WEPP INTERNET INTERFACES FOR FOREST EROSION PREDICTION[1]

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ABSTRACT: The Water Erosion Prediction Project (WEPP) is a physically based erosion model for applications to dryland and irrigated agriculture, rangeland, and forests. U.S. Forest Service (USFS) experience showed that WEPP was not being adapted because of the difficulty in building files describing the input conditions in the existing interfaces. To address this difficulty, a suite of Internet interfaces with a database was developed to more easily predict soil erosion for a wide range of climatic and forest conditions, including roads, fires, and timber harvest. The database included a much larger climate database than was previously available for applications in remote forest and rangeland areas. Validation results showed reasonable agreement between erosion values reported in the literature and values predicted by the interfaces to the WEPP model.
(KEY TERMS: erosion; sedimentation; forest hydrology; modeling; forest roads.)

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INTRODUCTION

Predicting soil erosion by water is a common practice in natural resource management for evaluating the impacts of upland erosion on sediment delivery, soil productivity, and offsite water quality. Erosion prediction methods are used to evaluate different management practices and control techniques. The first widely accepted erosion prediction tool was the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The USLE continues to be applied throughout the world. In recent years, it has been superseded by the Revised USLE (RUSLE) (Renard *et al.,* 1997). The USLE technology, however, does not adequately address sediment delivery, nor is it appropriate for steep slopes that are typical of forest conditions. Numerous variations have been developed to incorporate sediment delivery into the USLE technology, and alternative empirical models were developed to address this shortfall.

With the advent of personal computers, the ability to apply process based models to soil erosion became feasible. With the process models such as CREAMS, a field scale model for chemicals, runoff, and erosion from agricultural management systems (Knisel, 1980), came the requirement of much larger and more complex input data sets. Later models, such as WEPP (Flanagan and Livingston, 1995), included file building interfaces. Windows based interfaces are currently available for the RUSLE and WEPP models.

The U.S. Forest Service wanted to apply the WEPP model to forest road and disturbed hillside conditions. The science base of WEPP was considered important to support agency management plans that are frequently challenged in courts. The physically based aspects of WEPP also meant that the same model could be applied to a wide range of topographies and climates managed by the agency. This is possible because the physical nature of the WEPP model does not rely on locally developed factors, but rather on locally observed data. This means that WEPP can be applied to climates with annual precipitation values ranging from under 250 to over 2,500 mm, to slopes ranging from research plots 0.5 m long to hillslopes longer than 500 m, and to any soil, including cropland, rangeland, forest, road, and construction sites. To make the model more user friendly, a set of Internet interfaces was developed to run WEPP for many

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common forest conditions on USFS Internet servers using a Web browser. This paper describes these interfaces.

THE WEPP MODEL

The WEPP soil erosion model was developed by an interagency group of scientists working for the U.S. Department of Agriculture's Agricultural Research Service (ARS), Natural Resources Conservation Service, and Forest Service; and the U.S. Department of Interior's Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS). Scientists from these agencies throughout the United States have been working since 1985 to develop this erosion prediction model originally intended to replace the USLE (Foster and Lane, 1987).

The WEPP model is a complex computer program that describes the physical processes that lead to erosion. These processes include infiltration and runoff; soil detachment, transport, and deposition; and plant growth, senescence, and residue decomposition. For each simulation day, the model calculates the soil water content in multiple layers, plant growth, and residue decomposition. The effects of tillage processes and soil consolidation are also modeled.

WEPP does not have a direct input for cover, but rather calculates the cover every day of the run by decomposing surface cover and increasing surface cover from plant senescence (Stott *et al.,* 1995). Thus, the soil cover depends on a number of plant growth parameters, especially the biomass energy conversion ratio and the amount of vegetation remaining after senescence, the daily temperatures both for growth and decomposition rates, and the availability of soil water.

The WEPP model can be run for a hillslope or a watershed. The base model is designed for a hillslope, predicting soil erosion from a single hillslope profile of any length up to about 400 m. The hillslope can have a complex shape and include numerous soils and plant types along the hillslope. Each unique combination of soil and vegetation is considered to be an overland flow element (OFE) (Figure 1). The watershed option links hillslope elements of specified widths with channel and impoundment elements.

The hillslope option requires four input files: a daily climate file that includes the values of daily precipitation, temperatures, solar radiation, and wind speed and direction; a slope file that contains two or more sets of points describing the slope at intervals along the hillslope profile; a soil file that can contain up to 10 layers of soil describing the texture and other physical and erodibility properties of the soil; and a management file that contains descriptions of plant communities, surface disturbances such as tillage, and the surface condition at the start of the simulation.

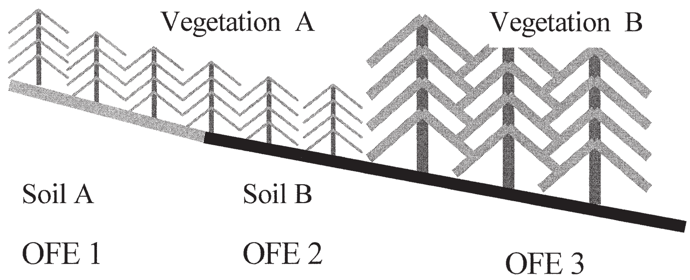


Figure 1. Overland Flow Elements.

A climate generator (CLIGEN) is available to generate typical weather sequences for WEPP. The generator has a database of weather station statistics mainly on nonmountainous terrain distributed on approximately a 100 km grid for the entire United States.

The 1995 release of WEPP Version 95.7 (Flanagan and Livingston, 1995) included a functional user interface that operated on an MS DOS platform. The watershed option, however, was difficult to use. The complex management file builder required more memory than was available on some computers at that time and did not work when running in an MS DOS window on a Windows 95 or later operating system. A Windows interface is the recommended platform for running the WEPP model. The Windows interface allows users to select from large agricultural and rangeland plant and soil databases and to alter approximately 400 input variables needed for a typical WEPP run.

FOREST APPLICATIONS

Most sediment in forests comes from disturbed areas including forest roads, skid trails, log landings, or burned areas. Since 1989, much field research has been focused on determining the WEPP soil erodibility values for forest conditions (Elliot *et al.,* 1993). Soil erodibility was measured with rainfall simulation and from natural rainfall on forest roads (methods described in Foltz, 1998, and Elliot *et al.,* 1995), forests disturbed by logging, prescribed fire (methods described in Robichaud *et al.,* 1993) and by wildfire (methods described in Robichaud and Brown, 1999), and on rangeland after wildfire (methods described in Pierson *et al.,* 2001).

It has been found that soil erodibility properties in forest conditions depend on the surface cover amount and the disturbance resulting in that cover (Robichaud *et al.,* 1993). For example, the same soil experiencing different fire severities will have different erodibility properties (Robichaud, 1996). A soil that has been altered to become a road has different erodibility properties than a forest soil regardless of disturbance (Elliot and Hall, 1997). Soil erodibility values were much lower for all forest conditions, including roads, than those observed on agricultural soils with similar textures. Hydraulic conductivity was lower on roads than on agricultural sites, but much higher for all other forest conditions (Figure 2).

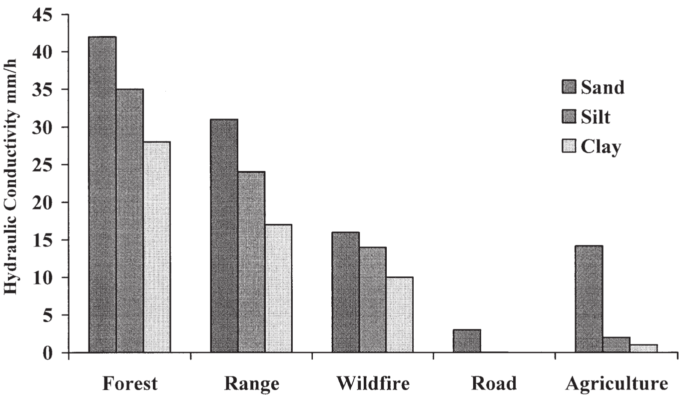


Figure 2. Typical Hydraulic Conductivity Values for Wildland and Agricultural Soils.

Most forest sites that are severely disturbed by forest operations or fire tend to recover quickly, with observed erosion rates dropping by 90 percent between the first and second years after a wildfire (Elliot and Robichaud, 2001). Hence, it is important to consider the erosion in each year of recovery, rather than lumping the disturbance and recovery years together to get an "average" erosion rate, the technology developed for agricultural rotations in the USLE (Wischmeier and Smith, 1978).

WEPP Interfaces

We trained more than 200 Forest Service specialists to use the WEPP model between 1993 and 1998. Of those specialists, only three or four subsequently applied the model because the interface was too difficult to operate and too much time was required to assemble the data and interpret the results. Occasional users found it difficult to keep track of which combinations of files should be used for typical forest and range conditions. Some users were observed to specify unlikely combinations of soil and management files on these highly flexible interfaces, such as specifying a high severity fire soil in combination with a forest road management file. To offer the erosion and sedimentation prediction capabilities of the WEPP model to a greater number of forest users, a set of simplified user interfaces was developed. These interfaces can be run with a Web browser from USFS Web sites. Stand-alone versions have also been developed. Online documentation aids in selection of input conditions and provides example applications.

Three linked Internet interfaces were developed: WEPP:Road for predicting road erosion and sediment delivery; Disturbed WEPP for predicting erosion from hillslopes disturbed by forest operations, prescribed fire, or wildfire; and Rock:Clime for generating files for the above interfaces or WEPP stand-alone applications. The interfaces ensure that soil and vegetation conditions match and only require input values for the essential variables. All other variables are stored in databases that may be viewed but cannot be altered by users.

The interface technology consists of html screens for input and output. PERL scripting is used to accept the input data from the user, build input files for the WEPP model, run the model, and interpret the output. The WEPP and CLIGEN FORTRAN programs predict the erosion rates and generate stochastic weather sequences, respectively. The interfaces are supported by soil, management, and climate databases. The interfaces are installed on two servers (Elliot, 2003; 2004).

Multiple users can be accommodated simultaneously on either server by linking each user's active files to his or her IP address. Descriptions of each interface follow.

WEPP:Road. The WEPP:Road interface assumes that excess runoff and sediment generated by the road traveled way is routed over a fill slope and across a forested buffer to the stream system (Figure 3). The widths of the flow across the fill and buffer are assumed to be the same as the road width.

The WEPP:Road input and output screens are shown in Figures 4, 5, and 6. On the WEPP:Road input screen the user can specify the climate from a short list of climate stations on the input screen, a database of more than 2,600 climate stations available in the CLIGEN database (Scheele *et al.,* 2001), or from an extended database described later. The user has a choice of four soil textures. The road surface can be insloped with a bare or covered roadside ditch, outsloped with or without wheel ruts, and have a native, graveled, or paved surface. The steepness of the road and buffer can range from 0.3 to 100 percent, the length from 1 to 300 m, and the width of the road surface from 0.3 to 100 m. The number of years of climate can range from 1 to 200.

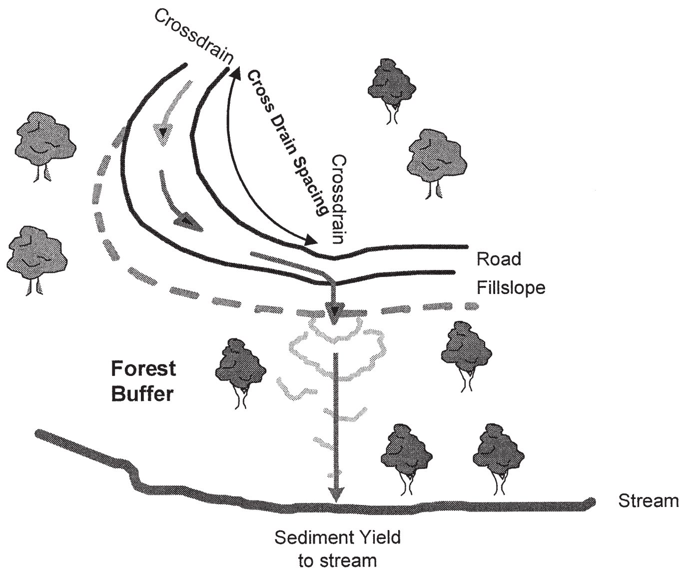


Figure 3. Template for the WEPP:Road Interface.

The output from WEPP:Road (Figure 5) presents the average precipitation, the average annual runoff from the buffer, and the sediment delivered from both the eroding part of the road prism and the bottom of the buffer. An optional extended output shows the distribution of erosion and deposition along the road, fill, and buffer, the presence of a sediment plume in the buffer, and the particle size distribution on the hillslope and in the delivered sediment. The results from a series of runs of WEPP:Road can be added to a log file (Figure 6) for saving, printing, or copying and pasting into another document such as a word processor or spreadsheet file.

Disturbed WEPP. The Disturbed WEPP interface is intended for erosion prediction from forest conditions including: skid trails; prescribed fires; wildfires; early years of vegetation and soil recovery following prescribed or wildfire; and young, thinned, harvested, and mature forests. Three vegetation options are also available for rangeland conditions: "short" or sod forming grasses, "tall" or bunch grasses, and "shrubs" for sage and pinyon juniper plant communities.

The rangeland options can also be appropriate to describe forest conditions during periods of recovery following a severe fire or logging operation. Disturbed WEPP has two OFEs (Figure 1) so that users can study numerous combinations of uphill and downhill disturbances, such as a skid trail or harvest area above a buffer zone, or a heavily grazed area above a riparian zone. Users are also required to enter the amount of soil surface cover for all vegetation conditions except mature forest, which is assumed to be 100 percent.

Disturbed WEPP has one input screen similar to WEPP:Road and two output screens – one for a vegetation calibration check and another for a return period analysis (Figures 7 and 8). The input screen allows the user to make selections similar to WEPP:Road, with the addition of two OFEs for the vegetation. There are two run options: a vegetation check to see the average amount of simulated surface cover during the WEPP run and a WEPP run to predict average and return period annual runoff and erosion amounts.

The soil database includes 32 permutations for four textures and eight vegetation conditions. There are separate files containing initial conditions and plant descriptions for each vegetation condition. To ensure that the correct amount of cover is generated for a given scenario, a calibration option is offered on the input the screen and the WEPP generated cover is presented on an output screen (Figure 7). If the generated cover does not approximate the desired cover, the user can adjust the cover value on the input screen until the desired cover is generated.

The output for a Disturbed WEPP run is presented in Figure 8. The mean values and the first, second, fifth, 10th and 20th greatest annual values for precipitation, runoff, erosion, and sediment yield from the entire length of run are presented. The probability that any of these same values were nonzero is also presented.

Rock:Clime. Rock:Clime is an interface to build custom input files for the ARS CLIGEN weather generator. It can be accessed from either WEPP:Road or Disturbed WEPP screens. Users can also use the Rock:Clime interface to generate daily climate input files formatted for WEPP for downloading to use with the ARS WEPP stand-alone applications or other models that may require a daily stochastic weather sequence for a remote site.

The Rock:Clime interface incorporates the ARS CLIGEN climate generator (Flanagan and Livingston, 1995). The climate station database from the ARS database was expanded from about 1,200 stations to more than 2,600 climates from all 50 states, Puerto Rico, and the Pacific Islands (Scheele *et al.,* 2001).

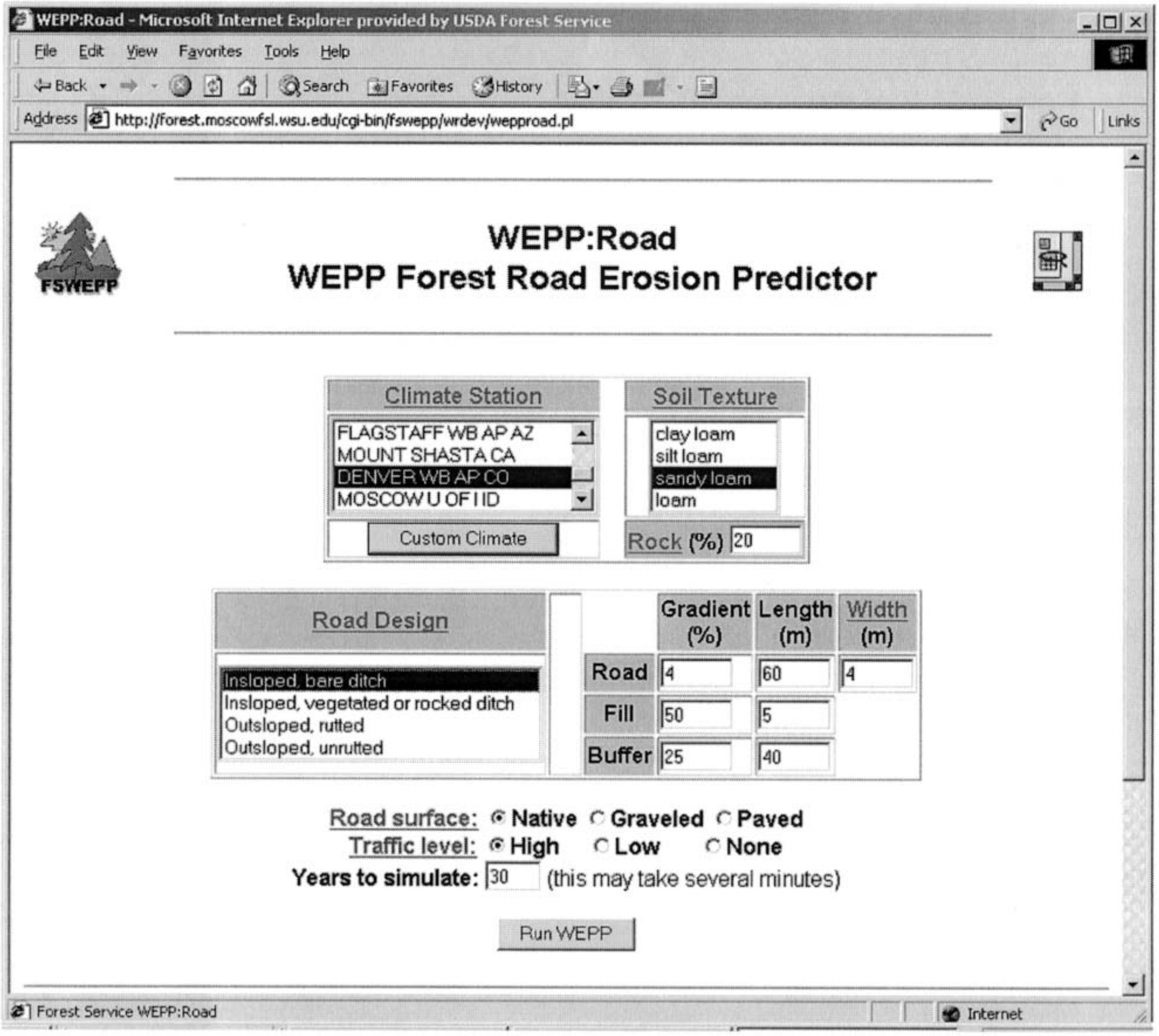


Figure 4. WEPP:Road Input Screen.

The CLIGEN database is supplemented with the Parameter-elevation Regressions on Independent Slopes Model (PRISM) monthly precipitation values estimated at a 4 km grid for the entire United States (Daly *et al.,* 1994), which includes about 900,000 points. Daly *et al.* (1994) built this grid of values by developing regional regression relationships between grid elevation and aspect. A region included all of the local weather stations within an area approximately 500 km in diameter. The region was shifted across the landscape to cover the entire United States. With the Rock:Clime interface, PRISM monthly precipitation values are accessible through a suite of complementing interfaces, including the selection interface that shows the precipitation and elevation of the current grid as well as the values for each of the surrounding grids (Figure 9). Users can also modify the monthly precipitation amounts, number of wet days, and maximum and minimum temperatures from a "nearby" climate to more nearly reflect the site of concern from either the CLIGEN station values or the PRISM values. A button allows the user to let the interface adjust the temperatures by adiabatic lapse rate (6°C/km for maximum and 5°C/km for minimum temperatures), or the user can specify the desired average values for each month.

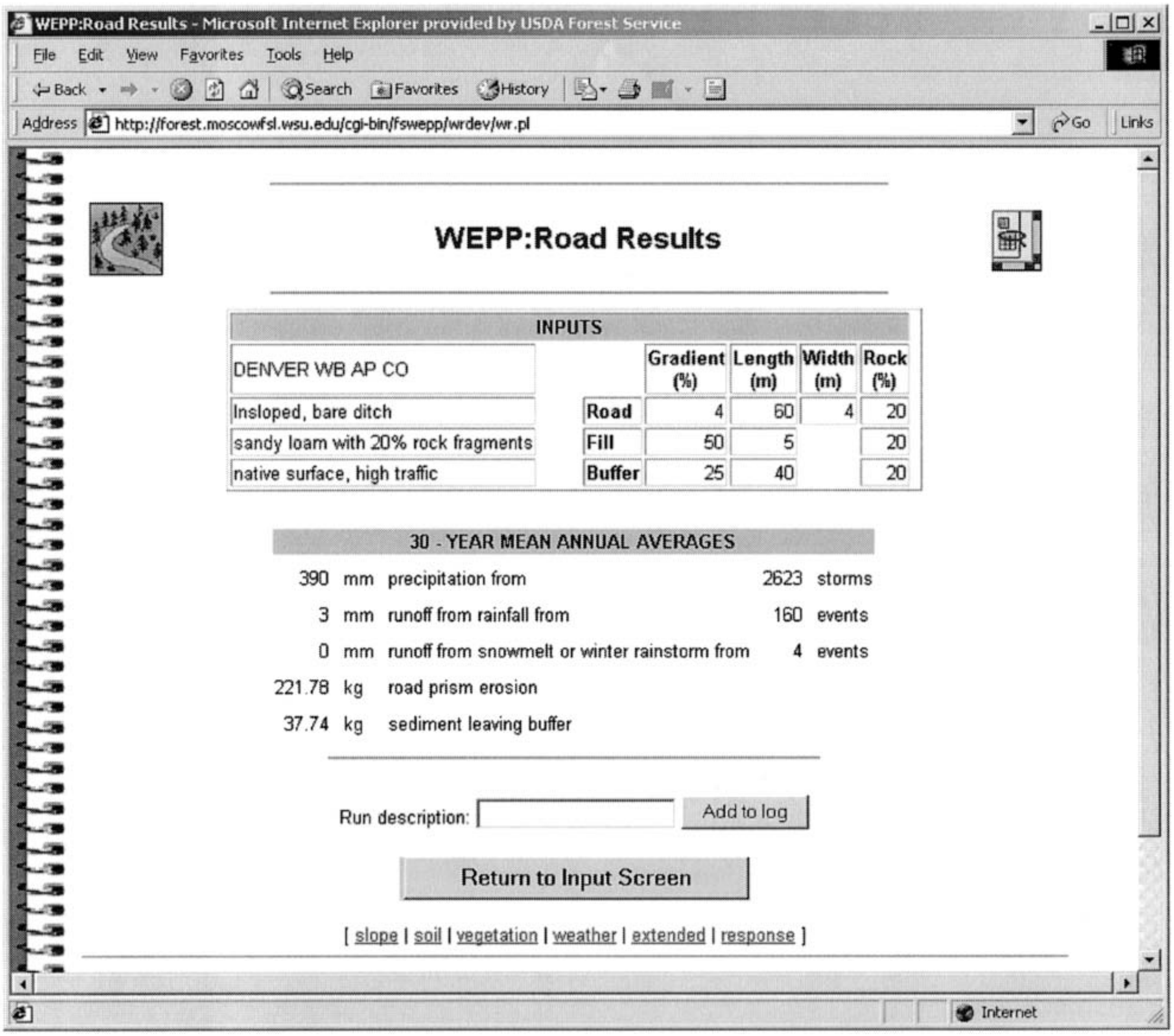


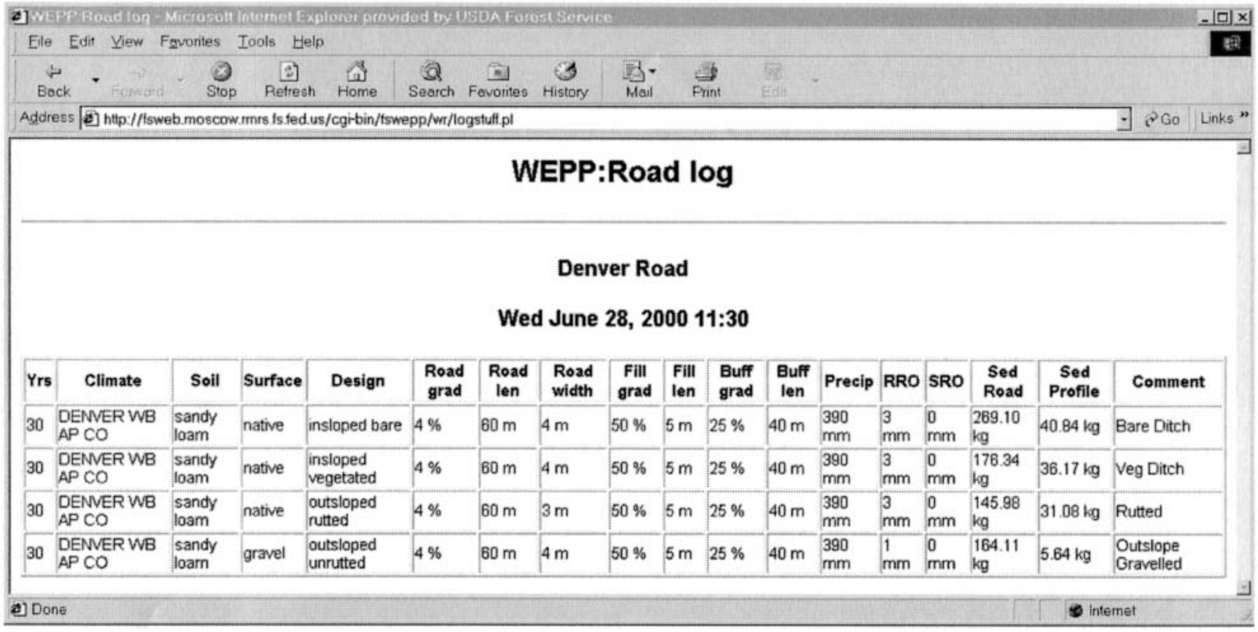
Figure 5. WEPP:Road Output Screen.

Validation

In a study on Colorado rangeland, the WEPP model as run from USFS Internet interfaces performed better than the ARS WEPP rangeland templates distributed prior to 2000 and performed better than the RUSLE model (Elliot, 2001). Elliot and Foltz (2001) validated the USFS Internet interfaces for forest roads and disturbed forest hillsides (Figure 10). The Internet interfaces predicted average erosion rates for 30 to 50 years of stochastic climate for the site, while the observed rates were from shorter periods of record, perhaps a single year. This might account for the overprediction of low erosion rates and the underprediction of high erosion rates from the WEPP:Road interface. The observed values also could have included watershed channel processes that the WEPP hillslope model cannot address. Note that there is more than an order of magnitude difference in erosion rates between roads and disturbed hillslopes.

RESULTS

Prior to the development of these interfaces, approximately 200 potential users were trained on the application of the WEPP model to forest conditions using the 1995 interface. In 1998, an informal survey showed that only two users were using this



WEPP:Road log

Denver Road

Wed June 28, 2000 11:30

Yrs	Climate	Soil	Surface	Design	Road grad	Road len	Road width	Fill grad	Fill len	Buff grad	Buff len	Precip	RRO	SRO	Sed Road	Sed Profile	Comment
30	DENVER WB AP CO	sandy loam	native	insloped bare	4 %	60 m	4 m	50 %	5 m	25 %	40 m	390 mm	3 mm	0 mm	269.10 kg	40.84 kg	Bare Ditch
30	DENVER WB AP CO	sandy loam	native	insloped vegetated	4 %	60 m	4 m	50 %	5 m	25 %	40 m	390 mm	3 mm	0 mm	176.34 kg	36.17 kg	Veg Ditch
30	DENVER WB AP CO	sandy loam	native	outsloped rutted	4 %	60 m	3 m	50 %	5 m	25 %	40 m	390 mm	3 mm	0 mm	145.98 kg	31.08 kg	Rutted
30	DENVER WB AP CO	sandy loam	gravel	outsloped unrutted	4 %	60 m	4 m	50 %	5 m	25 %	40 m	390 mm	1 mm	0 mm	164.11 kg	5.64 kg	Outslope Gravelled

Figure 6. Example of WEPP:Road Log File.

technology. The Internet interfaces were first demonstrated in 2000. In 2001, on the two USFS servers, more than 600 users carried out more than 20,000 runs. The number of runs increased to 34,000 in 2002 and to more than 40,000 in 2003, with an estimated 1,200 users from federal, state, university, and private organizations. Demand is high for workshops about the new technology, and more than 100 users a year have been trained in the past three years.

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LITERATURE CITED

Daly, C., R.P. Neilson, and D.L. Phillips, 1994. A Statistical-Topographic Model for Mapping Climatological Precipitation Over Mountainous Terrain. Journal of Applied Meteorology 33:140-148.

Elliot, W.J., 2001. Comparing RUSLE to WEPP Cropland and Rangeland Formats. *In:* Proceedings of the International Symposium of Soil Erosion Research for the 21st Century, J.C. Ascough II and D.C. Flanagan (Editors). American Society of Agricultural Engineers (ASAE), St. Joseph, Michigan, pp. 388-391.

Elliot, W.J., 2003. Forest Service WEPP Interfaces. *Available at* http://fsweb.moscow.rmrs.fs.fed.us/fswepp/. *Accessed in* March 2004.

Elliot, W.J., 2004. Forest Service WEPP Interfaces. *Available at* http://forest.moscowfsl.wsu.edu/fswepp/. *Accessed in* March 2004.

Elliot, W.J. and M.H. Foltz, 2001. Validation of the FSWEPP Interfaces for Forest Roads and Disturbances. Paper No. 01-9009, Presented at the ASAE Annual International Meeting, Sacramento, California, ASAE, St. Joseph, Michigan, 13 pp.

Elliot, W.J., R.B. Foltz, and C.H. Luce, 1995. Validation of Water Erosion Prediction Project (WEPP) Model for Low-Volume Forest Roads. Conference Proceedings Sixth International Conference on Low-Volume Roads, Minneapolis, Minnesota. Transport Research Board, National Academy Press, Washington, D.C., pp. 178-186.

Elliot, W.J., R.B. Foltz, P.R. Robichaud, and C.H. Luce, 1993. A Tool for Estimating Disturbed Forest Site Sediment Production. *In:* Interior Cedar-Hemlock-White Pine Forests: Ecology and Management Symposium Proceedings, D.M. Baumgartner, J.E. Lotan, and J.R. Tonn (Editors). Department of Natural Resource Sciences, Cooperative Extension, Washington State University, Pullman, Washington, pp. 233-236.

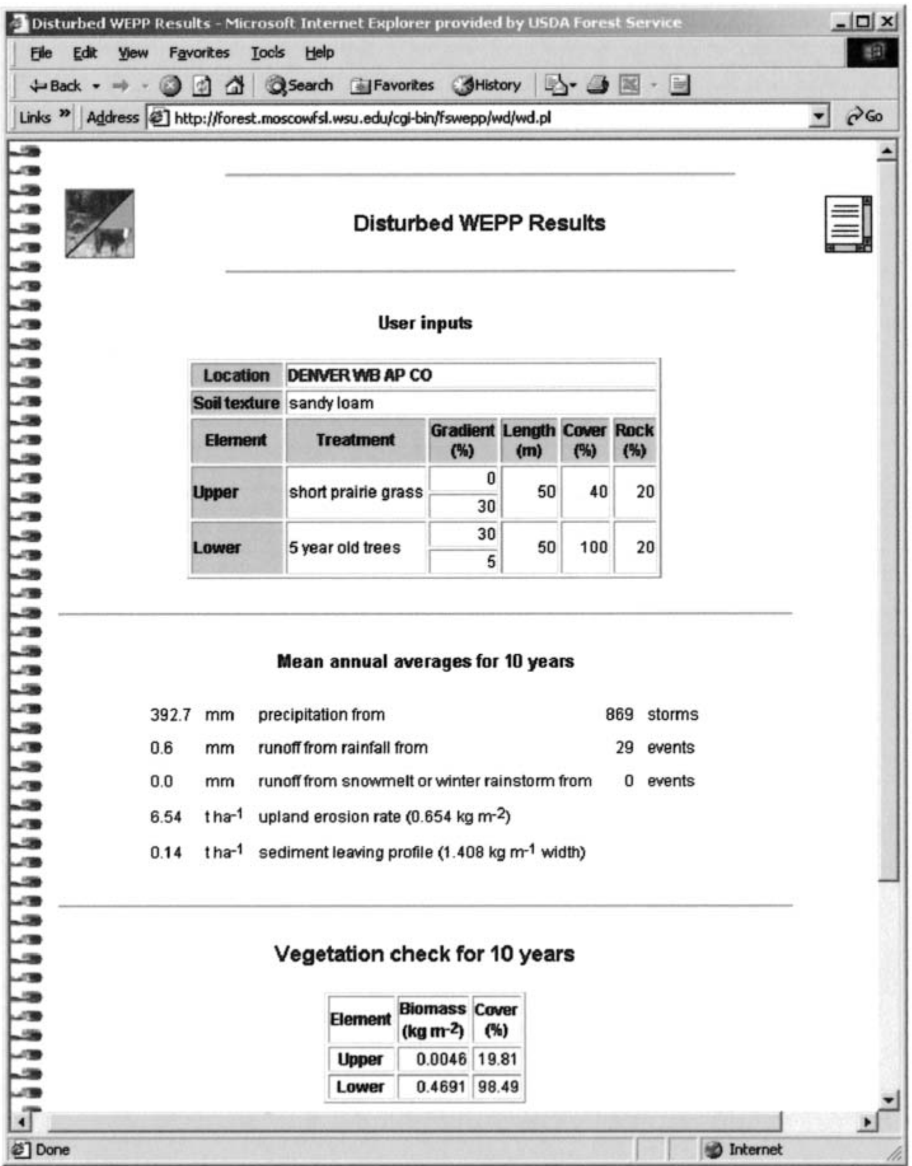

Figure 7. Disturbed WEPP Output for 10-Year Vegetation Calibration.

Elliot, W.J. and D.E. Hall, 1997. Water Erosion Prediction Project (WEPP) Forest Applications. General Technical Report INT-GTR-365, USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah, 11 pp. *Available at* < http://forest.moscowfsl.wsu.edu/4702/forestap/forestap.pdf. *Accessed in* June 2003.

Elliot, W.J. and P.R. Robichaud, 2001. Comparing Erosion Risks From Forest Operations to Wildfire. Proceedings of the 2001 International Mountain Logging and 11th Pacific Northwest Skyline Symposium, Seattle, Washington, University of Washington, Seattle, Washington, 13 pp.

Flanagan, D.C. and S.J. Livingston (Editors), 1995. WEPP User Summary. NSERL Report No. 11, National Soil Erosion Research Laboratory, West Lafayette, Indiana, 131 pp.

Foltz, R.B., 1998. Traffic and No-Traffic on an Aggregate Surfaced Road: Sediment Production Differences. Proceedings of the Seminar on Environmentally Sound Forest Roads and Wood Transport, Sinaia, Romania. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 195-204.

Foster, G.R. and L.J. Lane (Compilers), 1987. User Requirements: USDA-Water Erosion Prediction Project (WEPP). NSERL Report No. 1, USDA-ARS National Soil Erosion Research Laboratory, West Lafayette, Indiana, 43 pp.

Knisel, W.G. (Editor), 1980. CREAMS: A Field Scale Model for Chemicals, Runoff, and Erosion From Agricultural Management Systems. Conservation Research Report No. 26, USDA, Washington D.C., 643 pp.

Pierson, Jr., F.B., K.E. Spaeth, and D.H. Carlson, 2001. Fire Effects on Sediment and Runoff in Steep Rangeland Watersheds. Proc. of the Seventh Interagency Sedimentation Conference, Reno, Nevada, USGS, Reston, Virginia, pp. X-33 to X-38.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder (Coordinators), 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal

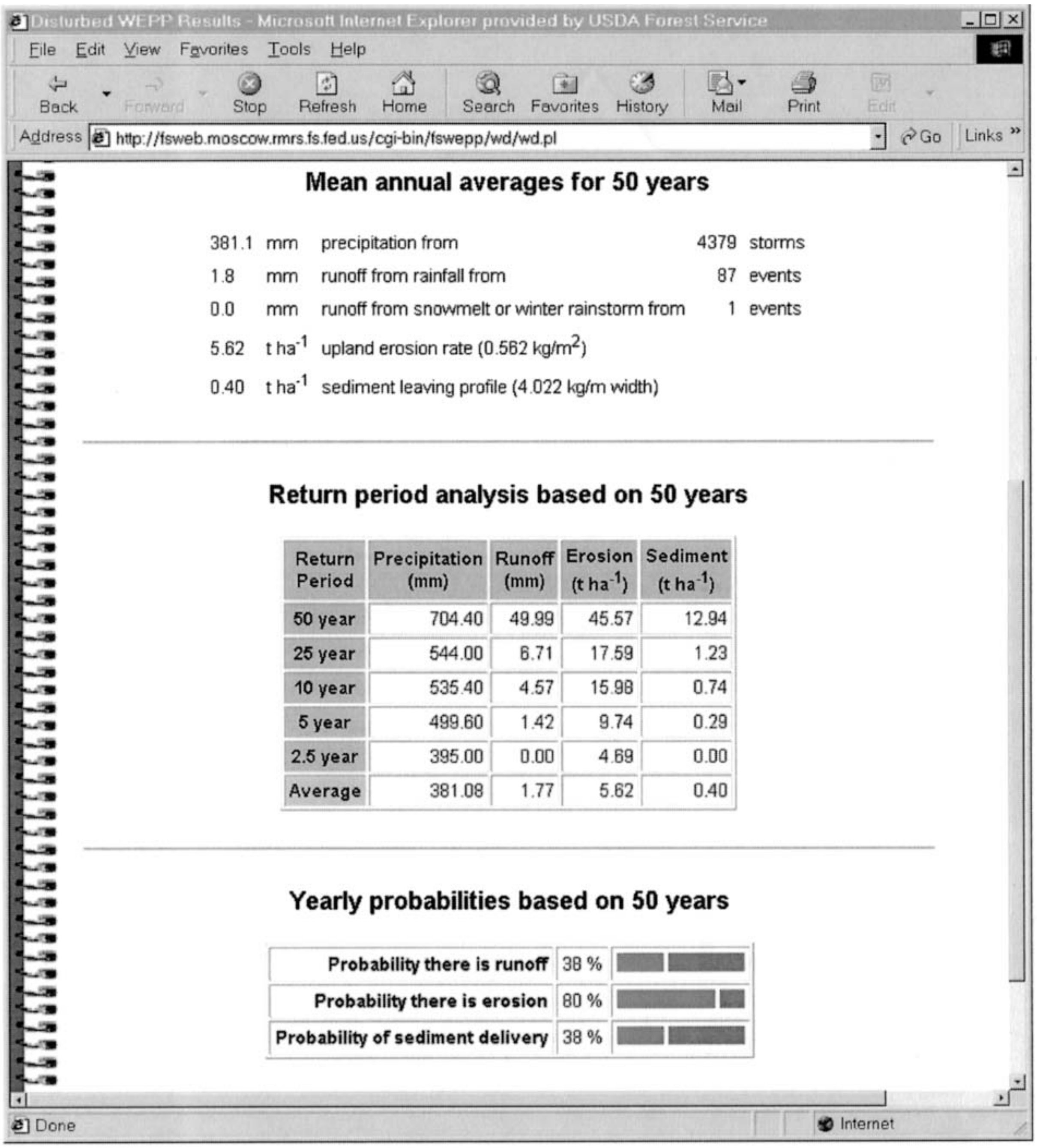

Figure 8. Disturbed WEPP Output From WEPP Run.

Soil Loss Equation (RUSLE). Agricultural Handbook No. 703, USDA, Washington, D.C., 404 pp.

Robichaud, P.R., 1996. Spatially-Varied Erosion Potential From Harvested Hillslopes After Prescribed Fire in the Interior Northwest. PhD Dissertation, University of Idaho, Moscow, Idaho, 219 pp.

Robichaud, P.R. and R.E. Brown, 1999. What Happened After the Smoke Cleared: Onsite Erosion Rates After a Wildfire in Eastern Oregon. *In:* Wildland Hydrology, Darren S Olsen and John P. Potyondy (Editors). American Water Resources Association, Middleburg, Virginia, TPS-99-3, pp. 419-426.

Robichaud, P.R., C.H. Luce, and R.E. Brown, 1993. Variation Among Different Surface Conditions in Timber Harvest Sites in the Southern Appalachians. International Workshop on Soil Erosion, Proceedings. Moscow, Russia. The Center of Technology Transfer and Pollution Prevention, Purdue University, West Lafayette, Indiana, pp. 231-241.

Scheele, D.L., W.J. Elliot, and D.E. Hall, 2001. Enhancements to the CLIGEN Weather Generator for Mountainous or Custom Applications. *In:* Proceedings of the International Symposium of Soil Erosion Research for the 21st Century, J.C. Ascough II and

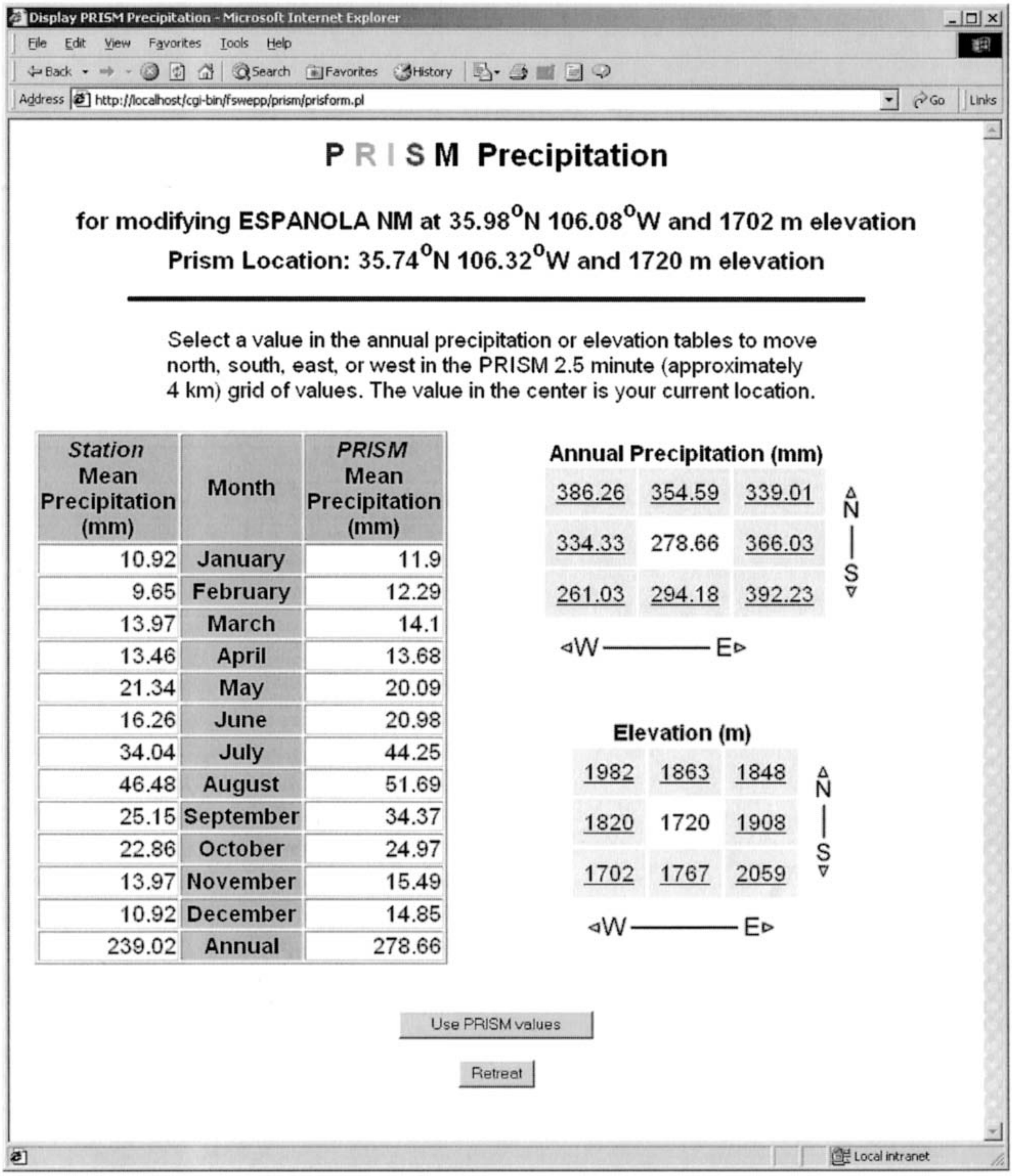

Figure 9. Rock:Clime Selection Screen.

D.C. Flanagan (Editors). ASAE, St. Joseph, Michigan, pp. 392-395.

Stott, D.E., E.E. Alberts, and M.A. Weltz, 1995. Residue Decomposition and Management. *In:* USDA Water Erosion Prediction Project Hillslope Profile and Watershed Model Documentation, D.C. Flanagan and M.A. Nearing (Editors). NSERL Report No. 10, USDA-ARS National Soil Erosion Laboratory, West Lafayette, Indiana, pp. 9.1-9.16.

Wischmeier, W.H. and D.D. Smith, 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agricultural Handbook No. 282, USDA, Washington, D.C., 58 pp.

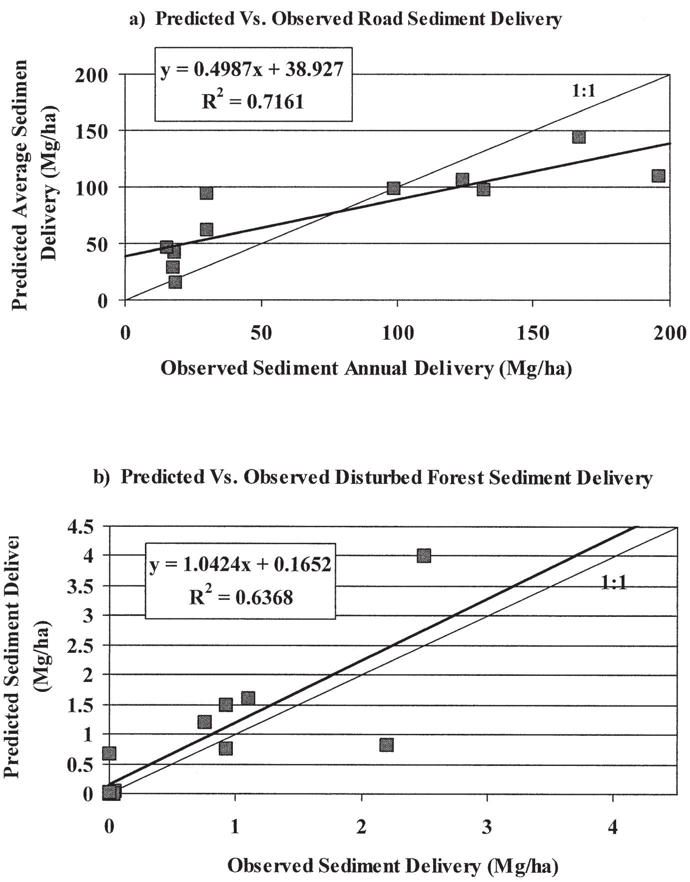

Figure 10. Predicted Versus Observed Sediment Yields (a) for Roads and (b) for Disturbed Forest Hillslopes (derived from data in Elliot and Foltz, 2001).