Using WEPP: Road Model in Estimating Sediment Yield from the Road Network in KSU Baskonus Research and Application Forest in...

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USING THE WEPP:ROAD MODEL IN ESTIMATING SEDIMENT YIELD FROM A ROAD NETWORK IN THE KSU BASKONUS RESEARCH AND APPLICATION FOREST IN KAHRAMANMARAS, TURKEY

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Abstract: Forest roads are the main source of sediment yield in managed forest areas. The sediment delivered to a stream from a road section highly depends on road template, road surfacing, road gradient, traffic density, soil types, terrain conditions, and vegetative cover. There are various sediment prediction models to estimate average annual sediment production from forest road sections. The Forest Road Erosion Predictor model (WEPP:Road) is widely used to calculate the amount of transported soils and sedimentation as a result of runoff. Using the WEPP Road model integrated with a Geographic Information System (GIS) is very effective in predicting place, time, and extent of sediment yield from forest roads. This allows us to plan and implement proper road construction and maintenance activities. WEPP:Road has been used in only a few applications for estimating sediment production from a forest roads in Turkey. In this study, average sediment production from the road network in the Baskonus Research and Application Forest of Kahramanmaras Sutcu Imam University (KSU) was estimated using WEPP:Road and GIS technologies. The required GIS coverages such as roads, streams, Digital Terrain Model (DTM), soil types, and vegetation types are generated to provide input data for calculations in WEPP. The results indicated that using WEPP:Road technologies provide results with a high accuracy and time effectiveness.

Key words: WEPP:Road, Forest Roads, Erosion Factors, Sediment Yield, GIS

Introduction

Designing a forest road network in a watershed can be time-consuming and complex subject to economic and environmental constraints. Constructing and maintaining forest roads is considered as the most costly activities in the process of timber production (Akay and Sessions, 2005). Due to removal of vegetation from the area of road prism, road construction can produce more sediment yield than any other activity in forest management (Grace, 2002). Therefore, accurately predicting sediment yield from forest roads is important to plan and implement proper road construction and maintenance activities.

There have been several sediment prediction models developed to estimate average sediment from a road section to streams. The common models include FROSAM (WFPB, 1997), WEPP:Road (Elliot et al., 1999a), X-DRAIN (Elliot et al., 1999b), and SEDMODL (Boise Cascade Corporation, 1999). To estimate sediment yields, these models consider the specific erosion factors such as soil type, climate, ground cover, road surface, ditch, and topography. Among these models, WEPP:Road (WEPP Forest Road Erosion Predictor) is widely used to predict runoff and sediment yield from low-volume forest roads, compacted landings and skid trails, and off-road vehicle trails. The WEPP:Road model integrates with a geographic information system (GIS) to predict place, time, and extent of sediment yield from forest roads.

WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) soil erosion model which is a physical based computer program that predicts soil erosion. WEPP:Road generates climate data by integration with the ROCK:Clime model (Arnold and Elliot, 1996), which is a climate generator with a database from more than 2600 weather stations. Then, the WEPP:Road model presents the results as a summary and extended WEPP output. In the model, the user can specify the road characteristics such as climate, soil and gravel addition, local topography, drain spacing, road design and surface condition, and ditch condition.

In the WEPP:Road model, it is assumed that sediment yield is generated from road surface, fill-slope, and a forested buffer area. Then, the sediment yield is predicted by considering five major erosion factors including road gradient, road width, surface type, road design, and traffic density.

The objective of this study was to utilize the WEPP:Road model in estimating sediment yield from the road sections in the KSU Baskonus Research and Application Forest in Kahramanmaras, Turkey.

Material and Methods

Study Area

The KSU Baskonus Research and Application Forest is located approximately 45 km from the city of Kahramanmaras. The common tree species are Pinus brutia, Pinus nigra, Cedrus libani, and Abies cilicica. The average side-slope and ground elevation aree 73% and 1165 m, respectively. In the research forest, there are secondary forest roads and asphalt roads, with the lengths of 3155 m and 7250 m, respectively. The stream network in the research forest consists of medium and small streams.

WEPP:Road Model

The WEPP:Road model can be applied to any condition where the necessary input data are available. In the WEPP:Road model interface, the input data include climate, soil texture, road design, gravel addition, topography, road width, and management (Figure 1). To simplify the application of WEPP to forest roads anywhere in the U.S., a user can utilize internet based the WEPP:Road interface model to estimate sediment yield from the forest road (Elliot et al., 1999a). The users from the outside of the U.S. have to generate a climate file by changing the original data used in the US.

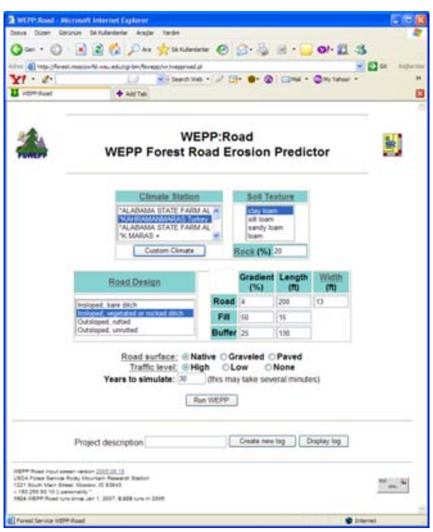

Figure 1. WEPP:Road Input Screen.

Climate

To run WEPP:Road model, the Rock:Clime, weather generator interface, has been generated to specify a climate from the database. When Rock:Clime is run from WEPP:Road model, the selected climate should be added into the "Personal Climate List" of a user (Figure 2). A user can have up to five different climates to run in the WEPP:Road model.

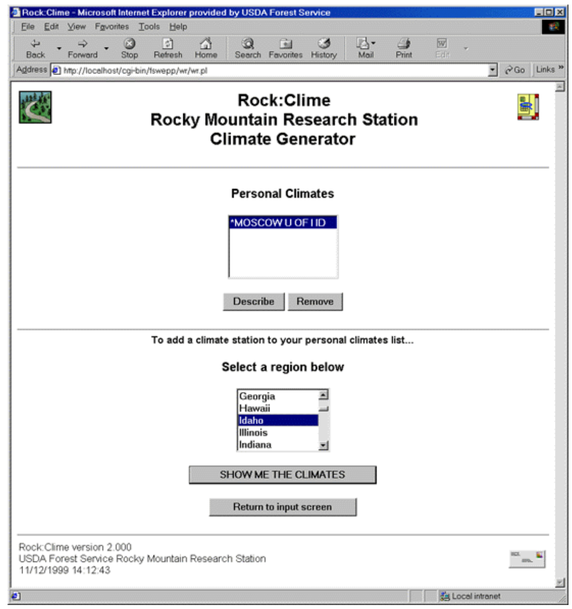

Figure 2. Initial screen for running Rock:Clime from WEPP:Road.

In the summer 2006, a series of collaborative studies were conducted between the authors and the WEPP: Road Project team members in Rocky Mountain Research Station in Moscow, Idaho. During previous work, a specific climate file for Kahramanmaras region, covering Baskonus Research and Application Forest, was generated in Rock:Clime Generator and included in the FS-WEPP database as "Non-US Climate Station" under "International Regions" (Figure 3, 4).

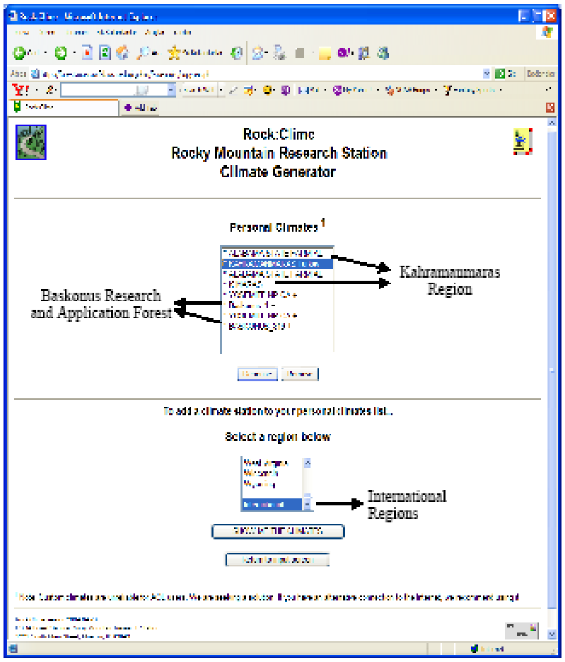

Figure 3. Initial Screen for running Rock:Clime from FS WEPP.

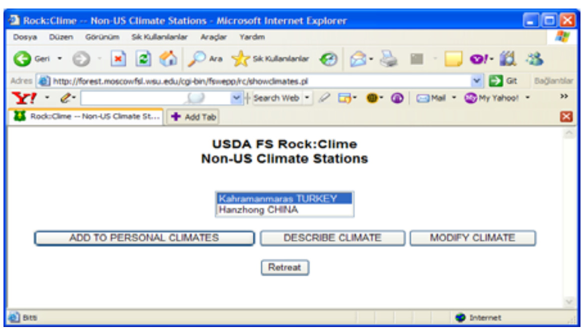

Figure 4. Non-US Climate station screen in Rock:Clime.

To obtain monthly based climate parameters (Min and Max Temperature, Average Precipitation, and Number of wet days) for the study area, 20 years of climate data from the Kahramanmaras region were entered into the Rock:Clime Generator and climate files were generated in WEPP:Road model (Figure 5).

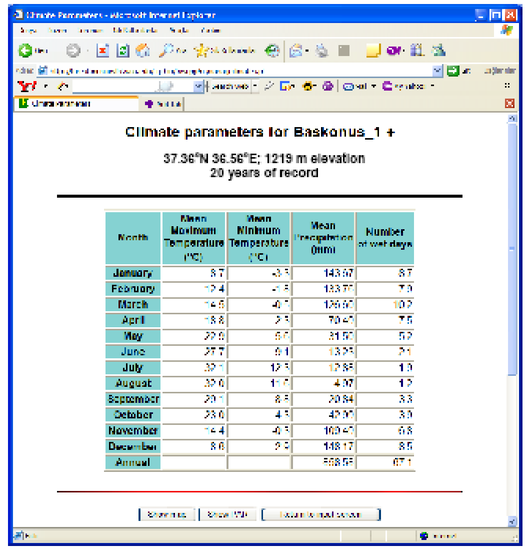

Figure 5. Climate description screen for the study area.

Soil Texture

The erosion potential of a given soil depends more on the vegetation cover than on the soil texture. In the WEPP:Road model, the texture and other physical properties for up to 10 layers of soil can be described in the soil file. Among these properties, the erodibility and hydraulic conductivity of the surface layer are the most critical inputs (Elliot et al., 1999a).

In the research area, the soil texture was generally clay loam with 20% rock content. Figure 6 indicates the soil parameters defined in the WEPP:Road model. In the WEPP model, it was assumed that hydraulic conductivity of the soil is reduced in direct proportion to the rock content (i.e., 20 percent rock will reduce the hydraulic conductivity by 20 percent). Table 1 indicates the categories of common forest soils in the WEPP:Road model.

Table 1. Common Forest Soils in relation to WEPP:Road soil parameters.

Soil type	Soil Description	Classifications
Clay loam	Native-surface roads on shales and similar decomposing fine-grained sedimentary rock	CH
Silt loam	Ash cap native-surface road; alluvial loess native-surface road	ML,CL
Sandy loam	Glacial outwash areas; granitics and sand	GP, GM, SW, SP
Loam	Glacial tills, aluvium	GC, SM, SC, MH

WEPP:Road Soil Parameters

Road texture: clay loam		
Albedo of the bare dry surface soil	0.6	
Initial saturation level of the soil profile porosity	0.5	m/m
Baseline interrill erodibility parameter (k_i)	1.5e+006	kg*s/m4
Baseline rill erodibility parameter (k_r)	0.0002	s/m
Baseline critical shear parameter	10.0	N/m2
Effective hydraulic conductivity of surface soil	0.1	mm/h
	layer 1	
Depth from soil surface to bottom of soil layer	200	mm
Percentage of sand	30	%
Percentage of clay	30	%
Percentage of organic matter (by volume)	0.01	%
Cation exchange capacity	24	meq per 100 g of soil
Percentage of rock fragments (by volume)	20	%
Fill texture: clay loam		
Albedo of the bare dry surface soil	0.12	
Initial saturation level of the soil profile porosity	0.45	m/m
Baseline interrill erodibility parameter (k_i)	1.5e+006	kg*s/m4
Baseline rill erodibility parameter (k_r)	0.0002	s/m
Baseline critical shear parameter	2.0	N/m2
Effective hydraulic conductivity of surface soil	6.3	mm/h
	layer 1	
Depth from soil surface to bottom of soil layer	300	mm
Percentage of sand	30	%
Percentage of clay	30	%
Percentage of organic matter (by volume)	4	%
Cation exchange capacity	26	meq per 100 g of soil
Percentage of rock fragments (by volume)	20	%
Forest texture: clay loam		
Albedo of the bare dry surface soil	0.02	
Initial saturation level of the soil profile porosity	0.40	m/m
Baseline interrill erodibility parameter (k_i)	1e+004	kg*s/m4
Baseline rill erodibility parameter (k_r)	0.0002	s/m
Baseline critical shear parameter	2.0	N/m2
Effective hydraulic conductivity of surface soil	20	mm/h
	layer 1	
Depth from soil surface to bottom of soil layer	300	mm
Percentage of sand	30	%
Percentage of clay	30	%
Percentage of organic matter (by volume)	8	%
Cation exchange capacity	27	meq per 100 g of soil
Percentage of rock fragments (by volume)	20	%

Figure 6. WEPP:Road Soil Parameters for Clay Loam.

Road Design

In the WEPP:Road model, four main road design types are considered: (1) Insloped, bare ditch, (2) Insloped, vegetated or rocked ditch, (3) Outsloped, unrutted, and (4) Outsloped, rutted. In the study area, the forest roads are insloped with a vegetated or rocked ditch (Figure 7). The "Insloped, vegetated or rocked ditch" design option uses a critical shear for the road element of 10 N m-2. The ditch is to transport the sediment eroded from the road surface. In WEPP:Road model, the vegetated or rocked ditch generally reduces road erosion by 50 to 90 percent.

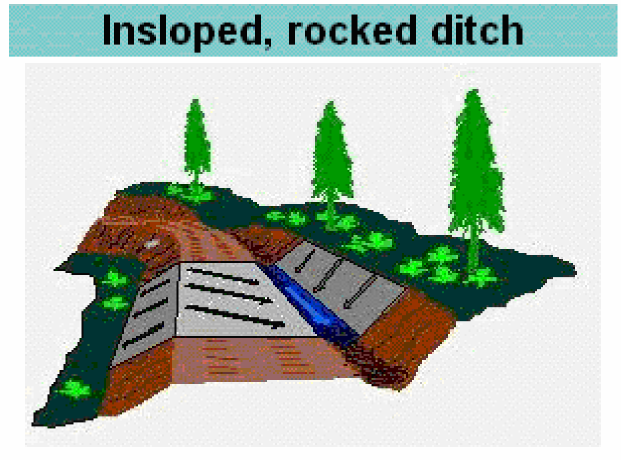

Figure 7. Diagram of the road design in WEPP:Road model (Elliot et al., 1999a).

Gravel Addition

The previous studies indicated that using surface gravel changes the flow path length of the road due to the hydraulic conductivity of the soil (Foltz and Truebe, 1995). Increasing the amount of gravel can increase the porosity and the hydraulic conductivity of the road, which leads to reduction in the runoff (Flerchinger and Watts, 1987). In the WEPP:Road model, there are three alternatives for road surface types: (1) native, (2) gravel, and (3) paved. In the study area, the county-maintained roads were paved while secondary forest roads were graveled surface.

Topography

After selecting road design type, WEPP:Road allows the users to describe the topography by entering data such as road gradient, length, width, fill slope and buffer slopes, and length of fill slope and buffer. In the study area, average road gradient was 7% and the average fill slope was 50%. Topography data was generated by using the GIS tool, Ilwis 3.2 Academic (ITC, Enschede, Netherlands).

Road Width

In WEPP:Road, the road width includes the width of the ditch or ditches if they are eroding. If the road is outsloped and rutted, only that portion of the width of road contributing runoff to the ruts should be specified (Elliot et al., 1999a). In the study area, the road widths for the county-maintained road and secondary forest road were 10 m and 5 m, respectively.

Road Traffic Level

The traffic level of road section was divided into high traffic, low traffic, and no traffic. The high level is associated with roads that receive considerable traffic during much of the year. Low traffic roads are roads with administrative or light recreational use during dry weather. No traffic roads are roads with restricted or no access, and have vegetation growing on more than half of the road surface. In the study area, the traffic levels in county-maintained roads and secondary forest roads are defined as high level and low level traffic, respectively.

Results and Conclusions

The road grade and length for each road segment was found based on a 10 meter DEM. Figure 8 shows the DEM of the study area with road and steam layers. Total average annual sediment yield from two county-maintained and four secondary forest road sections in the study area was computed using WEPP:Road. The sediment yield summary is illustrated in Table 2. The results indicated that the total sediment yield from paved road sections and graveled road sections were 45.47 and 7.89 ton, respectively.

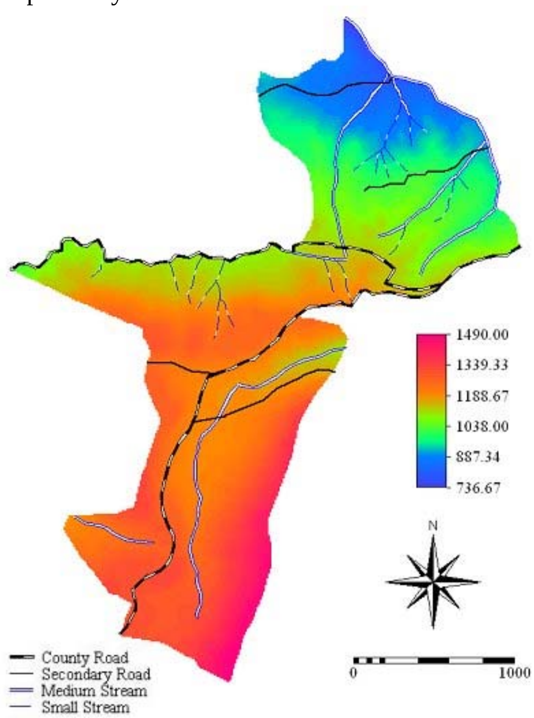

Figure 8. DEM of the study area.

It can be concluded that in paved road sections, the amount of road surface erosion was reduced, but the runoff was increased, which resulted in high amount of erosion on fill slopes, ditches, and flow paths leading from the road to the forest. Elliot et al. (1999a) indicated paved roads are least beneficial for insloped roads, or roads a moderate distance from the stream.

Table 2. Specification summary for road sections located in the research forest.

Road Classes	Length (m)	Road Width (m)	Traffic Level	Average Road Grade (%)	Sediment (ton/year)
Paved	7249	10	High	9.50	45.47
Graveled	3155	5	Low	12.25	7.89

The average annual sediment delivery from a square meter of the road sections was also computed. The amount of sediment yield (i.e. in ton/m2) from paved and graveled roads was 0.00063 and 0.0005, respectively. Therefore, the highest amount of total sediment yield in tons per square meter was also produced by paved roads.

Even though increasing road gradient increases the sediment yield from a road section (Luce and Black, 1999), the results indicated that paved road sections with 9.5% road grade produced more sediment than the graveled road sections with 12.25% road grade. Therefore, the effect of road surface type and road length factors on sediment yield were more signify-cant than the road grade factor in the study area.

The results from the simple application indicated that WEPP:Road model is an effective tool to help forest engineers estimate sediment yield from forest road sections. They can also evaluate the performances of the alternative sediment prevention techniques by using the WEPP:Road interface.

The limitation of the current version of the model is that there are only few international data sets avail-able in the FS WEPP database. In order to use the model in areas outside the US, local data must be preprocessed by the Rock:Clime Generator to build input files in WEPP:Road. It is anticipated that having climate data available in the database from outside the US can make WEPP:Road model more attractive for the researchers from around the world, especially in the field of forestry.

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