USING THE WEPP MODEL TO PREDICT SEDIMENT YIELD IN A SAMPLE WATERSHED IN KAHRAMANMARAS REGION

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ABSTRACT

Considerable amount of sediment yield reaches into streams, lakes, and dam reservoirs from 26 major watersheds in Turkey. Several models have been developed to estimate the sediment yield from watersheds. WEPP (Water Erosion Prediction Project) model is one of the most common model which not only predicts the amount of sediment yield but also determines where and when the sediment production occurs and locates possible deposition places. Besides, the geo-spatial interface for WEPP model (GeoWEPP) can use digital geo-referenced information by integrating with the most common GIS tools (i.e. ArcView, ArcGIS) . Therefore, watershed managers can decide the most appropriate soil erosion conservation and sediment prevention techniques for a specific watershed based on the WEPP outputs in text or graphical format. The sediment yield from a watershed in Kahramanmaraş region (Ayvalı Dam Watershed) was estimated by using GeoWEPP model. In this study, process of estimating sediment yield from a specific sub watershed located in a forested area was presented to indicate the performance of GeoWEPP. This study indicated that using GeoWEPP can provide watershed managers with quick estimation of sediment yield from large watersheds in high accuracy.

Keywords: WEPP, GeoWEPP, Sedimentation, Dam Watershed, Kahramanmaraş,

1. INTRODUCTION

In Turkey, 20% of the topsoil has moderate, 36% has severe and 22% has very severe soil erosion occurs due to uncontrolled runoff and top soil removal by water in the mountainous regions and by wind in forest steppes [GDREC, 2001]. Especially in heavily populated areas, extreme exploitation of forest for fuel, charcoal, and grazing results in excessive deforestation. Soil erosion and unimpeded runoff changes the streamflow regime and generates considerable amount of sediment yield, which leads to dramatic environmental impacts on water quality and aquatic habitat. Over 345 million ton sediment yield reaches to the rivers in Turkey [GDREC, 2001]. Sediment yield can reduce economic lifetime of the dams which are very important in preserving water resources and generating hydroelectricity in Turkey. There are over 550 dams constructed on major rivers and most of them are subject to severe sedimentation impacts. Therefore, accurate and quick sediment prediction in dam watersheds is crucial in planning and applying necessary soil conservation techniques.

There have been several sediment prediction models developed to estimate sediment yield such as RUSLE, EPIC, ANSWERS, CORINE, ICONA and WEPP. In RUSLE (Revised Universal Soil Loss Equation) , the annual soil loss per unit are is estimated using an emprical equation developed based on various erosion factors considering all climates, soil types, topography, and land types [Renard, et al., 1997].

The EPIC (Erosion Productivity Impact Calculator) model assesses the effect of soil erosion on soil productivity to determine the effect of management strategies on soil and water resources [EPIC, 2004]. EPIC has some advanced features including weather simulation, hydrology, erosionsedimentation, nutrient cycling, pesticide fate, plant growth, soil temperature, 17 tillage, economics, and plant environment control.

ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation) , one of the first true distributed parameter hydrologic models, was developed to evaluate the effects of best management practices on surface runoff and sediment loss from agricultural watersheds [Beasley et al., 1980] . The upgraded version of this model was developed to improve nutrient submodels and to allow a user to perform long term continuous simulation [Bouraoui and Dillaha, 1996]. CORINE model was developed by European Community based on Universal Soil Loss Equation (USLE) [Wischmeier W.H, 1976.], which is well-known methodology in soil erosion assesment studies [CORINE, 1992]. The CORINE has the advantage of providing erosion prediction for the entire research area. Mapping soil erosion risk with CORINE methodology is very important for the integration of future scientific studies between European Community and Turkey [Bayramin et al., 2006]. ICONA erosion model, which is similar to CORINE, requires entering large amount of detailed geological data [Bayramin et al., 2006]. ICONA is useful for large areas but does not consider climatic data.

WEPP, The Water Erosion Prediction Project, was developed to estimate sediment yield and soil erosion based on specific erosion factors including soil type, climate conditions, ground cover percentage, and topographic condition [Flanagan and Livingston, 1995]. WEPP model calculates infiltration, runoff, erosion and deposition rates for every day and multiple time periods. Since WEPP is process-based model, it requires great amount of input data to evaluate erosion and sediment yield potentials [Flanagan, D.C.,et al.1995]. In order to simplify WEPP applications, FS WEPP (Forest Service WEPP) was developed as a set of internet-base interfaces which assists a user to quickly predict erosion and sediment yield from forest roads, forest lands, rangelands, and wild-fire [Elliot et al. 1999a].

GeoWEPP, a geo-spatial erosion prediction model, was developed to integrate the advanced features of GIS (Geographical Information System) within WEPP model such as processing digital data sources and generating digital outputs [Renschler 2002]. The current version of GeoWEPP allows a user to process digital data such as Digital Elevation Model (DEM), ortho-photos, soil surveys, land use maps, and precision farming data. In this study, GeoWEPP was used to estimate the sediment yield from a sample watershed located in the city of Kahramanmaraş. The functions and capabilities of GeoWEPP were presented by appliying the model for a sub-watershed in the study area.

2. MATERIAL AND METHODS

2.1. STUDY AREA

Ayvalı Dam Watershed, located in approximately 25 km southeastern of Kahramanmaras, was selected as a study area because it represents the land, soil, and vegetation characteristics of the region (Figure 1). The study area is 11 531 ha in which 6984 ha is forest land, 1688 ha is rangeland, and 2859 ha is agricultural area. The dominant tree species in the forest are *Pinus brutia*, *Cedrus libani*, *and Quercus brantii*. The average ground elevation and average-slope were 1 430 m and 35 %, respectively. A sample sub-watershed was selected from forested areas in the study area. The sub-watershed with 12 hillslopes covers approximately 48 ha forested area and receives average annual precipitation of 552.42 mm.

2.2. SEDIMENT PREDICTION

GeoWEPP integrates WEPP, TOPAZ (TOpography PArameteriZation) , and ArcView to predict sediment yield at the hillslope and watershed scale [Renschler, 2002] (Figure 2) . In GeoWEPP, necessary input files (slope, climate, soil, and management) are generated within WEPP and topographic data is parameterized by using TOPAZ based on DEMs. Finally, watershed outputs are produced by using GIS functions in ArcView.

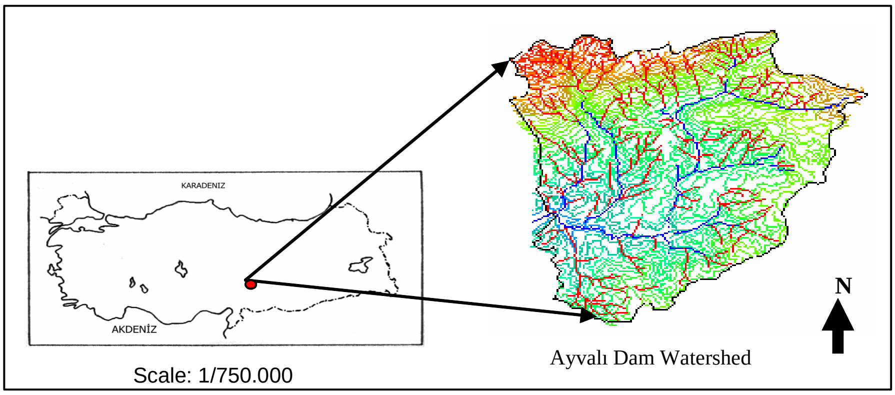

Figure 1. Study area.

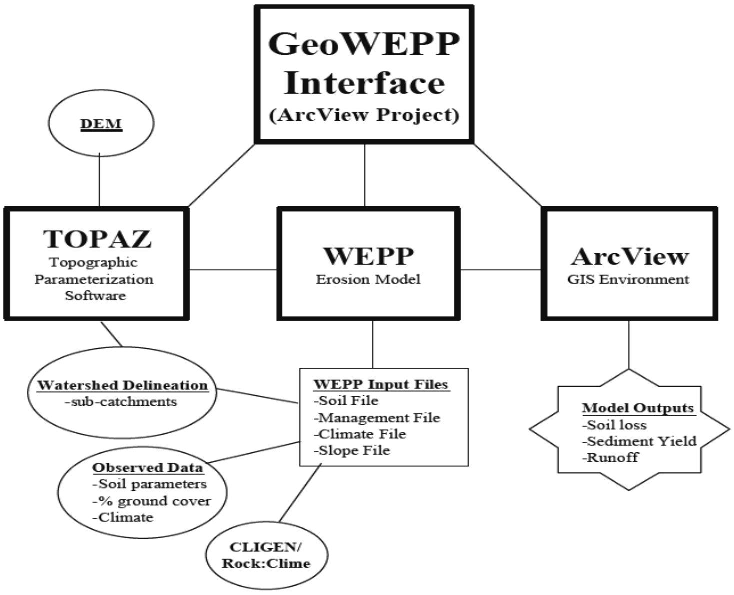

Figure 2. Logic flowchart of the GeoWEPP in estimating sediment yield [Covert, 2003].

2.2.1. WEPP INPUT FILES

WEPP model requires four input files including slope, climate, soil, and management files to describe hillslope geometry, meteorological characteristics, soil properties, and ground cover, respectively.

Slope File

The slope file is generated based on necessary hillslope parameters such as slope gradient, shape, width, and orientation along its length. GeoWEPP utilizes TOPAZ to produce sub-catchment profiles. The soil and management data can be assigned into each sub-catchment; therefore, users can represent spatial variability between sub-catchments. In this study, sub-catchments and channels in the study area was derived from 30-m DEMs, generated by using TOPAZ based on the 1/25 000 scale topographic maps (Figure 3). The functionality and features of TOPAZ will be described in the following section.

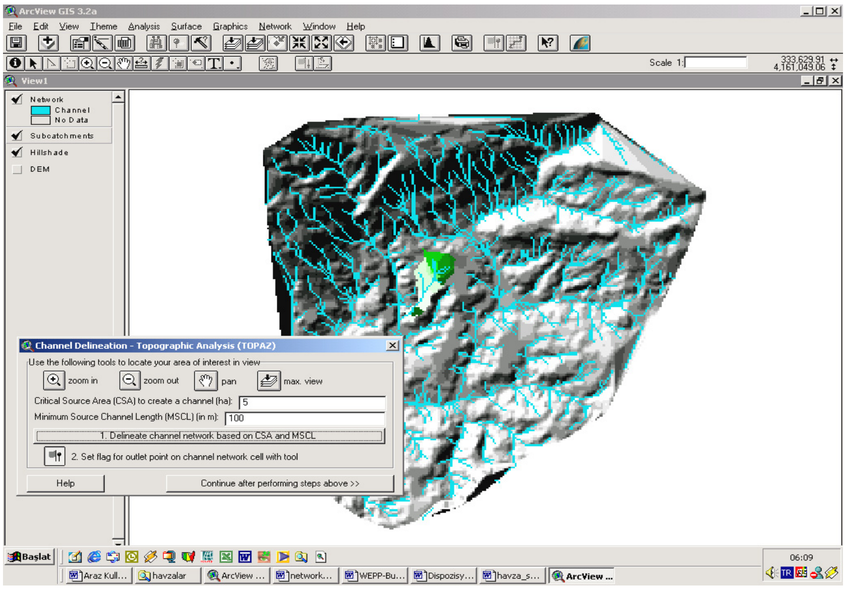

Figure 3. Delineation of watershed using the TOPAZ.

Climate File

To generate climate file with daily values of precipitation, temperature, solar radiation, and wind speed obtained from the weather stations, the WEPP model uses CLIGEN, which is a stochastic weather generation model [USDA ARS and USFS 2003]. For a specific location and length of time, the Rock: Clime application in FS WEPP is used to determine spatial climate variability in mountain regions [Elliot et al. 2002]. To generate climate data, Rock: Clime can access database of PRISM (Parameter-elevation Regressions on Independent Slopes Model), which estimates precipitation and temperature based on orographic effects [Daly et al. 1994] . In Rock: Clime, the inputs of monthly average precipitation and temperature values can be adjusted [Elliot, W.J., and D.E, Hall., 2000]. Since meteorological database in Turkey is not generated in the data format of CLIGEN model, climate parameters for the study area were obtained from the weather station in the cith of Kahramanmaras and tramsformed into the format used in CLIGEN (Figure 4). The climate parameters incude maximum and minimum air temperature, relative humidity, precipitation, solar radiation, and wind speed.

```
0.00
1  1  0
Station: KMARAS                    CLIGEN VERSION 0.0
Latitude Longitude Elevation ( m)  Obs. Years   Beginning year  Years simulated
37.36  36.56       572                  50              99              1
Observed monthly ave max temperature ( C)
7.0     10.0     15.2   22.4      27.4    33.4    39.2    36.3      31.9     24.2     20.7      11.4
Observed monthly ave min temperature ( C)
0.3     0.4      3.8    11.8      14.8     19.6    23.3    22.2     18.6 1     2.3       7.1        3.0
Observed monthly ave solar radiation ( Langleys/day)
143.6  226.38  371.17   392.05 568.81 677.63 634.88  527.48 430.04 285.33 210.40  145.75
Observed monthly ave precipitation ( mm)
237.5  105.6   68.3  36.5   4.7   0.1   0.0  3.0    30.2 37.2   54.5    102.7
da      mo      year    nbrkpt   tmax )  tmin    rad     wind    wind    tdpt
( mm)   ( C)    ( C)    ( l/d)   ( m/sn) ( deg)  ( C)
1       1       99      0        14.2    3.0     229.    0.0     0.      -0.1
2       1       99      0         9.0    1.6     152.    0.0     0.      -1.0
3       1       99      0        12.4    -1.0    208.    0.0     0.      -0.8
4       1       99      0        13.6    1.8     187.    0.4     250.    -1.3
5       1       99      2         8.0    1.8      74.    0.4     270.    1.5
19.38   0.0
24.00   1.4
6       1       99      2        11.0    2.8     134.    0.3     250.    3.3
00.00   0.0
00.58   3.1
7       1       99      0        14.0    2.8     200.    0.0     0.      0.4
8       1       99      0        11.6    1.6     192.    0.0     0.      0.7
9       1       99      0        14.2    0.8     199.    0.2     250.    2.5
10      1       99      6         9.4    5.4      74.    0.2     250.    6.5
23.08   0.0
24.00   0.6
00.05   0.6
00.58   1.2
10.48   1.2
24.0    2.6
11 1    99      0       12.2     0.7     190.    0.1     0 .     4.5
12 1    99      0       11.6     0.5     199.    0.2     250.    2.5
```

Figure 4. Climate file generated by CLIGEN.

Soil File

Accurate representation of soil property values in WEPP is essential for sediment prediction. In WEPP, critical parameters in the soil file are soil texture, albedo, saturation level, hydraulic conductivity, rill erodibility and interrill erodibility, and critical shear. These parameters can be obtained from data collection or calculated by the WEPP model. In this study, after collecting soil samples from the selected sub-watersheds in study area and analyzing them in the soil labrotary, some of the soil properties including soil texture, albedo, saturation level, soil depth, sand-clay-organic matter ratios, cation exchange capacity, and rockness were entered into soil input file. The values of the other properties such as rill and interrill erodibility, critical shear, and hydraulic conductivity were calculated by WEPP model. Finally, soil input file is generated for each sub-watersheds (Figure 5).

Management File

The amount of ground cover is indicated in management file based on growth and mortality parameters. WEPP generates interrill cover data for each year using growth parameters, soil data, and climate data. To generate the desired amounts of ground cover for each site for each year, WEPP adjusts the biomass energy ratio in the management file. In this study, after entering necessary management file data for the study area, the management file was generated for each sub- watershed for each year of simulation (Figure 6).

```
97.5 ( satır 1)
#
# Created by A YUKSEL, Mon Oct 10, 12:55:53, PM 2001 ( satır 2)
# Author: Alaaddin YUKSEL
#
Kızılcam Mescersi
1   1
“Ayvalı_Forest”  Kumlu Balcık'      3       0.23     0.7500   2e+005  0.0005  2   20
        200     67.940   11.650   2.640   12.00    20
        500     66.090   12.810   1.320   9.000    15
        1000    64.250   14.550   0.450   9.000    14
```

Figure 5. Soil file produced by WEPP.

```
8.4
#
1 # number of OFE's
1 # (total) years in simulation

#
# Plant Section
#

1  # Number of plant scenarios

Tre_2932
Twenty-year old forest  for disturbed WEPP  A. YUKSEL  02/01  1  #landuse
WeppWillSet
14.00000 3.00000 150.00000 2.00000 5.00000 5.00000 0.00000 20.00000 0.50000 0.25000
0.25000 0.70000 0.90000 0.99000 17.00000 0.00000 0.42000 5.00000
2  # mfo - <non fragile>
0.00600 0.00600 20.00000 0.10000 2.00000 2.00000 0.33000 0.50000 300 40.00000
0.00000 6.00000 0.00000
```

Figure 6. Management file produced by WEPP.

2.2.2. TOPAZ

In GeoWEPP, hillslope profiles are generated by utilizing TOPAZ, which parameterizes topographic data based on DEMs. TOPAZ determines the channel network based on the steepest downslope path, considering 8 adjacent cells of each raster cell (pixel) [Garbrecht and Martz, 1997]. The channel network can be adjusted by changing values of Mean Source Channel Length (MSCL) and Critical Source Area (CSA). The MSCL defines the shortest channel length and the CSA is the minimum drainage area [Garbrecht and Martz, 1997]. After defining the channel network, TOPAZ generates the sub-catchments which represent the watershed.

2.2.3. ARCVIEW

The GeoWEPP model has a feature of being run in ArcView. The watershed outputs are generated as grid layers representing soil loss as a percentage of the tolerable soil loss (TSL) . In the grid layers, areas that generate soil loss values greater than or less than the TSL are highlighted. The runoff and sediment yield data for each pixel can be produced in text files or in grid outputs. Text files indicate average annual rainfall and number of storms, total runoff, soil loss, and sediment yield for each sub-watersheds and for the entire watershed.

3. RESULTS

The sediment yield from Ayvalı Dam Watershed was estimated and the results from the sediment yield assessment of a specific sub-watershed located in a forested area were indicated (Figure 7). Sediment yield from diffirent landuse types in the entire watershed were presented in Table 1. The results indicated that the highest sediment yield per unit area produced from agricultural lands, and followed by rangelands and forest lands.

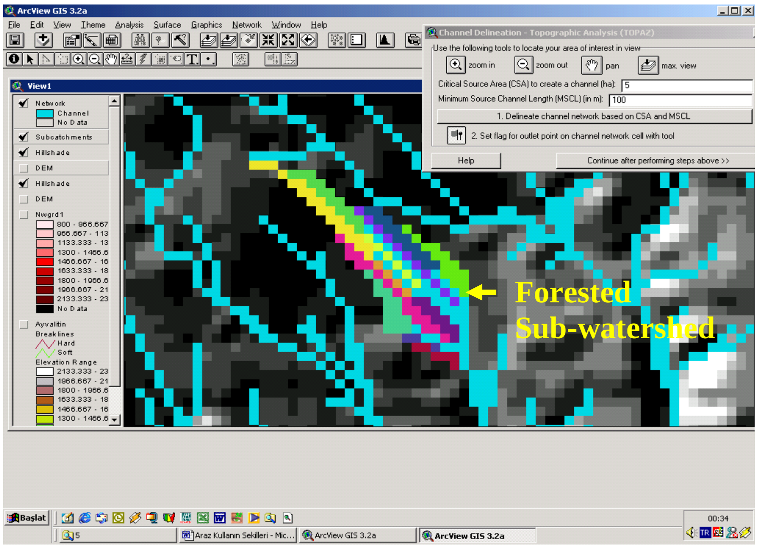

Figure 7. Delineation of sub-watershed in GeoWEPP environment.

Table 1. The sediment yield predictions from the study area considering different land use types.

Land Use Types	Area (ha)	Ratio (%)	Sediment (ton/yr)	Average Sediment (ton/ha/yr)
Forest	6983,66	60,56	9035,06	1,32
Rangeland	1687,74	14,64	7910,31	4,69
Agricultural	2859,60	24,80	68589,62	23,95
Total	11531,0	100	85534,99	29,96

The sample sub-watershed selected from a forested land in the study area consisted of 12 hillslopes (Figure 8). In the sub-watershed, the total contributing area to outlet, average annual precipitation volume, and water discharge from outlet were found to be 48.39 ha, 267 298 m^3/yr, and 4480 m^3/yr, respectively. Total of 68 storms produced 552.42 mm of rainfall and 9.26 mm of runoff passing through the watershed outlet on an average annual basis.

The results indicated that average annual sediment discharge from the outlet was 44.9 ton/yr, which resulted in unit sediment delivery of 0.9 ton/ha/yr. Total sediment deposition of 4.53 ton/yr occurred in three hilslopes.

WEPP Watershed Simulation for Representative Hillslopes and Channels

1 YEAR AVERAGE ANNUAL VALUES FOR WATERSHED

# Hillslopes		Runoff Volume (m^3/yr)	Soil Loss (kg/yr)	Sediment Deposition (kg/yr)	Sediment Yield (kg/yr)
22	1	191.0	98.2	0.0	98.2
33	2	538.2	708.4	0.0	708.4
31	3	359.4	97.3	0.0	97.3
32	4	151.3	129.1	0.0	129.1
42	5	273.9	127.7	0.0	127.7
51	6	366.6	3690.7	3690.5	0.2
52	7	201.8	170.1	0.0	170.1
71	8	273.3	69.3	69.0	0.3
72	9	302.6	255.2	0.0	255.2
82	10	430.4	1428.7	0.0	1428.6
81	11	359.2	767.8	767.4	0.4
83	12	456.7	389.6	0.0	389.6

# Channels and Impoundments		Discharge Volume (m^3/yr)	Sediment Yield (tonne/yr)
84 Channel	1	1338.0	7.3
74 Channel	2	738.8	9.4
64 Channel	3	2094.6	18.5
54 Channel	4	714.3	7.9
44 Channel	5	3118.3	33.4
34 Channel	6	1143.1	5.4
24 Channel	7	4479.9	44.9

68 storms produced 552.42 mm. of rainfall on an AVERAGE ANNUAL basis

71 8 events produced 9.26 mm. of runoff passing through the watershed outlet on an AVERAGE ANNUAL basis

Average Annual Delivery From Channel Outlet:

Total contributing area to outlet	=	48.39 ha
Avg. Ann. Precipitation volume in contributing area	=	267298.0 m^3/yr
Avg. Ann. irrigation volume in contributing area	=	0.0 m^3/yr
Avg. Ann. water discharge from outlet	=	4480.0 m^3/yr
Avg. Ann. sediment discharge from outlet	=	44.9 tonnes/yr
Avg. Ann. Sed. delivery per unit area of watershed	=	0.9 T/ha/yr
Sediment Delivery Ratio for Watershed	=	0.914

Figure 8. Sediment yield summary for the sub-watershed.

4. CONCLUSIONS

GeoWEPP model was implemented to estimate total sediment prediction from a dam watershed from Kahramanmaras region. The results from a sample forested sub-watershed were also presented. It was indicated that the GeoWEPP model can assist watershed menagers to quickly and accurately generate runoff and sediment yield outputs in textual or graphical format based on digital data sources of a watershed. Besides, the model provides the managers with the information of areas with high sediment delivery potential. Therefore, watershed managers can locate the problematic areas in a dam watershed and implement necessary precaution measures to minimize or prevent sediment yield.

In this study, the components and input files of GeoWEPP were briefly described to provide scientists and practioners with a simple example, so that, they can use GeoWEPP in their field of interests. It is highly anticipated that interests in using GeoWEPP will be increasing in Turkey as more people utilize advanced GIS techniques and computer-based methods in their erosion and sediment yield prediction studies.

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