ACTA HYDROLOGICA
SLOVACA

Ročník 18, č. 1, 2017, 76 – 79

SOIL WATER REGIME BALANCING AT THE SELECTED LOCATION OF EAST SLOVAKIAN LOWLAND DURING THE VERIFICATION PERIOD

Branislav Kandra, Danka Pavelková

The individual members of the balance equation were calculated and evaluated, using the mathematical model GLOBAL, in the selected growing seasons 2004, 2005 and 2015. The analysis was based on the calculated daily values of infiltration, interception, water flow through the lower boundary of soil profile, evaporation, transpiration and precipitation. The aim was to quantify the above elements of the water regime in the selected soil profile of Milhostov and also evaluate the suitability of this model. Verification showed a high level of dependence between calculated and measured values, which means that the model GLOBAL is an appropriate tool for simulation and balancing of soil water regime in conditions of the selected locality.

KEY WORDS: soil water regime, numerical simulation, soil water balancing, East Slovakian Lowland

BILANCOVANIE VODNÉHO REŽIMU PÔD NA VYBRANEJ LOKALITE VÝCHODOSLOVENSKEJ NÍŽINY POČAS VERIFIKAČNÉHO OBDOBIA. Vo vybraných vegetačných obdobiach 2004, 2006 a 2015 boli pomocou matematického modelu GLOBAL vypočítané a hodnotené jednotlivé členy bilančnej rovnice. Analýza vychádzala z vypočítaných denných hodnôt infiltrácie, intercepcie, toku vody cez dolnú hranicu pôdy, evaporácie, transpirácie a zrážok. Cieľom bolo kvantifikovať vyššie uvedené zložky vodného režimu na vybranom profile Milhostova a zároveň zhodnotiť vhodnosť použitia uvedeného modelu. Verifikácia preukázala vysokú mieru závislosti medzi vypočítanými a meranými hodnotami, čo znamená, že model GLOBAL je vhodným nástrojom k simulácii a bilancii zložiek vodného režimu pôdy v podmienkach vybranej lokality.

KĽÚČOVÉ SLOVÁ: vodný režim pôd, numerická simulácia, bilancovavanie vody v pôde, Východoslovenská nížina

Introduction

Water regime of soils can be classified from different aspects (hydrological, ecological, agronomic, etc.). Regardless of the manner of classification is the knowledge and assessment of the water regime important from the crop production and ecological point of view. In general, the water regime described through the dynamics of water in time and space under the influence of various factors. The main factors that quantify the soil water regime are the soil water content and soil water potential (Gomboš et al., 2014). Soil moisture is determined by the volume of water in the soil at a certain time and place and the water potential means the energy state of water in the soil. The water potential along with the saturated and unsaturated hydraulic conductivity expresses motion properties of water in the soil. Soil water content is during the hydrological year under the influence of meteorological elements, plant cover and groundwater level. Important time period during the year is the growing season. From the crop production perspective the plants have different requirements for water consumption depending on the type of crops and its growth phase. Soil water content during the growing season directly affects the possibility of achieving optimal economic results. Accordingly, the soil water dynamics evaluation has two aspects. The first aspect is hydrological and second agro-climato-hydropedological. Hydrological approach is based on the evaluation of the water balance members, which are determined by the phenomena that influence the soil water dynamics. For evaluating and balancing the soil water regime it is necessary to know and quantify its processes. These processes can be divided into processes of soil unsaturated zone interaction with the atmosphere and vegetation cover . These include water evaporation from the soil, water transpiration by plants and precipitation. Further, the interaction processes of soil unsaturated zone with ground water level, which forms the lower limit. These include the capillary inflow of water from the ground water level, or vice versa outflow of water from the soil aeration zone into ground water level, respectively into the lower soil horizons. In the slope areas it is necessary to calculate with hypodermic outflow which is from the water balance on the lowlands excluded. Soil water content can be quantified by monitoring of soil moisture along the vertical direction of soil profile or by calculation of the individual components of the water balance. For this, two approaches are used. The first requires direct measurement of these components on a particular site. The second is a calculation based on numerical simulation of soil water regime using mathematical models. The aim of present paper is to verify the suitability of a mathematical model for quantification of selected components of the water regime and the subsequent balance of water in the soil. Evaluation is based on the analysis of the daily values of balance equation members during the verification period.

Material and methods

For the purpose of soil water regime balancing a research locality, situated near a village of Milhostov in the Trebišov town area, was selected. The research site is managed by the National agricultural and food center Nitra. The area is divided into individual fields, where the research center conducts its experiments. Within the test fields, the research base of ÚH SAV Michalovce uses the field no. 9 for the regular data collection of soil moisture and ground water level. Furthermore, a hydro-physical characteristics of collected soil samples were measured in laboratory (Tall and Gomboš, 2013). In terms of soil classification, the site is characterized by the occurrence of moderate, clay loam fluvisol. Daily meteorological data are available from the SHMÚ station located near the field. Weekly data monitoring on the locality is performed from the year of 2000, during growing seasons (April - September). The time period of growing seasons (2000 - 2015) was selected for numerical simulation of water regime elements by the mathematical model GLOBAL (Majerčák and Novák, 1994). Verification of the chosen model consisted of a comparison of the calculated and measured soil water storage to a depth of 0.8 meters. Due to the fact, that the model is not primarily intended for water regime modelling of heavy soils, for which is typical two domain structure (the soil matrix and the network of cracks), the model has tended to underestimate the results compared to measurements. Therefore, the modelled water storages were calibrated through the found correlation between the calculated and measured values. Within the verification process a regression analysis of results was also performed. After the model reliability verification followed a selection of the three growing seasons. The selection criterion was the average precipitation and average temperature of the evaluated period. The total rainfall of the growing season 2006 was near the average value, in 2004 proved to be highly above average and vice versa in period 2015 as far below average. In terms of temperature, the selection was located in the reverse order. The water regime balance in the investigated period was based on the simple balance equation (1), (Šútor and Majerčák, 2000).

$$W_w = V_i + H - E_e - E_t \qquad (1)$$

where

W_w – water storage change [mm],
V_i – water infiltration into the soil [mm],
H – H(+) water capillar inflow, H(-) water drainage outflow [mm],
E_e – evaporation [mm],
E_t – transpiration [mm].

The water capillary inflow, respectively water drainage outflow within the balanced soil profile was in the model realised through the lower boundary of the balancing layer. The soil water infiltration includes rainfall reduced by interception of real crop. Calculation of the evapotranspiration is based on the Penman method (1948) developed by Monteith (1965) and modified by Novak and Hurtalová (1987). In the paper were analysed daily courses of the individual members of balance equation during the selected growing seasons. It is also evaluated daily balance of water storages in the studied soil profile with respect to crop types.

Results and discussion

Model verification

For balancing the water in the selected soil profile it was first necessary to verify the reliability of model calculations. The GLOBAL verification was based on an analysis of calculated and measured values of soil water storages to a depth of 0.8 meter. The figure 1 shows the weekly courses of monitored (M), calculated (G_0) and calibrated (G) water storages for the entire verification period. From the value courses it is clear that the model (G_0) significantly underestimates the real state of soil water storage. The average deviation of the model relative to the measurements is 23.46%. The solution of this problem was the subsequent calibration of the model output. It was searched a suitable relationship between the calculated and measured values. The figure 2 presents the dependence for calculating of the model calibration indexes. The subsequent correction of the calculated water storages

(G) has improved the accuracy up to 5.66% of average deviation compared to measurements with the same trend. The using model suitability also shows the regression analysis (Tab. 1). In most cases, the values of correlation coefficients between measured and calculated water storages are highly significant.

Soil water balance

In Fig. 3 are shown daily courses of the individual members of balance equation for the growing seasons 2004, 2006 and 2015. The rainfall of the growing season 2004 in the verification period was above average (458mm) and the air temperature below average (16°C). During this growing season was recorded a continuous transpiration, which corresponds with the clover grass crop occurring the entire season. Here was the crop impact on the water balance throughout the period. In the figures 3 are also shown the daily value of calculated and monitored soil water storages. A daily water balance in the soil corresponds to a downward trend in soil water storage. The daily water balance values are mostly negative. The exception are few days in August and September. In those days there were high rainfall with the maximum up to 46 mm. This was reflected on the infiltration and soil water storage increase. In those days was water balance positive. The rainfall (402 mm) and air temperature (17°C) in the growing season 2006 were on an average due to the investigated period. Actual crop was the pea with a length of vegetation cover 71 days (15.5.06 – 24.7.06). During this period was observed transpiration totals culminating sometimes in the middle of the period. Similarly, as in the season 2004, the water storage trend has decreased and the daily water balance was negative, which indicated the dominant water outflow from the balanced soil profile. Significant decrease of the water storage was in July, when the long periods without precipitation occurred. On the other way, the soil water storage increase is visible only in days with high precipitation sum or greater number of precipitation days. In extremely dry period 2015 was the precipitation total 227 mm and average daily air temperature 18 °C. Real plant was the soybean with plant cover duration same as for pea 70 days. In analogy with previous periods prevailed the water outflow from the soil profile. Water balance was again in positive values and water storage in the profile had increased. The maximum rainfall was on 15. June (45 mm). Most sensitive impact on the rainfall amount was demonstrated in the processes of evaporation and transpiration. In Fig.4 are together shown the daily totals of the precipitation and crop interception. Amount of retained water through the crop interception culminates at the time, when the crop is fully developed, which corresponds with the maximum of leaf area index (LAI).

Conclusion

Currently, the computational tools in the form of different models are increasingly used in the assessment of soil water regime. The mathematical model GLOBAL is one of those that allow to quantify individual elements entering the water cycle within the system of atmosfphere – vegetation cover – soil unsaturated zone – ground water level. It is also possible through the model to realize the water balance in the soil profile with a daily step. The goal of this study was the verification of the model GLOBAL suitability for its using during the water balancing of the examined soil profile in the Milhostov locality. Verification of the model showed a high correlation between measured and calculated values of soil water storage. However, in case of heavier soils such as soil in Milhostov, the model had tended to underestimate the calculation. This problem was subsequently eliminated via the correction of the calculated water storages using an appropriate dependency between modelled and measured values. Subsequently, the three growing seasons 2004, 2006 and 2015 were selected from the verification period 2000 - 2015. In these periods the daily water balance and analysis of the balance equation members was done in the evaluated soil profile. The results indicated that used model is a suitable simulation tool for soil water balancing and water regime elements estimation. The advantage of the model is the possibility to count with a real vegetation what make the simulation closer to real conditions.

Acknowledgement

The authors would like to thank for the kind support of the project VEGA 2/0062/16, project APVV-0163-11 and this contribution is the result of the project implementation: Infrastructure completion of hydrological research stations, ITMS code 26210120009 supported by the Research & Development Operational Programme funded by the ERDF.

Európska únia
Európsky fond regionálneho rozvoja
VÝSKUMNÁ AGENTÚRA
Operačný program VÝSKUM a VÝVOJ

We support the research activities in Slovakia/ The project is co financed by the EU sources.

Literature

Gomboš, M., Tall, A., Pavelková, D. (2014): Evaluation of selected localities of east-Slovakian lowland by soil potential for volume changes. In: SGEM -14 th Geo Conference on Water Resources, Forest, Marine and Ocean Ecosystems : Conference Proceedings. - Sofia: STEF92 Technology Ltd. 1, 2014, 115 – 123. ISBN 978-619-7105-13-1.

Majerčák, J., Novák, V. (1994): GLOBAL one-dimensional variable saturated flow model, including root water uptake, evapotranspiration structure, corn yield, interception of precipitations and winter regime calculation: Research Report. Bratislava: Institute of Hydrology S.A.)S., 1994. 75 p.

Monteith, J.L. (1965): Evaporation and environment. In: The state and movement of water in living organism. 19th Symposia of the Society for Experimental Biology. 19: 205 – 234.

Novák, V., Hurtalová, T. (1987): Metóda výpočtu súčiniteľa rýchlosti turbulentného prenosu vodnej pary a jej využitie pri určovaní potenciálnej evapotranspirácie. Vodohospodársky časopis, 1987, r. 35, č. 1, 3 – 21.

Penman, H.L. (1948): Natural evaporation from open water, bare soil and grass. Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences, Vol. 193, No. 1032, 120 – 145.

Tall, A., Gomboš, M. (2013): Regionalization of Depressed Area of East Slovakian Lowland According to Soil´s Water Capacity. In: Water Management and Hydraulic Engineering: proceedings of the 13th International Symposium. STU, Bratislava, SR, 9.-12.9.2013, 533 – 540. ISBN 978-80-227-4003-6.

BILANCOVANIE VODNÉHO REŽIMU PÔD NA VYBRANEJ LOKALITE VSN POČAS VERIFIKAČNÉHO OBDOBIA

V súčasnosti sa pri hodnotení vodného režimu pôd čoraz viac využívajú výpočtové nástroje v podobe rôznych modelov. Matematický model GLOBAL je jedným z tých, ktoré umožňujú kvantifikovať jednotlivé zložky vstupujúce do kolobehu vody v rámci systému A-RK-NZ-HPV. Zároveň je možné prostredníctvom modelu realizovať bilanciu vody v pôdnom profile s denným krokom. Predmetom tejto práce bolo overenie vhodnosti použitia modelu GLOBAL pri bilancovaní vody v skúmanom pôdnom profile Milhostova. Verifikácia modelu preukázala vysokú závislosť medzi meranými a vypočítanými zásobami vody v pôde. Avšak, v prípade ťažších pôd, akou je aj pôda v Milhostove, má model tendenciu výpočet podhodnocovať. Tento problém bol odstránený následnou korekciou vypočítaných zásob vody pomocou vhodnej závislosti medzi modelovanými a meranými hodnotami. Následne boli z verifikačného obdobia 2000 – 2015 vybrané 3 vegetačné obdobia 2004, 2006 a 2015. V týchto obdobiach boli pomocou matematického modelu GLOBAL vypočítané a hodnotené jednotlivé členy bilančnej rovnice. Analýza vychádzala z vypočítaných denných hodnôt infiltrácie, intercepcie porastu, toku vody cez dolnú hranicu pôdy, odtoku vody do nižších vrstiev pôdneho profilu, evaporácie, transpirácie a zrážok. Z výsledkov vyplynulo, že použitý model je vhodným simulačným nástrojom pre bilancovanie vody v pôde a odhad jednotlivých zložiek vodného režimu. Výhodou modelu je aj možnosť počítať s konkrétnym porastom, čím sa simulácie viac približujú reálnym podmienkam.

Ing. Branislav Kandra, PhD.
Ing. Dana Pavelková, PhD.
Ústav hydrológie SAV Bratislava
Výskumná hydrologická základňa Michalovce
Hollého 42
Michalovce 071 01
Tel.: 056 / 6425 147
Fax: 056 / 6425 147
E-mail: kandra@uh.savba.sk
pavelkova@uh.savba.sk