 https://doi.org/10.1051/e3sconf/202234705004

# Flood risk assessment at Tundzha river basin, Bulgaria

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**Abstract.** Tundzha River is the third greatest river in Bulgaria and the largest tributary of the fourth largest river in the country, the Maritsa River. The risks for flood events in the Tundzha River basin was assessed based on the characteristics of the river basin and the main causes of floods as sources and mechanisms. The populated places at the highest risks of flood events were identified. The risk forecasting for the city of Yambol, the largest city on the river's banks, was also presented in the case of floods with different heights of the wave. It was found that flooding in the Bulgarian side of the Tundzha River basin could be caused mostly by high river water levels due to severe rainfall or the rapid melting of huge amounts of snow.

## 1 Introduction

During the last decade, the problems related to flood appearance in Bulgaria have been intensively studied [1, 2]. The reasons for floodings are mainly rigorous rains, landslides, and intensive snow melting [3, 4]. Floods in the warm half of the year are associated with meteorological conditions for the development of convective clouds or the creation of dynamic conditions for the appearance of convective processes to accumulate a large amount of precipitation for a short time in a comparatively small area. In the cold half of the year, floods are a typical result of Mediterranean cyclones or a series of cyclones passing near Bulgaria [5]. They also could result from the rapid melting of freshly fallen snow on a relatively large area and small altitude and subsequent rapid warming after the passage of a Mediterranean cyclone [6]. The process usually happens in late winter and early spring.

Since 2009 both forecasting systems and alert systems for floods have been operating in Bulgaria [1], as the appropriate measures and actions can reduce the likelihood of floods and limit their impact. Directive 2007/60/EC on the assessment and management of flood risks of the European Parliament [7] requires the EU member states to assess whether their rivers or coastlines are at risk of flooding; to map the territories, subject to possible floods and to take adequate and coordinated measures to reduce this risk. At the same time, Directive 2007/60/EC [7] strengthens the public's right to access information concerning flood risk and its participation in governmental and other activities related to reducing the flooding risk.

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The aim of the paper was to evaluate the risks for flood events in the Tundzha River basin, considering the characteristics of the river basin and the leading causes of floods as sources and mechanisms. An assessment was made about the populated places in the river basin at the highest risk of flood events. The risk forecasting for the city of Yambol, the largest city on the banks of the Tundzha River in the case of floods with different wave heights was also presented.

## 2 Characteristics of the river basin

The Tundzha River is the largest tributary of the Maritsa River, but it flows into it beyond the Bulgarian border with Turkey. It springs from the central part of the Balkan Mountains east of the Botev peak at 1940 m (42°43'40" N and 24°58'10" E). The length of the river to the southern border is 350 km. River's drainage basin is determined by the coordinates 41°55' and 42°45' N and 24°55' and 27°00' E and involves 8029 km$^2$, which represents 22.43% of the area of the East Aegean region.

Tundzha River flows straight to the east тo the town of Yambol, and after a 90° turn, it takes a southern direction, which direction it retains until the confluence with Maritsa river. The river receives about 50 tributaries, the top three of which are: Mochuritsa River, with 86 km length and a drainage basin of 1278 km$^2$, Sinapovska River with 55 km length and a drainage basin of 871 km$^2$, and Popovska River with 72 km length and a drainage basin of 533 km$^2$. Figure 1 shows the basins of the Tundzha and Maritsa Rivers, sharing a common area.

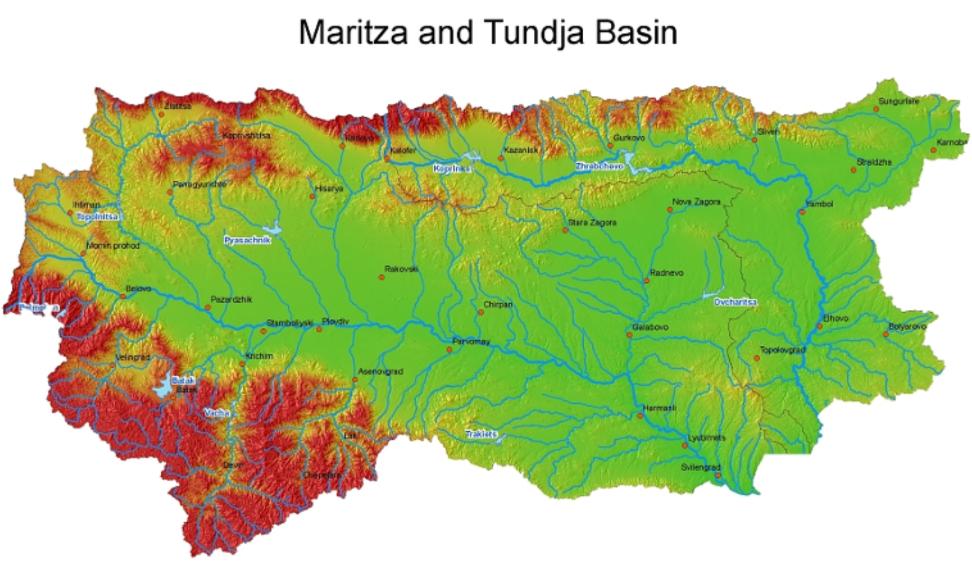


**Fig. 1.** Map of Tundzha and Maritsa basin

The average slope of the Tundzha River is 5.4 % with a 2.1 coefficient of curvature. The density of the river net for 15 of the most significant tributaries, as for the main river, has relatively low values and ranges between 0.23 km/km$^2$ (Marash River) and 0.66 km/km$^2$ (Popovska River). The main reason is the low altitude of the entire catchment area – 386 m above sea level.

Its significant spatial changes characterize the precipitation in the basin of Tundzha River: from over 1000-1200 mm in the high mountain zones to annual rainfall of 500-550 mm in the Yambol-Elhovo field and a part of the Polyanovgrad field. The highest seasonal rainfall is observed in the winter: over 250-300 mm, measured in the high parts of the mountain, affecting relatively low areas afterwards. The most extensive precipitation zone with 100-125 mm for the Yambol-Elhovo field is also in winter. Winter precipitation of 125-150 mm is observed in the Tundzha River basin near Elhovo. In the southern part of the river and some mountainous places, the winter precipitation is 150-175 mm, while in the rest of the area, the precipitation is 175-200 mm.

## 3 Main causes of floods: sources and mechanisms

According to the reporting requirements of the Directive 2007/60/EC [7], the floods are classified by sources and mechanism, as follows:

- Flood types, according to its source:
  - River flood: due to high water in rivers, mountain streams, canals, streams, lakes, including flooding due to snow melting.
  - Rain flood: due to water coming directly from rain or snow melting in urban and non-urban areas.
  - Groundwater: due to an increase in underground water level above ground level.
  - Sea flood: due to high marine waters, including near coastal lakes or river debouchment.
  - Infrastructure: due to failures of dam structures.
  - Others: when the reason for the flood is unknown.

- Flood type according to the flood mechanisms:
  - Natural overflow: due to increased water level.
  - Overflow in water transfer: due to transfer of water through flood structures.
  - Damage in a protective or infrastructural installation: due to the damage or destruction of natural or technical flood banks.
  - Block /undercutting: due to the emergence of an artificial or natural blockage of the watercourse
  - Others: when the flooding mechanism is unknown.

Our analysis shows that the foremost reason for the overflows registered in the Tundzha River basin is river floods, caused by highly intense and prolonged rainfall: 31 out of 33 past floods in the river basin. The other two floods were rain floods (from sloping waters), resulting from short-term, intense rainfalls that were the only source of flooding. There were no registered underground floods in the Tundzha River basin. The discharge of water volumes from water retention facilities (dams) due to overflow or destruction of a wall is the primary or aggravating reason for three floods in the Tundzha River basin.

In most cases, the cause of the flood in the river basin is a combination of more than one factor. In the uncorrected river sections, a natural overflow appears, while in the corrected ones, two mechanisms for flood arrival are observed:

- ✓ destruction of the protective facilities (dikes) where they are in poor technical condition as a result of poor operation or maintenance;
- ✓ overflow over the protective facilities when waters are higher than the flow for which the facilities are designed.

## 4 Flood assessment and forecasting

Table 1 summarizes data and calculations for the annual and monthly flow rate of the Tundzha River, near six towns in its basin and the boundary. The calculation of the minimum flow rate $\overline{Q}_{\min}$ and the dimensionless coefficient k shows that the most endangered towns to floods are Yambol, Elhovo and Banya.

Figure 2 illustrates the minimum, average and maximum annual values of the river flowrate near Yambol, Elhovo and Banya.

The preliminary assessment and forecasting of flood risks in a river basin can limit the impacts of floods and even reduce their appearance. The joint action of governmental bodies, scientific organizations and regional management, as well as appropriate measures, could decrease or prevent catastrophic floods, loss of human lives, economic losses and severe impact to the environment. The flood simulation tool used in our study was developed with the joint efforts of the Executive Agency (EA ECNIS) to the Ministry of Transport, Information Technology and Communications, the Remote Sensing Application Center (ReSAC), and the Agency of Sustainable Development and Eurointegration – Ecoregions (ASDE) [8]. The forecasting is based on simplified simulation models that take into account the influence of the relief and analysis of the land cover and land use. The relief information is created using both topographic maps and high-resolution satellite images.

**Table 1**. Tundzha River flow rate in the river banks at different towns

| Town | Annual values | | Monthly values | |
|---|---|---|---|---|
| | $\overline{Q}_{\min}$ | $k = \frac{\overline{Q}_{\min}}{\overline{\overline{Q}}}$ | $\overline{Q}_{\min}$ | $k = \frac{\overline{Q}_{\min}}{\overline{\overline{Q}}}$ |
| | $m^3/s$ | $m^3/s$ | $m^3/s$ | $m^3/s$ |
| Pavel Banya | 0.231 | 0.491 | 0.007 | 0.015 |
| Dam Koprinka | 1.303 | 0.399 | 0.046 | 0.014 |
| Razhena | 7.501 | 0.582 | 1.353 | 0.105 |
| Banya | 13.049 | 0.578 | 2.255 | 0.100 |
| Yambol | 17.981 | 0.55 | 3.434 | 0.105 |
| Elhovo | 18.189 | 0.543 | 3.437 | 0.103 |
| At the boundary | 19.816 | 0.499 | 4.067 | 0.102 |

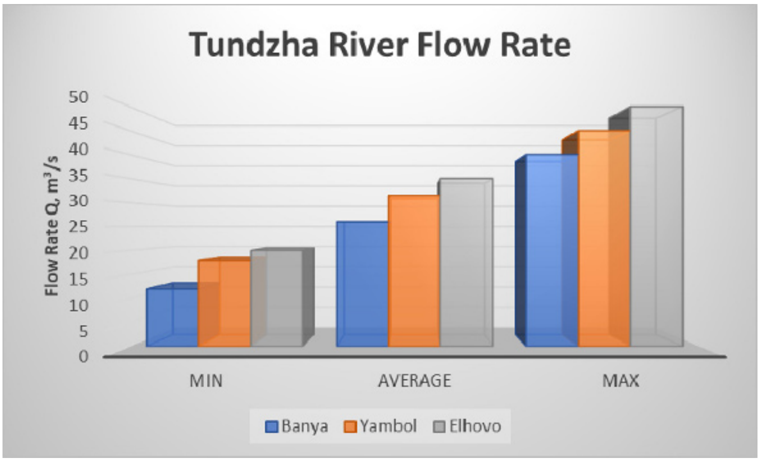


**Fig. 2.** Values of Tundzha River flow rate at Banya, Yambol and Elhovo

The simulation tool was used to assess the flood risk for Yambol (Figs. 3-6), Elhovo (Figs. 7-10) and Banya (Figs. 11-14). It is shown the flood effect at three different heights of the wave: 1m, 3m and 5m, respectively. The relief scale is 1:5000.

The simulation shows that, indeed, the risk for the town strongly depends on the high water value. However, due to the flat relief, even 1m height to the wave would be dangerous for the densely populated regions in the city centre. The increment of the wave to 3m worsens the situation, as the flood affects more and more areas of the city. The rise of the wave up to 5m causes a worsening of the effect of the flood but does not lead to a significant increase in the affected areas of the city.

**Fig. 3**. Sattelite map of Yambol (Courtesy of ECNIS-ReSAC-ASDE)

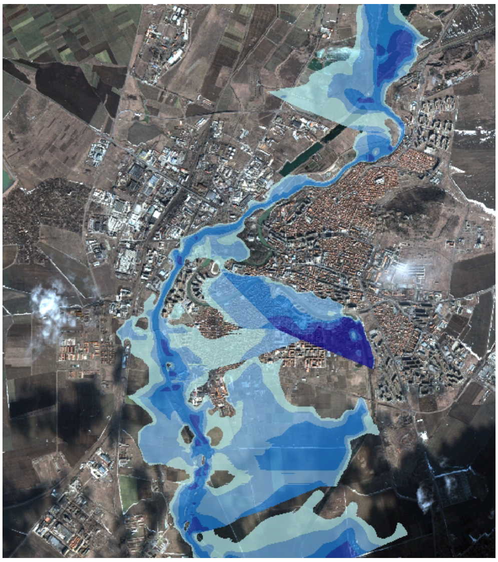

**Fig. 4.** Flood scenario for 1m wave height (Courtesy of ECNIS-ReSAC-ASDE)

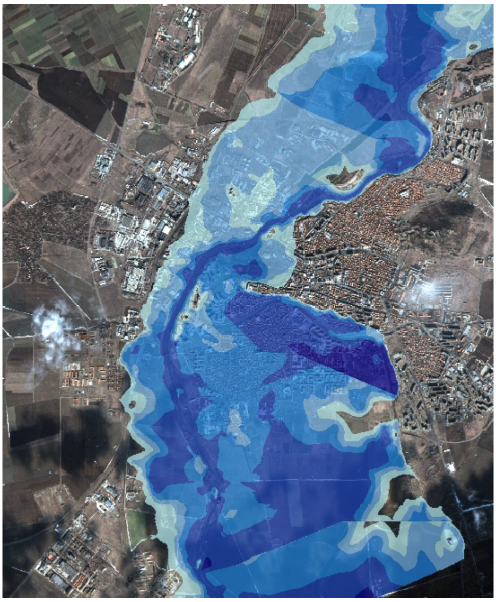

**Fig. 5.** Flood scenario for 3m wave height

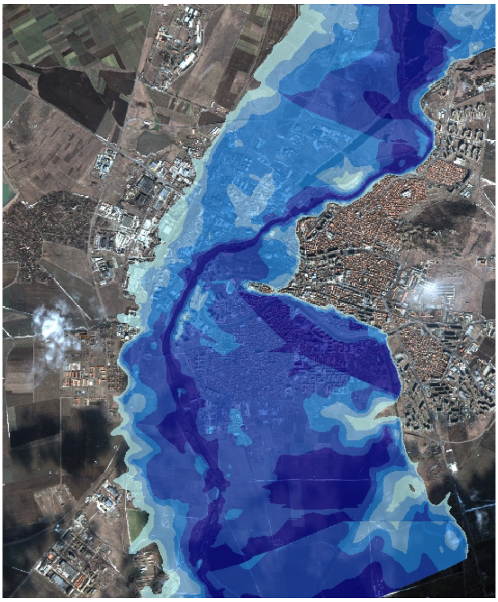

**Fig. 6**. Flood scenario for 5m wave height

 https://doi.org/10.1051/e3sconf/202234705004

(Courtesy of ECNIS-ReSAC-ASDE)

(Courtesy of ECNIS-ReSAC-ASDE)

**Fig. 7**. Sattelite map of Elhovo (Courtesy of ECNIS-ReSAC-ASDE)

**Fig. 8.** Flood scenario for 1m wave height (Courtesy of ECNIS-ReSAC-ASDE)

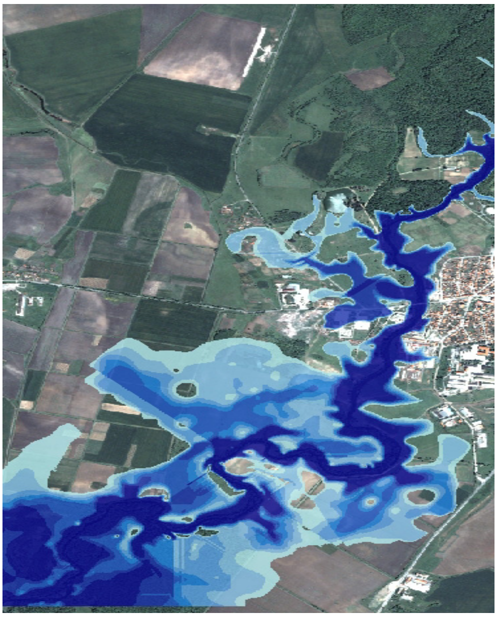

**Fig. 9.** Flood scenario for 3m wave height (Courtesy of ECNIS-ReSAC-ASDE)

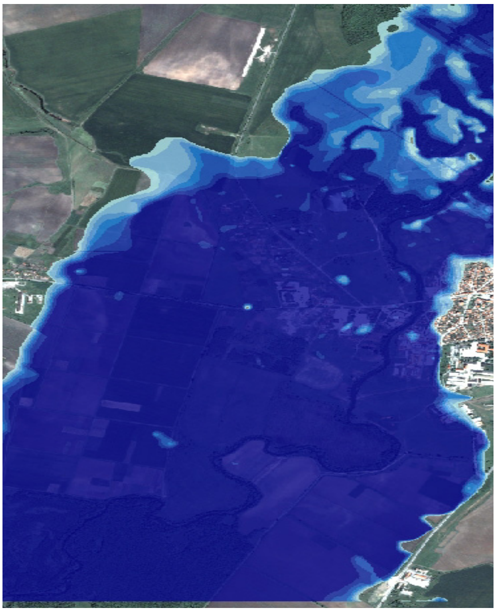

**Fig. 10**. Flood scenario for 5m wave height (Courtesy of ECNIS-ReSAC-ASDE)

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**Fig. 11**. Sattelite map of Banya (Courtesy of ECNIS-ReSAC-ASDE)

**Fig. 12.** Flood scenario for 1m wave height (Courtesy of ECNIS-ReSAC-ASDE)

**Fig. 13.** Flood scenario for 3m wave height (Courtesy of ECNIS-ReSAC-ASDE)

**Fig. 14**. Flood scenario for 5m wave height (Courtesy of ECNIS-ReSAC-ASDE)

## 5 Conclusions

A flood in the Bulgarian part of the Tundzha River basin could appear mainly as a result of high water in the river, due to heavy rains or the fast melting of large quantities of snow. The calculations show that the populated places in the river basin at the highest flood risks are Yambol, Elhovo and Banya.

The presented simulation of the flood effect in the region of Yambol, Elhovo and Banya shows that the flat relief preconditions a severe flood risk even for 1m wave height. he forecast information clearly shows the risks for the population and the buildings in the studied settlements. This data can be used effectively by civil protection organizations and potential decision-makers.

Acknowledgement: The authors would like to thank the Research and Development Sector at the Technical University of Sofia for the financial support in publishing this study.

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