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MODELLING RUNOFF ON A SMALL LOWLAND CATCHMENT, HUNGARIAN GREAT PLAINS

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Abstract

The lowland region of the South-Eastern Carpathian Basin faces extreme hydrological conditions, therefore the more detailed understanding, monitoring and predicting of the hydrological regime on catchments have high importance. However, in the region only few measured data are available in terms of evaporation, runoff, infiltration and water retention, and this is especially true concerning small catchments. In the meantime these areas support extensive agriculture, therefore more information is needed to manage future drying and irrigational demands. In the present research runoff and discharge were modelled for a ten year period and compared to at-a-station measurement data on the Fehértó-majsa Canal, a sub-catchment of the Tisza River, in order to test the predictability of hydrological changes related to future climate change. Modelling was made by applying a coupled MIKE SHE/MIKE 11 model and integrating all available topographic, pedologic, climatic, hydrologic and vegetation data. Consequently, another motivation of the research was to assess the suitability, data demand and limitations of the MIKE modelling environment on lowland catchments. As from all available data sources soil data seemed to be the least accurate, sensitivity tests were made by changing different soil parameter. Based on the results, the developed model is highly suitable for the estimation of annual and monthly runoff. Nevertheless, concerning daily data a general overestimation of discharge was experienced during low flow periods, and a time lag appeared between measured and modelled discharge peaks during high flow periods. In all, the results of the study can greatly support the realization of water management and planning projects in the drought prone sand land catchments where only a few directly measured data are available.

Keywords: modelling, runoff, MIKE, lowland catchments

INTRODUCTION

Water resources has become more and more important in the last decades in many regions of the world due to the increasing water demand of agriculture, industry and population and also due to climate change. The main difficulties with resources arisen from their great spatial and temporal variability. Therefore sustainable water management require detailed and accurate information about the processes of the hydrological cycle (e.g. spatial and temporal variation of runoff, infiltration, soil moisture). The growing significance of this issue led to the development of hydrological models, since simulated results of hydrologic models are useful in water and land resource management (Sahoo et al., 2006). Hydrological models were developed for understanding and quantifying the factors of the complex hydrological cycle by mathematic, physical or empirical functions on a well-defined hydrological system or catchment. The components of the hydrological system (surface and subsurface waters, urban drainage or sewage systems) are in close connection and this system involves complex, incompletely understood interactions among flow, sediment transport and channel form (Rodrigez et al., 2004). Thus a well-designed hydrological modelling software should take into account these components (Singh and Frevert, 2001). Hydrological models can be 1) conceptual: rough simplifications of reality, conceptualising the ideas of important processes and simulating internal variables or 2) physically based: processes are described by detailed physical equations. Based on spatial resolution, they can be 1) lumped, representing the entire catchment by a few boxes and no spatial differentiations are considered, and “) distributed models dividing the catchment into a large number of cells (Lundin et al., 2000).

Physically distributed hydrological models use parameters related directly to the physical characteristics of the watershed (e.g., distribution of topographic, geologic, soil and vegetation parameters) and spatial variability in both physical characteristics and meteorological conditions (Sahoo et al., 2006). The applied MIKE SHE hydrological modelling software is a widely used physically distributed hydrologic model, suitable for modelling different components of a hydrological system e.g. rainfall–runoff (Makungo et al., 2010; Odiyo et al., 2012), evapotranspiration (Vázquez and Feyen, 2003), groundwater movement (Demetriou and Punthakey, 1999), rivers stage (Panda et al., 2010), soil hydraulic properties (Romano and Palladino, 2002), or the complete hydrological system of a catchment (Singh et al., 1999; Liu et al., 2007; Doummar et al., 2012).

On hydrologically extreme areas, such as the lowland small catchments of the Carpathian Basin, more accurate description and forecast of the water balance is a very important objective, since only a few exact data are available about evaporation, runoff, infiltration and water storage conditions of the area. The aim of the research was to model runoff and discharge for a ten year period on the Fehértó-majsa Canal, a sub-catchment of the Tisza River, in order to test the predictability of hydrological changes related to future climate change. Modelled data were compared to at-a-station measurement data in order to verify the modelling process. In the meantime the applicability and data demand of the MIKE environment was also assessed.

STUDY AREA

The modelling was carried out on the catchment of the Fehértó-majsa Canal (SE Hungary), a 290 km^2 sub-catchment of the Tisza River. The Canal has 9 tributary canals and canal density is 0.68 km/km^2 on the basis of the total length of canals managed by water directorate (Fig. 1). The major part of the catchment (the western, upstream section) is located on the Dorozsmai-majsai Sand Ridge, while the eastern, downstream section of the catchment is located on the South-Tisza Valley *(*Dövényi 2010*)*.

Low slope conditions exist on the catchment, despite the ridge-like character of the area. The slope of the major canal is 0.78-1.16 m/km on the upper reach and 0.27-0.78 m/km on the lower reach. The maximum relief of the major canal is 24.4 m. The vertical fragmentation of the catchment is relatively high compared to lowland landscapes (the relative relief is 3-6 m/ km2) due to the system of the residual ridges and blown-out depressions, arranged into northwest-southeast direction, defining also the main runoff direction of the major and tributary canals (Marosi-Somogyi 1990).

The climate of the region is humid continental, facing drying in the past decades. Based on meteorological data, this drying tendency means that the precipitation distribution was increasingly uneven, characterised by less frequent and decreased amount of summer precipitation. In the region of the studied catchment, the annual mean temperature and the average annual duration of sunshine is the highest in the country (Pálfai, 1990), and the annual precipitation amount is quite low (520-570 mm), thus the climatic water stress is an important factor in this region (the average annual water scarcity is 520-570 mm –OMSZ 2001). The aridity of the region is enhanced by the unfavourable moisture regime of the dominantly sandy soils, because the water retention capacity of these soils is low. Based on the climatic and physical geographical parameters the area faces with moderate inland excess water hazard and high drought hazard (Fiala et al., 2014; Mezősi et al., 2014). Due to the regionally elevated situation of the upper-catchment, the groundwater regime is different on the lower-catchment (near to Szatymaz), –where the average groundwater level is 115-155 cm below the surface – and on the upper-catchment (in the sand ridge area), where the average groundwater level is 200-300 cm below the surface (ATIVIZIG).

DATA AND METHODS

The modelling of water balance on the Fehértó-majsa Canal was carried out by using a coupled MIKE SHE/MIKE 11 model. Setting up the model requires the input of a number of data sets, explained in detail below.

The modelling software

From the wide range of MIKE software products, MIKE 11 and MIKE SHE were used. MIKE 11 is a one dimension (1D) river and channel modelling software, while MIKE

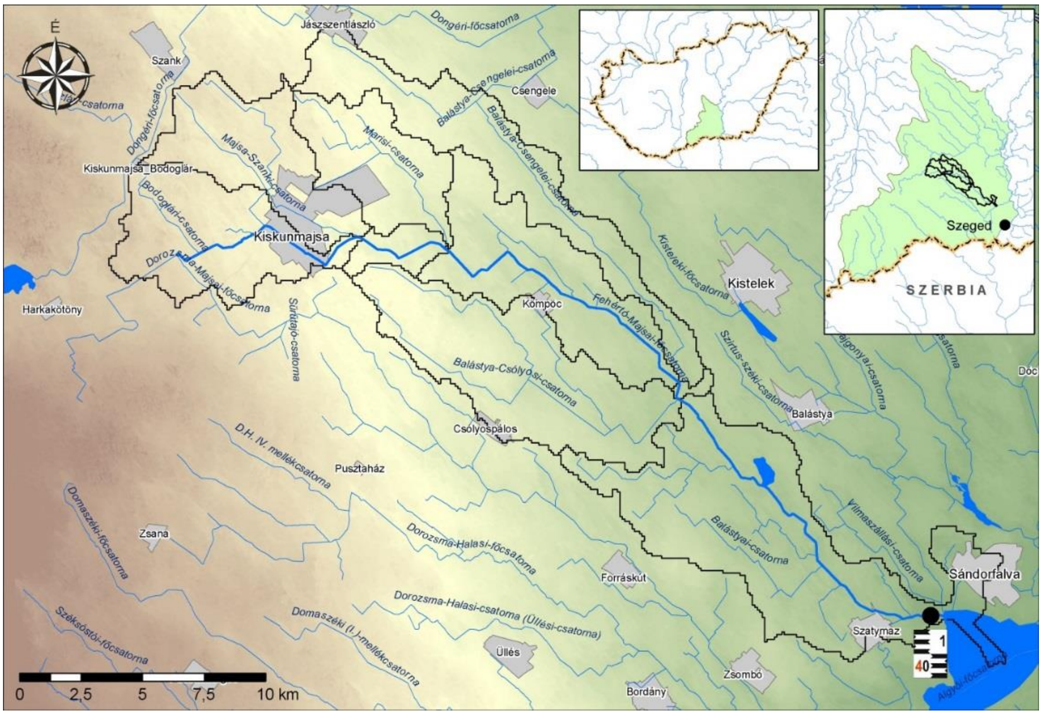

Fig. 1 Location of the studied catchment

SHE is 2D integrated catchment modelling software. The two modelling environments can be coupled, thus the interactions between the water flow and the catchment could also be interpreted. The MIKE 11 is an implicit finite difference model for computation of one dimensional unsteady flow with free surface. MIKE 11 applied with the fully dynamic descriptions solves the vertically integrated equations of conservation of volume and momentum (the 'Saint Venant' equations), based on the assumptions that the water is incompressible and homogeneous.

The MIKE SHE is a deterministic, fully distributed and physically based modelling system for modelling the major processes of water flow in the land phase of the hydrological cycle, including a range of numerical methods for modelling each hydrological processes. Each of these processes can be represented at different levels of spatial distribution and complexity, according to the goals of the modelling study and the availability of field data. The advantage of the MIKE SHE is the high integration of the elements of the hydrological process, in which the interrelations between these processes are counted. Due to the modular approach implemented in the MIKE SHE, each of the hydrologic processes are calculated separately and integrated on the basis of the interrelations between these processes (Graham and Butts, 2005).

The integration of different input data into the model

Land cover data

To evaluate the effect of vegetation cover of the modelled catchment, 1:100.000 scale Corine Land Cover (CLC) database was applied. The parameters of the different land cover types has importance in modelling surface runoff, since land cover type define the runoff factor of the precipitation. On the analysed catchment, 17 different land cover types were identified, thus defining the parameters for each land cover type is important (Fig. 2.).

Land cover affects overland flow and Evapotranspiration Component during modelling. The calculation of overland flow is based on the Manning's roughness coefficient (Chow 1959) in the MIKE software. The Manning's roughness values for the CLC land cover types are indicated in Table 1. For calculating the Evapotranspiration Component MIKE SHE requires the leaf area index (LAI) and the root zone depth for each land-use type. These values were defined based on the CLC classes (Table 1).

Soil data

The soil data can be integrated into the model as polygon features. For the modelling the effect of soil on the, the parameters of the unsaturated soil are important (depth of the soil layer, water retention parameters, hydraulic conductivity). The parameters of the unsaturated soil zone were described for the model on the basis of the 1:100 000 scale Agrotopographical map (Agrotopographical Database, 1991) (Fig. 2). The water retention parameter of the soil can be defined by the pF curves of the different soil types to estimate the soil moisture balance. These pF curves were described by Stefanovits et al. (2010) for the main soil texture classes (sand, loam, clay), thus the soils of the study area were categorised into these classes:

1. Sand: blown sand, humic sandy soil, chernozem type sandy soil
2. Loam: meadow chernozem, solonetzic meadow chernozem, meadow soil
3. Clay: solonchak solonetz, meadow solonetz, Solonetzic meadow soil

Table 1 Parameters related to the Corine Land Cover (CLC) classes used in the model (Zhao et al., 2012; Chow, 1959*)*

Corine Code	Type	LAI index	Root zone depth (m)	Roughness
112	Discontinuous urban fabric	0	0	0.1
121	Industrial or commercial units	0	0	0.1
131	Mineral extraction sites	0.98	0.5	0.04
142	Sport and leisure facilities	0.98	0.5	0.05
211	Non-irrigated arable land	1.375	0.5	0.04
221	Vineyards	1.5	1	0.05
222	Fruit trees and berry plantations	1.5	1	0.05
231	Pastures	1.76	0.5	0.035
242	Complex cultivation	1.375	0.5	0.04
243	Land principally occupied by agriculture, with significant areas of natural vegetation	1.375	0.5	0.05
311	Broad-leaved forest	2.33	2	0.09
312	Coniferous forest	2.45	2	0.09
313	Mixed forest	2.53	2	0.09
321	Natural grassland	1.76	0.5	0.035
324	Transitional woodland shrub	1.97	1	0.07
411	Inland marshes	1.82	0.5	0.07
512	Water bodies	1.81	0	0

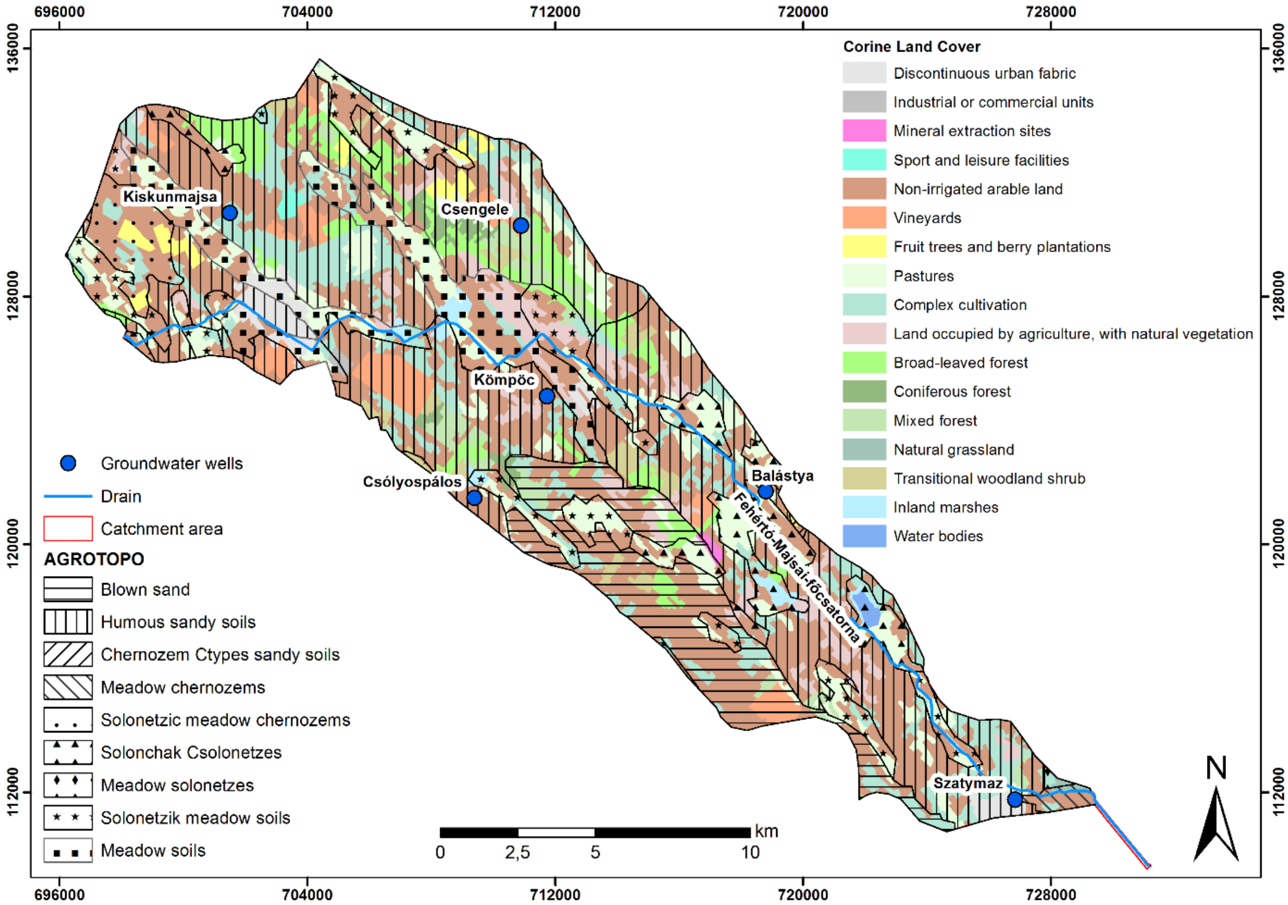

Fig. 2 Soil and land cover types on the studied catchment

The hydraulic conductivity can be defined by several methods e.g. Averjanov, van Genuchten, Campbell/Burdin. Important input parameters in the calculation of hydraulic conductivity are the saturated hydraulic conductivity (Ksat), saturated soil water content (ϴsat), residual soil water content (Θ_{res}) and empirical values of the inverse of the air entry value (α) and the shape parameters of the van Genuchten (n). MIKE SHE needs these parameters to estimate the water content of unsaturated soil during the simulation, however the evaluation of these parameters are very complex, requiring extensive field and laboratory measurement, thus the catchment-scale evaluation is problematic. Therefore the reference values, defined by Cook (2012) for different soil texture types (Table 2) were used in the modelling.

Topography

The runoff directions throughout the catchment were evaluated using surface topographical data. The topography input data was obtained from a 5 m resolution digital elevation model (DEM). The MIKE SHE re-

Table 2 Hydraulic parameters for soil texture types (Cook, 2012)

Type	Θ_{res}	Θ_{sat}	α, cm^{-1}	n	K_{sat} ft/day
Sand	0.045	0.43	0.145	2.68	23.39
Loamy Sand	0.057	0.41	0.124	2.28	11.49
Loam	0.078	0.43	0.036	1.56	0.82
Silt Loam	0.067	0.45	0.02	1.41	0.35
Sandy Clay Loam	0.1	0.39	0.059	1.48	1.03
Clay Loam	0.095	0.41	0.019	1.31	0.2
Silty Clay Loam	0.089	0.43	0.01	1.23	0.06
Loam	0.078	0.43	0.036	1.56	0.82
Sandy Clay	0.1	0.38	0.027	1.23	0.09
Silty Clay	0.07	0.36	0.005	1.09	0.02
Peat	0.1	0.7	0.05	1.1-1.3	0.05-1

quires a special raster dataset, a (.dsf2) grid point file. Hence the original DEM requires some transformation procedures. Firstly, a point file was created using ArcGIS and the elevation data of the DEM was linked for each point. The resulted point shape file can be used as input and a digital elevation model can be generated by interpolation in the model.

Water flows (canals)

To evaluate the canal network and the features of the canals, a MIKE 11 model was developed. The canal network was implemented using polyline GIS maps and cross-sectional and longitudinal section data were joined to the canals. The description of the canals was achieved through the specification of cross-sections of the canal. In defining the cross-section geometry, the maximum elevation is specified in such a way that the cross-section will accommodate the maximum expected water levels. The placed markers of the canal bank define the horizontal boundary of the hydraulic area. If, during a simulation, the water level rises above the maximum elevation in the processed data table, the hydraulic area is calculated by assuming the river banks extend vertically upward. This is not realistic, however the computation of the runoff is simpler, moreover the model cannot compute horizontal flooding as a 1D model. Important parameter is the channel bed roughness (n), since it has an impact on the runoff velocity. The roughness factor is defined by the shape of the channel and the vegetation type and density. In this study, a uniform n value of 0.035 was used, which is consistent with values proposed by Chow (1959) for streams with hydraulic characteristics similar to the studied canals. As boundary condition, prescribed infow and outfow points and initial boundary conditions also have to be defined. Here, the inflow boundary conditions at the upstream end of the branch was closed end (Q=0), since there is no inflow at the upstream end of the modelled canal. As the outflow boundary conditions at the downstream end of the branch stage-discharge relation or a simple water level (in meter above sea level).

Groundwater data

To describe the effect of the saturated zone on the system relative groundwater depth data was used. The depth of the groundwater has effect on the runoff and water level of the canal in two ways: if the groundwater level is higher than the bottom of the canal, groundwater inflow represents additional water within the system; if the groundwater level is lower, water outflow from canal represents water loss within the system. The model processes the groundwater level changes over time, starting with a preliminary defined initial value. This value can be one value representing the whole catchment or an elevation model of the relative or absolute groundwater level. In this study elevation model was interpolated from the data of 6 groundwater wells (Fig. 2) and this elevation model (Fig. 3) was the input data for modelling. Beside ground water data, properties affecting subsurface activities include saturated hydraulic conductivity of the saturated zone layers and special geologic properties of the soil profile (e.g. less permeable lens). The inclusion of geologic data is op-

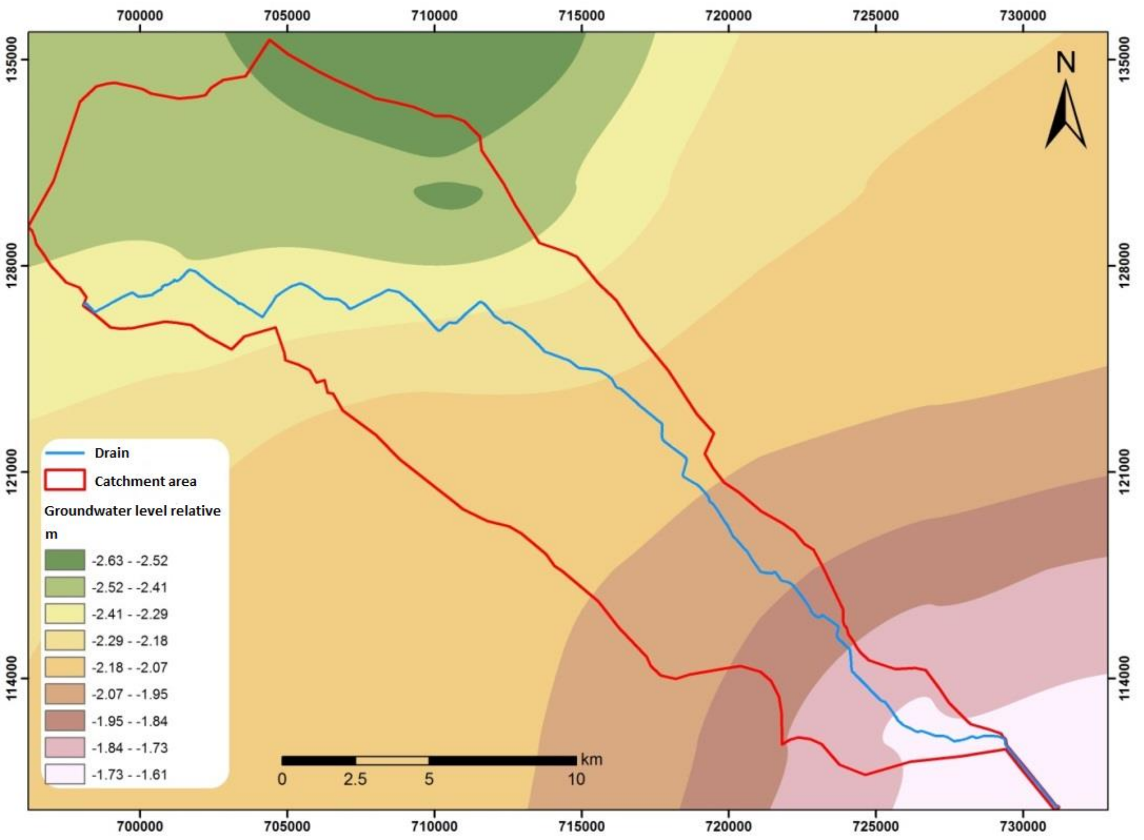

Fig. 3 Initial relative groundwater depth on the study area (01.01.2003)

tional in the model. The subsurface system was defined by closed boundary condition in the model, thus the horizontal inflow and outflow is not allowed during the modelling.

Meteorological data

To integrate the climatic conditions, MIKE SHE model requires three main inputs: precipitation rate air temperature and reference evapotranspiration. One of the most important meteorological input data of runoff models is the precipitation amount, since the precipitation is the main water input in the system. For the study area observed daily data of 4 meteorological stations was available in the simulated period (2003-2012). Into the model, the average data of the 4 stations was calculated and this value was applied for the whole area. In the model, the precipitation can runoff, infiltrate or temporarily store in the soil. The storing capacity (mm) is an input parameter of the model and this value defines the thresholds of infiltration or runoff. The model is very sensitive to this parameter, significantly influencing the model results, thus preliminary testing is essential (Frana, 2012). The infiltration and runoff are defined by the vegetation and roughness of the land cover and the parameters of the unsaturated soil zone.

The physical state of the precipitation (rain, snow) is also important, thus the data series of temperature is also necessary for the simulated time period. Temperature has influence on the model result because of the water storing in case of frost periods or the increased evapotranspiration in case of high temperatures. In the model, daily average temperature data was used. The most problematic meteorological parameter is the evapotranspiration. Detailed catchment scale evapotranspiration data are not available for the study area, only large scale yearly average values. This yearly average could be used in the model by calculating daily values, however this constant value is not realistic due to the significant temperature variation during the year and this would resulted in large errors in the model result. To provide more accurate values for the model, the evapotranspiration data should be corrected with the daily temperature variation using the correction values. For this correction, data of FAO (2015) was used.

The modelling process

After uploading the necessary data simulation was run for a 10-year period between 2003 and 2012. In all 9 model variations were generated. The first is termed as the initial model, containing the data in the form detailed above. Since from among the input datasets soil parameters can be attributed with the greatest uncertainty as a consequence of their relatively poor resolution (1:100 000) and the lack of measured data concerning physical properties, in the following variations the sensitivity of the model to the variation of these were tested. Primarily, parameters related to hydraulic conductivity and storage capacity, influencing infiltration and ground water flow were changed by considering possible minimum and maximum values concerning loamy soils.

In all 9 different model variations were set up (Table 3). In the first two variations specific storage was increased and decreased by 50%, in the following two variations specific yield was modified similarly. In case of model variation No. 6 and 7 hydraulic conductivity was increased and decreased by an order of magnitude. Subsequently, the detention storage parameter was increased to 2 and 5 mm. Concerning the final variation the calculation method of the water retention parameter was modified and instead of soil pF curves the Van Genuchten formula was applied with empirical values for α and *n* (Cook, 2012). All model variations were run and discrepancies between the simulated and the measured discharges were analysed.

Model variations were validated against discharge data recorded near the outlet of the catchment at the Szatymaz gauge station. The station records the discharge of the canal daily at 7:00 am since the 1990s, therefore simulated discharge data were retrieved from the model also for this time of the day. For comparisons the differences (in m^3/s and %) between calculated and the measured daily data were averaged for the entire period, and also on a yearly and a monthly base. The agreement between modelled and measured data was also analysed by calculating correlation coefficients.

Table 3 Modified input parameters in the different model variations

Model variations	Specific Storage (1/m)	Specific Yield	Hydraulic Conductivity (m/s)	Detention Storage (mm)	Retention Curve
Initial	0.2	0.2	2.8e-005	0	pF curve
1.	0.3	0.2	2.8e-005	0	pF curve
2.	0.1	0.2	2.8e-005	0	pF curve
3.	0.2	0.3	2.8e-005	0	pF curve
4.	0.2	0.1	2.8e-005	0	pF curve
5.	0.2	0.2	2.8e-006	0	pF curve
6.	0.2	0.2	2.8e-004	0	pF curve
7.	0.2	0.2	2.8e-005	2	pF curve
8.	0.2	0.2	2.8e-005	5	pF curve
9.	0.2	0.2	2.8e-005	0	van Genuchten

Data were also compared in terms of dry (low water) and humid (high water) periods. The distinction was made by calculating the mean of the measured data series (0.208 m^3/s). Consequently, values below and above this value were considered as low water and high water data.

RESULTS

Concerning the initial model the average discrepancy of the simulated data for the whole period (2003-2012) was +0.027 m^3/s, meaning a 12% overestimation of the measured discharge (Table 4). The simulated data of the initial model were in a good agreement with the measured data in low flow periods. On the other hand in more humid periods the model overestimated runoff and simulated peak discharges were in delay to the measured data (Fig. 4). The maximum difference experienced in the daily data series was -2.5 m^3/s and occurred during the 2006 excess water period. The correlation coefficient between the daily data of the simulated and modelled series was extremely poor as a consequence of overestimation and time lags between the two datasets. Naturally, if monthly and annual means are compared the results improve. On a monthly and annual basis the value of R^2 is 0.51 and 0.94 (Table 4).

Concerning the entire modelling period the lowest differences were experienced in case of the initial model and in case of model variation No. 3 and 4 (discrepancy: +0.026-0.027 m^3/s and 12-13%), where the specific yield parameter was modified. The highest discrepancy was found in case of model variation 8, run with a 5 mm detention storage value (discrepancy: +0.314 m^3/s and 502%).

Each of the modified model variations overestimated runoff during low flow periods. The fitting of the modelled data series to the control data was varying. Based on the tests, the modification of the specific yield parameter hardly caused any change in the results compared to the initial model (Table 4). In these variations the overestimation was 43%, being only 0.07-0.08 m^3/s, which is reasonable if we consider that during low flow mean discharge is only 0.128 m^3/s. Greater differences were seen when changing the values of the specific storage parameter. Nevertheless, the largest discrepancy was experienced in case of model variation No. 5 and 8, when hydraulic conductivity was considerably decreased and detention storage was increased. In these cases modelled discharges were in averages 5 times higher than the control values (Table 4). When hydraulic conductivity was increased in model variation No. 6, low water values were still considerably higher than in case of the initial model, probably as a result of increased ground water yield to canals.

Concerning high flows both underestimation and overestimation occurred in comparison to the measured data series. Best correspondence was experienced in case of the initial model (-0.115 m^3/s, -17%), and model variation No. 7 (+0.103 m^3/s, +15%). Tests showed that high flow results are again hardly sensitive to changes in the specific yield parameter just like in the case of low flow data (Table 4). When specific storage is modified more considerable deviations occur. In model variation No. 5 and 6 the modification of

Table 4 Mean absolute and relative deviation of models compared to the measured data. The best three results are highlighted by bold letters

Model variations	Low water period			High water period			Complete period			R^2 - monthly mean values	R^2 - annual mean values
	Mean absolute difference (m^3/s)	Mean relative difference (%)	Mean discharge (m^3/s)	Mean absolute difference (m^3/s)	Mean relative difference (%)	Mean discharge (m^3/s)	Mean absolute difference (m^3/s)	Mean relative difference (%)	Mean discharge (m^3/s)		
initial	+0.075	**+43**	0.128	-0.115	**-17**	0.547	0.027	**+12**	0.235	**0.51**	**0.94**
1.	+0.094	+80	0.146	-0.157	-23	0.506	0.031	**+15**	0.238	**0.48**	0.78
2.	+0.136	+160	0.188	+0.186	+28	0.848	0.148	+71	0.356	0.31	**0.89**
3.	+0.075	**+43**	0.127	-0.121	**-18**	0.542	0.026	**+13**	0.233	**0.51**	**0.94**
4.	+0.076	**+45**	0.128	-0.119	**-18**	0.543	0.026	**+13**	0.234	**0.51**	**0.93**
5.	+0.311	+496	0.363	+0.327	+49	0.991	0.315	+152	0.523	0.14	0.41
6.	+0.202	+287	0.253	-0.264	-39	0.399	0.083	+39	0.291	**0.63**	0.54
7.	+0.148	+184	0.199	+0.103	**+15**	0.766	0.136	+65	0.344	0.28	0.82
8.	+0.314	+502	0.366	+0.358	+53	1.021	0.325	+156	0.533	0.11	0.41
9.	+0.205	+293	0.257	-0.128	-19	0.535	0.119	+57	0.328	0.17	0.39

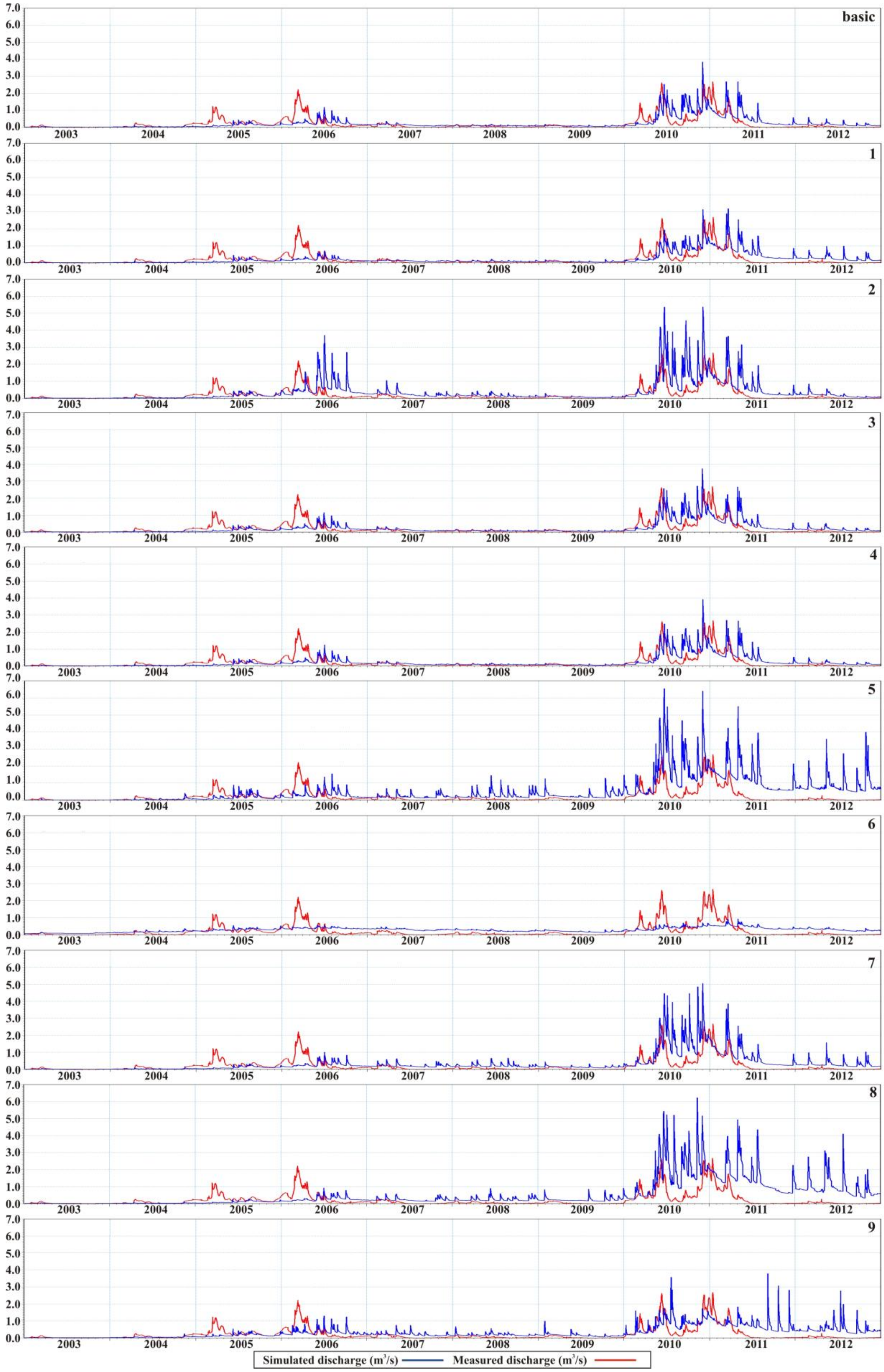

Fig. 4 Simulated discharge (m^3/s) curves of the different model variations compared to the measured data series

hydraulic conductivity resulted high deviations, the model seems to be sensitive to this parameter. It is also obvious that changing the value of detention storage the outcome of the model at high flows can be greatly affected. In case of periods with higher precipitation the use of the Van Genuchten method instead of the pF will not make a significant difference if average deviations are considered (Table 4).

Correlation coefficients calculated by plotting against modelled and measured data show that a daily based precise prediction of discharge data is not possible at the present state of the model. In terms of monthly means the highest R^2 (0.63) was received in case of model variation No. 6, with a low hydraulic conductivity (Table 4). However, as it was seen earlier this variation resulted high deviations in both low water and high water periods, therefore, the relatively high correlation in monthly data is rather the result of an averaging effect of positive and negative deviations. The second highest correlation (0.51) was experienced in case of the initial model and model variations No. 3 and 4, reinforcing previous results (Fig. 5a). The lowest correlation coefficient (0.11) was received for model variation No. 8 which is in harmony with expectations based on absolute and relative deviations.

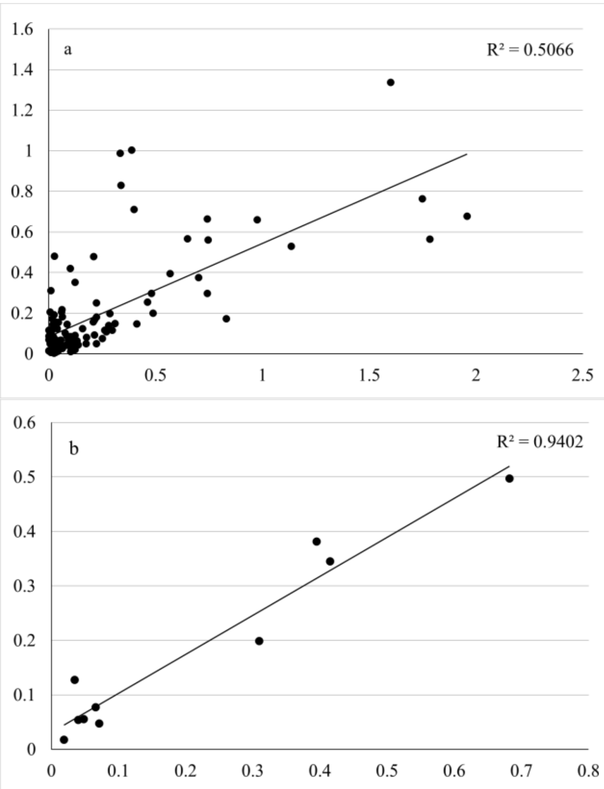

Fig. 5 Correlation of modelled and control data on a monthly (a) and on an annual (b) base in case of the initial model variation

The values of R^2 naturally improve if annual means are considered. In this case coefficients were as high as 0.94 in terms of the initial model and model variation No. 4 (Table 4). This means that predictions can have a high accuracy on a yearly basis (Fig. 5b). Coefficients above 0.80 were received for model variations No. 2, 4 and 7. Thus, at an annual resolution most of the model variations are well applicable.

Another key issue of the model is the time lag between measured and modelled peak discharges. This can explain the relatively low R^2 values in terms of monthly values. In case of the 2010 high flow period the first peak of the flooding was missed by most of the model variations, and only those showed some overlay, which anyway performed poor during the deviation and correlation analysis. Nevertheless, the second wave was captured well by the initial model and those variations where specific yield and specific storage were modified (Fig. 4). The overlap with the following 2-3 peaks is variable, and in certain cases fake peaks also appear in the modelled data series.

The situation in terms of the 2006 peak is even more interesting, as in this case actually none of the models captured the flood wave and increasing discharge values appeared with a several month delay (Fig. 4). This phenomenon might be explained by human interventions on the catchment, namely in this period there was an extensive inland excess water cover on agricultural areas, which was managed by draining and pumping the water directly into the main canal. As exact data on the amount of the drained water was not available, this effect could not be integrated to the model. Similar issues may affect the time lags experienced in terms of the 2010 flood period.

CONCLUSIONS

After performing several runs with modified soil parameters we found that the initial model, comprising average values advised by the literature and values retrieved from low spatial resolution data, proved to be relatively accurate in predicting monthly and annual discharges.

The model is not sensitive in general to the modification of the specific yield parameter and slightly sensitive to the modification of the specific storage parameter. Much higher deviations were experienced as a matter of changing hydraulic conductivity and detention storage.

Concerning low flow periods in relative terms a significant overestimation was experienced, and not any of the model variations could improve deviations. The modification of sensitive parameters listed above caused dramatic changes in the results and ruined comparability to the control data. As most of the modelled period is comprised of low flow events, the field assessment of the above listed parameters, especially hydraulic conductivity would be crucial in the future to improve the output of the model.

In terms of high flows relative differences between modelled and control data are lower. Best performing models underestimate discharge, which can be significantly improved by modifying the detention storage parameter. Consequently, in the future dry (low flow) and wet (high flow) periods of the model should be fine tuned by adjusting different parameters.

The overall validation of the model is significantly hindered by the observed time lags between measured and modelled peak discharges. This problem is partly caused by artificial draining activity on the catchment, especially during the spring period. The issue could be overcome, and correlation between measured and modelled data could be increased if measured or calculated data of draining were introduced to the model.

As far as the above measurements and estimations are not completed and integrated to the calculations, the model is rather applicable to predict monthly and annual runoff and discharge. Nevertheless in terms of a lowland catchment with such a low relief this can still provide valuable data for water management. Moreover, applying the above introduced methodology and input data the runoff on other small catchments in the Lower Tisza Region could also be modelled.

The initial model variation at its present stage can also be applied to predict general changes in runoff related to climate change. Based on the performance of the present model, if the simulation data of regional climate models are applied annual changes can supposedly be predicted at a high accuracy.

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