UDK 630* 116 (001)

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 11–12 (2017): 563–569

USING GEOWEPP MODEL TO DETERMINE SEDIMENT YIELD AND RUNOFF IN THE KEKLIK WATERSHED IN KAHRAMANMARAS, TURKEY

KORIŠTENJE MODELA GEOWEPP ZA ODREĐIVANJE PRODUKCIJE NANOSA I OTJECANJA U SLIVU RIJEKE KEKLIK U KAHRAMANMARASU U TURSKOJ

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Summary

GeoWEPP is a geo-spatial interface of the WEPP (The Water Erosion Prediction Project) model that predicts sediment yield and runoff using digital georeferenced information integrated with GIS tools. Besides, the model has ability to determine where the sediment yield and runoff occurs and locates possible deposition places. In this study, GeoWEPP model was used to estimate sediment yield and runoff from Keklik watershed, which is located 12 km from Kahramanmaras in the eastern Mediterranean region. The digital maps of the input files required for GeoWEPP model were generated using GIS tools. The estimated average annual sediment discharge and delivery of watershed were 34533.5 tones and 44.2 tones/ha, respectively. This study indicated that GeoWEPP model can provide decision makers with quick estimation of sediment yield from large watersheds with high accuracy.

KEY WORDS: Sediment Yield, Runoff, WEPP, GeoWEPP, GIS

INTRODUCTION
UVOD

For many years, renewable natural resources in Turkey have been excessively used without considering sustainable management plans; therefore, the natural balance that exists among plant, soil, and water has been adversely affected. However, the future of existing and next generation highly depends on continuous and efficient use of natural resources. Therefore, necessary environmental protection measures should be implemented immediately so that natural resources can be sustainably managed and improved in Turkey.

In Turkey, one of the most important factors that result in detrimental effects on natural resources is considered to be soil loss due to surface runoff by water in the mountainous regions and topsoil removal by wind in steppes (Yuksel et al., 2008). About 54% of the forest lands, 59% of agriculture areas, and 64% of rangelands are subject moderate and severe soil erosion incidents (GDCDE, 2012). In Turkey, slight (7.2%), moderate (20%), severe (36.4%), and very severe (22.3%) soil erosion are observed (GDREC, 2008). Relatively very small proportion of the land area is not subject to erosion incident.

The main reasons of erosion problem in Turkey are rough topographic conditions, destruction of vegetation, unsuitable land use practices, and inadequate erosion control measures. Especially Mediterranean region experiences significant levels of soil erosion due to steep slope throughout

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the region. Soil erosion and runoff generates considerable amount of sediment yield, which leads to dramatic impacts on natural resources. Therefore, it is very important to predict sediment yield and runoff accurately in terms of applying necessary soil conservation techniques in Turkey (Akay et al., 2008).

There have been several models developed to estimate soil loss, erosion assessment, and sediment yield such as RUSLE, CORINE and WEPP. RUSLE (Revised Universal Soil Loss Equation) is used to compute annual soil loss per unit area based on an empirical equation, considering various erosion factors such as climate, soil type, topography, and land type (Renard et al., 1997; Covert, 2003; Yuksel at al., 2007). Based on Universal Soil Loss Equation (USLE) (Wischmeier, 1976), which is well-known methodology in soil erosion assessment studies, CORINE model was developed by European Community (CORINE, 1992). The CORINE has the advantage of providing soil erosion risk maps for entire study area.

The WEPP, The Water Erosion Prediction Project, was developed to estimate sediment yield and soil erosion considering soil type, climate conditions, ground cover percentage, and topographic condition (Flanagan and Livingston, 1995). The WEPP model is capable of calculating infiltration, runoff, erosion and deposition rates for every day and multiple time periods. In WEPP, there is a set of internet-base interfaces which assists users to quickly predict erosion and sediment yield from forest roads, forest lands, rangelands, and wildfire (Elliot et al., 1999; Flanagan and Nearing, 1995).

In recent decades, advances in Geographic Information Systems (GIS) technology made it possible to utilize GIS tools for effectively assessing soil loss and predicting sediment yield (Burrough and McDonnell, 1998). GeoWEPP, a geospatial erosion prediction model, was developed to integrate the advanced features of GIS within WEPP model (Renschler, 2002; Wu et al., 2009). GeoWEPP model provides user with ability to process digital data such as Digital Elevation Model (DEM), air photos, soil maps, and land use maps.

In this study, GeoWEPP was used to estimate the sediment yield from a sample watershed located in the city of Kahramanmaras. The current land use type in the study area is classified as rangeland. Even though there are several studies

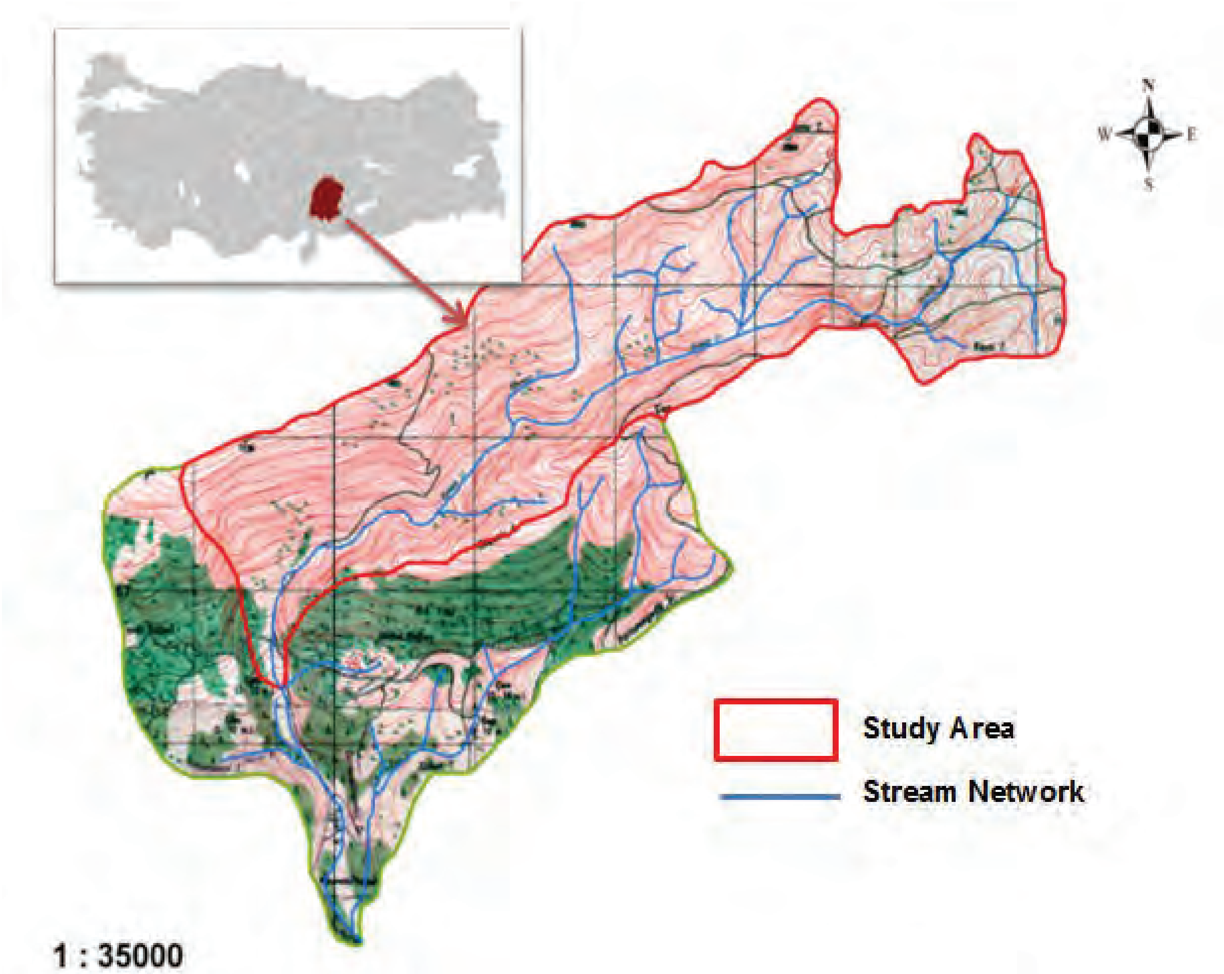

Figure 1. Location map of the study area
Slika 1. Područje istraživanja

in which GeoWEPP was used for various land use types, there are no previous studies that consider only rangeland. Thus, this study will be one of the first researches that utilized GeoWEPP to estimate sediment yield and surface runoff for a study area covered by only rangeland in Turkey.

MATERIAL AND METHOD
MATERIJALI I METODE

Study Area – *Područje istraživanja*

The study area, Keklik watershed, is located 12 km away from the city of Kahramanmaras in the Eastern Mediterranean region of Turkey. Keklik watershed is covered by only rangelands. The bounding geographical coordinates of the study area are 36°52' 30" to 37°37' 30" north latitudes and 37°46' 00" to 37°47' 30" east longitudes (Figure 1). The watershed covers an area of nearly 780.83 hectares and there is no residential area in the basin.

Streams in the study area generally flow into the direction from North to South. The highest point of the study area is Köseburun Hill with 2084 meters and the lowest point is Güzlek Vineyards with 1200 meters of elevation. The region can be defined as a transition zone which has some characteristics of both Mediterranean climate and Continental climate. Thus, there are hot and dry summers and warm and rainy winters. Average annual precipitation of the study area is over 976.50 mm. Average, annual maximum and minimum temperatures are 41.1 °C (July) and -10 °C (February), respectively. In soil water balance; excess water is seen during January to March and the water deficit is seen during June to October.

According to soil maps which were produced by The General Directorate of Rural Service, the majority of the soils are consisted of Brown Forest Soils with Marn-Chalk and Reddish Brown Mediterranean Soils with limestone. The study area was used for grazing purposes. Uncontrolled and over capacity grazing over years has led to destruction of both herbaceous and climax vegetation significantly. There are number of endemic species (*Astragalus akmanii, Polygonum ekimianum, Helleborus vesicarius, Echinops vaginatus, Ankyropetalum reuteri,* etc.) in the study area; however, heavy grazing has negatively affected existence of these species. Besides, rangeland activities have been made without any soil and water conservation measures. As a result, actively continuing surface erosion is observed in the area, which is the main source of sedimentation.

GeoWEPP – *GeoWEPP*

GeoWEPP is a model that integrates WEPP v2006.5 model with TOPAZ (TOpography PArameteriZation), CLIGEN (CLImate GENeration) and GIS tool (ArcView 3.2) (Renschler, 2002) (Figure 2). TOPAZ was used to generate hillslope profiles by parameterizing topographic data based on DEMs. (Minkowski, 2007; Garbrecht and Martz, 1997) Subcatchment profiles were produced by defining the channel network based on the steepest downslope path.

CLIGEN, a stochastic weather generation model, was used to generate various climate data including daily values of precipitation, temperature, relative humidity, and wind speed. ArcView 3.2 was used to generate the watershed outputs as grid layers representing soil loss as a percentage of the Tolerable Soil Loss (TSL). Then, the runoff and sediment yield data for each pixel were produced in grid outputs as well as in text files. Text files also indicated average annual rainfall, number of storms, and soil loss for each sub-watershed.

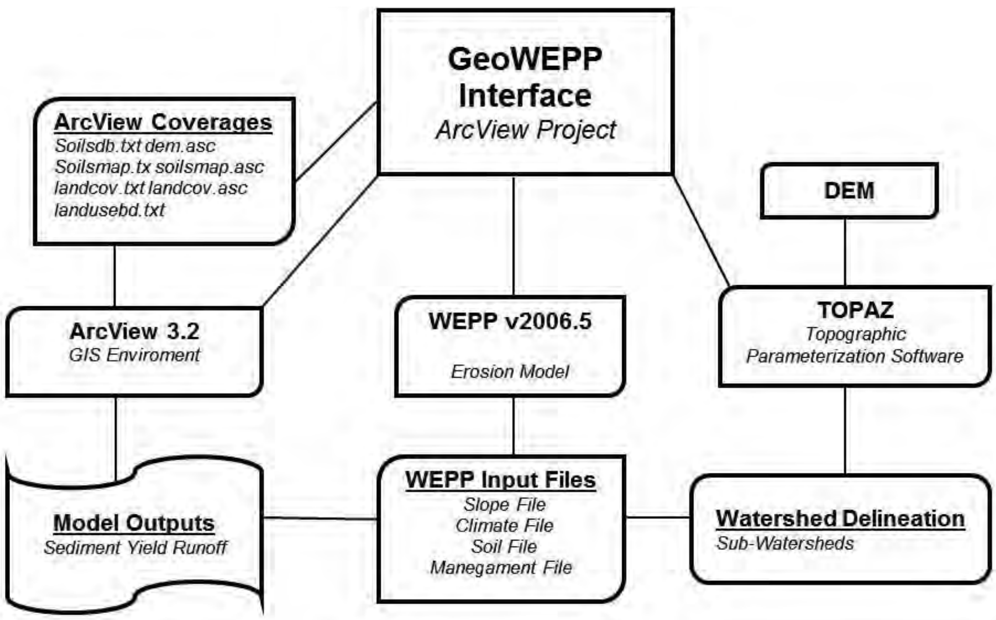

Figure 2. Logic flowchart of the GeoWEPP (Covert, 2003)
Slika 2. Logički dijagram toka modela GeoWEPP

WEPP INPUT DATA FILES
ULAZNI PODACI PROJEKTA WEPP

To describe hillslope geometry, meteorological characteristics, soil properties, and ground cover, four input files including slope, climate, soil, and management files were produced. The slope file consisted of necessary hillslope parameters such as slope gradient, shape, width and orientation along its length. TOPAZ was used to produce sub-catchment profiles based on DEMs (30 m x 30 m). Then, the soil and management data are assigned into each sub-catchment so that spatial variability between sub-catchments can be represented.

To generate climate data, „Rock: Clime" application in WEPP was used to access database of PRISM (Parameter-elevation Regressions on Independent Slopes Model), which estimates precipitation and temperature based on orographic effects (Daly et al., 1994). „Rock: Clime" is able to read and adjust the inputs of monthly average precipitation and temperature values (Elliot and Hall, 2000). Climate data for the study area were first obtained from the weather station in the city of Kahramanmaras, and then entered into the WEPP as a climate file of CLIGEN.

The soil data, which are used in GeoWEPP to predict erosion, include soil texture (sand, **dust**, and clay ratio), organic matter content, and cation exchange capacity values. These soil properties were determined based on field study and laboratory analysis. Soil sample plots were taken from different bedrocks (sandstone and limestone), elevation levels (1250-1650 m and 1650-2050 m) and aspect groups (north and south), according to „Factorial Trial Design" approach. Besides, disturbed and undisturbed soil samples were taken from two different soil depth classes (0-20 cm and 20-50 cm).

Table 1. Slope classes of the study area
Tablica 1. Klase nagiba područja istraživanja

Slope Classes *Klase nagiba*	Area (ha) *Područje (ha)*	Ratio (%) *Omjer (%)*
Flat (0–2%) *Ravni (0–2%)*	5.13	0.6
Low (2–6%) *Blagi (2–6%)*	23.13	2.9
Medium (6–12%) *Umjereni (6–12%)*	97.74	12.1
High (12–20%) *Veliki (12–20%)*	214.29	26.6
Very high (20–30%) *Vrlo veliki (20–30%)*	327.87	40.7
Steep (> 30%) *Strmi (> 30%)*	138.06	17.1
Total *Ukupno*	806.00	100.0

Management file data (i.e. plant height, vegetation surface ground cover, grazing periods, etc.) were obtained by field studies and then entered into the model. The management file was generated for each sub-watershed for every year of simulation. Then, the land cover layer was generated based on management file using GIS tool.

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

Physiographic and climatic factors – *Fiziografski i klimatski čimbenici*

In this study, the soil loss, sediment yield, and runoff values for a sample watershed in Kahramanmaras were predicted by using GeoWEPP model. The study was conducted in

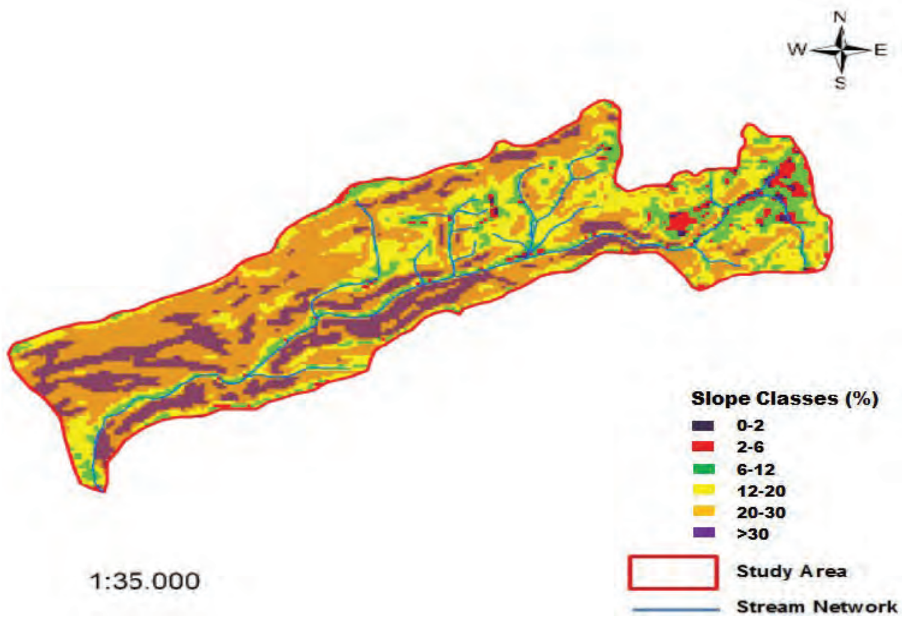

Figure 3. Slope map of the study area
Slika 3. *Karta nagiba područja istraživanja*

Figure 4. A view from Keklik watershed indicating steep topography
Slika 4. Pogled sa sliva rijeke Keklik, koji prikazuje strmu topografiju

Keklik watershed covered by only rangeland. Physiographic and climatic factors (slope, aspect, soil, landuse, and climate) of the study area were determined to provide WEPP input data files required for the prediction process.

The topographic conditions are important in terms of erosion and surface runoff in watersheds (Yuksel et al., 2007). Especially, average ground slope plays important role in formation of surface runoff. The results indicated that the average slope in the watershed was 45.7%. Based on the digital slope map of the study area (Figure 3), about 84.4% of the watershed was classified as high, very high, and steep slope (Table 1). This topographic condition increases water erosion and sediment delivery (Figure 4).

The aspect of the study area was mostly south aspect (55.7%), followed by north (31.5%), west (10.9%), and east aspects (1.9%). In general, the watershed represents the typical climate and vegetation features of southern aspects. The soil loss and runoff is usually higher in southern aspects since vegetation cover density is potentially less than that of other aspects (Balci, 1996).

The results from laboratory analysis and field studies indicated soils are usually located on sandstone and limestone bedrocks. Soil textures characteristics formed from these rocks were sandy loam, clay, sandy clay loam, and loam. Geological and pedological properties of soils affect soil losses (Butorac et al., 2009). The watershed can be subject to surface runoff risk due to lower infiltration capacity of clay soils. It was also found that the average dispersion ratio (76%), as one of the erodibility indices, was greater than the boundary value of 15% (Nipon and Kasem, 1969). Thus, it can be concluded that the study area of soils in Keklik watershed is generally susceptible to erosion.

Climate data including average precipitation and temperature values, obtained from local weather station, were 976.50 mm, and 15.2 °C, respectively. Since most of the precipitation in the watershed occurs as snow, rainfalls and melted snow during spring season results in high runoff effects.

Management data obtained by field studies indicated that plant height and vegetation surface ground cover was found as 30 cm (maximum) and 16%, respectively. The grazing periods in the watershed was from April to mid of November.

Sediment Yield and Runoff – *Produkcija nanosa i otjecanje*

Sediment yield and runoff values were computed once generating WEPP input data files using CLIGENE, TOPAZ,

Table 2. The summary table showing hydrological and sediment yield data computed by WEPP
Tablica 2. Sažeti prikaz podataka hidrološke produkcije i produkcije nanosa izračunatih pomoću WEPP-a

Average Annual Delivery From *Prosječna godišnja produkcija iz*	Values *Vrijednosti*
Total contributing area *Ukupno područje utjecaja*	780.83 ha
Precipitation volume in contributing area *Količina padalina u području utjecaja*	7624810 m^3/yr
Water discharge *Protok vode*	710201 m^3/yr
Sediment discharge *Protok nanosa*	34533.5 tones/yr
Sediment delivery per unit area of watershed *Produkcija nanosa po jedinici površine sliva*	44.2 tones/ha/yr
Sediment Delivery Ratio for Watershed *Omjer produkcije nanosa za sliv*	0.591

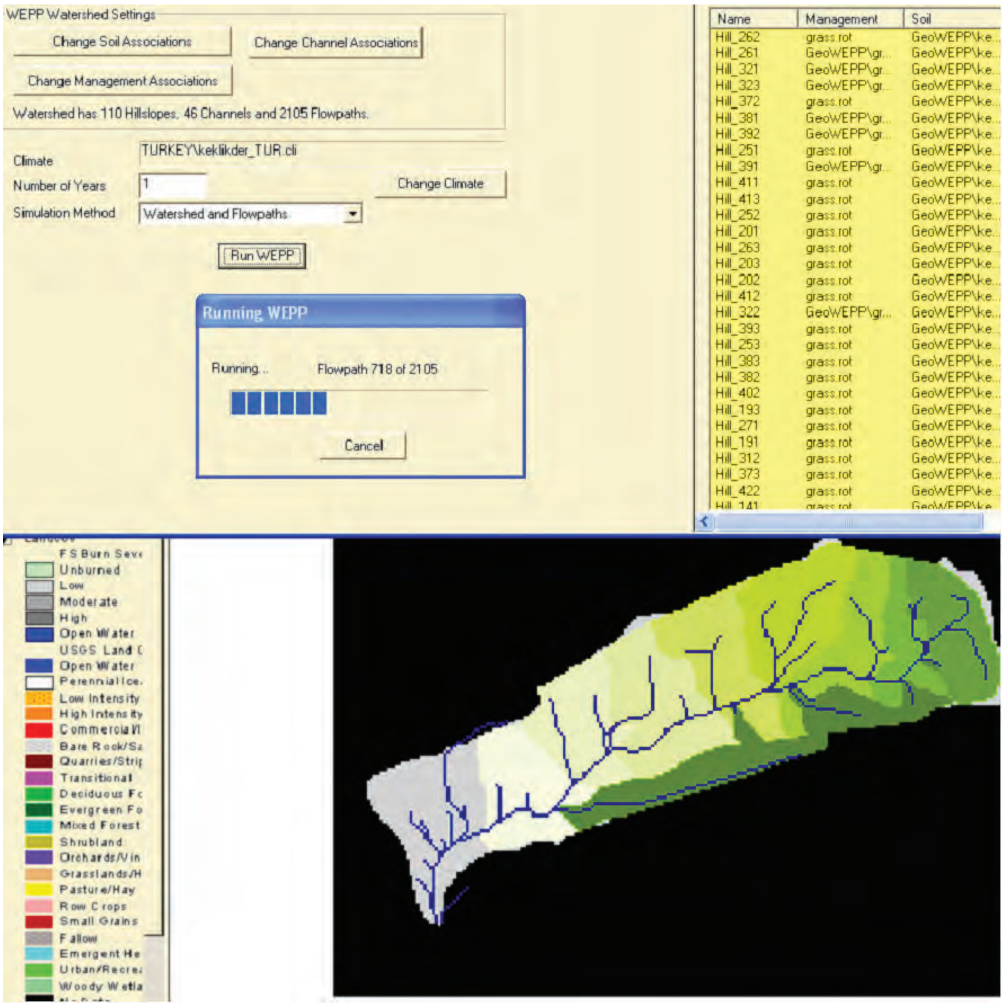

Figure 5. GeoWEPP interface working with WEPP/TOPAZ integration

Slika 5. Sučelje GeoWEPP u radu s integracijom WEPP/TOPAZ

and GIS tool (Figure 5), based on 110 hill slopes in the basin. The hydrological and sediment yield data computed by WEPP model was indicated in Table 2. The annual sediment yield occurring in the basin was 34533.5 tones, while annual sediment yield per unit area (hectare) was computed as **44,2 tones**. The annual sediment deposition from the basin was determined as 7395.52 tones. The results indicated that runoff passing through the watershed outlet on an average annual basis was 600036 m^3 based on the 17 storm events.

CONCLUSIONS
ZAKLJUČCI

This study was one of the first applications of GeoWEPP that searched for sediment yield and runoff in a rangeland area in Turkey. The results indicated that sample watershed was subject to erosion risk because the vegetation cover density was low (16%) and ground slope was classified as high, very high, and steep in most of the study area. It was found that GeoWEPP model could help watershed managers to generate accurate runoff and sediment yield outputs in text and/or graphical format using the digital data sources of a watershed. The model also gives the information for areas with high sediment delivery potential to watershed managers. For this reason, watershed managers can locate the problematic areas easily in a dam watershed and implement necessary precautions to prevent or minimize the sediment yield. In this particular study, input data and the components of GeoWEPP were described briefly and a sample was given as an example so that people who are interested in can use GeoWEPP in their areas of interests. It is highly expected that GeoWEPP users will increase in Turkey within a short period of time as more people use GIS techniques and computer based methods in their erosion prediction studies.

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Sažetak

GeoWEPP predstavlja geoprostorno sučelje modela iz Projekta predviđanja vodene erozije (eng. WEPP), kojim se predviđa produkcija nanosa i otjecanja pomoću digitalnih georeferentnih informacija integriranih s alatima GIS-a. Osim toga, modelom se može odrediti mjesto produkcije nanosa i otjecanja te moguća mjesta sakupljanja nanosa. U ovom je istraživanju model GeoWEPP korišten za procjenu produkcije nanosa i otjecanja u slivu rijeke Keklik, koja je smještena 12 km od Kahramanmarasa u istočnoj sredozemnoj regiji. Digitalne karte ulaznih datoteka koje su potrebne za model GeoWEPP generirane su pomoću alata GIS-a. Procijenjeni prosječni godišnji protok nanosa sliva iznosio je 34533,5 tona, dok je produkcija nanosa iznosila 44,2 tone/ha. Ovo je istraživanje pokazalo da model GeoWEPP može donositeljima odluka dati brzu i vrlo preciznu procjenu produkcije nanosa u velikim slivovima.

KLJUČNE RIJEČI: produkcija nanosa, otjecanje, Projekt predviđanja vodene erozije (WEPP, GeoWEPP), GIS