

POSSIBLE HYDROGRAPHIC EFFECTS OF CLIMATE CHANGE ON LOWER PART OF TRANSBOUNDARY MERİÇ RIVER BASIN (TURKEY)

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Abstract: Meriç (Maritsa, Evros) River is not only a transboundary river but also a border river among Turkey, Bulgaria and Greece. 65% of its catchment area is within the borders of Bulgaria. A portion of the lower part of Meriç River constitutes the Turkey-Greece border, and the other portion of it flows in Turkey. The effects of global climate change are observed in the Meriç River Basin. The changes on precipitation and temperature over the upper part of Meriç River Basin situated in Bulgaria cause major problems in the lower part of the river basin in Turkey. Climate changes that have occurred in Bulgaria and projections on climate change over region, the Maritsa River water management approaches, Maritsa River floods and water shortages in Turkey were investigated in this study. As a result; flood and water scarcity problems, deterioration of water quality, ecosystem problems and socio-economic problems of the local population are increasing in the section of the river basin in Turkey. Prevention and/or mitigation of these problems depend on the effective implementation of integrated transboundary watershed management strategies in the joint coordination among Turkey, Bulgaria and Greece.

Key words: Meriç River, transboundary water, climate change, challenges.

İklim Değişikliğinin Sınır Aşan Meriç Nehri Havzası'nın Aşağı Bölümündeki Olası Hidrografik Etkileri

Özet: Meriç (Maritsa, Evros) Nehri; Türkiye, Bulgaristan ve Yunanistan arasında, hem sınır aşan ve hem de sınır oluşturan bir nehirdir. Su toplama havzasının %65'i Bulgaristan sınırları içindedir. Meriç Nehri'nin aşağı çıkışı ise; bir bölümü Türkiye sınırları içinde ve bir bölümü ise Türkiye-Yunanistan sınırını oluşturur. Küresel iklim değişikliğinin etkileri Meriç Nehri Havzası'nda da görülmektedir. Bulgaristan'da kalan, havzanın yukarı bölümünde meydana gelen sıcaklık ve yağış özelliklerindeki değişiklikler; havzanın Türkiye'deki bölümünde önemli problemlere neden olmaktadır. Bu çalışmada; Bulgaristan'da meydana gelen iklim değişiklikleri ve bu konudaki öngörüler, Meriç Nehri su yönetimi yaklaşımları, Türkiye'deki Meriç Nehri taşkınları ve su yetersizlikleri araştırılmıştır. Sonuçta; Meriç Nehri Havzası'nın Türkiye'deki bölümünde; taşkın ve su yetersizliği sorunları, su kalitesi kötüleşmesi, ekosistem problemleri ve yerel halkın sosyo-ekonomik problemleri giderek artmaktadır. Bu sorunların önlenmesi ya da zararlarının azaltılması; Türkiye, Bulgaristan ve Yunanistan ortaklaşa koordinasyonunda, sınır aşan sular bütünlük havza yönetimi stratejilerinin etkili şekilde uygulanmasına bağlıdır.

Anahtar kelimeler: Meriç Nehri, sınır aşan su, iklim değişikliği, sorunlar.

Introduction

The Meriç (Maritsa, Evros) River (40°30'-44°00' N, 22°30'-28°30' E) is one of the most important drainage systems of the Balkans. It has a basin of 52.600 km² that stores water and its length is 550 km. The Meriç River stems from the Rhodope Mountains (Rila, 2925m) in Bulgaria and Tunca River, Arda River and Ergene River form its sub-basin (Fig. 1). The Meriç River is fed by rain and snow melt. Climatic characteristics are important for the river's flow rate and regime. Although the river flows throughout the year, it is possible to observe flow rate shifts depending on the temperature and precipitation features of the river Basin.

It is possible to list the characteristics that make the Meriç River important as follows. Its basin is within

the borders of three different countries. It both flows beyond the borders and sets the borders. The flow rate and regime characteristics are controlled by multiple dams in Bulgaria, and weather conditions are other important features of the river. The river is also important for agricultural activities in all three countries. It is possible to observe hydrological drought and floods in the lower Meriç River Basin in particular periods of a year. Because of the climate changes which have been taking place as a result of global warming, the problems of flood and drought have started to occur frequently in the Lower Meriç Basin. Thus, it is predicted that drought and floods will create problems at different rates and types in the parts of the Meriç basin within the Turkish borders. In this study,

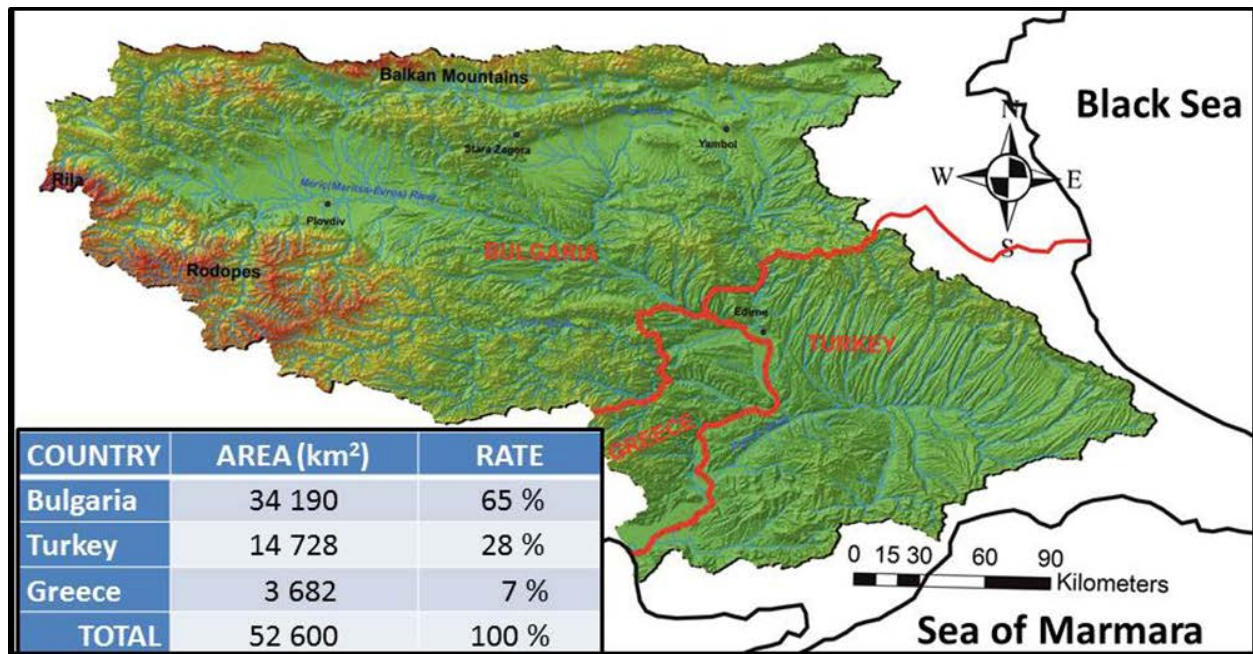


Fig. 1. The Meriç River drainage system and basin.

the effects of global climate change on the Lower Meriç Basin within the Turkish borders are examined with Integrated Water Management perspective. In this context, the study is focused on the current climate data over the basin, climate change scenarios, land use and water management characteristics, flood statistics of the past and climate data.

Method

One of the primary issues that need to be considered in water management is current climate conditions and climate change (Vano et al. 2010). Another major factor for transboundary waters is to create an integrated management strategy including the stakeholder countries (Wester & Warner 2002; Timmerman & Bernardini 2009). In order to be successful in water management, it is important to design management strategies in river basin scale (Turođlu 2007, 2011, 2014). If these issues are not taken into consideration, it will be impossible to create long term water management strategies, solve problems created by humans or nature, and reduce the effects of the damage created by these problems. Within the framework of these basic principles; to create solution for present and future water management problems in the Lower Meriç River Basin within the borders of Turkey should be assessment together with natural and anthropogenic characteristic of Meriç River Basin.

The primary current and future issues that need to be closely examined in the lower Meriç Basin are floods, the effects of flow and regime irregularities on agriculture, water shortage and deterioration in water quality, ecosystem problems, and changes on the

channels of the river. Both human and nature factors played role in emergence, dimensions of impacts, and frequency of these problems.

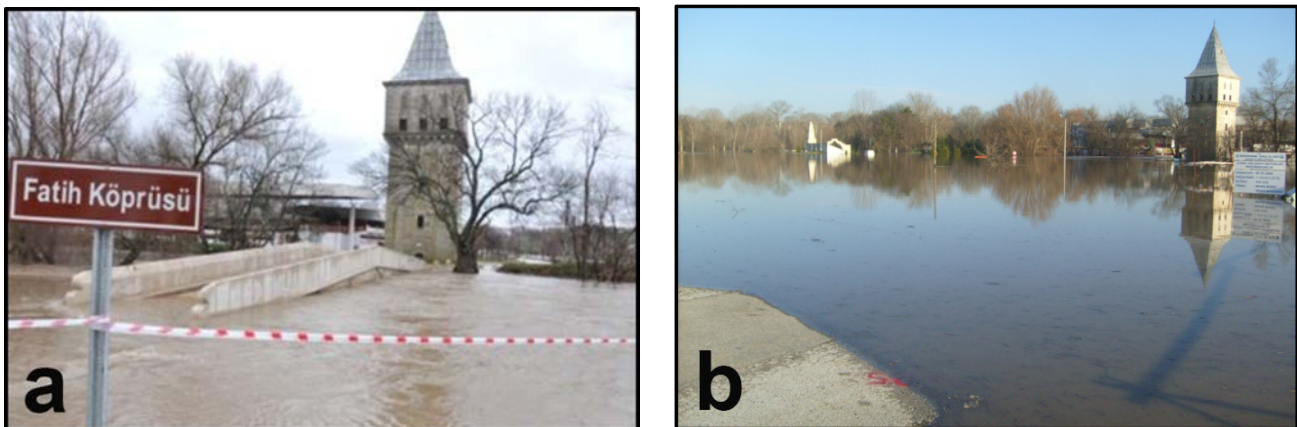
Extreme Flow Problems in the Lower Meriç River Basin

Extreme flow rate problems have always been witnessed in the Lower Meriç River Basin. Historical records indicate that flood disasters have occurred since 1500 years (Table 1). Changes on the frequency and severity of floods were observed in the historical period. Decreasing the flow rates have been experienced more since 1980s. Ascending and descending extreme flow rate problems and their impacts have been felt in critical rates during the 2000s.

The Arda River and the Tunca River sub-basins connect to the Meriç River in Edirne. The water of these sub-basins forms a substantial water body on plain areas in times of extraordinary rain. Existing channels of the Meriç River cannot carry this water body. The huge water body accumulated in the river channel overflow destroying the flood embankments along the river, flooding and ponding into the environment (Turođlu & Uludađ 2010; Turođlu & Uludađ 2012). Disasters caused by floods have frequently happened in Edirne since 1509 (Turođlu and Uludađ 2013). These catastrophes in the lower river basin were caused by nature related reasons such as climate changes, drainage systems, and topographic characteristics. However, in the occurrence of the recent floods, human factor plays an important role in addition to the natural reasons (Fig. 2).

Table 1. The list of archive record of high impact floods that took place since 1500 in Edirne (Kazancıgil 1995; Genç 2006; Turoğlu & Uludağ 2012, 2013).

Some major floods in chronological order		
September 1509	13 February 1937	30 December 1960
1571	27 January 1940	02 October 1962
1657	13 November 1940	03-10 February 1963
January 1747	21 December 1940	08-09 December 1966
18 January 1845	05 March 1946	13-23 January 1981
07 November 1857	29 January 1947	06-07 February 1981
26 January 1863	15 February 1947	06-10 March 1984
December 1894	04-05 March 1950	15-24 February 2005
10 January 1896	06 November 1950	07 January 2006
May-June 1897	10 October 1953	20 October 2007
13 March 1929	05 March 1954	13-16 February 2010
December 1929	20-21 November 1954	07 February 2012
17- 27 February 1931	11 January 1955	16 July 2014
14 December 1931	January /February 1956	
March 1936	22 May 1956	

**Fig. 2(a-b).** Flood caused huge damage in Edirne on 07 February 2012.

When the floods that have taken place since 1500 in Edirne are examined, it is possible to mention 3 different periods (Table 1). The first period includes the floods that took place once nearly every 30 years (before 1930s). The second period is the timeline between 1930 and 2000. The floods that happened between these years took place once in almost every 10 years. One noteworthy characteristic of the second period is the disorder in the frequency and intensity of the floods. After 2000s the floods took place in different forms almost every year.

Especially after 2000s, the climatic changes as increase in temperature and variation in precipitation rates in Bulgaria directly influenced the Lower Meriç River Basin in Turkey. As a result, low flow rates were often observed. Moreover, these climatic changes caused a demand for water resources in Bulgaria and

thus, Bulgaria preserved the river's water in its dams. Although the river's flow rate increases during the winter time precipitations, it dramatically decreases after May and the river even ceases to flow almost every summer (Figs. 3, 4).

Organizations and Benefit from the Meriç River

There are so many dams at the Upper Meriç River Basin which is within the Bulgarian borders. There are seven dams on the Meriç River, 4 dams on the Arda River, and two dams on the Tunca River. Also, there are plans to construct one more dam on both Arda and Tunca rivers (Fig. 5). These dams are located in the sub-basins and in Upper Meriç River Basin. The higher parts of the Rhodope Mountains receive a lot of rain and snow. Thus, these dams store the rain and snow melt waters. The stored water is used for electricity production and agricultural irrigation.

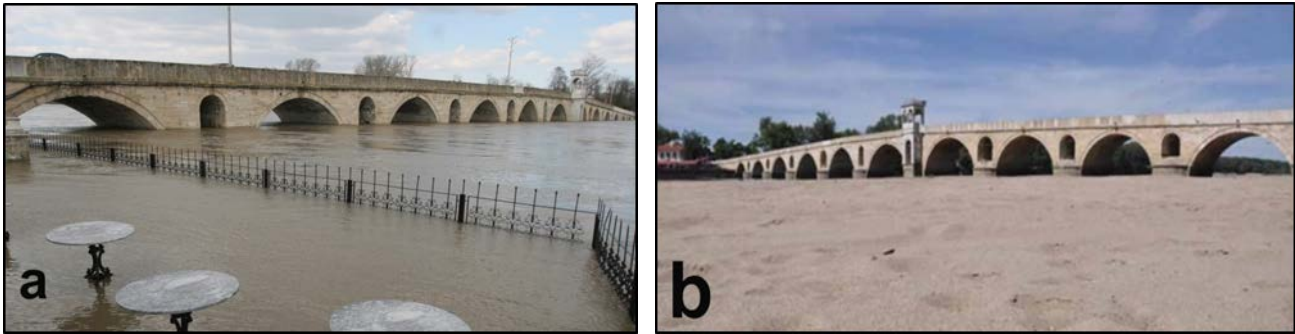


Fig. 3(a-b). During the end of May, the flow rate of the Meriç River dramatically decreases and even ceases at some parts.

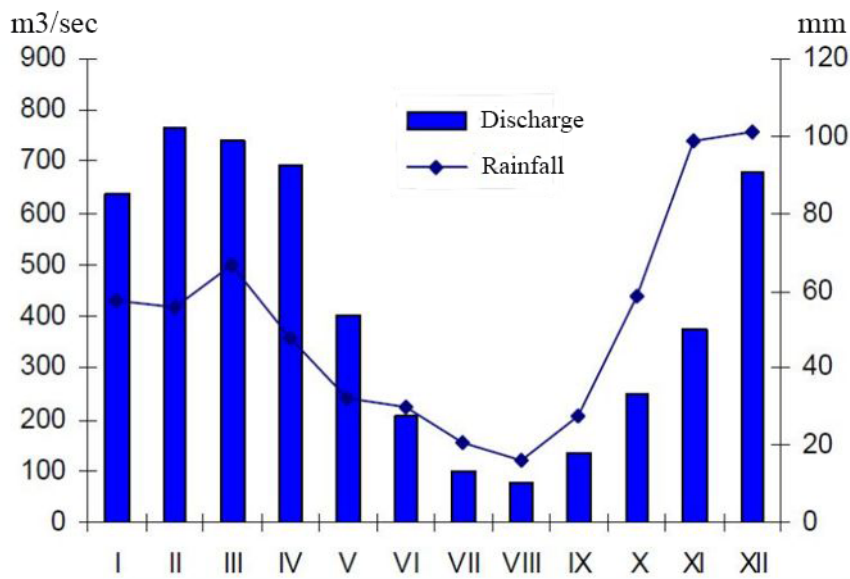


Fig. 4. Years of 1986-2003, the average annual Rainfall-discharge relationship belonging the Ipsala Bridge cross section of Meriç River. (Zal 2006)

Background of the Fluvial Problems in Lower Meriç River Basin

The dams on the Meriç River are fed by rain and snow melt (Fig. 5). As these dams were constructed for electricity production and agricultural irrigation, their fullness level is kept at a high a rate. Thus, in times of heavy rain and excessive snow melt, these dams do not have the potential and ability to keep water, to water storage, to prevent floods. As a consequence penstocks of these dams are opened and excessive water is released in times of heavy rain and excessive snow melt. This application results in unexpected flow rate increases in the Meriç River and floods take place (Fig. 6). Hydrological drought during summer time brings the flow rate of the Meriç River to a halting point especially at the Arda River's sub-basin. The adverse influences of hydrological drought have been also increasing in Meriç and Tunca rivers every year.

Meriç River flows in its Turkish section with a meandering drainage system through a large flood plain that has a slight slope. The river drains off its water to the Aegean Sea. Varying erosional and

depositional activities take place as a consequence of flow rate irregularities, drainage system, slope, and fluvial geomorphology. These changes in the Lower Meriç River basin will create variations in the properties of the river channels in near future.

Climate Change over the Meriç River Basin

It has been reported that climate change has affected the Meriç River basin over the last 20 years in Bulgaria (UNECE 2011). Both an approximately 30% decrease in precipitation, and a subsequent decrease in water resources are accepted as evidence in the Upper Meriç River basin (UNECE 2011). The average temperature has started to increase in Bulgaria after mid-1980s. However, this increase has started to reach extraordinary high rates after 1997. 2007 has been the hottest year since the first climatic measurement took place. Between 1961 and 1990, the temperatures exceeded the average temperature by 1.6°C. 1994, 2000, 2002, 2007, and 2009 have been the warmest years in Bulgaria for the last 53 years. The increasing temperature, sweltering heat waves, and the maximum temperatures measured are indicators of climate change

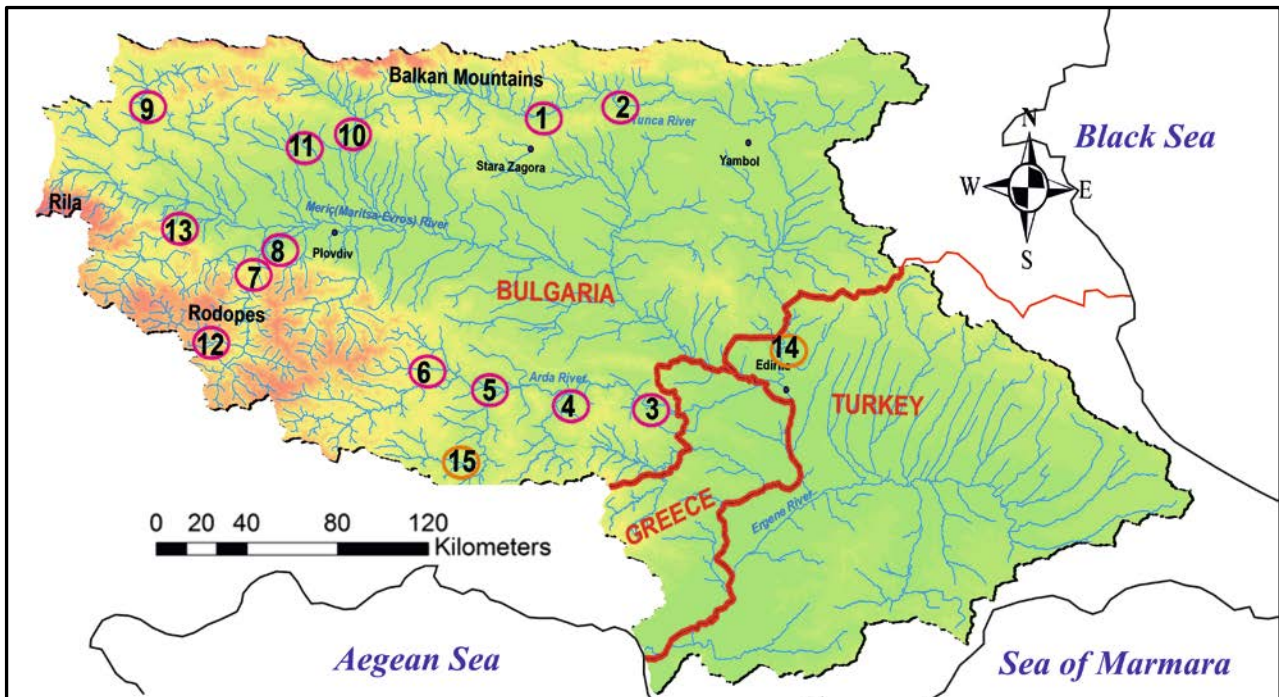


Fig. 5. The dams on the Meriç River and their locations [1-Koprinka(Georgi Dimitrov) Dam, 2-Zhrebchevo Dam, 3-Ivaylovgrad Dam, 4- Studen Kladenets Dam, 5- Kardzhali Dam, 6 Borovitsa Dam, 7- Vacha (Antonivanovtsi) Dam, 8-Krichim Dam, 9- Topolnitsa Dam, 10- Domlian Dam, 11- Pyasachnik Dam, 12- Golyam Baglık (Vasil Kolarov) Dam, 13- Batak Dam, 14- Suakacağı Dam (canceled) Çömlekköy Dam (planned in Turkey) 15- Goma Dam(planned)].



Fig. 6. Drainage and landcover characteristics of the Meriç River at Edirne section and its flood impact area (modified from Google Earth).

in Bulgaria (Gocheva et al. 2006; Gocheva & Malcheva 2010; Georgieva & Kazandjiev 2013; Gocheva 2014). Considering the temperatures between 1961 and 2000, it is estimated that the average annual temperature will increase by 5-8 °C (CCA 2014). Although the heavy rain falls during the last 10 years increased the average precipitation rates on a yearly basis, aridification has been observed in Bulgaria's

climate since the last years of the 20th century (Ivanova & Mishev 2012; CCA 2014).

The following numbers display Bulgaria's altitude rates; 31% lowlands (0–200 m), 41% hills (200–600 m), 25% highlands (600–1,600 m), and 3% mountains (>1,600 m) (CCA 2014). Highlands and mountains (Balkan and Rodopes) receive the highest precipitation

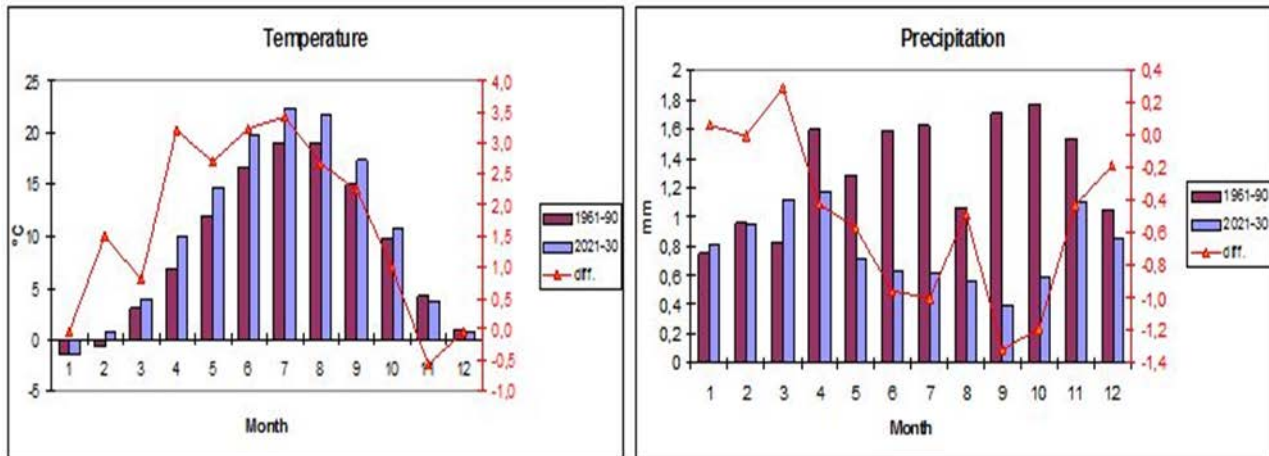


Fig. 7. Expected temperature and precipitation changes over the territory of Bulgaria (Ivanova & Mishev 2012).

in Bulgaria (28%). These areas are the Upper part of the Meriç River Basin and its sub-basins and the dams are located in these areas (Figs. 1, 5). The average temperature in this part of Bulgaria has been increasing and the precipitation rates during the winter season have been decreasing (CCA 2014). Although the current drought level is slight in Bulgaria, it is predicted that this level will increase to a serious level in less than 60 years (Fig. 7) (Alexandrov & Genev 2003; Ivanova & Mishev 2012; CCA 2014).

Expected challenges

The climatic characteristics of the Meriç River Basin vary due to variation in temperature and precipitation from year to year. This change becomes apparent because of temperature rise and variation in precipitation regime, and causes changes in the flow and regime characteristics of Meriç River in a negative way.

The effects of temperature and precipitation variations in the Upper Meriç River Basin and within the Bulgarian borders to the Lower Meriç River Basin in Turkey borders and on the border of Turkey-Greece will be more serious. This situation is directly related to the “Integrated Water Management” and “Integrated Meriç River Basin Management” approaches that will be applied in the river basin. It is possible to gather these effects under the titles of hydrologic drought, the frequency and severity of floods and droughts, deterioration of the water quality, ecosystem problem, and changes in the channel properties of the Lower Meriç River.

Hydrologic drought

Increase of the average temperature, variation in types and intensity of precipitation, and seasonal distribution of the precipitation cause drought in spite of increase in annual amount of rainfall (Confalonieri et al. 2007; Vano et al. 2010). Temperature rise in the Meriç River Basin and variation in precipitation regime will decrease water amount of surface runoff in the

basin. For this reason, the flow of Meriç River will also decrease. In this respect, this situation will create hydrologic drought. It is predicted that hydrologic drought of Meriç River will be particularly effective in the Lower Meriç River Basin. This means that drought in this part of the river within the Turkish borders creates an agricultural drought in terms of agricultural activities. Dams that are situated in the Bulgarian part of the river will seriously cause the problem of drought that will occur in Turkey. Therefore, it is predicted to have surface runoff and feeding of the Meriç River that are decreases due to both natural reasons and dams to keep decreasing surface runoff. Decreases in surface runoff, and even completely disappears in the Lower Meriç River Basin at certain periods of the year can be expected.

The frequency and severity of floods and droughts

One of the effects of climate change in the Meriç River Basin is the change in precipitation regime. While occurs decrease in winter precipitations, heavy rains starting in hot periods of the year and being predicted to increase in the future by climatic statistics will cause the increase in frequency and severity of floods. Heavy rains, which occur during the period of snow melting, will provide to gather body of water in huge volumes in a short time. Dams in Bulgaria do not have flood prevention; for this reason this makes floods and overflows cause huge damage both in Bulgaria and Turkey. This effect is particularly predicted to be more in the Lower Meriç River Basin. Temperature rise and extension of hot season of the year will cause the need for water, so it should be considered that the problem of drought will emerge and become more important.

Deterioration of the water quality

One of the fundamental reasons of deterioration of water quality of available water is drought. Snow cover thickness and variation in the snow cover duration from year to year and region to region in the Upper Meriç River Basin in Bulgaria, and variation in annual

amount of precipitation in the form of rain from year to year play a distinctive role in generating surface runoff in the form of flood and in terms of frequency and severity characteristics. Surface run off in flood character is one of the significant reasons of organic and chemical pollution by means of erosion and drifting of surface water (Nearinga et al. 2005; Confalonieri et al. 2007; Turoğlu 2014). Floodwater will seriously cause dissolved wreck and organic waste to be cleared, removed and pollution originating from chemical fertilizers, solid and liquid wastes. Thus, water amount that is decreased climatically will incur losses due to pollution once again. A part of Lower Meriç River flows in a large alluvial flood plain within the Turkish borders. The other part of Lower Meriç River forms the border between Greece and Turkey. The water whose quality is deteriorated can be easily infiltrated into underground water because of the geomorphological and lithological characteristics of the Lower Meriç River Basin. Underground water in this region is commonly used agriculturally by farmers. Deteriorated quality or polluted water prevents utilization of ground water. It is clear that groundwater level goes deeper and the water quality becomes worse from year to year in Edirne-Enez (Turkey) part of Meriç River.

Ecosystem problems

The relational system of biotic and abiotic environment that forms ecosystem shows continuity under the control of climate characteristics to a large extent on condition that human effect is disregarded. For this reason, changes in temperature and precipitation characteristics trigger ecosystem problems by being effective in both biotic and abiotic environment (MEA 2005; Fischlin et al. 2007). The Water Ecosystems of Meriç River and Terrestrial Ecosystems of Meriç River Basin will be negatively affected due to the changes in the characteristics of climate, temperature and precipitation year by year. It is seriously predicted that there will be an immigration of biotic environment, decrease and extinction of populations of species. In addition to this, it is predicted to have cross section of cycles that cause ecosystem problems and variations.

Socio-Economical Effects

The Lower Meriç River Basin, partly located within the Turkish borders and partly constituting the boundary between Turkey and Greece, faces with both the flood hazards which are expected to increase in frequency in future and the hydrological drought severity increase according to gradually decrease of flow. These two extreme developments are particularly assumed to affect directly or indirectly the needs of agriculture, forest, energy, drinking water, urban and industry. These developments deteriorate life quality and welfare level both in local and regional scales.

Fluvial Geomorphology

Changes in properties of the river channels occur naturally by means of either human or climate change effects. River channels are extremely sensitive to erosion and deposition (Rumsby & Mackin 1994; Kundzewicz et al. 2007). In this regard, properties of the Lower Meriç River are very sensitive. Flow and regime variations due to climate change cause significant fluvial geomorphology variations and problems in this part of the river. This part of the river which constitutes the border between Turkey and Greece will be more sensitive in terms of fluvial geomorphology.

Discussion

The Meriç River is an international water qualified stream whose basin is within the Bulgarian, Turkish and Greek borders and at the same time forming the border between Greece and Turkey. In addition, it is one of the biggest rivers in the Balkans. Change in the climate characteristics of the river basin occurs year by year. This change becomes particularly apparent due to temperature rise and variation in precipitation regime. It is recognized by all scientists that this situation becomes intensified gradually.

The variation in the temperature and precipitation characteristics, which is observed in the Upper Meriç River Basin and becomes gradually intensified, will provide a basis for flow and regime characteristics disorder, increase in hydrological drought, degradation of water quality, ecosystem problems, and changes on river channel, making social life difficult due to local and regional socio-economic problems.

It is crucial for rivers that form borders to have changes in their flow and regime characteristics. Flow and regime variation will also have an effect on the erosional and depositional characteristics of Meriç River in the flood plain. It is required to show sensitivity to the fluvial geomorphology developments, specifically possible streambed shifts that occur naturally.

Despite all the agreements and cooperation, it is apparent that an effective "Transboundary Water Management" strategy cannot be put into practice without the participation of stakeholders countries. Floods, flash floods, water scarcity, etc. problems occurred in the past are the most tangible evidences of this situation in the Lower Meriç River Basin within Turkish borders. The effects of climate change also make the problems of this situation become more significant. Hence, it is essential to have the "Integrated Water Management" practice in the river basin scale for the problem solution of climate change that will be effective in the basin scale concerning the part in the Lower Meriç River within the Turkish borders and for being successful in terms of damage reduction approaches. It is necessary to develop

Integrated Water Management Strategies by using nearby, medium and long term climate models as a base. The Meriç River is both a transboundary and border forming river. In this context, it is necessary for each of three countries to be participants in this practice in accordance with the principles of Integrated Water Management.

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