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Risk Assessment at the Beginning and the End of Strouma River in Bulgaria Using Integral Indices

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Summary: The present work considers Strouma River on the Bulgarian territory using the integral method for evaluation of climatic and anthropogenic impacts on the average annual water volume and maximum and minimum water flow. The level of this impact and risk assessment is determined by the index $M_{max,i}$ for the deviation of the maximum water flow from the maximum flow norm $Q_{max,o}$ and the index $M_{min,i}$ for the deviation of the minimum water flow from the minimum flow norm $Q_{min,o}$. Using the dynamics of the integral indices $M_{max,i}$, $M_{min,i}$ and information on extreme events from the past, a preliminary risk assessment of future extreme events such as floods and draughts could be made. This is done for the first time in risk assessment of extreme events and has been checked at Pernik (in the beginning) and Marino pole (at the border in Greece) for the period 1948 - 2006.

Keywords: Integral indices, Climate impact, Risk assessment, River flow.

1. INTRODUCTION

The transborder river of Strouma flows in the western part of Bulgaria and has a catchment area of 107.97 km^2 and length of 290 km. The river water sources are in the high mountain part of the Vitosha and Rila Mountains. Strouma River flows through Bulgaria and Greece to the Aegean.

The catchment area of Strouma River is a part of a region that experiences the influence of European continental climate. The southernmost part of the river valley serves as a corridor for the Mediterranean climate impact.

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The water quantity of Strouma River is controlled at 6 hydrometric stations – Pernik, Razhdavitsa, Dupnitsa, Boboshevo, Krupnik, Marino pole, four of them being located along the River (Fig. 1).

Fig. 1 Catchment of Strouma River in Bulgaria

The relief of the investigated area is diverse: the difference between the highest point (2180 m) and the lowest point at the Greek border (270 m) is significant. Preliminary studies have shown that the natural state of the river flow formation depends on the altitude [1].

The main objectives of this research are to study:

- the tendency of the multi-annual dynamics of the absolute maximum values of the river flow with respect to the risk assessment of flood events during the period 1948 - 2006.
- the tendencies of the multi-annual dynamics of the absolute minimum values of the river flow with respect to drought events.

2. MATERIALS AND METHODS

The retrospective analysis of the river water flow dynamics is performed on the basis of information collected at the hydrometric stations of Pernik and Marino pole. For this purpose, the Origin 6.0 software has been applied for data analysis.

The type of the function describing the trend was determined on the basis of statistical criteria as correlation coefficients and Fishers tests [4, 7].

Statistical methods are used in hydrology for the assessment of climatic and anthropogenic impact on the river flow formation in a specific cross section of the river basin [8].

In the present work, an integral approach to evaluating the level of climate impact on the river flow formation is applied, following earlier studies of Diadovski et al. [1, 2]. With respect to the risk assessment of flood or drought events, specific integral indicators are introduced, which are based on the ratios between the highest water discharge for the year $Q_{max,i}$ to the multi-annual-average value of the maximum water discharge $Q_{max,0}$ and on the ratio between the minimum water discharge $Q_{min,i}$ to the multi-annual-average value of the minimum water discharge $Q_{min,0}$.

The proposed indices are found according to the equations:

$$M_{\max,i} = Q_{\max,i} / Q_{\max,0} \qquad (1)$$

$$M_{\min,i} = Q_{\min,i} / Q_{\min,0} \qquad (2)$$

The fluctuations of the $M_{max,i}$ and $M_{min,i}$ indices for a certain period give the possibility of making integral assessment of the climatic impact on the river flow formation on a river basin scale and risk assessment along the Strouma river flow using extreme events of the past and integral indices.

The higher the integral indices $M_{max,i}$ than 1, the higher the flood risk. It means that the higher the level of deviation of the maximal water flow values from the norm ($Q_{max,0}$), the higher the risk of flooding ($M_{max,i} > 2$).

The lower the integral indices $M_{min,i}$ than 1, the higher the draught risk. It means that higher the level of deviation of the minimal water flow values from the norm, the higher gets the risk of draught ($M_{min,i} < 0.5$).

Although no exact numbers are given, according to Simeonov [5, 6] and with respect to his experience in the environmetric studies it indicates that the correlation could be interpreted for the values: 1) for $0.0 < r < 0.1$ – no tendency; 2) for $0.1 < r < 0.2$ – insignificant tendency; 3) for $0.2 < r < 0.3$ – slight tendency; 4) for $0.3 < r < 0.5$ – moderate tendency; 5) for $0.5 < r$ – significant tendency.

3. RESULTS AND DISCUSSION

The theoretical correlation coefficient of the trend functions at degrees of freedom $No = 59$ and a probability of error $\alpha = 5\%$ has a value $r = 0.253$. The calculated values of the correlation coefficients for the investigated period are in the interval 0.2 ÷ 0.59. This fact shows that the model for the trend characterizes in an adequately clear way the expressed tendency and significant tendency.

The assessment of the flow change in the hydrometric stations of Pernik and Marino pole for period of 59 years (1948-2006) is made on the basis of integral parameter dynamics (Table 1).

Table 1. Dynamics of the river flow water characteristics

Sampling site	Q_0 (multi-annual average river flow)	$Q_{max,0}$ (multi-annual average maximum river flow)	$Q_{min,0}$ (multi-annual average minimum river flow)
Pernik	$2.11\ m^3 \cdot s^{-1}$	$31.42\ m^3 \cdot s^{-1}$	$0.72\ m^3 \cdot s^{-1}$
Marino pole	$72.42\ m^3 \cdot s^{-1}$	$443.85\ m^3 \cdot s^{-1}$	$10.52\ m^3 \cdot s^{-1}$

The trend in the dynamics of the $M_{max,i}$ index is described best by a linear function with a correlation coefficient $R = -0.52$ for Pernik (Fig. 2), and $R = -0.55$ for Marino pole (Fig. 3).

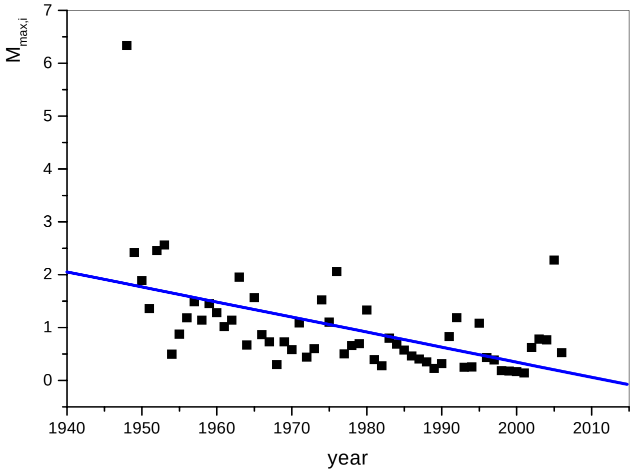

Fig. 2 Dynamics of the $M_{max,i}$ index for Strouma River at Pernik point

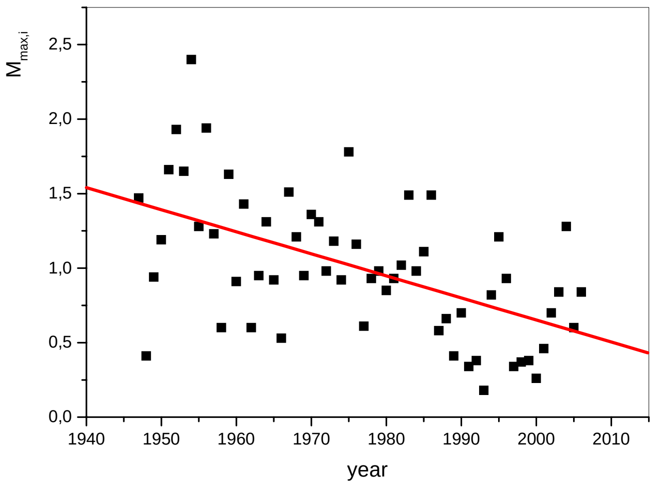

Fig. 3 Dynamics of the $M_{max,i}$ index for Strouma River at Marino pole point

The values of $M_{max,i}$ in the point of Pernik vary within the range 0.3 ÷ 6.2, which indicates the higher and the lower maximum water flow and thus the norm (the average multi-annual value of the maximum water flow) is observed. Years with hazardous flooding are outlined ($M_{max,i}$ > 2), for example 1950-1953, 1962, 1965, 1975, 2005. It has to be noted that the years with values of the maximum water flow $Q_{max,i}$, which are lower or insignificantly higher than the norm of the maximum water flow for the considered period, are predominant.

The values of $M_{max,i}$ in Marino pole control point vary within the range 2.4 ÷ 0.25, which indicates that in certain years the maximum water flow $Q_{max,i}$ significantly exceeds the norm of the maximum water flow $Q_{max,0}$, thus forming hazardous floods. Years with hazardous flooding are outlined as 1954-1956, 1975.

The trend in the dynamics of the $M_{min,i}$ index for Pernik (Fig. 4) is described by a 3rd order polynomial with a value of the correlation coefficient R = 0.54 and R = 0.36 for Marino pole (Fig. 5).

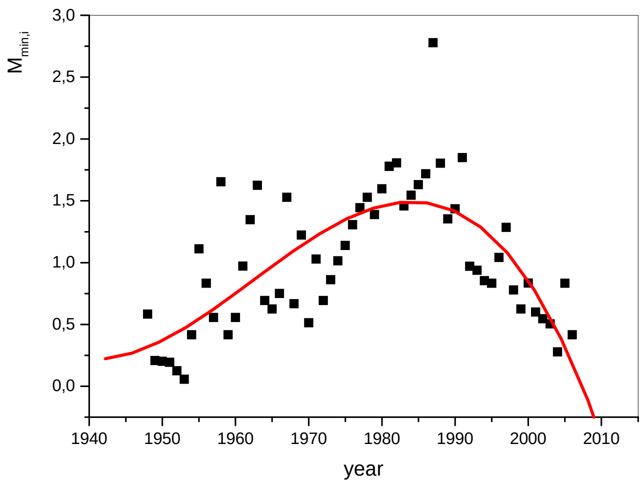

Fig. 4 Dynamics of the $M_{min,i}$ index for Strouma River at Pernik point

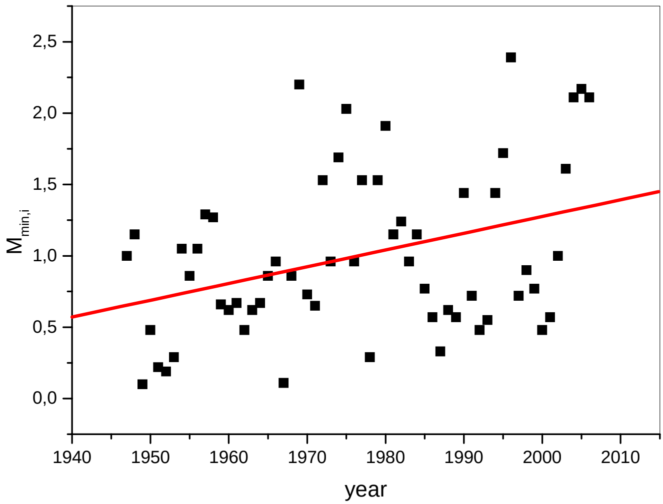

Fig. 5 Dynamics of the $M_{min,i}$ index for Strouma River at Marino pole point

The years with extreme events like floods and draughts already happened in the samplings sites – Pernik and Marino pole, presented in Table 2.

Table 2. Years of extreme events for sampling site

Sampling sites	Years of flood events	Years of draught events
Pernik	1950-1953, 1962, 1965, 1975, 2005	1950-1953, 1960, 1970, 2000-2005
Marino pole	1954-1956, 1975	1948-1953, 1963, 1978, 1985-1990, 1992, 1993, 2000, 2001

For the whole period of observation (1948-2006) the years with flood events are 16.32% and 8.16% for Pernik and Marino pole site, respectively. Years of draught events for the same period are 26.48% and 36.73% for Pernik and Marino pole site, respectively.

Studying the dynamics of the indices $M_{max,i}$ and $M_{min,i}$ it could be found that for one and the same sampling site and one and the same time period extreme events of two types are observed – floods and draughts. This event could be explained by the climatic changes and the physical-geographical conditions along Strouma River catchment.

Flood effects during high water are observed in the years with $M_{max,i} > 2$, while for the years with $M_{max,i} > 1$ high water with possible negative effect may be observed. Low water with possible negative effect is observed during the years with $M_{min,i} < 1$, while for the years with $M_{min,i} < 0.5$ low water with drought effect may be observed.

The presented results confirm the importance of using the integral assessment of the climatic and anthropogenic impact within a catchment as a reliable tool for water management.

4. CONCLUSIONS

1. The character of the changes in the maximum water flow at the two river points with respect to the average multi-annual value of the maximum water flow $Q_{max,0}$ is the same.
2. Two periods are outlined for the three points: first 1948-1975 and second 1976-2006.
3. The 1948-1975 period is characterized by maximum water flow, which is higher than the average multi-annual value $Q_{max,0}$ ($M_{max,i} > 2$ - high water and flood effect; $M_{max,i} > 1$ - high water, possible negative effect). For the two points, a biannual cycle is outlined (1955-1956), when the maximum water flow is lower than the average multi-annual value $Q_{max,0}$.
4. The period 1976-2006 is characterized by maximum water flow, which is lower than the average multi-annual value $Q_{max,0}$ for two points ($M_{max,i} < 1$). For the two points, a three-year cycle is outlined (1974-1976), when the maximum water flow is higher than the average multi-annual value $Q_{max,0}$.

5. Two periods are outlined at the river points for the changes in the minimum water flow. The 1948-1974 period is characterized by minimum water flow, which is lower than the average multi-annual value $Q_{min,0}$ ($M_{min,i}$ <0.5 – low water and drought effect; $M_{min,i}$ < 1 – low water, possible negative effect). For the two points a three-year cycle is outlined (1961-1964), when the minimum water flow is higher than the average multi-annual value $Q_{min,0}$.
6. The 1975-2006 period is characterized by minimum water flow, which is higher than the average multi-annual value $Q_{min,0}$ ($M_{min,i}$ > 1). For the two points a four-year cycle is outlined (1998-2001), when the minimum water flow is lower than the average multi-annual value $Q_{min,0}$.
7. The proposed integral indices provide the possibility of evaluating the climate impact on the flow formation of Strouma River, but they may also be applied to other rivers on regional, national and transboundary level. Using integral indicators, high water years, dry years, maximum water flow and flood effect, minimum water flow and drought effect, are identified, which is a preliminary estimation of the risk assessment of flood events and drought events.
8. Using the data from Table 2 and the calculated percentage of flood and draught events for the two sampling sites in consideration, it could be stated that for the coming years the probability for flood events is much lower that that of draught events.

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