A COMPARATIVE ANALYSIS OF MESTA-NESTOS RIVER RUNOFF MODULUS ON BULGARIAN AND GREEK TERRITORY

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Abstract

The River Basin Management Plans and relevant Integrated Water Management of the transboundary river Mesta-Nestos between Bulgaria and Greece require sufficiently complete information about the water resources in the watershed and natural risk of expected climate change. The present study aims to present the surface runoff modulus (specific discharge as a characteristic of water resources) in the watershed based on measurements from 3 hydrometric stations on Bulgarian territory for the period 1935 - 2019 and 2 on Greek territory for the hydrological years 1965–1966 to 1989–1990. An attempt has been made for assessment of Climate Change impact on the Mesta-Nestos river runoff for years 2025, 2050 and 2100 based on two different scenarios HadCM2 and ECHM4. The results show an decrease in yearly specific discharge, both in the near future and in the longer time horizon compared to the reference period 1961-1990.

Keywords: Balkans, transboundary river, surface runoff, risk

I. Introduction

The Mesta-Nestos River basin of Mediterranean watershed is located in the Balkan peninsula, in South Eastern Europe and is shared between Bulgaria and Greece (known in Greece as Nestos). The river flows some 255 km and its catchment area covers 6,218 km^2 (the catchment of Dospat river included), and is almost equally divided between Bulgaria and Greece. It flows from the North, where the headwaters are located in the Rila mountain of Bulgaria, to the South East, where the river ends in a delta situated on the coast of the Aegean sea in Northern Greece. The Bulgarian territory of the catchment is located over 388 m above sea level and twenty-five percent of the territory is more than 1500 m above sea level (average level 1310 m a.s.l.). The Mesta river forms 6.5% of the river outflow of the country, while the area is only 2.49% of the entire area of Bulgaria [1]. It is characterised with very high specific water-power potential in comparison with the other Bulgarian rivers [1]. Beautiful mountains are popular and attractive destinations for international tourism, including winter sports. Part of the river waters are also used for electricity generation in a neighboring river catchment, while in Greek territory they are mainly used for electricity generation and irrigated agriculture. Currently, three hydroelectric power plants are located in the mountainous part of the Nestos basin in Greece: the Thissavros plant, with a reservoir capacity of 565 millions m^3 (construction completed in 1997), and further downstream the Platanovryssi dam (completed in 1990), with a reservoir capacity of 11 millions m^3 [2, 3, 4].

Both dams were designed to operate in pump-storage mode for electricity generation. The third dam, namely Toxotes, which is mainly a regulatory dam, is located in the delta's neck in order to divert the water to the plains of Kavala (western part of the delta) and Xanthi (eastern part of the delta) through two main channels [3]. The construction of a further fourth Temenos dam downstream of the Platanovryssi dam (6 millions m^3) was recently completed financed exclusively by private funds [3]. Situated downstream of the upper two dams, it is designed for electricity production, irrigation regulation and should contribute to increasing the total amount of power produced by the existing Greek complex.

The river water is of vital importance for the life and economic activity of the population in the Bulgarian and Greek territory. The river basin management plans and the implementation of the Bulgarian-Greek Integrated Water Management of the transboundary river need an assessment of water resources and natural risk of expected Climate Change, which is presented here through an analysis of the surface runoff modulus for the two territories.

II. Methods

The river runoff in the catchment is formed and fed by the surface runoff of rainwater (rainy and snowy) and by the drainage of the groundwater accumulated in the aquifers. Therefore, river runoff consists of these two components, and both components have the same primary genesis – precipitation. Surface water runoff forms the unsustainable component of total river runoff, and groundwater maintains its steady inflow - its sustainable component. There are also karst areas in the the catchment of the Mesta-Nestos river. Rainwater in karst areas is more quickly transformed into underground water.

Average annual and multi-year average water quantities are the main characteristics for evaluating the water resource of the river. In the case of assessing the water resource on the Bulgarian territory of the Mesta River, data from the monitoring in characteristic hydrometric stations - Yakoruda (functioning since 1948), Momina Kula (functioning since 1927 for water levels and from 1935-36 for water quantities) and Hadjidimovo (functioning since 1953) are used [1] (Fig. 1). Time series of undisturbed (natural) and disturbed (actually measured) water quantities for different time periods are used. Data from hydrometric stations Delta (operational since 1979, closed 1989), Papades (operational since 1965, closed 1990) and Temenos (operational since 1965) are used to assess the water resource of the Greek territory of the Nestos River [4] (Fig. 1). The aim is to reveal the trends in the nature of the change in the average annual water quantities of the main river over time and what the consequences of these trends over time may be.

The average water quantities along the river are used to determine the runoff modulus. The runoff modulus M is a hydrological characteristic expressing the water content of the river at a certain point along its length. It is determined by the formula

$$M = \frac{Q}{F}, \text{ m}^3\text{/s.km}^2 \quad \text{or} \quad M = 1000\frac{Q}{F}, \text{ l/s.km}^2 \qquad (1)$$

where Q is the average annual or multi-year average water quantity of the river at the point with the catchment area to the point F. The standard observation data as temperature, precipitation and river discharge are the source of information for analysis of the Climate Change risk. The historical temperature and precipitation information were taken from two Bulgarian meteorological stations: Bansko – 918 m a.s.l. and Gotze Delchev – 510 m a.s.l.

III. Results

The annual precipitation amounts and the runoff coefficient as a function of altitude for the mountainous parts of the Mesta watershed are shown in Table 1 (with some territories outside

Mesta).

The assessment of river discharge and water volume is based on measurement data from the Hadjidimovo gauging station closest to the Geek border, independent of water consumption in the basin and the volume of diverted water to other river basins (so called natural discharge). The basin runoff (discharge) modulus at the Hadjidimovo station for the period 1935/36 – 1974/75 and 1955 - 1983 is 14.30 l/s.km² and 13.582 l/s.km² respectively [1], Table 2.

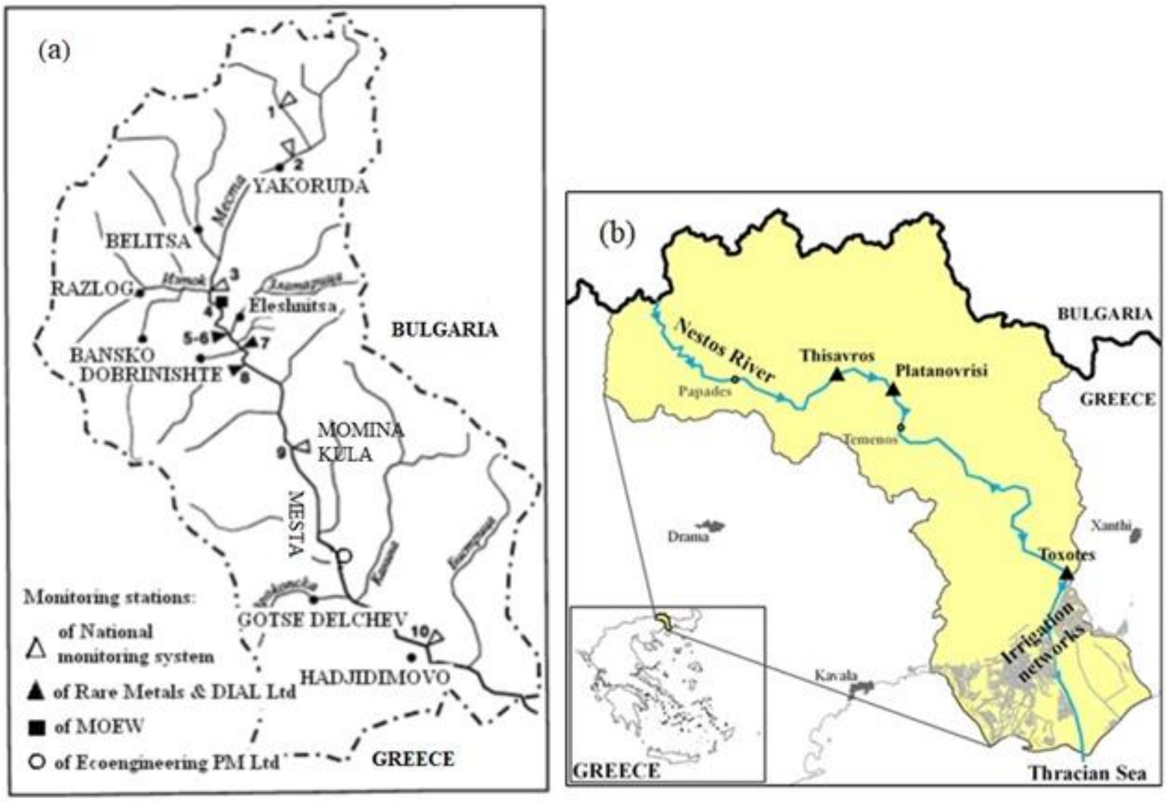

Figure 1: *Hydrometric stations on Mesta-Nestos River basin: (a) in Bulgarian territory [5], (b) in Greek territory [6].*

Table 1: *Water resources by Bulgarian mountain belts according to data from [7]*

mountain belt	Height, m a.s.l	Area, km²	Average water saturation, mm	Water resource, 10^6 m³	Annual rainfall, mm	Runoff coefficient,%
Rilo-Pirinsky	above 1600	1582	810	1280	950	85
	600 – 1600	3184	260	830	750	35
	300 – 600	659	80	50	600	14
	total:	5425	400	2160	790	51
Western Rhodope	above 1600	764	550	420	900	61
	600 – 1600	4471	280	1250	700	40
	300 – 600	490	180	90	600	30
	total:	5725	300	1760	720	41

Table 2: *Hydrological characteristics of the natural discharge of the Mesta River at the Hadjidimovo gauging station for different periods*

Time period	1935/36 – 1974/75	1955 - 1983
average Q, m^3/s	32.32	30.695
W, 10^6 m^3	1019.24	967.997
$M = 1000\dfrac{Q}{F}$, $l/s.km^2$	14.30	13.58

The measurements at the Greek rain gauge stations were taken for the years 1965/66 to 1989/90 for Papades, 1965/66 to 1994/95 at Temenos and 1979/80 to 1989/90 at Delta [4]. The runoff measurements at the Greek station Delta, excludes the runoff of Dospat, because Dospat outflows to Nestos downstream of Delta and upstream of station Papades. The annual runoff at Temenos minus the annual runoff at Papades (estimated area between these two stations 1116 km^2) for the years 1965 to 1990 is about 388 × 10^6 m^3 and the average discharge is 12.3 m^3/s. The specific discharge in this region according Eq. (1) is 12.3 × 1000/1116 = 11 $l/s.km^2$ [4]. Due to the absence of measurements, it was assumed that the specific discharge 11 l/ $s.km^2$ was also valid for the region of the Greek catchment from the Bulgarian border to Papades (area 406 km^2) and for the region Temenos-Toxotes (area 584 km^2). Therefore it was found that the mean annual discharge due exclusively to the subcatchment from the Bulgarian border up to Papades was 11 × 406/1000 = 4.47 m^3/s and therefore the contribution to average annual runoff was 140.9 × 10^6 m^3. Similarly, the mean annual discharge due exclusively to the subcatchment from Temenos to Toxotes was 11 × 584/1000 = 6.42 m^3/s and its contribution to the mean annual runoff was 202 × 10^6 m^3. From Toxotes to the Nestos outlet to the Aegean Sea (area about 420 km2) there is no essential contribution to the river runoff due to the constructed level of the river, and to the fact, that a great part of this area is flat estuary. The average total physical runoff from the Rila mountain up to the Nestos estuary is 2076 × 10^6 m^3 and the average discharge about 66.4 m^3/s, based on data of the hydrological years 1965/66 to 1989/90 [4].

IV. Discussion

To calculate climate changes, two scenarios HadCM2 and ECHM4 are used. The same scenarios with monthly data of weather stations Bansko and Gotze Delchev were used by V. Alexandrov and M. Genev [8, 9]. Here we use the results obtained for years 2025, 2050 and 2100 from literature [9], where 30 years base period (1961 – 1990) was used for calibration of the HBV model (a semi-distributed conceptual model) with runoff data at station Hadjidimovo, Table 3. The available monthly data for precipitation and temperature of the weather stations are first corrected with the values of different climate change scenarios and after that the model was applied for the assessment of climate change impacts on the elements of hydrological cycle [9]. The model was not applied to the Greek catchment of the river due to a lack of precipitation and temperature data for a long period, assuming that climate changes are similar to those calculated for the Bulgarian catchment. The results for the hydrological parameters Q, annual volume and M are shown in Table 3 for stations Hadajidimovo and Temenos for 3 future periods.

The increase in mean monthly temperature results in an increase of the potential evapotranspiration and together with the predicted decrease in precipitation, they lead to a decrease in the river runoff, respectively the surface runoff modulus, Table 3. Both catchment areas are experiencing reductions in river modulus. And other studies of the same catchment indicate a decrease in the long-term annual mean runoff in comparison with the standard (baseline) period [10].

Table 3: *Calculated results for two different climate change scenarios and different years.*

		Mesta, Hadjidimovo, area 2260 km²			Nestos, between Papades and Temenos, area 1116 km²		
Year	scenarios	*Q*, m³/s	annual volume, mm	*M*, l/s.km²	Q, m³/s	annual volume, mm	*M*, l/s.km²
1961 – 1990 Base period		27.27	372.66	11.817	12,3	347.67	11,024
2025	HadCM2	23.98	327.73	10.392	10.82	305.75	9.695
	ECHM4	24.15	330.08	10.467	10.89	307.94	9.765
2050	HadCM2	21.38	292.20	9.266	9.64	272.61	8.644
	ECHM4	21.71	296.61	9.405	9.79	276.72	8.774
2100	HadCM2	16.21	221.47	7.023	7.31	206.62	6.552
	ECHM4	16.94	231.44	7.339	7.64	215.92	6.847

The results presented here are not a forecast, but an attempt to assess the possible future risk of changes in the Mesta-Nestos river flow, which could serve in making decisions related to the use and management of water resources. As we know primary sector plays an important role both to regional and national economy in the Balkans Peninsula, thus the coverage of irrigation demands on water is highly prioritized. For the fertile and agriculturally developed territory of the Nestos river delta such kind climate scenarios and climatic models indicate the existing difficulty in fully meeting the needs of irrigated agriculture. Difficulties may also arise in hydropower. Also in case of decreased streamflows, as predicted here, the maintenance of the environmental flow is bound to not be met.

In practice a hydrological model of the catchment areas coupled with a sequence of models such as irrigation models, reservoir simulation models, etc. and economic evaluation (based on priorities) enable a realistic assessment of the sustainability of the human activity in the water sector under various hypotheses of climate change.

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