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Review

Water balance calculation capability of hydrological models

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ABSTRACT - Currently, in the world, there are many different hydrological models built and developed to solve problems related to the hydrological cycle. Each model has its specific mathematical foundations to describe physical processes in nature. Therefore, each model has its various characteristics: setting up the model, input data requirements, model calibration and verification, and output results. Water balance is still playing an important role in the effective management and use of water resources for agriculture. Based on the results of the hydrological parameter's calculation, the water balance of the study basin can be calculated by the user or by the separated module of each model. Each hydrological models have its advantages and disadvantages. However, it is impossible to simulate hydrological processes and water balance completely accurately in nature. Still, simulation results can give us a view of the changing trend of hydrological components and the water balance. Model developers are gradually completing the shortcomings and improving the efficiency and accuracy so that the model can simulate reality with the highest accuracy. This paper sets out to review the fifteen hydrological models currently widely used in the world. Within the frame of the present study, some models are only briefly introduced; the rest are considered in more detail, from more aspects, from specific examples so that readers can decide for themselves which model is suitable for their study area and simulation needs, especially in the identity of the complex and unpredictable impacts of climate change on the agricultural sector.

Keywords: integrated watershed modelling, water balance

INTRODUCTION

Hydrologic problems are usually calculated based on statistical methods; hydrologic time series are analysed based on autoregressive components methods, and components of the hydrological cycle are calculated based on differential equations. *Freeze and Harlan (1969)* questioned the application of mathematical descriptions to the modelling of hydrological systems, which included equations to simulate individual hydrological processes and the interactions between hydrological components. The two authors laid the main foundations for the model structure, model parameter values and model execution *(Clark*

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et al., 2017). As a result of the developments in information technology, applying the geographical information system (GIS) and various mathematical- and physical-based hydrological modelling software has also become feasible for related research. Since then, several hydrological models have been built and developed according to the development of information technology in general and the technologies of hydrology, geographical information system and remote sensing. During the hydrology and water balance research in different study areas, scientists have also found that only integrated modelling methods can understand the ongoing hydrological processes. In the following sections of the study, some specific examples related to the necessity of hydrological models in the simulation, analysis of the results of water balance, and hydrological parameters calculation. The question is that among many hydrological models widely used, which model is an effective tool and suitable to achieve the research purpose and what criteria to choose the model or the combination with other models? In this study, we try to give insight into hydrological models. The models were analysed in detail, including technical background, data requirements, calibration, and some application fields. Based on this information, readers can make the right decision in choosing the suitable model to apply to their research.

APPLICATIONS FOR PROCESS-BASED HYDROLOGICAL MODELLING

Fatichi et al. (2016) defined the process-based hydrological model as*: "a mathematical formulation that explicitly represents and/or incorporates through assimilation approaches, the hydrologic state variables and fluxes that are theoretically observable and can be used in the closure of assumed forms of the laws of conservation of mass, energy, and momentum at temporal scales characterizing the underlying physical processes".* Process-based hydrological models based on the observation and scalability of hydrological processes have a history of development since the 1960s. At first, this approach was popularised, but later, scientists realised that it is difficult to provide accurate simulation results for climate conditions, hydrological regimes, and different catchments with mathematical modelling based on physical laws. Besides hydrological process nonlinearity, spatial and temporal scale variation, and the ability to observe, heterogeneity and parameter equifinality has made it necessary for the user to consider the simulation objectives and purposes, as well as the data availability conditions, to be able to consider the usefulness of the approach or to proposals of other alternatives *(Fatichi et al., 2016).* However, this method is applied to make hydrological forecasts in non-stationary climate conditions and the effects of land-use change. Below are the process-based hydrological models that are widely used today *(Table 1.).*

Table 1.
Descriptions of process-based hydrological models

Model	**Category**	**Type**	**Description**
HEC-RAS	Hydraulic modelling	1D	HEC-RAS is a 1D hydraulic model used for steady and unsteady open channel flow computations. HEC-RAS includes tools for running sediment transport and water quality analyses. HEC-RAS is capable of modelling subcritical, supercritical, and mixed flow regime profiles and can model inline channel structures such as culverts, weirs, and bridges.
HEC-HMS	Hydrologic modelling	1D/2D	HEC-HMS is a lumped parameter/quasi-distributed hydrologic model that includes support for MODClark - a quasi-distributed hydrologic model. HEC-HMS has most of the functionality in HEC-1 and is used for modelling single or multiple storm events. It supports several different options for modelling rainfall, losses, unit hydrographs and stream routing.
SWAT	Soil and Water process-based model	2D	This model can simulate the quality and quantity of surface water, as well as groundwater. Besides, it is also possible to determine the impacts of land use, as well as climate change on the environment.[1]
PAWS	Parallel hydrologic, process-based watershed	3D	The PAWS model can simulate hydrological processes based on the laws of conservation of energy such as evapotranspiration, vegetation growth, surface and groundwater, flow in the unsaturated zone, and interactions between the components.[2]
AQUAVEO SMS	Surface-water Modeling System	3D	SMS include full range of coastal, riverine solution modules for simulating riverine and flood modeling processes.[3]
AQUAVEO WMS	Watershed Modeling System	3D	WMS include complete watershed solution such as GIS, web-based data, Terrain data. The model has features such as automated watershed delineation & hydrologic modeling, hydraulic modeling & floodplain mapping, storm drain modeling and export to Google Earth.[4]

[1] https://swat.tamu.edu/

[2] http://water.engr.psu.edu/shen/PAWS/PAWS_Documentation.pdf

[3] https://www.aquaveo.com/

[4] https://www.aquaveo.com/software/wms-watershed-modeling-system-introduction

INTEGRATED HYDROLOGICAL MODELLING ENVIRONMENTS

Integrated hydrological models can simulate hydrological processes occurring on the surface and subsurface at a wide range of spatial and temporal scales (*Paudel and Benjankar, 2022*). Especially, the approach integrates hydrodynamic models to simulate river hydraulics, water quality, sediment transport, floods and forecasting changes in surface flows. Thus, integrated hydrological models enable the experts to look into interactions across the entire hydrologic cycle. The research group of *Kollet et al. (2017)* reviewed and compared integrated hydrological models, including Cast3M, ATS, CATHY, HydroGeoSphere (HGS), GEOtop, MIKE-SHE, and ParFlow (PF). Due to the limitation of the paper, below we only review the technical background of the Cast3M, ATS, CATHY, HydroGeoSphere (HGS), GEOtop models based on the research paper of *Kollet et al. (2017)* and go into a more detailed analysis with MIKE SHE and ParFlow models. In addition, LISEM, PAWS, WATERISK, and InHM models were also considered in more detail. Thus, a total of 12 integrated hydrological models are considered in this paper.

Cast3M

The Cast3M model is developed based on the French Alternative Energies and Atomic Energy Commission (CEA) in France with the primary purpose of solving problems related to solid and fluid mechanics. The model can also solve hydrology and hydrogeology problems in finite elements or finite volumes. Cast3M uses the Darcy multidomain approach to integrate surface flows and subsurface to apply to 2-D and 3-D configurations (*Weill et al., 2009)*. Surface flow is calculated based on a 3D porous layer. The equations are discretised with a finite volume scheme to combine the Darcy and Richards equations in the subsurface with the diffuse wave approximation of the Saint Venant equations to the surface flows into a single generalised Richards equation (*Kollet et al., 2017*). According to the researchers, the Richards equation can also be integrated into the advection, diffusion, and dispersion of transport equation.

Advanced Terrestrial Simulator

According to *Kollet et al. (2017)*, the Advanced Terrestrial Simulator (ATS) model is a specialized model that simulates ecosystem hydrology processes based on the Amanzi model and the Arcos multiphysics management strategy. The utilities of the ATS model include freeze processes, a surface energy balance, snow processes and thermal hydrology in the surface and subsurface. To determine dynamic vegetation and deformation capacity, carbon cycle, and transport response, the ATS model used both large-leaf models for combination and execution. To determine the subsurface and the diffuse wave model for the surface Richards equation was applied to the ATS model. Surface-to-surface coupling via modelled continuous pressure formula. The finite difference method has been used by ATS model to accurately compute unstructured meshes and layering structures for hydrology applications.

CATchment HYdrology

The CATchment Hydrology (CATHY) model applies Richards 3D equation with the finite element approach, based on 1-D kinematic approximation of the Saint Venant equation. Based on a time decomposition process that solved subsurface-surface coupling, this work requires iterative updating of boundary conditions to be able to automatically split potential fluxes into actual flows on the land surface *(Kollet et al., 2017)*. CATHY uses the mass balance equation to determine variations in subsurface and surface storage. The CATHY model can also be combined with the Noah-MP land surface model, in addition, the vegetation models can also be integrated with boundary layer dynamics and hydrogeophysical inversion.

HydroGeoSphere

3D control volume and finite element simulator used in the HydroGeoSphere (HGS) model to simulate the entire terrestrial part of the hydrological cycle *(Aquanty, 2015).* To solve the problem of the differential wave equation for surface water and Richards' equation for subsurface flow is solved by global implicit method. Synthesized review and analysis of important components of the hydrologic cycle such as soil evaporation, evaporation from water bodies, evapotranspiration based on LAI values, root depth, root density, snow processes. The HGS model can also use the integration of subsurface-surface interactions to calculate contaminant and energy transport processes at the surface and in the subsurface. To simulate atmosphere, surface, and subsurface interactions, the HGS Model can be combined with the Weather Research and Forecasting (WRF) model *(Davison et al., 2015).* To solve the non-linear points in the governed flow equations, the model used Newton's method in combination with an iterative sparse matrix solver *(Kollet et al., 2017).*

GEOtop

GEOtop is a distributed, grid-based hydrological model developed to describe in 3D water flow in the surface of topsoil. The model can also account for the exchange of water and energy with the atmosphere and considers vegetation processes and the influence of complex topography on radiant flux *(Kollet et al., 2017)*. The equations of heat and water flow are solved by the Newton-Raphson method and expressed as a 3D finite volume. Water content in the saturated zone is calculated based on the retention curve according to the van Genuchten formula, while in the saturated zone the concept of specific storability is applied *(Kollet et al., 2017).*

WEAP

WEAP is an integrated hydrological model for planning complex systems of the distribution of water resources. The purpose is to use an integrated approach to the calculation of water systems and the direction of policy for water resources management.

The WEAP model features a detailed analysis of water demand for rural, urban, and agricultural use. WEAP can establish water use management methods and water users and set up a model to calculate the amount of water loss and to manage water reuse. In addition, WEAP can also do financial analysis, thus enabling the effective assessment of profit and cost models of water use. This is one of the strengths of WEAP to help decision-makers, stakeholders and farmers have a better view of water as a commodity and calculate more efficient use of water. This is very important in the context of the ongoing climate change, which is more unpredictable and extreme than before. In addition, water gradually becomes the most affected resource. This model can give the necessary results for rational planning and integrated use of water resources.

The WEAP model does not have a separate module to calculate the basin's water balance. *Kandera and Výleta (2020)* used the WEAP model to estimate the quantitative water balance of surface water in the Hron River basin from 2010 to 2015. They stated that the model does not need too much input data, however, it provides an integrated approach to solving problems in water resource management. *Kirilov and Bournaski (2019)* published the steps to perform water balance modelling based on describing relevant computational aspects of water movement through the water cycle. *Avilés et al. (2020)* used the WEAP model to evaluate the system's water balance by considering the allocation of available water to satisfy the demands of the different sectors. *Bozorgy et al. (2012)* used the WEAP model to estimate the amount of water lost by an existing irrigation infrastructure and the amount of water that could be saved by modernising the scheme. They proved the possibility of saving significant water resources, thereby improving profits. The WEAP model can also be used to assess the current water balance and change the water balance in the future, to build a scientific basis for the integrated management of water resources in Benin's largest catchment Ouémé *(Höllermann et al., 2010)*.

MIKE SHE

The MIKE SHE integrated hydrological model was developed based on the blueprint of *Freeze and Harlan (1969).* The model can simulate important hydrological cycle processes such as evapotranspiration, overland flow, unsaturated flow, groundwater flow, channel flow and their interactions. *Tran et al. (2019)* applied the MIKE SHE model combined with the IFS rain forecasting products to forecast discharge to the reservoir in the Tra Khuc-Song Ve basin. Some studies use integrated modelling of surface water and groundwater *(Hughes and Liu, 2008)*. Other studies apply MIKE SHE and GIS to simulate hydrological processes for several basins *(Paparrizos and Maris, 2015; Právetz et al., 2015)* and assess the effects of land change and climate change on groundwater and the ecosystem by *Keilholz et al. (2015)*. The process of modelling inland excess water with MIKE SHE and using satellite imagery for validation by *Van Leeuwen et al. (2016)*. Combining models of MIKE SHE, MIKE URBAN, and MIKE 11 to create probabilistic inundation maps (*Oliver et al., 2018*). *Nagy et al. (2019)* built a MIKE SHE model to simulate the accumulation processes of excess water, water storage, and excess water maps.

One of the most advanced and flexible features of MIKE SHE is its separate water balance calculator. The water balance calculation module is an effective water balance calculation tool as it can simulate the water balance at the entire catchment and local scale in any phase of the simulation *(DHI, 2017).* The results are presented in many different formats, such as text format, times series file, and map formation. Below is the MIKE SHE water balance flow chart created by authors for the Hungarian part of the Berettyó river catchment *(Figure.1).*

Asadusjjaman and Farnaz (2014) use MIKE SHE to calculate water balance and investigate the effect of land-use changes on water balance components in the subsurface. *Loliyana and Patel (2020)* the model's effectiveness in simulating hydrological processes in land-use change, groundwater variability and irrigation practices.

MIKE SHE provides several different approaches to calculating water movements, including overland flow, river and lakes, unsaturated flow, evapotranspiration, and saturated flow. The essential input data required to perform the simulation of hydrologic processes are topography, precipitation, reference evapotranspiration, air temperature, solar radiation, sub-catchment delineation (for runoff distribution), river morphology (geometries, cross-

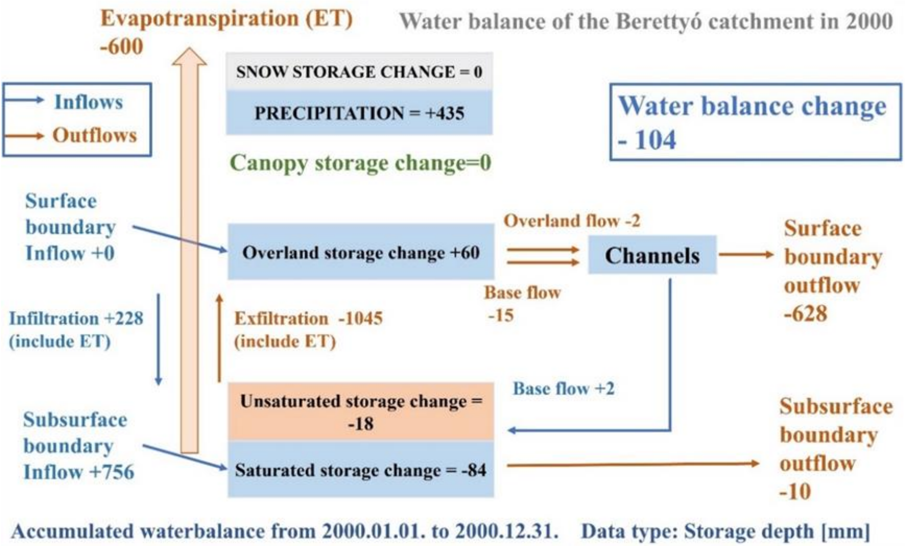


Figure 1. Water balance of the Hungarian part of the Berettyó river catchment in the dry year 2000 using the MIKE SHE model

sections for river flow and water level calculations) and land use distribution (for vegetation and paved runoff calculations), soil distribution (for infiltration and runoff), and subsurface geology (for calculating groundwater flow).

In the case of a lack of input data for simulation and the complexity of the processes taking place in the unsaturated zone, MIKE SHE has the solution to apply the linear reservoir module for simulation. *Sun et al. (2006)* identified several advantages of the MIKE SHE model including 1) it is a distributed model, and most of the algorithms in describing the complete water cycles are physically based 2) it simulates explicitly groundwater-surface water interactions, so it is ideal for wetland dominated systems as well as storage-based systems commonly found in humid regions, 3) it has been commercialised, and a GIS user interface was built in the system that can directly use spatial GIS databases for model inputs. Also, the model has an advanced visualisation facility that makes the interpretation of modelling outputs much easier.

PARFLOW

According to *Maxwell et al. (2019),* ParFlow model (PARallel FLOW) is an integrated hydrological model that can simulate surface and underground flows.

The main function of the ParFlow model is to compute 3-dimensional saturated groundwater flows in heterogeneous porous layers *(Maxwell, 2019)*. In this complex environment, ParFlow is implemented in three different modes: 1) variably saturated; 2). steady-state saturated; and 3). integrated–watershed flows. Capable of handling large scale problems on single and multi-processor computing platforms. ParFlow uses a modular architecture and contains a flexible communication layer to encapsulate parallel interaction across a wide range of platforms. The ParFlow model contains a flexible communication layer that encapsulates parallel interaction across a range of platforms based on a modular architecture. PARFLOW has also combined surface water and groundwater to simulate synthetically the process of slope surface runoff and channel runoff, besides it has also integrated a surface land-use model. *Kuffour et al., (2019)* provide an overview, applications, and ongoing development of ParFlow, for a small watershed threatened by flash floods in Germany.

According to *Maxwell et al., (2019),* ParFlow uses the to calculate the water balance for the 3D Richards' equation, overland flow, and land surface model (Community Land Model) capabilities. For shallow overland flow, the 2D kinematic wave equation can be chosen. To calculate the flow depth-discharge relationship, Manning's equation was used. Community Land Model is fully integrated into the ParFlow model as a module and can be run in parallel with other simulations. ParFlow is built to be easily connected to applications (e.g. climate models, land surface models).

ParFlow's water balance conceptual models are incomplete because, in fact, the groundwater division is difficult to determine; in many cases, the watershed of surface water and groundwater do not coincide, even in some basins, for example, in Dong-er catchment, surface water flow depends largely on underground flow from outside *(Tran, 2021)*.

In the ParFLOW model, there is no mode to visualise the results. The special advantage of ParFlow is that with only the TCL script, users can set up and can fully automate hundreds of simulations. PARFLOW has the advantage of parallel simulation platforms of saturated flows in equilibrium layers, variable saturated heterogeneous porous, and the use of complex octree-space partitioning algorithms to simulate aggregate flow in the catchment.

WateRisk

The WateRisk integrated hydrological model was developed by *Koncsos et al. (2011),* the model is developed based on 1D and 2D models integrations. The processes described in 1D are a hydrodynamic model of water movements.

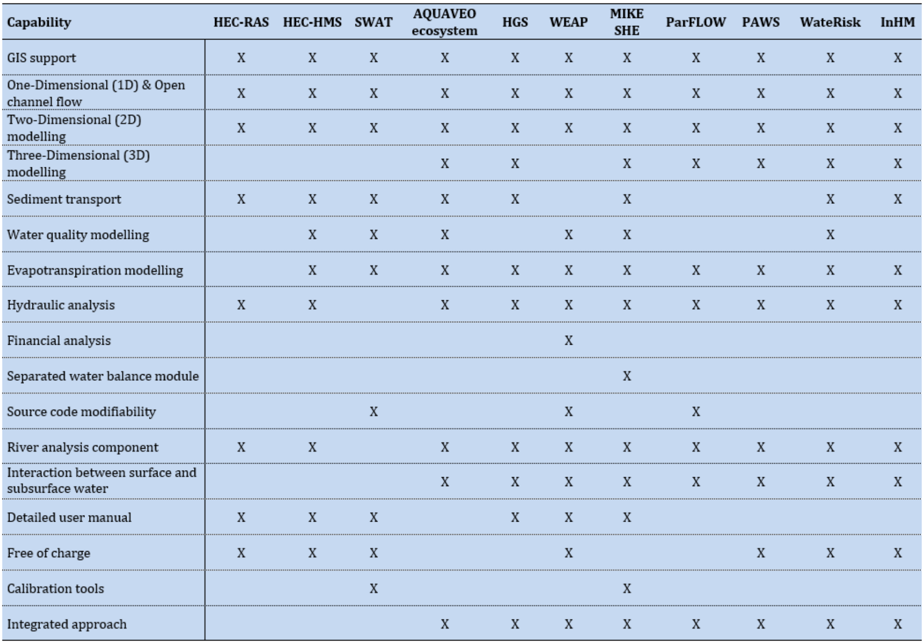
The 2D model describes hydraulic models representing precipitation, snow accumulation, evaporation, and surface spreading, as well as infiltration and groundwater movement. The model is developed based on the distribution of cells with homogeneous physical properties. By writing the hydrological balance equations on the cells, a three-dimensional description of the flow can be obtained *(Kardos and Koncsos, 2018)*. The conceptional algorithm and components of the WateRisk model are built on top of the ARES (Flood protection decision support system) model system *(Koncsos et al., 2011)*. The structure of algorithms is modular, which means that simulations at cells don't only work individually but can be combined to simulate more complex processes in space and time. The WateRisk model aims to solve problems such as describing hydraulic processes in the channel, reducing the number of cells, reducing iteration steps, and improving the model's calibration capabilities. Besides, the WateRisk model also applies the method of analysis of change scenarios to predict changes in hydrological processes and includes economic analysis methods. The model can simulate large basins (~50-5 000 km^2) with a long simulation time (1-30 years) with detailed spatial and temporal resolution and fast computation speed. However, the model does not account for processes in the atmosphere and in groundwater movements.

Koncsos et al. (2011) compared the WateRisk model with the HEC-RAS model. Accordingly, the authors made a comparison based on the results of the water surface profile, the water level in the upper and middle sections under time series, water flow, and downstream water level under boundary conditions. Based on the results, the WateRisk 1D hydrodynamic model gives the same results as simulated by the HEC-RAS model. *Kozma (2013)* applied the WateRisk model to simulate hydrologic and hydrodynamic processes for the integrating surface and subsurface in both the two pilot areas, Szamos-Kraszna Interfluve (with hydrologic characteristics like wetlands) and Danube-Tisza Interfluve (characterized by drought). As a result, an inland water hazard map was created, integrating climate change scenarios and cost-benefit analysis into the water resources assessment. In a research paper by *Kozma (2013)*, water balance analysis was performed including surface storages water balance, surface - subsurface water system water balance and comparison of natural factors and factors affecting water balance at Szamos-Kraszna Interfluve inland water area. Also, in this study area, *Kozma (2013)* used the WateRisk model to conduct risk-related studies and build flood maps. The results show that the water balance calculations of the model can determine which hydrological factors can predict inland excess water occurrence.

Integrated Hydrologic Model

The Integrated Hydrologic Model (InHM) model was developed in partnership between Tampa Bay Water and the Southwest Florida Water Management District in the late 1980s. This model belongs to the advanced model of integrated hydrology modelling (IHM), which helps users to simulate and better understand the complex hydrological processes taking place at the surface and subsurface. This model is a combination of two models that have been widely applied in research, namely Hydrologic Simulation Program–FORTRAN (HSPF) and MODFLOW. The HSPF model is responsible for simulating relationships and processes taking place in the surface and vadose zone. MODFLOW is aimed to simulate the flows taking place in saturated layers.

Table 2.
Comparison the features of the models



Capability	HEC-RAS	HEC-HMS	SWAT	AQUAVEO ecosystem	HGS	WEAP	MIKE SHE	ParFLOW	PAWS	WateRisk	InHM
GIS support	X	X	X	X	X	X	X	X	X	X	X
One-Dimensional (1D) & Open channel flow	X	X	X	X	X	X	X	X	X	X	X
Two-Dimensional (2D) modelling	X	X	X	X	X	X	X	X	X	X	X
Three-Dimensional (3D) modelling				X	X		X	X	X	X	X
Sediment transport	X	X	X	X	X		X			X	X
Water quality modelling		X	X	X		X	X			X	
Evapotranspiration modelling		X	X	X	X	X	X	X	X	X	X
Hydraulic analysis	X	X		X	X	X	X	X	X	X	X
Financial analysis						X					
Separated water balance module							X				
Source code modifiability			X			X		X			
River analysis component	X	X		X	X	X	X	X	X	X	X
Interaction between surface and subsurface water				X	X	X	X	X	X	X	X
Detailed user manual	X	X	X		X	X	X				
Free of charge	X	X	X			X			X	X	X
Calibration tools			X				X				
Integrated approach				X	X	X	X	X	X	X	X

The InHM model provides simulation tools for space (from small to 25 000 km^2) and for long time interval (from 1 day to tens of years). Some studies using InHM model, such as *Loague et al. (2004)* have shown that the uncertainty in initial soil-water content is a major limitation in event-based simulations.

The InHM model with a quasi-physically based rainfall-runoff model performed well in the peak stormflow simulations but poorly for the storm flow depth estimations. *Heppner et al. (2006)* used erosion experiments to determine the performance of the sediment transport component. They demonstrated the interaction between surface water hydrology and sediment transport caused by rain and flood. *Tang et al. (2019)* used the InHM model to simulate the effects of the check dam system on hydrologic responses and landforms at Hilly-Gully Catchment, Loess Plateau. The results also show that the InHM model has worked effectively, helping to understand better the impacts related to hydrology and predict changes in sediment transport.

CONCLUSIONS

Among the process-based models, the SWAT and HEC-HMS can simulate the hydrological processes taking place on the surface and in the channel, evapotranspiration, and precipitation. However, since the catchment is usually assessed as separate sub-basins and HRUs, it is limited or impossible to calculate the hydrological processes that take place periodically, and the spatial changes in the groundwater table cannot be calculated *(Kozma, 2013).* The database of the SWAT model has not yet met the practical application needs of each region, especially Hungary, and needs revision.

The WEAP model has features suitable for simulating hydrological processes and is widely used in hydrology. However, the WEAP does not have a separate water balance calculation capability. This can make it difficult and time-consuming to calculate the water balance. AQUAVEO company has built an ecosystem of models that can support each other. To simulate surface water and groundwater, AQUAVEO company provides two separate models for implementation. Furthermore, the Watershed Modelling System (WMS) includes 20 auxiliary models for watershed simulation, including several popular models such as HEC-1, HEC-HMS, HEC-RAS. This may cause difficulties for users when they have to approach too many different models at once and then connect them into a unified whole. In the current AQUAVEO, there are no models or modules with dedicated water balance calculation capability.

Hydrological models such as ATS specialise in simulating ecosystem hydrology processes. Cast3M model specialises in solving problems related to solid and fluid mechanics. The CATHY model is widely used to simulate the variation of soil moisture, groundwater flow and surface runoff in space and time. However, there is no separate water balance calculation module. GEOtop is a distributed hydrological model for the description of soil and surface water flows based on the developed grid system. HydroGeoSphere includes features like surface and groundwater modelling, thermal and solute transport modelling, and advanced numerical methods.

The MIKE SHE model is an integrated model, so many outputs are computed. MIKE SHE has its own module to get the water balance simulation results, including total water balance, error of each component, snowmelt component, canopy interception component, overland flow, unsaturated zone, saturated zone, irrigation component. MIKE SHE is very focused on this module, so the results are presented in many different formats such as text format, times series file, and map formation. It can be said that MIKE SHE provides a full range of *"perspectives"* to help users analyse, evaluate, and determine water balance accurately, from detailed to general. ParFlow can calculate water balance, but the manual for the water balance section is very limited. To use ParFlow effectively and easily, users need to have the skills to understand the Linux/UNIX system and the ability to compose and execute commands in different programming languages. PAWS model can simulate large watersheds. Thus, the basic components of the water cycle can be simulated, and it is also possible to simulate the interaction between the water cycle and other natural cycles such as carbon/nitrogen and the ecosystem. Another disadvantage of the model is that there is no separate water balance calculation module. Besides, the data presented through different software makes the balance calculation more complicated. The main task of the WateRisk model is to solve problems such as describing the hydraulic processes in the channel, reducing the number of cells, reducing repeated steps, and improving the model's calibration. However, it has not been widely used, especially among international researchers. This model does not include a separate water balance calculation module. The InHM model has strengths in calculating and analysing sediment transport processes. The InHM model is an advanced model specialised in simulating complex processes, including auxiliary models such as HSPF and MODFLOW to realise the connection between surface water and groundwater.

Each model has its characteristics, strengths, and weaknesses *(Table 2.)*. The best model is the one that can simulate most closely the processes occurring in nature but requires the least and simplest data. The choice of a reasonable model must be based on many factors. What is the purpose of simulation? What are the characteristics of the study area (soil heterogeneity, soil permeability, extreme hydroclimatic conditions, the role of groundwater, etc.)? What does the result want to achieve? Is the scope of the study large or small? What is the research object or process? Avoid using complex models that require many input parameters but only simulate a simple hydrological process. Many factors govern the choice of one model or the other or a combination of models to support each other to achieve simulation purposes. Criteria for selecting a model or combining it with a specific model are based on 1) spatial and temporal interval, which defines simulation objectives and features of the study basin; 2) Demand for input data, costs to have data; 3) uncertainties of the model (uncertainties of parameters, aggregated parameters, empirical equations) 4) previous studies 5) knowledge of model theory. It is, therefore, necessary to have an overview of the models, especially their application to basins with a high percentage of agricultural lands, like Hungary. This is a difficult task because most studies have specific reasons for applying a particular model. Very few studies compare hydrological models and comment on the capabilities, advantages, and disadvantages. The result of our study is to give an overview of the hydrological models currently widely used in the world. On this basis, we hope that users can choose a suitable model to perform the proposed task.

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