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A BASE MODEL FOR WATER BALANCE OF MESTA RIVER WATERSHED

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Abstract

Mesta River is a transboundary river. It flows from Bulgaria, through Greece to the Aegean Sea. In Bulgaria, it is located in West Aegean region. Mesta River is important because it is rich in water resources. In this paper a base model for water balance of Mesta river watershed is proposed. It is realized by means of decision support system WEAP. The problem for water balance is one of the most important problems in water management. It can be used to assess water resources in areas of different sizes, to make forecasts, to plan the future development of various sectors of human activity.

Key words: water evaluation and planning (WEAP), water balance, computer modelling, Mesta river – Bulgaria, decision support

Introduction and related works. Effectively solving various water management problems has a great impact not only on human development but also on land resources. One such problem is the calculating of water balance [1]. The

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development of Information and Communication Technologies has allowed incorporating of mathematical models and software systems and thus to solve more complex water management problems [2].

In Bulgaria, the application of mathematical models and methods for solving water management problems started in 1968 with a complex programme/project for “development of system and tools for optimal using of water resources in People’s Republic of Bulgaria”. A number of problems [3–7] were successfully resolved by the end of the 90’s. Nowadays, several results about modelling of the rainfall-runoff processes, climate modelling, general decision support methodology, etc., can be pointed out [8–11].

In the beginning of the 21st century with the rapid development of computer hardware powerful software systems for solving different water problems were proposed such as WEAP, STREAM, SWAP, SWAT, etc. These systems offer a wide range of options for compiling and solving complex water management models.

The goal of this paper is to propose a base model for water balance of Mesta river watershed by means of the decision support system WEAP (Water Evaluation and Planning). A decision support system WEAP is developed and maintained by SEI (Stockholm Environment Institute) [12]. The system is in process of continuous development and improvement. During the years a lot of water management problems have been solved by means of WEAP in many countries. A small subset of studies focused on river basin modelling that take into account future climate changes follows.

In [13] WEAP is applied to study the impact of climate change to Gurara reservoir catchment in Nigeria according to different scenarios. Alana river basin in Iraq was modelled in order to optimize future water needs in [14].

In [15] the long-term future water use for Dwarakeswar-Gandherswari river basin (India) is studied under changing climatic conditions. The retrospective water balance for 2010–2015 for Upper Hron River Basin (Slovakia) is proposed in [16]. In [17] it is shown that the streamflow of the Songhua River Basin (Northeast China) could be decreased by 19% due to the climate variability from 1.12 °C to 5.82 °C and this could be critical to the water management.

Modelling. The Mesta river watershed is located in Southwestern Bulgaria. Actually, Mesta river is a transboundary river between Bulgaria and Greece. There are not many manufacturing plants in the area and therefore we do not take into account their activities. So, we consider natural factors, the consumption of drinking water and the use of water for agricultural purposes.

The process of computer modelling of water balance by means of DSS WEAP consists of several main steps. First, preparing the so-called schematic view using a set of basic elements to represent the region to be modelled. WEAP has a set of 14 basic elements such as river, diversion, demand site, catchment, etc. Second, to choose one of the predefined methods for simulating the operation of each element

included in the schematic view. Third, to set input data according to the nature of the element and selected method for simulating. Fourth, to run the model and get the results.

Schematic view. As a first step, the schematic view (or model) in terms of WEAP modelling is prepared. It is based on the following GIS information (see Fig. 1): municipalities data, river data, watershed boundary.

It can be seen that a number of eight municipalities are located in Mesta catchment: Yakoruda, Razlog, Bansko, Gotse Delchev, Hadzhidimovo, Satovcha, Garmen and Belitsa. The boundaries between municipalities are given in black lines and the municipality centres are marked in brown. The boundary of the Mesta catchment is marked in dark blue line. To the right the catchment of Dospat river is marked in light blue line. We consider it because some quantity of water is transferred to it from Mesta river via several channels. The tributaries of the Mesta river and the main river are given in blue lines and can be easily identified. The four fields in green are irrigated fields.

Besides these preliminary considerations it is natural to consider the following **main elements** (demand sites in terms of WEAP): eight municipalities where the water consumption of people living in Mesta catchment is reflected; eight catchments matching with the territory of eight municipalities; four irrigation fields as follows: field Razlog, field Gotse Delchev, field Ablanitsa, field Valkosel; three channels to transfer water from Mesta river to the Dospat catchment. Namely: channel Granchar located in the territory of Yakoruda municipality, channel Vishteritsa-Kanina located in the territory of Garmen municipality, channel Bistritsa located in the territory of Satovcha municipality.

All demand sites are connected with transmission links and return links for municipalities and runoff/infiltration links for catchments. As a basic (accountant) year we choose 2015. The schematic view is displayed in Fig. 1.

Input data. According to the specifics of demand sites the following data are required:

- 1) For demand sites of type municipality these data are population, annual water use rate, monthly variation, consumption (lost from the system).

For example, for Belitsa municipality demand site we have: Population (annual activity level) – 9617 cap; annual water use rate – 51 m³ per person; monthly variation – “Monthly Values (Jan, 0.9; Feb, 0.9; Mar, 1; Apr, 1; May, 1; Jun, 1.1; Jul, 1.15; Aug, 1.15; Sep, 1; Oct, 1; Nov, 0.9; Dec, 0.9)”; consumption (lost from the system) – 59.4%.

- 2) For demand sites of type catchment these data are (when Rainfall Runoff – simplified coefficient method is chosen):
 - <Land use> including area, crop coefficient and effective precipitation (precipitation available for evapotranspiration).

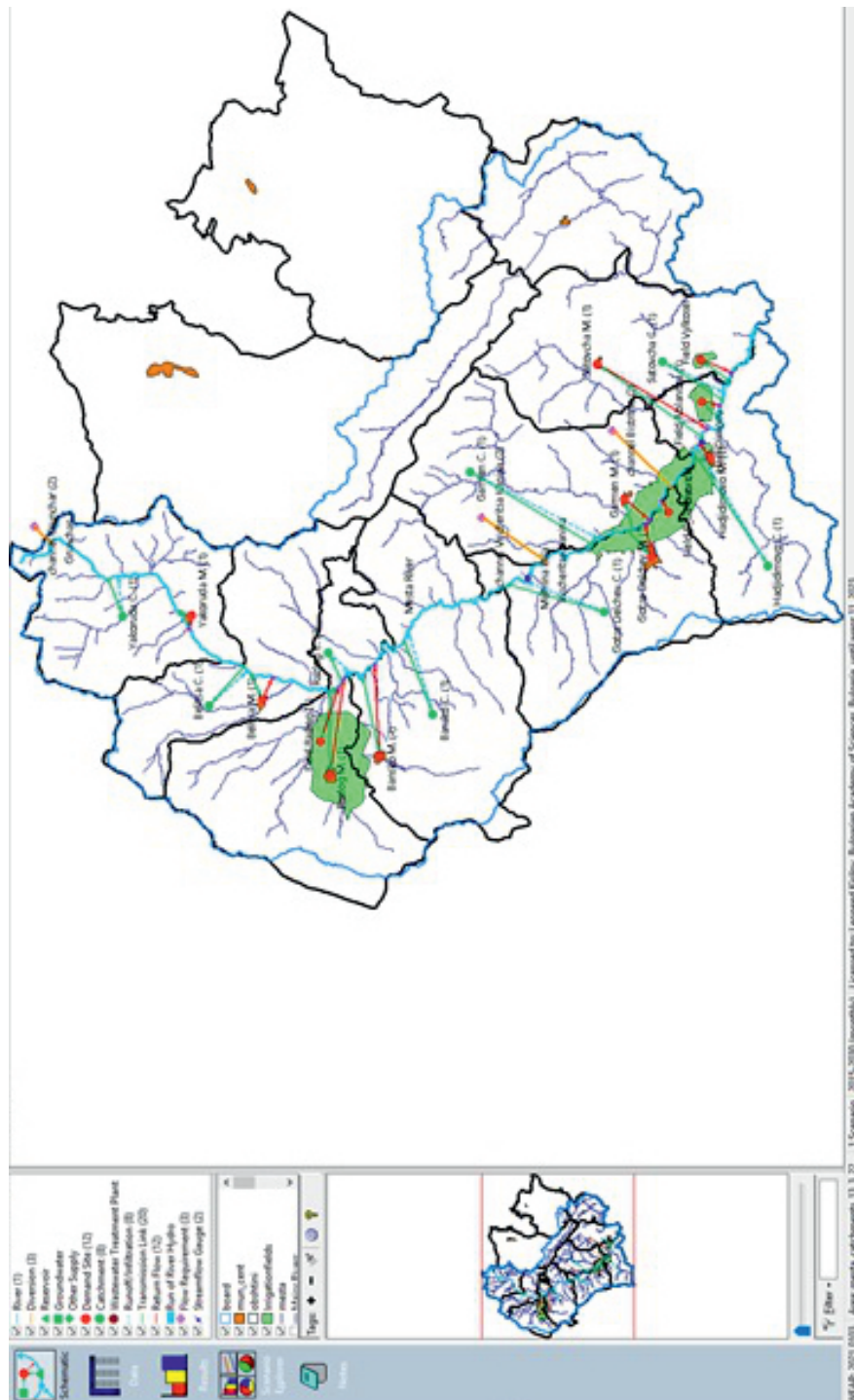


Fig. 1. Mesta river watershed model – schematic view and GIS information

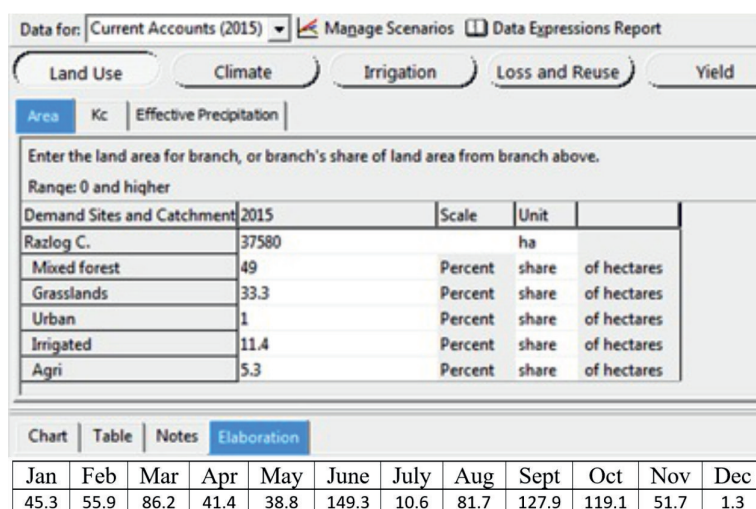


Fig. 2. Land use, Razlog catchment and Precipitation (mm/month), 2015, Razlog Catchment, Scenario: Current Accounts

- <Climate> including precipitation (monthly) and ET_{ref} (monthly evapotranspiration for a reference land class).

For each catchment we define a number of five subareas (reference land class) as follows: Mixed forests; Grasslands; Urban; Irrigated agricultural areas; Non-irrigated agricultural areas.

- <Irrigation> including two sub-parameters: the first one indicates if the area is irrigated or not and irrigation fraction (percentage of supplied water available for evapotranspiration).

For example, for Razlog catchment and for <land use, area> parameter we have the data presented in Fig. 2.

We use information from Climate Change Knowledge Portal of World Bank for precipitation data (monthly) (Fig. 2).

Data for ET_{ref} (monthly evapotranspiration) was taken from AQUASTAT – FAO's Global Information System on Water and Agriculture.

- 3) Data for channels is available from Water management of river basins in West Aegean Basin District.
- 4) Two gauges are available on Mesta river: Momina kula and Hadzhidimovo. Here the data for streamflow (monthly) is entered to check the accuracy of the model.

We work with standard year with monthly data equal to the average monthly values for a period of 18 years for Hadzhidimovo gauge.

Results. After preparing the schematic view and entering the necessary data in each of the components the model is solved. DSS WEAP provides a lot of opportunities to investigate the results. Different types of results can be visualized.

The monthly total inflow for 2015 along all the nodes of Mesta river model is shown in Fig. 3. It is seen that the max inflow is in June for all nodes, but the second max inflow is in October for some of them and for other the max is in September.

The total water balance on an annual basis, comparing streamflow of Mesta river for 2015 at Hadzhidimovo gauge with standard year is shown in Fig. 4.

The accuracy of the model is 9.7% on an annual basis.

The models for determining the water balance are oriented to specific time scales (monthly and annual, even daily and hourly, etc.). They have different degrees of complexity. There is an emphasized practical interest in monthly water balance models, which serve a wide range of hydrological and water management problems, recently also for studying the impact of climate change [18]. Hourly or daily models naturally require more data and need to input more parameters than the corresponding monthly models. They are suitable to solve other problems such as real-time monitoring, flood forecasting, etc., and they cover relatively small territories.

The developed monthly water balance model considers precipitation, temperature, and potential evaporation as input data. A comparison of the model results with the measurements from the monitoring of river runoff and available water volumes in main hydrometric stations of the main river is made. This allows to

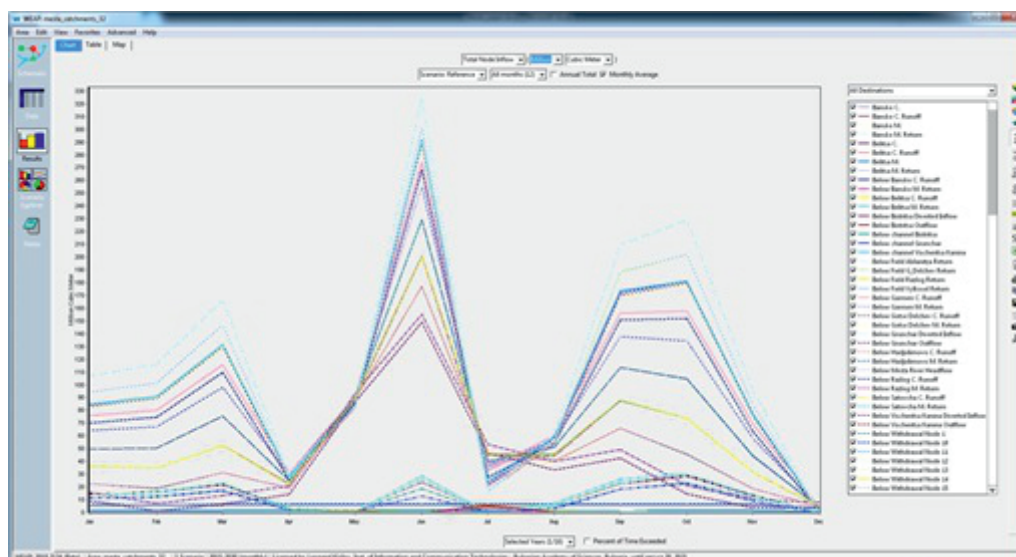


Fig. 3. Total inflow node



Fig. 4. Streamflow of Mesta river for 2015 at Hadzhidimovo gauge with standard year

use the model assessments for the impact of climate change on water resources, for river flow forecasting, for the design and operation of various water projects, etc.

We choose DSS WEAP as a modelling tool because it has a user-friendly modelling interface and has also key advantages over other well-known products [19].

Conclusion. The analysis and calculation of the water balance of a river basin is one of the most important problems in water resources management. It can be used to assess water resources in areas of different sizes, to make forecasts, to plan the future development of various sectors of human activity. In this paper a base model for water balance for the Bulgarian territory of the Mesta River basin is realized by means of decision support system WEAP. Mesta river flows from Bulgaria through Greece to the Aegean Sea. The river is rich in water resources which are used by the local population and the hydropower industry of Bulgaria. A relevant schematic WEAP view of the river basin is prepared based on GIS information, and the required inputs in each of the model components as water use rate, precipitation, land use, irrigation fraction, etc. are entered for model's calculation. The elements of the model are constructed following municipality structure in the region. The Rainfall Runoff (simplified coefficient method) is used for demand sites of type catchment. The yearly-demand and monthly-variation method is used for demand sites of type municipality.

As a direction of future research can be pointed out to look for modifications of the model incorporating different sub-details. This could be exploring the fuzziness of the problem [20]. Another direction is to check different scenarios for water balance in the Mesta river watershed for a long period of time according to the possible climate changes – rising temperatures and insufficient rainfall.

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