm; 20 - 30 %), and in deeper Bt horizon (0,4m) it was

loamy soil (content of particles < 0.01 mm; 30 – 45 %) (Chlpík, Pospíšil 2004). Experimental site is located in a maize agricultural region and belongs to the climatic region MT2 (slightly warm, slightly wet) with temperature sums ranging from 2200 up to 2 500 °C with annual mean air temperature ranging from 7 up to 8 °C and precipitation ranging from 550 up to 700 mm. Duration of sunshine during year is from 2000 up to 2400 hours and during growing season it is 1 500 up to 1 600 hours. Experimental site is influenced by dominating NW winds. There are monitored soil moisture and meteorological parameters. Grown crops of crop rotation are corn, spring barley, sugar beet and sunflower. Evaluation of influence of hydraulic conductivity coefficient estimated in the laboratory and in the field was made for year 2004 under sugar beet crop. Plot was fertilized with manure (50 $t.ha^{-1}$). Basic, sowing, tillage, mechanical and chemical treatment of crop were carried out by usual mechanizations and procedures used in production practices.

2.2 Soil moisture monitoring

Soil moisture was measured by 4 pieces of electromagnetic sensors of soil moisture VIRRIB produced by AMET company, Velké Bílovice, (Czech Republic) working on principle of TDT (Time domain transmissometry). Sensor measures soil moisture (% volume) using electromagnetic signal by transmissions phase method. Sensor consists of two concentric circles made from stainless steel connected inside sensor in which is located electronic part. The diameter of the outer circle is 280 mm and volume of measured soil is from 15 up to 20 liters. Accuracy of sensors is ± 1 % of volumetric soil moisture. Part of the sensor is also evaluation unit showing directly volumetric soil moisture on the screen. Sensors were placed in the upper third of the slope of the plot, due to mostly average moisture conditions there. Sensors were put at depth of 25 cm in horizontal position so we eliminated possible errors of measured values compared to vertical positioning influenced by different soil moistures at the top and bottom side of the sensor. First measurements were taken 10 days after sensor installation. Soil moisture was measured in weekly steps during growing season from May to the end of September (V. – IX.).

2.3 Determination of hydraulic conductivity using double ring infiltrometer - (DRI)

Saturated soil hydraulic conductivity was carried out in the field by infiltration experiment using two concentric cylinders. Cylinders were pressed vertically into the prepared flat terrain. Measurement took place in inner cylinder with base area of 400 cm^2. Base area of outer cylinder was 1600 cm^2. Ring defined by two cylinders created balancing zone, which reduced the influence of water flowing to the sides and thereby helped to accuracy of measurement results inside the inner cylinder. There was placed perforated plate on the soil surface of inner cylinder which protected soil against mechanical disturbance and there were also placed Mariott's containers on the cylinders to keep the water level inside the cylinders at the range of 0,5 cm.

Water level was 4 cm above the soil surface. Values of cumulative infiltration were determined by measuring the amount of water infiltrated only from inner cylinder. Experiment was finished at the time, in which the dosage of water was at equal time intervals. Evaluation of infiltration experiment consisted in analytical expression of dependency of cumulative infiltration I = f(t) and in derivation of infiltration rate course i = f(t). There are several equations of infiltration curve suitable for conditions of Slovakia: Green and Ampt (1911); Kostiakov (1932); Horton (1940); Mezencev (1948); Philip (1957). These equations are based on experimental measurements or on the theories of water movement in the soil.

In this study, measured values of infiltration experiment were evaluated using equations according to Mezencev:

$$i_{(t)} = i_f + (i_1 - i_f).t^{-\beta} \qquad (1)$$

$$I_{(t)} = i_f.t + \frac{(i_1 - i_f)}{1-\beta}.t^{1-\beta} \qquad (2)$$

where:

$i_{(t)}$ is a speed of infiltration at the time t (min) from the beginning of infiltration ($mm.min^{-1}$), i_1 is the speed of infiltration at the end of the first minute after the start of measuring ($mm.min^{-1}$), i_f is the final speed of infiltration ($mm.min^{-1}$), $I_{(t)}$ is cumulative infiltration, total amount of infiltrated water (mm), t is a time from the

beginning of infiltration, for which is making determination of infiltration speed (min), β is the coefficient, whose value depends mainly on the soil properties.

Infiltration experiment is usually influenced by many experimental inaccuracies. The problem is the foliation of the soil profile, existence of preferential ways, count, diameter and the depth of infiltration cylinders pressed into the soil as well as initial saturation of soil profile which influence measurement results.

Except studying total amount and the time course of infiltration there was estimated final value of infiltration rate i_f, which is approximately equal to saturated hydraulic conductivity of soil profile *K*.

2.4 Determination of hydraulic conductivity using falling head method - (FHM)

There was used device working on principle of measurement with variable hydraulic slope (i.e. above the measured soil sample changes the water level during time) to determine the hydraulic conductivity in laboratory condition.

It is better to use principle of measurement with constant hydraulic slope for lighter sandy soils and on the contrary it is better to use principle of variable slope for heavier soils which was also our case. Both principles require determination of hydraulic conductivity on undisturbed soil samples taken into sampling soil rollers. Soil samples were taken into non-corrodible metal rollers with volume of 100 cm^3. It is necessary to have soil moisture at the value close to field capacity for taking undisturbed soil samples so therefore the sampling date was 2 days after intensive precipitations. Soil sample roller was lightly pressed into to soil using lever lifter. Soil sample was saturated by water before taking a measurement. The saturation lasted for 24 hours.

The value of hydraulic conductivity coefficient was calculated according to equation:

$$K = \frac{L}{t}.\ln\frac{H_2}{H_1} \qquad (\text{cm.s}^{-1}) \qquad (3)$$

where:

L is the length of roller (cm), t is time of water drop from height H2 to H1(s),

H2 is an initial height of water in the extension piece, it is another roller whose flow surface is equal to flow surface of soil sample (cm), H1 is the height of water in the extension piece after drop of water level (cm).

After determination of hydraulic conductivity were determined retention curves of soil samples. Retention curves of the soil sample means relation between soil moisture and negative pressure head measured in laboratory with pressure extractor. They were then drained to water suctions, *h*, of 0.20; 5.48; 19.59; 55.12; 98.18; and 296.51 kPa on ceramic pressure plate extractors. The water contents were then measured gravimetrically by drying the samples at 105°C for 24 hours.

2.5 Soil moisture model

Global Model is a numerical model for water movement in the soil root zones (Research Report Institute of Hydrology, Slovak Academy of Sciences, Bratislava, Slovak Republic) (Majerčák, Novák 1995). The basic saturated and unsaturated water flow is simulated by using Richard's equation:

$$\frac{\partial h_w}{\partial t} = \frac{1}{c(h_w)}\frac{\partial}{\partial z}\left[k(h_w)\left(\frac{\partial h_w}{\partial z}+1\right)\right] - \frac{S(z,t)}{c(h_w)} \qquad (4)$$

where:

h_w is a soil water pressure head (cm), *k* is an unsaturated hydraulic conductivity (cm.s^{-1}), *S*(z,*t)* is an intensity of water uptake by roots (s^{-1}), *z* is a vertical co-ordinate (cm), *t* is a time (s), $c(h_w)$ is a capacity defined as:

$$c(h_w) = \frac{\partial \theta}{\partial h_w} \qquad (5)$$

where:

θ is a volumetric soil moisture ($cm^3.cm^{-3}$). It can be used for the layers porous media, composed from 4 layers with different hydro-physical characteristics.

Hydro-physical characteristics of GLOBAL model are expressed by analytic relations. Retention curve is described by van Genuchten's equation (1980):

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + |\alpha \quad h|^n\right]^m} \text{ for } h < 0$$

$$\theta(h) = \theta_s \qquad \text{for } h \geq 0 \qquad (6)$$

and unsaturated hydraulic conductivity of soil

$$K(h) = K_s S_e^l \left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2 \qquad (7)$$

where:

$m = 1 - 1/n \quad , \quad n > 1$

$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r}$ is a relative soil moisture (8),

where:

θ_s is a volumetric soil moisture of soil saturated by water ($cm^3.cm^{-3}$), θ_r is a residual volumetric soil moisture ($cm^3.cm^{-3}$), K_s is a saturated hydraulic conductivity of soil ($cm.day^{-1}$), h_w is a moisture potential of soil (cm), α, n are van Genuchten's parameters (cm^{-1}).

The boundary condition on the soil surface is given by the mean intensity of precipitation reduced by interception of canopy. Part of precipitation or irrigation amount which is not infiltrated into the soil is then accumulated on the soil surface. In the days without any precipitation, the intensity of water transport from surface to the atmosphere equals to evaporation intensity. Transpiration intensity equals to intensities of water uptake by roots. In the view of relatively small interception quantities and high intensities of evaporation of intercepted water a quantitative influencing of evaporation by interception is not assumed in the model.

The lower boundary condition is defined by the mean values of soil water potential, or by the vertical water flow in the corresponding depth under the soil surface. Zero value of the soil potencial assumed at the groundwater flow is not the subject of simulation in the Global model.

Top boundary condition are defined by the meteorological and fenological factors and bottom boundary condition are limited by ground water level.

It is important to have exact inputs into the model, for example depth of soil profile, Genuchten′s coefficients for calculating retention curve, saturated hydraulic conductivity, residual water content, drying branches of retention curve, and initial boundary conditions.

2.5.1 Inputs parameters

1. Hydro-physical parameters of soil profile: moisture of saturated soil by water θ_S ($cm^3.cm^{-3}$), residual volumetric soil moisture θ_r ($cm^3.cm^{-3}$), saturated hydraulic conductivity of soil *K* ($cm.day^{-1}$), parameter α (cm^{-1}), the parameter n (-), bulk density ρ_d ($g.cm^{-3}$),

2. Daily meteorological data: precipitation, air temperature, wind velocity, pressure of saturated water vapor, duration of sunshine,

3. Crop parameters: LAI, roughness of evapotranspiraton surfaces, albedo, depth of roots, average water content %

4. Initial moisture profile

5. Lower, top boundary conditon

2.5.2 Model outputs

The outputs of Global model are daily results of soil moisture content, moisture potential of soil, intensity of water uptake by root zone, daily evapotranspiration totals, transpiration, total water content in the soil profile, water balance in the unsaturated zone of soil, interception, daily values of yield.

3. RESULTS AND DISCUSSION

There were calculated basic statistical characteristics (tab. 1.) for values of hydraulic conductivity which was measured by two different methods (DRI, FHM). These statistical characteristics describe the distribution of values within individual data sets. Figure 2 shows the average input values of soil hydraulic conductivity into the mathematical simulation. The values of $K_{(DRI)}$ a $K_{(FHM)}$ shows that the preferential ways reduce towards the deeper horizons. DRI infiltrometer is mainly used for infiltration characteristics determination and for determination of saturated hydraulic conductivity through the soil surface. Water flow from a ring infiltrometer into tho soil is a three-dimensional (3-D) problem (Reynolds and Elrick, 1990). Main cause of higher values of $K_{(DRI)}$ at soil surface compared to values of $K_{(FHM)}$ is a fact that the total water flow is a combination of vertical and horizontal flow (Tricker 1978, Skalová, 2008). Horizontal flow is partially eliminated by using a two-roller infiltrometer but also is significantly influenced by soil fraction and by previous agro-technical management.

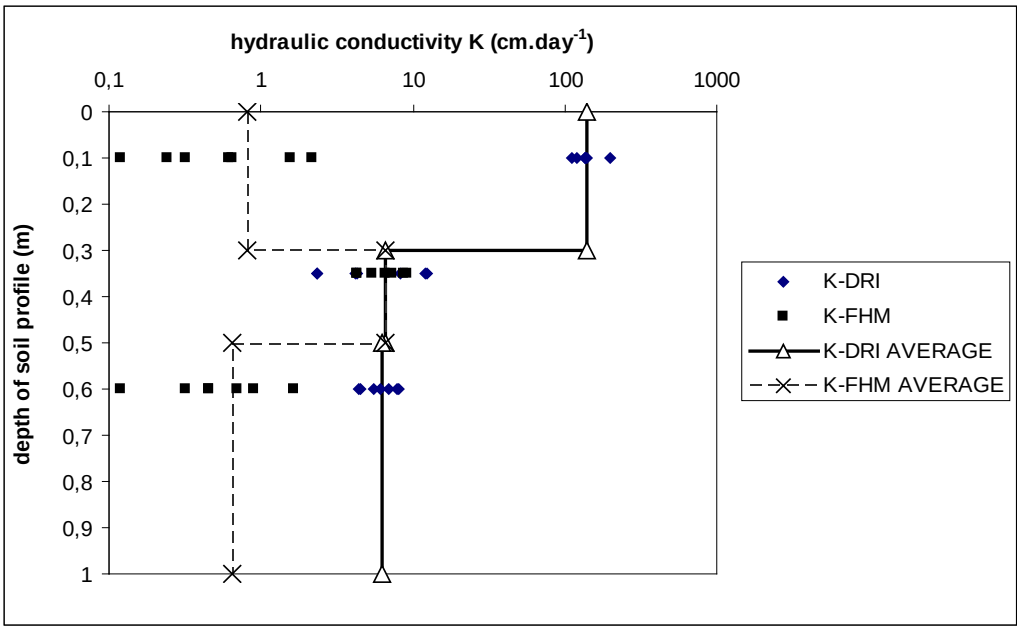

Fig. 2. Measured (points) and average (lines) values of soil hydraulic conductivity obtained by using DRI and FHM method

Statistical parameter	K_{DRI}			K_{FHM}		
	soil layer 0-0.3 (m)	soil layer 0.3-0.5 (m)	soil layer 0.5-1.0 (m)	soil layer 0-0.3 (m)	soil layer 0.3-0.5 (m)	soil layer 0.5-1.0 (m)
Average	139.68	6,58	6,21	0,81	6,51	0,65
Mean	140,40	7,29	6,53	0,59	6,15	0,74
Mean error	12,47	1,78	0,57	0,21	0,76	0,20
Median	136,56	6,26	6,57	0,47	5,97	0,57
Standard deviation	30,54	4,35	1,39	0,52	1,86	0,49
Max-Min	87,33	10,11	3,55	1,44	4,80	1,33
Minimum	111,35	2,34	4,56	0,12	4,32	0,32
Maximum	198,68	12,45	8,11	1,56	9,12	1,65
n	6,00	6,00	6,00	6,00	6,00	6,00
Confidence level (95,0%)	32,05	4,57	1,46	0,55	1,96	0,51

Table 1 Descriptive statistical evaluation of measured data of soil hydraulic conductivity for individual soil profile layers

Depth (m)	K_{DRI} (cm.day^{-1})	K_{FHM} (cm.day^{-1})	□ □(cm^{-1})	*n* (-)	□d (g.cm^{-3})	□r (cm^{-3}.cm^{-3})	□FC (cm^{-3}.cm^{-3})	□s (cm^{-3}.cm^{-3})
0-0.30	139,68	0,802	0,00249	1,2411	1,30	0,021	0,352	0,423
0.30-0.50	6,58	6 515	0,00242	1,2601	1,48	0,011	0,347	0,416
0.50-1.0	6,21	0,655	0,00016	1,4890	1,48	0,013	0,378	0,422

Table 2 Hydro-physical characteristics of soil profile at the experimental site Kolíňany

Table 2 shows all input hydro-physical characteristics used for mathematical simulation. There were determinated pF curves from soil samples which were the object of measurement in the pressure vessels and after that were calculated values of θ_s – soil moisture at the saturation point, θ_{FC} – field capacity, θ_r – residual soil moisture, and Genuchten`s parameters α, n. There are also listed values of ρ_d - bulk density for individual soil profile layers. Mathematical simulation was carried out in year 2004. Evaluation of individual months of year 2004 compared to 30- year reference climatic period of precipitation (1951 – 80) is listed in table 3. The highest amount of precipitation was in June (93.8 mm) and the lowest in August (19.4 mm) with precipitation total of 514.5 mm for the whole studied year. Figure 2 shows distribution of precipitation and temperature in daily time step.

There were obtained courses of soil moisture and other water balance parameters from simulation of soil moisture using GLOBAL model with input values of $K_{(DRI)}$ and $K_{(FHM)}$. Courses of simulation results were then compared with soil moisture measured at the experimental site (Figure. 4). The highest number of maximum soil moisture values was in simulation using input values of $K_{(FHM)}$. The course of simulated soil moisture using input values $K_{(FHM)}$ is comparable with the measured values. Measured values are a bit lower, but not throughout the whole simulation. If we evaluate the courses of simulated and measured soil moisture in relation to precipitation it can be concluded that there is a satisfactory match mainly during months with sufficient precipitation. It means that during months with sufficient precipitation is the influence of *K* obtained using different methodology lower then during months without sufficient precipitation.

Month	P [mm]	RCP 1951-80	% from RCP	characteristic
January	55,9	31	180	very wet
February	31,1	32	97,2	normal
March	52,8	33	160	very wet
April	36,3	43	84,42	normal
May	36,9	55	67,1	dry
June	93,8	70	134	wet
July	33,8	64	52,81	dry
August	19,4	58	33,44	very dry
September	36,7	37	99,19	normal
October	45,3	41	110,5	normal
November	45,7	54	84,6	normal
December	26,8	43	62,3	dry

Table 3 Evaluation of months according to precipitation reference climatic period (RCP) 1951-80 in Nitra for year 2004

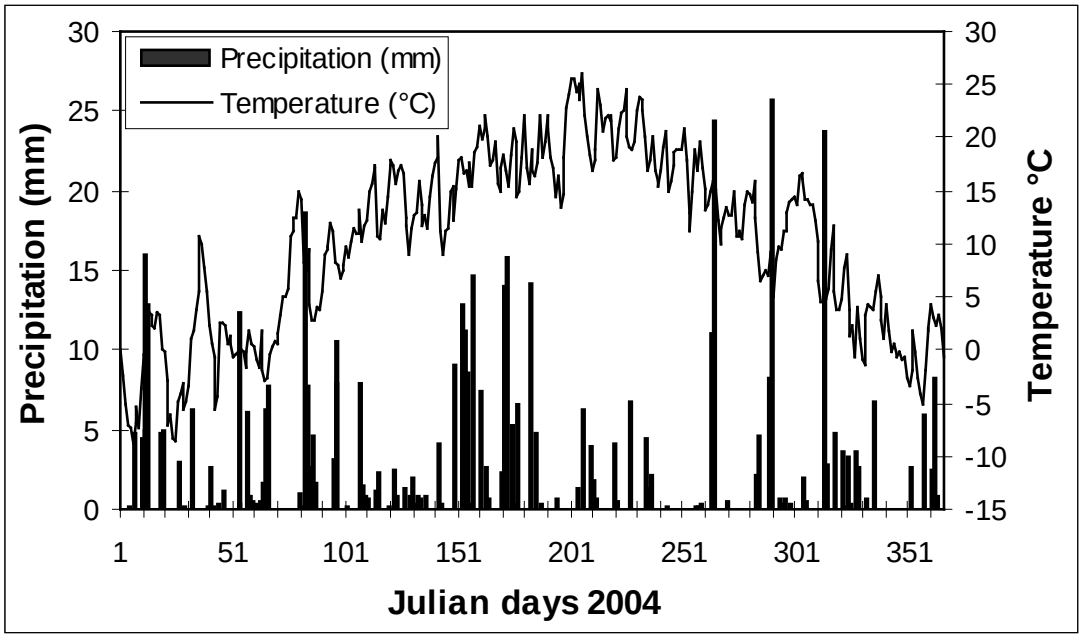

Fig. 3. Precipitation and air temperature measured at the locality Kolíňany in 2004

Precipitations of the spring months can be evaluated as a period with normal precipitation (96.2 % of reference climatic period 1951-80 RCP). The input value of *K* doesn't significantly influence the result of soil moisture simulation compared to measured values during the period with sufficient amount of equally distributed precipitation events. The same can be concluded for simulation using input values of $K_{(DRI)}$ as well as using values of $K_{(FHM)}$. A summer period characterized by lack of precipitation can be evaluated as a period to be under normal precipitation (76.6 % of the reference climatic period 1951-80 RCP). It is necessary to seriously evaluate the summer moths of vegetative period (June - August) in 2004, in which the soil moisture simulation using *K* obtained by measurement using DRI methodology doesn't correspond with courses of measured soil moisture in

the field. It is caused by high average value of $K_{(DRI)}$ measured at the surface layer of soil horizon 0-0.3m, which is 174 times higher compared to $K_{(FHM)}$ ($K_{(DRI)}$ = 139.68 cm.day^{-1}, $K_{(FHM)}$ = 0.802 cm.day^{-1}). From the point of using DRI method for obtaining saturated soil hydraulic conductivity and followed usage of this value as an input value into the GLOBAL model can be concluded that is not suitable for simulation of soil moisture. As it was already mentioned above, there was negative experience mainly by simulating soil moisture during the summer months. The influence of the preferential ways and the soil structure at the surface soil profile consequently caused high value of *K* with following influence on the whole simulation.

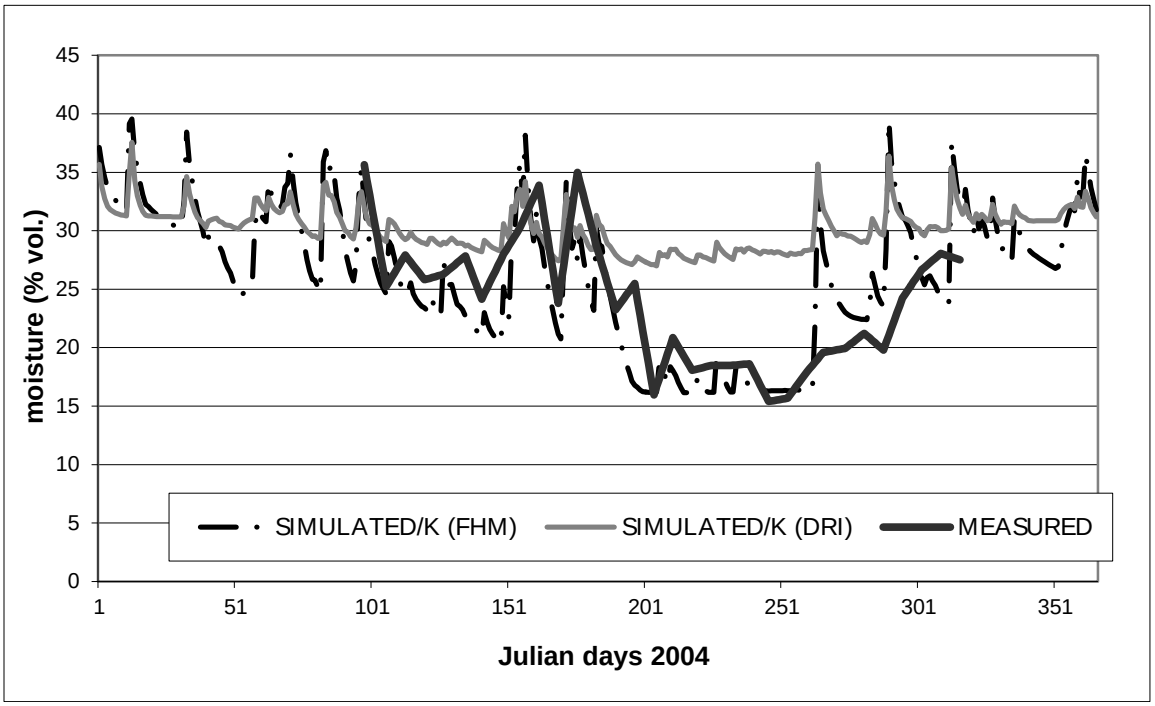

Fig. 4. Measured and simulated values of soil moisture at depth 0.2 m (experimental site Kolíňany, 2004)

Depth 0.2 (m)	simulated values with $K_{(FHM)}$	simulated values with $K_{(DRI)}$
Measured values	0,902	0,679

Table 4 Correlation coefficient between measured and simulated values of soil moisture at depth 0.2 m

There was estimated a linear dependence so-called correlation coefficient between simulated and measured values of soil moisture at the experimental site during year 2004. The correlation coefficient between measured and simulated values using $K_{(DRI)}$ reached significant degree of linear dependence with r= 0.679. Simulation using $K_{(FHM)}$ sufficiently express the course of measured values of soil moisture with correlation coefficient r = 0.902 which is a high degree of linear dependence. Both values of correlation coefficients reached values r > 0, which means that it is a direct linear dependence. The linear dependence between measured and simulated values is shown in Figures 5 and 6.

One of the model outputs are also the daily values of potential and actual evapotranspiration in vesture of Sugar beet. Figure 5 shows the courses of actual evapotranspiration E_{act} simulated during year 2004 using $K_{(DRI)}$ a $K_{(FHM)}$. Simulated values of E_{act} using $K_{(DRI)}$ are higher almost during the whole year compared to simulated values using $K_{(FHM)}$. The daily average value of E_{act} using $K_{(FHM)}$ and $K_{(DRI)}$ was 2.8 mm and 3.5 mm respectively during summer months of growing season.

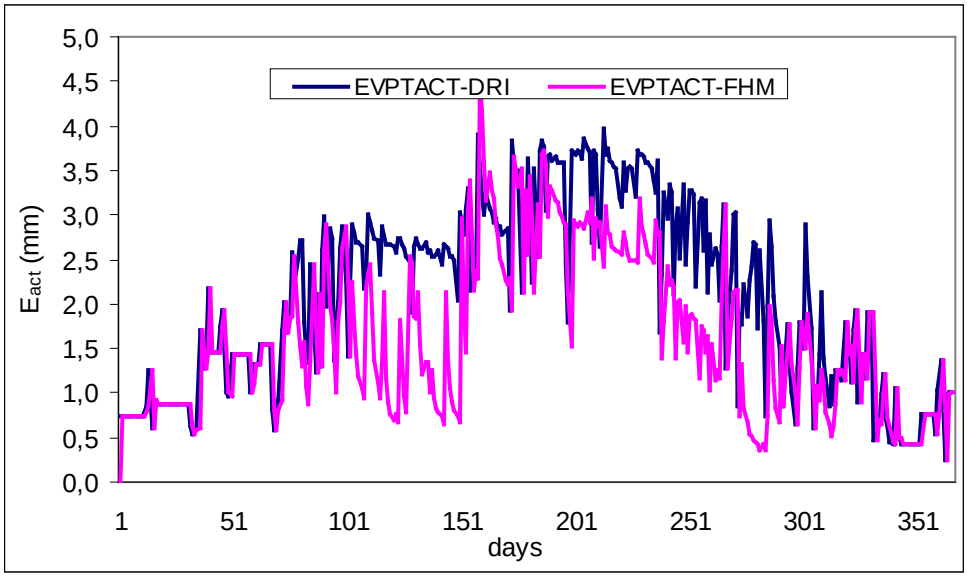

Fig. 5. Daily values of actual evapotranspiration under Sugar beet crop (Experimental site Kolíňany, 2004)

4. CONCLUSION

Direct methods for determination of soil hydraulic conductivity *K* and their use for mathematical simulations bring certain risks associated to the provided outputs of the model. Mathematical model of water movement in the soil GLOBAL reacted sensitively on chosen values of *K* obtained by the two measurement methods; [1] **falling head method - (FHM) and [2] double ring infiltrometer - (DRI).** Average value of $K_{(DRI)}$ measured at surface layer of soil horizon was higher compared to measured value of $K_{(FHM)}$. It was caused by the presence of preferential ways, which increase the amount of water infiltrated through the soils surface. A comparison of simulated and measured values of soil moisture showed that simulated values follow quite well the measured values using the coefficient of soil hydraulic conductivity obtained using laboratory method **(FHM).** Correlation coefficient was r = 0.90 which is a high degree of linear dependence. The obtaining value of *K* using the field method **(DRI)** turned out to be not suitable for soil moisture simulation. Simulated course of soil moisture using $K_{(DRI)}$ compared to measured soil moisture is not in such a close dependence and reached the value of r = 0.68.

If we evaluate the courses of simulated and measured soil moisture in relation to the precipitation the satisfactory match was mainly during months with sufficient amount of precipitation. This means that the influence of *K* obtained by different method during the months rich on precipitation is lower compared to *K* obtained during the months with lack of precipitation. Simulated results of actual evapotranspiration E_{act} courses using $K_{(DRI)}$ are higher compared to results using the $K_{(FHM)}$ method .The daily average value of E_{act} using K_{FHM} and K_{DRI} was 2.8 mm and 3.5 mm respectively during summer months of growing season.

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