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EVALUATION OF THE EFFECTS OF SOME WATERSHED CHARACTERISTICS ON WATER AND SUSPENDED SEDIMENT YIELD IN AGRICULTURAL AND FOREST DOMINATED WATERSHEDS

PROCJENA UTJECAJA NEKIH ZNAČAJKI SLIVA OBILJEŽENIH DOMINANTNO ŠUMARSTVOM I POLJOPRIVREDOM NA OTJECANJE VODE I PRODUKCIJU SUSPENDIRANOG EROZIJSKOG NANOSA

Tarık ÇİTGEZ[1]*, Refik KARAGÜL[1], Mehmet ÖZCAN[1]

SUMMARY

Topography, geological structure and land use play a determinative role in the streamflow and total suspended sediment yield of watersheds having similar climate, soil and vegetation characteristics. In order to facilitate sustainable water resource management and effective land use planning, there is an increasing need for research investigating the effects of these factors. This study was carried out in forested and agricultural dominated subwatersheds of the Big Melen watershed in the Western Black Sea Region of Turkey. Hazelnut plantations are grown on most of the agricultural areas in both watersheds. The forested watershed has a steep topography and its geological structure consists of sandstone-mudstone and sedimentary rock. The agricultural watershed area is larger and unlike the forested watershed, there is argillaceous limestone in its geological structure. The precipitation, streamflow and total suspended sediment yield in the watersheds were measured for two years. The total precipitation of the study area over the two years was 2217.3 mm. The water yield of the forested watershed was 867.6 mm, while that of the agricultural watershed was 654.9 mm. In the two years, the total suspended sediment transported from the forested watershed was 19.51 t ha^{-1} and from the agricultural watershed 7.70 t ha^{-1}. However, except for the high values measured after an extreme rainfall event, the unit surface suspended sediment yield of the agricultural watershed was found to be higher than that of the forested watershed. These findings showed that watershed characteristics such as slope, geological structure and rainfall intensity may be more effective on the streamflow and total suspended sediment yield of the watersheds than land use.

KEY WORDS: Big Melen watershed, land use, suspended sediment yield, watershed characteristics, water yield

INTRODUCTION
UVOD

Many factors such as precipitation, land use, topography, geological structure, and soil are effective on the streamflow and sediment yield of watersheds (Zhang et al., 2010, 2014; Ebabu et al., 2018). Accordingly, it can be said that land use, geological structure, and topography are the determinative factors controlling precipitation-streamflow relationships for watersheds that have similar vegetation types, precipitation, and soil characteristics. When the effects of one of

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these factors are combined with other factors, the results obtained may vary from region to region (Wang et al., 2018). Therefore, for effective watershed management planning and sustainable water resources management, further studies are needed to determine how various factors affect the water and sediment yield of the watershed (Yan et al., 2013).

Among land use types, forests are known to play a very important role in the hydrological processes of watersheds (Li et al., 2017; Shi et al., 2018). Studies on watersheds in various countries (Swank et al., 2001; Siriwardena et al., 2006; Serengil et al., 2007; Ganatsios et al., 2010; Wei and Zhang, 2010; Nadal-Romero et al., 2016; Yu et al., 2019), review articles (Bosch and Hewlett, 1982; Brown et al., 2005; Cui et al., 2012; Li et al., 2017; Zhang et al., 2017), and hydrological model simulations (Yu et al., 2010; Can et al., 2015) have shown that treatments in forests such as clear cutting, thinning, and changing the land use affect water yield positively, whereas afforestation has a negative effect. Another study investigating the contribution of different vegetation types to the watershed water yield determined that forests provided the lowest contribution to water yield (Liu et al., 2011; He et al., 2012).

The hydrological responses of watersheds to increasing or decreasing of forest areas may not be the same. In fact, some researchers working on this subject in different countries have reached a common conclusion that the response of watersheds to forest change is quite variable and that watershed characteristics differ as well (Chen et al., 2010; Nippgen et al., 2011; Price, 2011; Zhang and Wei, 2014; Karlsen et al., 2016; Liu et al., 2016; Duan and Cai, 2018; Li et al., 2018). Warburton et al. (2012), who investigated the hydrological impacts of land use change, reported that the contribution of land use to watershed streamflow is not proportional to the land use area and suggested that the location of the changing land use in the watershed may affect the response on the streamflow. Therefore, it is not correct to make generalizations because hydrological process are complex and results may vary from watershed to watershed (Zhang and Wei, 2014).

It has been stated in watershed scale studies that compared to forest land, agricultural land use causes an increase in water yield; in other words, the rate of water loss in forested areas is higher than that of agricultural land (Zhang et al., 2010; Lana-Renault et al., 2011; Yan et al., 2013; Dias et al., 2015; Shi et al., 2018). Contrary to these studies, Rientjes et al. (2010) found a decrease in the water yield although it had been 32 years since the forested land in the watershed had been turned into agricultural lands. They maintained that the reason for this was that the decrease in annual rainfall amount and the change in the distribution of dry and wet season rainfall. Chow et al. (2011) found that the average annual water yield of forested watersheds was higher than that of agricultural watersheds and that this may have been related to the soil and water conservation measures applied in agricultural areas. Sriwongsitanon and Taesombat (2011) found that as the percentage of forest increased, the runoff coefficient between the watersheds increased for large flood events, and decreased for small flood events, and they associated this with the antecedent moisture content of the forest soils being higher.

In studies comparing the hydrological relationships in different watersheds, the effects of the watershed characteristics are striking. In a study conducted in 23 watersheds, Zhang et al. (2014) found a positive correlation between the runoff coefficient and the slope and a negative correlation between the runoff coefficent and proportion of carbonate rock. Wang et al. (2018) found that the surface flow, base flow, and streamflow of the steep sloped forested watershed were higher than of flat sloped agricultural watershed. However, in 29 watersheds, Zengin et al. (2017) found no significant relationship between the runoff coefficient and slope and some other watershed characteristics. Peng and Wang (2012) reported that the surface flow and soil loss of karstic slopes were lower than in non-karstic slopes.

The factors that have a significant impact on the sediment yield of watersheds are also quite diverse and are known to vary region to region. In order to understand the relationship between these factors and sediment yield, a large number of measurements for different precipitation-streamflow events and seasons are needed over a long period of time (Nearing et al., 2007; Sadeghi et al., 2008). Therefore, as they vary greatly depending on time and site, watersheds sediment yields have a complex process (Nu-Fang et al., 2011; Bywater-Reyes et al., 2018; Ebabu et al., 2018). Agricultural and forested areas have a significant effect on the total suspended sediment (TSS) carried from the watersheds. Many studies have found a positive relationship between TSS and agricultural areas and a negative relationship between TSS and forest areas (Ahearn et al., 2005; Yan et al., 2013; Kibena et al., 2014). Chow et al. (2011) found that the annual average suspended sediment yield increased from watersheds with low agricultural intensity to those with high agricultural intensity. Erdoğan et al. (2018) determined that the average monthly suspended sediment concentration in streamwater increased after 18% forest thinning.

Turkey ranks first among the few countries in the world that produce hazelnuts and the country's largest hazelnut production areas are located in the Black Sea region. The research watersheds consist of two adjacent subwatersheds of the Big Melen in the Western Black Sea Region. The Big Melen Stream is the most important source of water for Istanbul, one of the most populous metropolitan areas in the world (Karakaya and Evrendilek, 2010; Akiner and Akkoyunlu, 2012).

The aim of this study was to investigate the effect of various watershed characteristics on the water and TSS yields of forest and agricultural (hazelnut) dominated watersheds and thus, to contribute to the sustainable management of water resources.

MATERIALS AND METHODS
MATERIJALI I METODE

Description of study watersheds – *Opis istraživanih slivova*

The study was carried out in two adjacent subwatersheds of the Big Melen watershed situated in Duzce Province in the Western Black Sea Region of Turkey, located between 40°53'19"- 40°55'24" North latitude and 30°58'20"- 31°02'12" East longitude (Fig. 1).

The study watesheds have similar climate characteristics. According to the Thornthwaite climate classification, Duzce Province is classified as B1B'2sb'4, i.e., it is humid, moderately mesothermal, and under an ocean climate effect, with a moderate water deficit in summer. The average annual precipitation is 827.4 mm, with most precipitation occcurring from October to January. The average annual temperature is 13.4 °C. July is the hottest month with an average temperature of 22.6 °C and January the coldest with an average of 3.8 °C (Zengin et al., 2017; Karagül and Çitgez, 2019). In a one-year study conducted in Duzce region, total rainfall, throughfall, stemflow and interception amount were investigated in beech forests for leafed and leafless periods (Yılmaz, 2014). In this study, total rainfall, throughfall, stemflow and interception amount were found to be 339.1, 218.3, 51.1, 69.6 mm for the leafed season, while 505.8, 383.7, 57.2, 12.8 mm for the leafless season, respectively.

The major land use types in the watersheds are agriculture and forest. The land use types in the agricultural watershed (AW) consist of 27% forest, 70% agriculture, and 3% settlement, and in the forested watershed (FW) 64% forest and 36% agriculture. The main natural tree species in the forest areas are beech (*Fagus orientalis* Lipsky), oak (*Quercus* sp.) and hornbeam (*Carpinus betulus* L.). Canopy coverage of 60-80 years old forests is higher than 70%. Hazelnuts are grown on most of the agricultural areas in the watersheds. Planting density of hazelnut plantation is 4x4 m (Fig. 2).

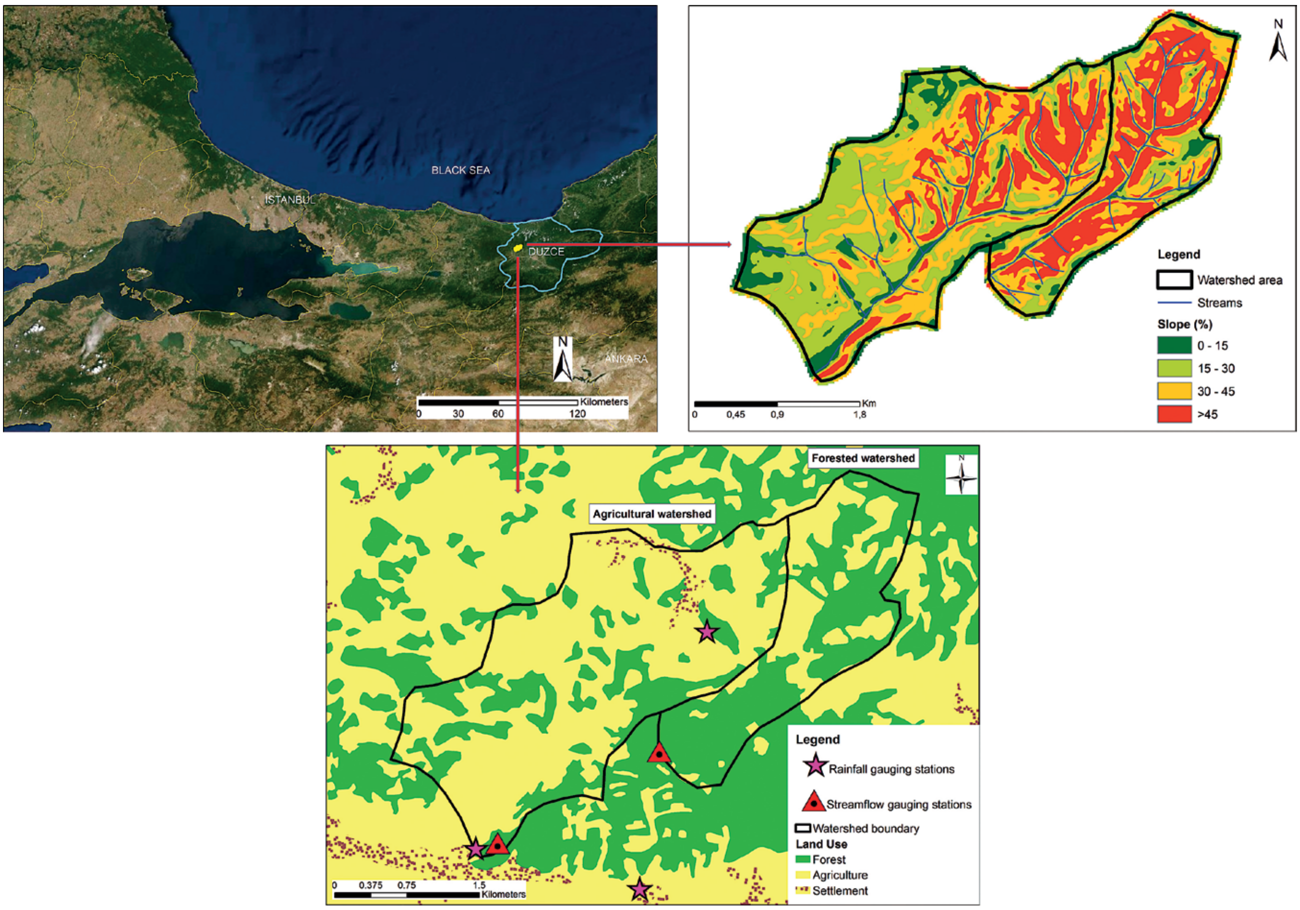

Figure 1. Location, land use and topography characteristics of study watersheds
Slika 1. Lokalitet, uporaba zemljišta i topografija istraživanih slivova

Figure 2. View of hazelnut and forest areas in the watersheds
Slika 2. Pogled na područja lješnjaka i šume u slivovima

The watersheds soil is generally shallow and has a heavy clay content. Soil samples were collected from three soil depths (0-20 cm, 20-40 cm, 46-60 cm) from twelve profile pits excavated in each of the watersheds. The mean soil textures found in the FW are 31% sand, 23% silt, and 46% clay and in the AW, 33% sand, 18% silt, and 49% clay. Moreover, the clay content is higher in the subsoil. The geological structure of the entire FW and nearly half of the AW consists of Lower Ordovician and Lower Eocene sandstone-mudstone, shelf and sedimentary rock groups, while that of the other half of the AW is Lower Eocene argillaceous limestone, shelf and sedimentary rock groups (GDMRE, 2002). In some parts of the AW, limestone bedrock is found on the surface and the soil depth drops to 20 cm.

Table 1. Some characteristics of the two watersheds
Tablica 1. Neke značajke dvaju slivova

Metrics *Metrika*	**Forested (FW)** *Šumski*	**Agricultural (AW)** *Poljoprivredni*
Area (ha) – *Površina (ha)*	334	714
Length (km) – *Duljina (km)*	3.72	4.54
Mean elevation (m) – *Prosječna visina (m)*	422	341
Mean slope (%) – *Prosječni nagib (%)*	43	32
Area with slope >30% (Jahn et al., 2006) (% of total) – *Područje s nagibom >30% (% od ukupnog)*	74.0	52.2
Main channel slope (%) – *Nagib glavnog korita (%)*	15	9
Total number of streams – *Ukupni broj vodotokova*	32	27
Total stream length (km) – *Ukupna dužina vodotoka (km)*	13.66	18.32
Drainage density (km/km^2) – *Gustoća mreže vodotokova (km/km^2)*	4.09	2.56
Stream frequency – *Frekvencija vodotokova*	9.59	3.78
Concentration time (min, Kirpich) – *Vrijeme koncentracije*	27.2	40.8
Soil texture – *Tekstura tlo*	Clay	Clay
Geological structure – Geološka struktura	Sandstone-Mudstone	Argillaceous limenstone--Sandstone-Mudstone
Proportion of land use types (% of total area) – *Odnos vrsti korištenja zemljišta (% ukupnog područja)*		
Forest – *Šuma*	64% (214 ha)	27% (194 ha)
Agriculture (Hazelnut cultivation) – *Poljoprivreda*	36% (120 ha)	70% (499 ha)
Settlement – *Naseljena mjesta*	–	3% (21 ha)

The AW area is larger than that of the FW. For the FW and AW, the elevation is between 210-780 m and 140-600 m a.s.l., respectively. The mean watershed slope, main channel slope, drainage density and stream frequency values of the FW are higher than those of the AW. According to the Kirpich (1940), the FW has a short concentration time. The watershed characteristics, determined by digitizing 1/25000 scale topographic and stand maps in ArcGIS software, are shown in detail in Table 1.

Precipitation, streamflow and total suspended sediment (TSS) measurements – *Mjerenje količine oborina, otjecanja vode i produkcije suspendiranog erozijskog nanosa (TSS)*

Precipitation was measured with three monitoring rain gauges (Tipping Bucket Rain Gauge, RG-200, Akim Hydrometry Co.) placed in sheltered areas at the upper and lower part of the watersheds (He et al., 2012; Nadal-Romero et al., 2016). Using the precipitation data, the average monthly precipitation of the study area was estimated according to the Thiessen polygon method (Liu et al., 2016; Duan and Cai, 2018).

Water level and discharge measurements were performed in both watershed outlets where the streamflow gauging stations were installed before the settlement sites. The water level was measured by automatic water level recorders (OEL-104, Akim Hydrometry Co.) (Serengil et al., 2007; Gökbulak et al., 2008; Durán Zuazo et al., 2012). These devices recorded the water level at 30-min intervals for two years (Fig. 3). Thus, 48 items of level data were obtained per day. The sediment accumulated at these gauging stations was cleaned at regular intervals to ensure that the water level recorders were measuring accurately.

Discharges were determined using velocity-area method. Streamflow velocity (m s^{-1}) was measured with a small current meter (MCM-02, Akim Hydrometry Co.) at four different points of the cross section every fifteen days or after a precipitation events and then average velocity was found. Thus, discharges (m^3 s^{-1}) for various water levels in the watersheds were calculated (Coulter et al., 2004; Zengin et al., 2017; Ebabu et al., 2018). Water samples taken at the same time as the discharge measurements were later evaporated in a drying oven. This evaporation method was used to find the TSS concentration per 100 mL of water (Gökbulak et al., 2008; Erdoğan et al., 2018).

Calculation of streamflow and TSS yields – *Kalkulacija otjecanja vode i produkcije TSS*

In order to determine the water yields of the watersheds, regression equations were produced showing the relationship between the measured discharges and water levels. These equations were used to estimate the unmeasured discharge values corresponding to the 30-min water level data recorded over the two years. The monthly average discharge values were found and than the monthly and annual water yields were determined for the watersheds (Özhan, 2004; Zengin et al., 2017). The runoff coefficients of the watersheds were determined for 2014 and 2015 based on the total precipitation and water yield data. The TSS yield of the watersheds was calculated by multiplying the monthly average suspended sediment concentration and the monthly water yield.

Statistical analyses – *Statistička analiza*

We conducted an independent t-test using SPSS to determine the differences between watersheds for two years in terms of monthly water yield and monthly TSS yield.

Figure 3. Streamflow gauging station installed in the FW (left) and the AW (right)
Slika 3. Mjerna stanica vodotokova u FW (lijevo) i AW(desno)

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

Water level-discharge relationship in study watersheds – *Odnos razine vode i oticanja u istraživanim slivovima*

Discharge measurements were made 46 times at various water levels in the watersheds. In June 2014, a heavy rainfall event (108.2 mm $24h^{-1}$) had occurred and water level in the watersheds had risen above 100 cm. Consequently, the discharge measurement could not be performed due to strong water and sediment flow. The highest discharge measurements in the FW and AW were realized at water levels of 18.5 cm and 21 cm, respectively. Regression equations and graphs in Figure 4 show the relationship between mesured discharge and water level in the watersheds. The R^2 value of the equation for both watersheds was above 0.95. This strong relationships shows the availability of these equations in the calculation of the watershed water yields (Zengin et al., 2017).

Precipitation-streamflow relationships in watersheds – *Odnosi oborina-vodotokova u slivovima*

With the increase in the amount of precipitation, the watershed water yield increased, but the response of the streamflow to similar precipitation amounts varied seasonally. The highest monthly rainfall in the study area was 194.1 mm (January 2015) and the lowest was 13.9 mm (July

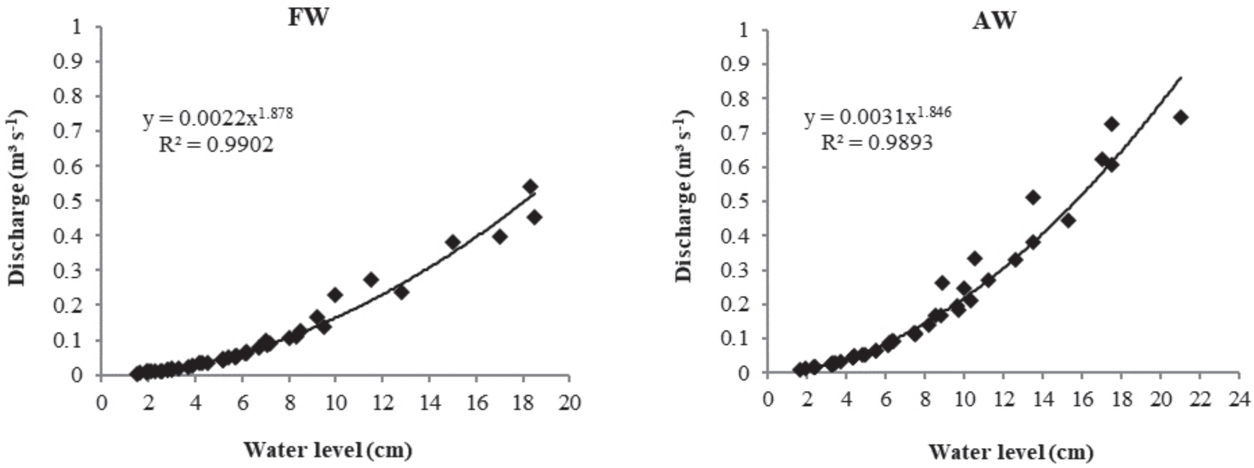

Figure 4. Relationship between measured discharge and water level in the watersheds
Slika 4. Odnos između izmjerenog otjecanja i razine vode u slivovima

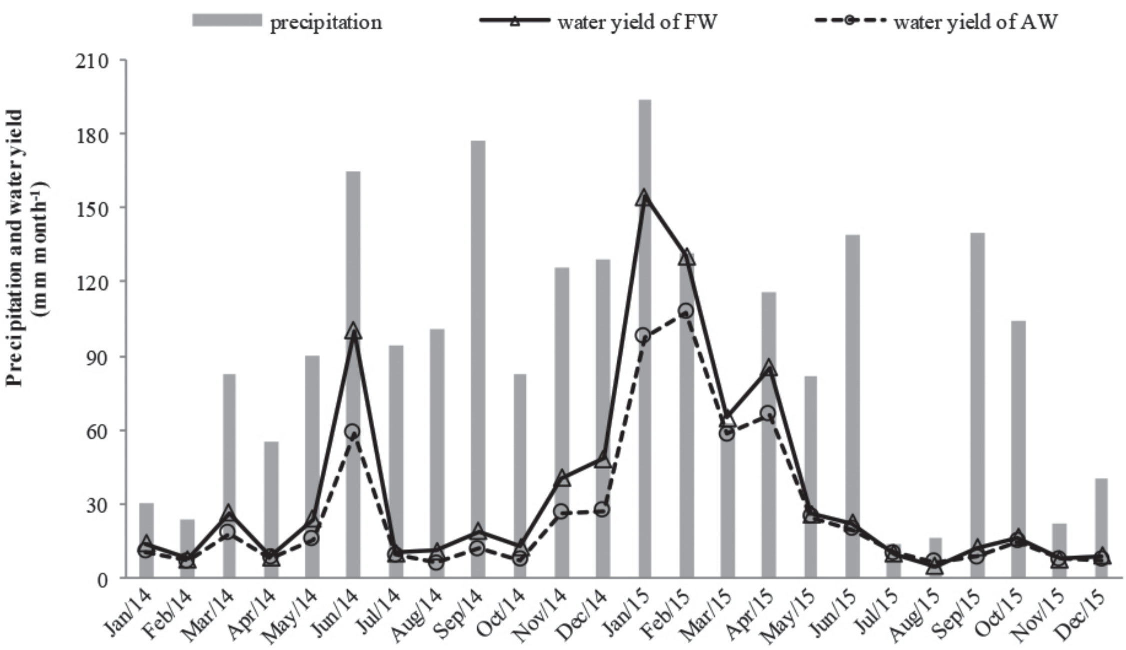

Figure 5. Monthly precipitation and water yield of the watersheds
Slika 5. Mjesečne oborine i otjecanje vode u slivovima

2015). In the FW, the monthly maximum and minimum water yields were 154.6 mm (January 2015) and 4.9 mm (August 2015), whereas in the AW these values were 107.8 mm (February 2015) and 6.0 mm (August. 2014) (Fig. 5).

Although the total amount of precipitation measured in the research area in 2015 was lower compared to 2014, an increase was observed in water yields of the watersheds. In 2014, with a total rainfall of 1156.9 mm, a water yield of 323 mm occurred in the FW and 224.6 mm in the AW. In 2015, despite a total rainfall of 1060.4 mm, a water yield of 544.6 mm occurred in the FW and 430.3 mm in the AW. This was due to the melting of the accumulated snow as a result of heavy snowfall in late December 2014 and in January, February and March of 2015. Thus, the snowmelt contributed to the water flow in the streams, which led to higher water yield values in these months compared to the amount of rainfall (Fig. 5).

The two-year average runoff coefficients of the FW and AW were calculated as 0.39 and 0.30, respectively. The two-year total water yield of FW and AW was 2.89 and 4.55 million m^3, respectively. Although the area of the AW is twice as large, the 2-year total water yield was approximately 1.5 times bigger that of the FW. According to the t-test, there is no significant difference between watersheds for two years in terms of monthly water yield, flow coefficient and unit surface flow ($P>0.05$). However, with the exception of July and August 2015, the unit surface water yield of the FW was higher than that of the AW. In a similar study conducted in Canada, water yields ranging from an agricultural dominated watershed to a forest dominated watershed were found to be 0.588, 0.849 and 0.901 million $m^3/km^2/year$, respectively (Chow et al., 2011). This may have resulted from increased evapotranspiration due to intensive cultivation and management of the agricultural areas, or to increased infiltration through from diversion terraces and grassed waterways. One study investigated the effect of land use and precipitation regime on surface flow and soil loss on karst hill slopes over a four-year period and found the annual surface runoff coefficient of the forested slope to be lower than agricultural slope in the first two years and higher in the last two years (Peng and Wang, 2012). As a result of this, it has been suggested that surface flow and soil loss in agricultural areas are very low for many rainfall events due to improved infiltration capacity of the soil by tillage, and that high runoff and soil loss occur in these areas only with heavy rainfall events. However, in the present study, it is thought that the land use had little effect on the lower water yield of the AW because partial and surface tillage is carried out for fertilization purposes in the hazelnut areas.

Although the difference between the water yields of the watersheds was great during the rainy period, it was less during the dry period. The response of the watersheds to precipitation varied seasonally. For example, when a 41-hour precipitation event occurred in November 2014 under moist soil conditions, the peak flow level of the FW was higher than that of the AW, and it reacted to the precipitation in a short time (Fig. 6). In July 2015, under dry conditions, the AW reacted to a 2-hour precipitation event in a shorter period, but the peak flow level was lower than that of the FW (Fig. 7). These findings are similar to the results of a study conducted in 11 subwatersheds of a river basin in Thailand (Sriwongsitanon and Taesombat, 2011). The researchers

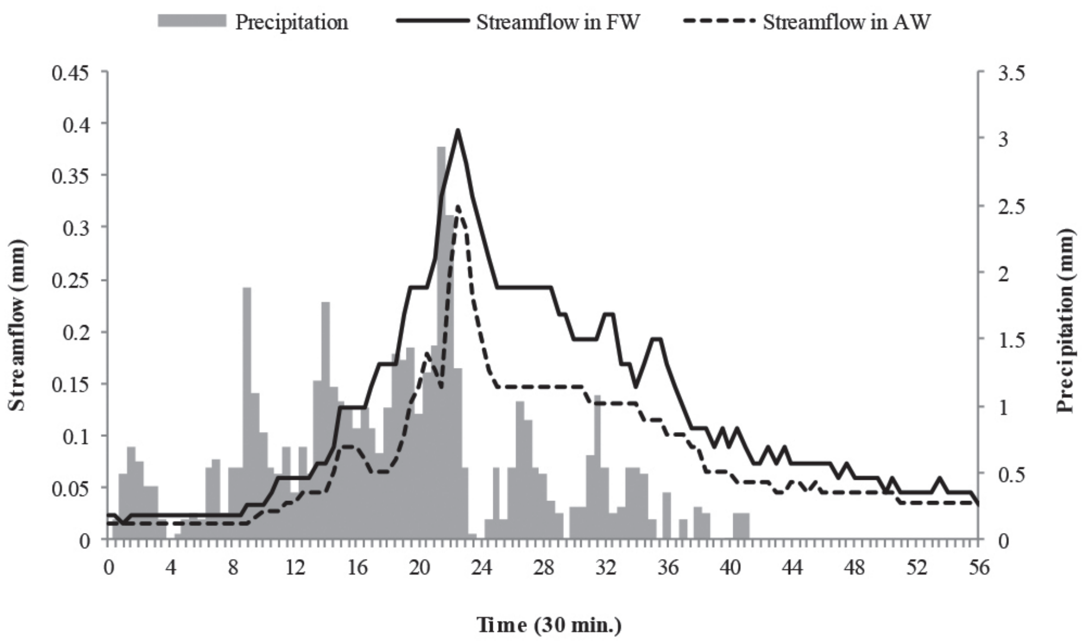

Figure 6. Temporal change of streamflow in 41-hour precipitation event under moist soil condition
Slika 6. Vremenska promjena otjecanja vode tijekom 41-satnog oborinskog događaja u uvjetima mokrog tla

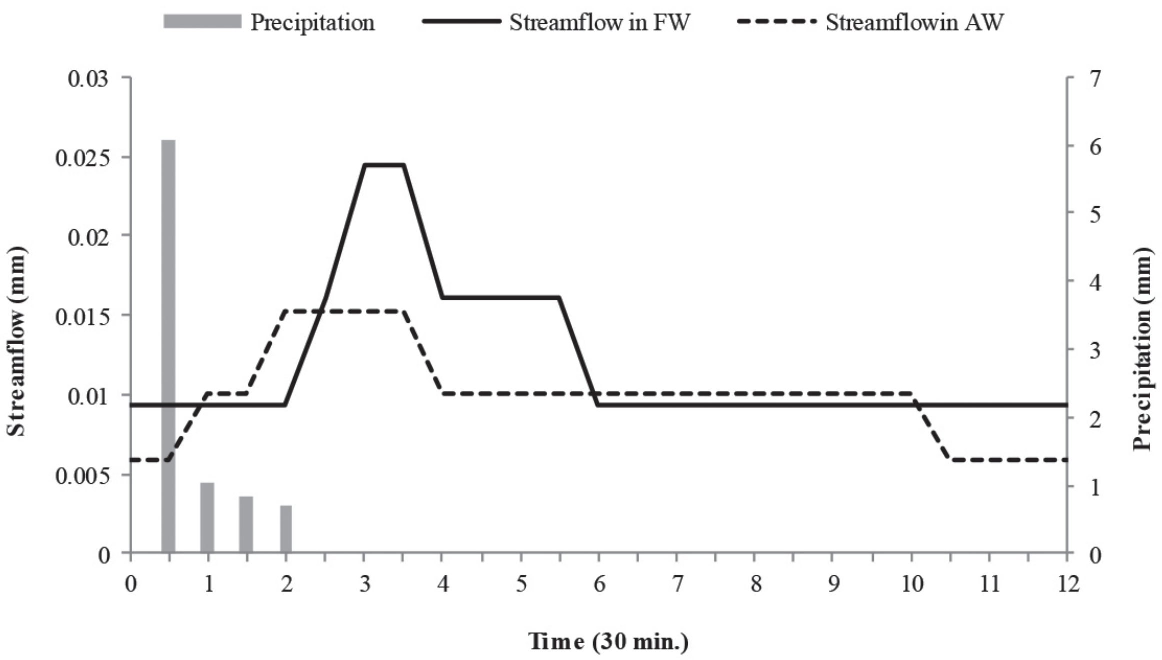

Figure 7. Temporal change of streamflow in 2-hour precipitation event under dry soil condition
Slika 7. Vremenska promjena otjecanja vode u 2-satnom oborinskom događaju u uvjetima suhog tla

found that a high forest cover reduced the runoff coefficient for smaller flood events, while for larger flood events, a high forest cover increased the runoff coefficient compared to agricultural areas due to increased antecedent soil moisture content and subsequent reduction of the moisture retention capacity. In this study, the streamflow of the FW was found to be high for many precipitation events. Similarly, Wang et al. (2014) examined the effect of land use change on runoff generation in two basins by using hydrological model and stated that forest areas have positive effect on runoff generation.

One of the important reasons for the low unit surface water yield of the AW may be the large area covered by limestone bedrock. As a matter of fact, it has been stated that the fissures and fractures in limestone on karst slopes play an important role in surface flow due to their large storage capacity and high infiltration rate (Peng and Wang, 2012). In a study conducted in karst watersheds in China, it was determined that carbonate rock reduced the runoff coefficient (Zhang et al., 2014).

However, in this study, the main reason for the high unit surface water yield of the FW in both wet and dry seasons, compared to that of the AW, was that the values were high for the watershed slope, main channel slope, drainage density and stream frequency, whereas they were low for the watershed area, stream length and flow concentration time. This result is consistent with the findings of studies conducted in other countries. For example, Chen et al. (2010) found that of two forested watersheds, the one on a steep slope generated a more runoff and has a larger quick flow rate than the watershed on a slight slope. Similarly, Liu et al. (2016) reported that the effect of reforestation on the hydrological response was limited and slower in the steeper watershed than the other. This means that in general, steep sloped watersheds have higher streamflow than slight sloped watersheds (Nippgen et al., 2011; Zhang et al., 2014; Wang et al., 2018). Zhang and Wei (2014) found that the varying hydrological responses of two neighboring watersheds where forest harvesting was at a similar level were related to the topography, geology and highly heterogeneous climate characteristics of these watersheds. Zhang et al. (2010) studied watersheds of different sizes and found that measures to reduce surface runoff such as reforestation and terracing in agricultural areas were similarly effective in large watersheds at different rainfall levels, whereas they were less effective in small watersheds at high precipitation levels.

Total suspended sediment (TSS) yields of watersheds – *Produkcija suspendiranog erozijskog nanosa (TSS) u slivovima*

The relationship between the average monthly discharge and the TSS yields of the watersheds was strong and significant ($R^2 = 0.65$ and $P<0.05$ for FW; $R^2 = 0.77$ and $P<0.05$ for AW) (Fig. 8). Gökbulak et al. (2008) and Bywater-Reyes et al. (2018) have also found similar results in their studies. Accordingly, it can be seen that the TSS yield increased with increasing discharge in both watersheds. However, different factors were effective on the amount of TSS in the FW. Therefore, in order to more reliable relationship, more data collection is required at the peak flows in watersheds.

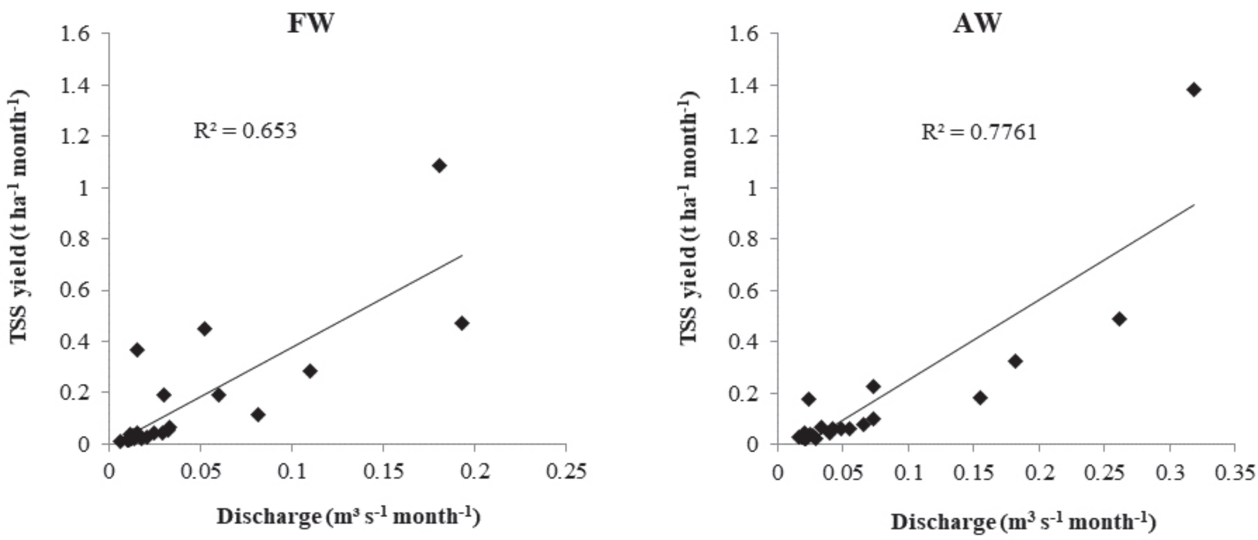

Figure 8. Relationship between average monthly discharge and TSS yields of the watersheds
Slika 8. Odnos između prosječnog mjesečnog otjecanja i produkcije TSS u slivovima

When all the TSS concentrations were examined during the study, it was determined that a higher amount of TSS was transported from the AW than from the FW (Fig. 9). However, after the extreme rainfall event (28.6 mm h^{-1}) in June 2014, the TSS concentrations measured in the FW and AW were 20.1 g L^{-1} and 10.2 g L^{-1}, respectively. Therefore, 5350.2 ton of TSS were transported from the FW and 2969.3 ton from the AW with the streamflow occurring in this month. A similar situation was observed with the TSS measurements after rainfall events in May 2014 (20.4 mm h^{-1}) and September 2015 (16.6 mm h^{-1}). In May 2014, 64.4 ton of TSS were transported from the FW and 43.6 ton from the AW, while in September 2015, 122.2 ton of TSS were transported from the FW and 125.6 ton from the AW.

In 2015, more sediment was carried away in the winter, whereas in 2014, more was carried away in the summer. This is an indication that high amounts of sediment can come from the FW even in the vegetation period or when there are dry soil conditions. There was heavy snowfall in November and December 2014. In February 2015, the amo-

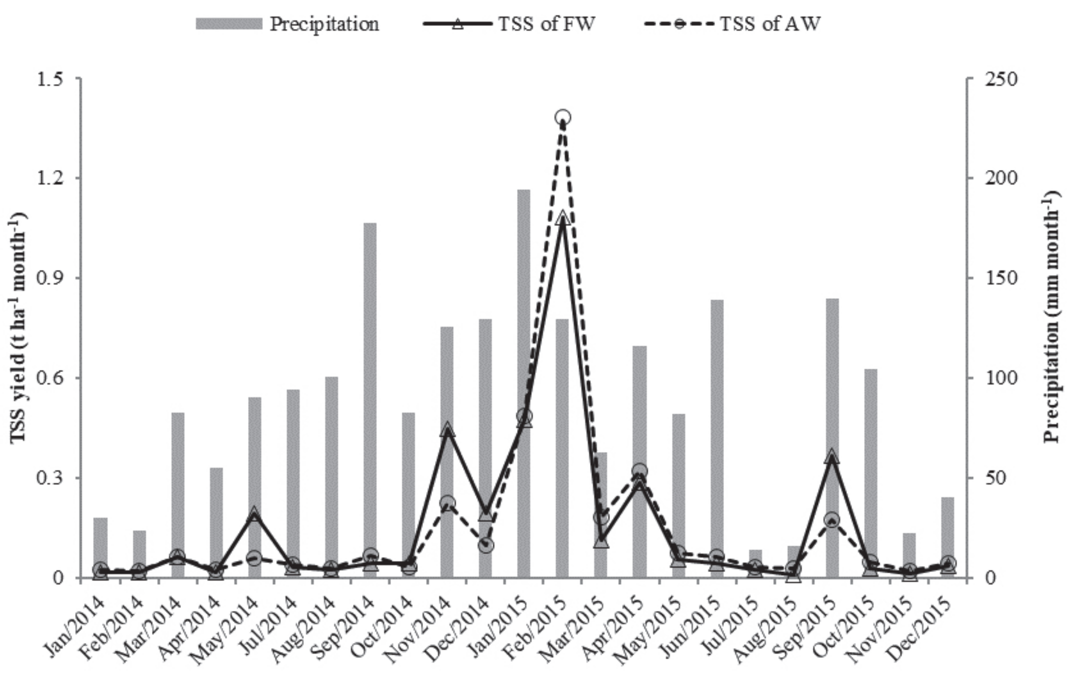

Figure 9. Monthly total precipitation and TSS yields of the watersheds
Slika 9. Ukupna mjesečna količina oborina i produkcija TSS u slivovima

unt of TSS transported from the watersheds was high because of sudden snow melts rather than from rainfall intensity.

In the two years, a total of 6511.7 ton of TSS were transported from the FW and 5503.8 ton from the AW. However there is no significant difference between watersheds for two years in terms of monthly TSS yields (P>0.05). Excluding the exceptionally high TSS yield in June 2014 when extreme rainfall occurred, the 2-year TSS yield was 1161.5 ton and 2534.5 ton for the FW and AW. The amounts in this month constituted 82% and 54% of the sediment transported from the FW and AW in the two years. Similarly, Nearing et al. (2007) determined that one of seven watersheds produced 60% of the 11-year total sediment during two storm events and that this was due to the difference in watershed geomorphology and vegetation cover. Although the unit surface water yield of the FW was higher than the AW, the presence of high amounts of sediment from the FW in only a small number of months shows that forests play an important role in reducing sediment. Therefore, it can be concluded in this study that, aside from extreme precipitation events, there was a positive relationship between the ratio of agricultural land in the watershed and the TSS yield and a negative relationship with the ratio of forested land. This finding was consistent with those of Ahearn et al. (2005), Yan et al. (2013) and Kibena et al. (2014).

Rainfall intensity was also effective in producing high TSS for several months in the FW. Indeed, Nu-Fang et al. (2011) found a significant correlation between sediment transport and total rainfall, peak flow, total water yield, and maximum 30-min precipitation intensity and stated that peak discharge and duration of rainfall were the most important factors controlling suspended sediment transport. Similarly, Zhang et al. (2010) found a positive correlation between precipitation and surface runoff and sediment yield in four watersheds. In a study conducted in watersheds with different land uses, it was found that the difference between suspended sediment concentrations of agricultural and forestred watersheds decreased at high streamflow and increased at low streamflow (Lenat and Crawford, 1994). This finding showed that the amount of TSS of FWs may be higher than in AWs due to the increase in the streamflow.

It is thought that there were two main reasons that more TSS was transported from the FW after an heavy rainfall events. The first reason was that the infiltration was reduced due to the high average slope and short main channel of the FW compared to AW. Thus, in heavy rainfall events, the speed and amount of surface runoff increased in a short time and caused stream bank and bottom erosion. Ebabu et al. (2018), in a similar study carried out in the paired watersheds, found that the unit surface sediment yield of the steep sloped watershed was greater. The second reason was the collapse of the suspended sediment in the stream bed due to be wide of the main channel in the outlet section of the AW and its very low slope. The third reason was that the speed and amount of the surface flow was decreased due to its storage in limestone fissures and fractures in the AW.

CONCLUSION
ZAKLJUČAK

This study evaluated the effects of some watershed characteristics on water and total suspended sediment yields in two adjacent subwatersheds of the Big Melen watershed having the similar climate and soil characteristics. As a result, the unit surface water yield in the steep sloped forested watershed was found to be higher than in the hazelnut plantation dominated watershed, where limestone bedrock occupied a large area. This result showed that the effect on reducing surface runoff in steep sloped forested watersheds was low and therefore, water yields may be higher than in hazelnut plantation dominated watersheds. After heavy rainfall events, a greater amount of suspended sediment was transported from the forested watershed. The forests have a more pronounced effect on reducing sediment transport during low rainfall and in periods of no rainfall. This finding indicated that the positive or negative effect on sediment transport in the forested watershed depended on topography and rainfall intensity. The results of the study showed that the effects of various factors such as slope, rainfall intensity, geological structure, drainage density and frequency of streams may be more dominant on the water and sediment yield of the watersheds than the effect of land use.

This study revealed that when investigating the effect of different land uses on water and sediment yields in paired watersheds, for a better understanding of the effects, the watershed characteristics should be similar. Due to the difficulty of finding paired watersheds and the expense of monitoring streamflows, long-term studies that provide more reliable results at lower cost can be carried out on single watersheds. Moreover, the factors affecting hydrological processes in single watersheds can remain constant over a long time period.

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SAŽETAK

U ovom smo radu istraživali utjecaj različitih značajki sliva na otjecanja vode i na produkciju suspendiranog erozijskog nanosa u slivovima obilježenih dominantno šumarstvom i poljoprivredom (lješnjak), te smo na taj način željeli doprinijeti održivom upravljanju vodnim resursima. Istraživanje je provedeno u podslivovima sliva rijeke Big Melen u zapadnoj crnomorskoj regiji Turske obilježenih dominantno šumarstvom i poljoprivredom. Istraživani slivovi imaju slične klimatske karakteristike. Tlo sliva uglavnom je plitko i ima visoki udio gline. Tipovi uporabe zemljišta u poljoprivrednom slivu sastoje se od 27% šume, 70 % poljoprivrednog zemljišta, i 3% naseljenih mjesta, dok se šumski sliv sastoji od 64 % šume i 36 % poljoprivrednog zemljišta. Topografija šumskog sliva je strma, a njezina geološka struktura sastoji se od pješčenjaka-muljnjaka i sedimentnih stijena. Područje poljoprivrednog sliva je veće i za razliku od šumskog sliva, u njegovoj strukturi nalazimo argilitni vapnenac. Oborine, otjecanje vode i produkcija suspendiranog erozivnog nanosa u slivovima mjereni su od siječnja 2014. do prosinca 2015. godine. Tijekom dvije godine ukupna količina oborina u području istraživanja iznosila je 2217,3 mm. Za određivanje otjecanja vode u slivovima kreirali smo regresijske jednadžbe koje pokazuju odnos između izmjerenog istjecanja i razina vode. Vrijednost R^2 jednadžbe za oba sliva bila je iznad 0,98. Dvogodišnji izračunati prosječni koeficijent otjecanja u šumskim i poljoprivrednim slivovima bio je 0,39, odnosno 0,30. Otjecanje vode u šumskom slivu iznosilo je 867,6 mm, dok je u poljoprivrednom slivu iznosilo 654,9 mm. Glavni razlog za visoku stopu otjecanja vode po jedinici površine u šumskom slivu kako u vlažnim tako i u suhim razdobljima, u usporedbi s poljoprivrednim slivom, leži u činjenici da su vrijednosti za nagib sliva, nagib glavnog kanala, gustoću mreže vodotokova te frekvenciju vodotoka bile visoke. Tijekom dvije godine, produkcija suspendiranog erozivnog nanosa transportiranog iz šumskog sliva iznosila je 19,51 t ha^{-1}, a iz poljoprivrednog sliva 7,70 t ha^{-1}. Međutim, s izuzetkom visokih vrijednosti izmjerenih nakon ekstremnih oborinskih događaja, produkcija suspendiranog erozijskog nanosa po jedinici površine u poljoprivrednom slivu pokazala se višom od one u šumskom slivu. Ovi rezultati pokazuju da značajke sliva, kao što se nagib, geološka struktura i intenzitet oborina, mogu imati veći utjecaj na vodu i ukupnu produkciju suspendiranog erozijskog nanosa slivova nego što to ima način uporabe zemljišta. Ovo je istraživanje pokazalo da bi za bolje razumijevanje utjecaja različitih načina uporabe zemljišta na otjecanje vode i produkciju nanosa u uparenim slivovima značajke slivova trebale biti slične.

KLJUČNE RIJEČI: sliv rijeke Big Melen, korištenje zemljišta, produkcija suspendiranog nanosa, značajke sliva, otjecanja vode