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SOIL EROSION AND SEDIMENT YIELD PREDICTION ACCURACY USING WEPP[1]

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ABSTRACT: The objectives of this paper are to discuss expectations for the Water Erosion Prediction Project (WEPP) accuracy, to review published studies related to WEPP goodness of fit, and to evaluate these in the context of expectations for WEPP's goodness of fit. WEPP model erosion predictions have been compared in numerous studies to observed values for soil loss and sediment delivery from cropland plots, forest roads, irrigated lands and small watersheds. A number of different techniques for evaluating WEPP have been used, including one recently developed where the ability of WEPP to accurately predict soil erosion can be compared to the accuracy of replicated plots to predict soil erosion. In one study involving 1,594 years of data from runoff plots, WEPP performed similarly to the Universal Soil Loss Erosion (USLE) technology, indicating that WEPP has met the criteria of results being "at least as good with respect to observed data and known relationships as those from the USLE," particularly when the USLE technology was developed using relationships derived from that data set, and using soil erodibility values measured on those plots using data sets from the same period of record. In many cases, WEPP performed as well as could be expected, based on comparisons with the variability in replicate data sets. One major finding has been that soil erodibility values calculated using the technology in WEPP for rainfall conditions may not be suitable for furrow irrigated conditions. WEPP was found to represent the major storms that account for high percentages of soil loss quite well – a single storm application that the USLE technology is unsuitable for – and WEPP has performed well for disturbed forests and forest roads. WEPP has been able to reflect the extremes of soil loss, being quite responsive to the wide differences in cropping, tillage, and other forms of management, one of the requirements for WEPP validation. WEPP was also found to perform well on a wide range of small watersheds, an area where USLE technology cannot be used.
(KEY TERMS: soil erosion; sediment; modeling; software; WEPP; accuracy.)

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INTRODUCTION

The accuracy of model prediction is important. The Water Erosion Prediction Project (WEPP) developed a computer model for predicting soil erosion by water. WEPP was developed by federal agencies with assistance from many other parties. The model has been evaluated by numerous scientists, with a particular emphasis on how well it predicts soil erosion and how well it stacks up against competing technologies.

The WEPP User Requirements (Foster and Lane, 1987) make several statements about the validation criteria for the model. The more quantitative statements are (1) the procedure gives expected responses that appear reasonable, (2) the model gives results that are more useful for agency program objectives than those given by the USLE (Universal Soil Loss Equation) (Wischmeier and Smith, 1978) and applies to situations not appropriate for the USLE, (3) the model provides a reasonable representation of data covering the range of conditions of key situations, (4) judgments on the "goodness of fit" of the estimates from the procedure to observed data are to be based on the data sets as a whole and not on a few specific and isolated data sets, and (5) the model is able to stand up in public hearings of management plans and assessments. Of particular significance is the statement that "Quantitative measures of the goodness of fits will be calculated and presented, but a specific quantitative level of accuracy figure is not being required because of the great variation in the experimental data that will be used in validation. However,

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the results are to be at least as good with respect to observed data and known relationships as those from the USLE" (Foster and Lane, 1987, p. 11).

The objectives of this paper are to discuss expectations for WEPP accuracy, to review published studies related to WEPP goodness of fit, and to evaluate these in the context of expectations for WEPP's goodness of fit.

EROSION PREDICTION ACCURACY EVALUATIONS AND EXPECTATIONS

There are a number of measurements of accuracy for any model. A good evaluation uses more than one measurement of accuracy to pass judgment on the quality of the model. In days past, in erosion prediction, the emphasis was on representing trends in the impact of land management and conservation treatment on soil erosion, and on prediction of average annual values. As the emphasis has moved from protecting a resource for production to protecting downstream water resources, the prediction needs have included soil erosion for individual storm events and hazards associated with chemical transport and with catastrophic events. The needs that have changed include estimation of the size distribution of sediment for constituent transport in water and adsorbed to sediment, estimation of extreme events including return periods, and, perhaps, real time estimates of erosion and runoff hazard.

Several different techniques have been used in evaluating WEPP. These include sensitivity analyses (Nearing *et al.*, 1990), linear regression (Zhang *et al.*, 1996), Nash-Sutcliffe Model efficiencies (Nash and Sutcliffe, 1970; Tiwari *et al.*, 2000), and statistical distributions of soil loss (Baffaut *et al.*, 1998). Each of these techniques provides valuable information for model evaluation, but none alone provides all the information needed.

A recent addition to the suite of techniques for evaluating models is the technology developed by Nearing (1998, 2000) and Nearing *et al.* (1999). Their major finding was that for soil erosion runoff plots, the coefficient of variation (CV) for replicated plots was a function of the value of the measured soil erosion (M). The relationship could be expressed as

$$CV = 0.73\ M^{-.306} \qquad (1)$$

where M is expressed in t/ha. They used replicated erosion plots to develop the relationship, and in these writings, expressed the view that an erosion model should not be expected to give better results than found when comparing replicates. The implication then is that using Equation (1), a confidence interval could be established about a measured soil erosion value within which a predicted soil loss would likely fall. Assuming that the variability in soil erosion rates is distributed normally about the measured value, the confidence interval (CI) about the measured value would be given by

$$CI\ (t/ha) = t_{(\alpha+1)/2}\ M\ CV \qquad (2)$$

where t is the cumulative distribution value for $(\alpha + 1)/2$ for an infinite number of points, and α is the probability level selected. For a 0.95 confidence interval (95 percent) CI (t = 1.96), and using Equation (1) for CV, CI can be written as

$$CI_{95} = 1.43\ M^{.694} \qquad (3)$$

Lower and upper bounds (LB and UB) for the 95 percent confidence interval are given by

$$LB\ (t/ha) = M - CI_{95} \qquad (4)$$

$$UB\ (t/ha) = M + CI_{95} \qquad (5)$$

Equations (4) and (5) express the 95 percent confidence intervals about a measured soil erosion value. If one had an infinite number of replicated plots with a mean value of M, measured soil erosion would be expected to fall within the confidence interval 95 percent of the time, with measured soil loss falling outside this interval 5 percent of the time.

The 95 percent confidence interval is very wide (Table 1). Yet, this interval is in the range of that experienced in other erosion studies. Elliot *et al.* (1990) in measuring rill and interrill erodibility and critical shear values using simulated rainfall on carefully controlled plots on a wide range of U.S. soils reported coefficient of variations averaging from 25 to 33 percent. The intervals shown in Table 1 are similar in magnitude for high erosion rates. Other confidence intervals could have been used, but, based on the findings in this paper, the 95 percent confidence interval was reasonable in that this level could be used to discern where the model performed poorly, and where it did not.

Nearing and his coworkers developed the relationship in Equation (1) using data collected on erosion plots. We have no comparable data from fields and watersheds that could be used to evaluate such a relationship. Yet, application of Equation (1) to evaluation of watershed data should provide additional useful information about model applications to watersheds.

TABLE 1. Coefficient of Variation (CV), 95 Percent Confidence Interval (CI), and Upper (UB) and Lower (LB) Limits for Soil Loss Measurements Computed From Nearing *et al.* (1999).

Soil Loss (t/ha)	CV (fraction)	95 Percent CI (t/ha)	Lower 95 Percent CI (LB) (t/ha)	Upper 95 Percent CI (UB) (t/ha)
0.01	2.99	0.058	0	0.07
0.1	1.48	0.289	0	0.39
1	0.73	1.43	0	2.43
5	0.45	4.37	0.63	9.37
10	0.36	7.07	2.93	17.07
100	0.18	34.9	65.1	134.9
1,000	0.09	173	827	1,173

WEPP TESTING ON HILLSLOPES

Tiwari *et al.* (2000) conducted an evaluation of WEPP using USLE plot data from 20 locations, with data collection periods beginning as early as 1931, and ending as late as 1971. A total of 1,594 plot years of record were used, with management including fallow, continuous monocropping and rotations, row crops, small grains, and grasses. Slopes ranged from as low as 3 percent up to a high of 21 percent. Slope lengths were generally the typical USLE unit plot length of 22 m, but some exceeded that length. Results are given in Table 2 and Figure 1. Also shown are comparisons with predictions by the USLE and RUSLE (Revised Universal Soil Loss Equation) (Renard *et al.*, 1997). The comparisons with RUSLE and WEPP are from Tiwari *et al.* (2000), where they

TABLE 2. Comparison of Measured and Predicted Soil Loss From Runoff Plots (from Tiwari *et al.*, 2000).

Site	Plot Years	Measured Average Annual Soil Loss (t/ha)	WEPP Predicted Average Annual Soil Loss (t/ha)*	USLE Predicted Average Annual Soil Loss (t/ha)*	RUSLE Predicted Average Annual Soil Loss (t/ha)*	Lower 95% CI (t/ha)	Upper 95% CI (t/ha)	Nash-Sutcliffe for WEPP (for annual soil loss)**	Nash-Sutcliffe for USLE (for annual soil loss)**	Nash-Sutcliffe for RUSLE (for annual soil loss)**
Bethany, Missouri	90	57.7	**23.8**	**23.8**	**20.1**	33.8	81.6	0.40	**0.73**	**0.73**
Castana, Iowa	44	76.5	**116.3**	**145.8**	102.3	47.5	105.5	0.23	0.30	**0.77**
Clarinda, Iowa	117	55.0	41.7	47.2	60.1	31.9	78.1	0.28	0.30	**0.48**
Clemson, S. Carolina	6	57.9	57.2	81.8	**83.6**	34.0	81.8	**0.94**	0.81	0.76
Dixon Springs, Illinois	96	20.9	**40.3**	20.5	21.8	9.1	32.7	-10.58	0.10	**0.34**
Geneva, New York	57	22.9	**8.4**	20.8	22.0	10.3	35.5	0.16	**0.69**	0.65
Guthrie, Oklahoma	153	22.6	34.5	28.5	20.2	10.2	35.0	0.14	**0.32**	0.31
Hayes, Kansas	88	3.1	4.6	6.7	4.7	0.0	6.2	-0.95	0.28	**0.39**
Holly Springs, Mississippi	24	88.8	69.8	109.7	114.9	56.6	121.0	0.47	**0.85**	0.82
Ithaca, New York	79	6.5	**41.0**	9.1	6.7	1.3	11.7	-37.74	**0.48**	0.30
La Crosse, Wisconsin	234	66.0	56.5	54.4	46.8	39.8	92.2	**0.68**	0.66	0.60
Madison, S. Dakota	72	17.1	11.0	12.0	12.9	6.8	27.4	**0.54**	0.38	0.33
Marcellus, New York	79	24.0	12.2	32.3	17.2	11.0	37.0	0.37	**0.80**	0.64
Morris, Minnesota	40	18.0	10.3	18.8	19.1	7.4	28.6	0.45	**0.73**	0.56
Presque Isle, Maine	45	19.9	31.0	15.0	18.5	8.5	31.3	-0.42	-0.50	**0.48**
Raleigh, N. Carolina	10	7.1	7.9	**25.0**	**14.7**	1.5	12.7	**-0.004**	-10.54	-2.88
Statesville, N. Carolina	72	54.1	16.5	**119.9**	72.5	31.3	76.9	-0.21	0.19	**0.25**
Temple, Texas	105	28.8	26.5	26.2	31.4	14.1	43.5	0.38	0.39	**0.44**
Tifton, Georgia	64	3.6	**18.0**	**7.6**	5.4	0.1	7.1	-18.05	**-0.31**	-0.82
Watkinsville, Georgia	119	32.1	**56.4**	28.8	13.0	16.2	48.0	**0.15**	-1.53	-0.54

*Bold values in the predicted columns are for predicted values outside 95 percent confidence interval.
**Bold values in the Nash-Sutcliffe (NS) column are for highest NS values for that row.

used the USLE results from Risse *et al.* (1993) and RUSLE results were taken from Rapp (1994).

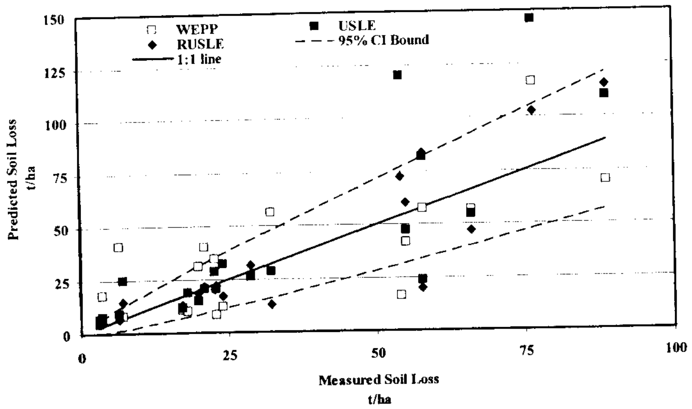


Figure 1. Comparison of Measured and Predicted Average Annual Soil Loss on USLE Type Plots at 20 Locations (data from Tiwari *et al.*, 2000) using WEPP, USLE, and RUSLE.

When predicted values are compared with upper and lower confidence interval values, about 40 percent of WEPP values fall outside this range, while about 30 percent of USLE values and 20 percent of RUSLE values also fall outside the range. All these levels of occurrence exceed that expected of a "perfect" model, indicating problems with all models, either in their formulation or parameterization.

It is clear that several sites had very wide disparities between measured and predicted values for one or more of the technologies. Generally, as shown in Figure 1, one would conclude there was not much difference in terms of prediction ability between the various technologies. USLE performed very poorly for several locations, as did WEPP. RUSLE performed better than USLE and WEPP in terms of predicting average annual soil loss, but in terms of the Nash-Sutcliffe model efficiency, RUSLE performed very similarly to USLE. As indicated by Tiwari *et al.* (2000), there was no technology that consistently outperformed the others. However, Tiwari *et al.* (2000) found that USLE and RUSLE predicted soil loss better than WEPP. This was a logical development because local measured erodibility parameters were used in the RUSLE and USLE predictions as compared to the parameters for WEPP that were computed from regression equations that never included data from a single plot used by Tiwari *et al.*(2000). Additionally, nearly all the plot data were included in the 10,000 plot years of data used in the development of USLE, and every location furnished data for the development of USLE (Wischmeier and Smith, 1978). These data were also used in RUSLE. WEPP soil loss predictions were made using uncalibrated parameters computed from equations furnished with the model. No attempt was made to optimize parameters. Tiwari *et al.* (2000) indicated that there was a need for further refinements in estimation of WEPP parameters, indicating that calibration would have greatly improved WEPP predictions. Tiwari *et al.* (2000) did not report any comparisons between event soil loss predictions by WEPP and USLE or RUSLE.

Ghidey and Alberts (1996) tested WEPP on 11 years of data from USLE type plots on a claypan soil in central Missouri. Tillage treatments included fallow, conventional plowing, chisel plowing and no till, and crops were continuous corn and soybeans. Average annual soil erosion by cropping periods is shown in Figures 2 and 3.

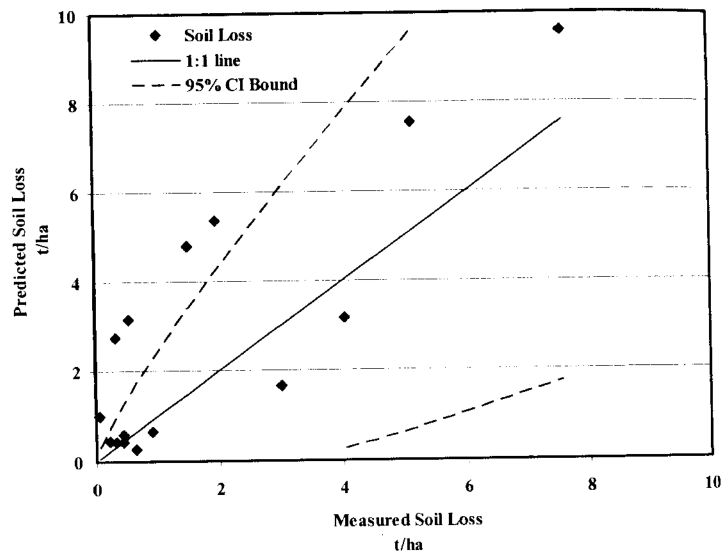


Figure 2. Mean Annual Measured and WEPP Predicted Soil Loss for Corn and Soybeans With Three Tillage Systems for a Midwest Claypan Soil. Note that the lower bound is less than zero for measured soil loss less than 3.2 t/ha (data from Ghidey and Alberts, 1996).

As shown in Figure 3, soil erosion was widely overpredicted for cropping period P3, the period from 60 days after planting to harvest, for all tillage systems. Predicted soil erosion for each of the tillage systems for the P3 period, plus predicted soil loss for the chisel and conventional tillage systems for the P12 period (from 30 to 60 days after planting) exceeded the upper 95 percent confidence interval bound (Figure 2).

WEPP predictions were evaluated for seven storms that accounted for over 80 percent of the total measured soil loss during the 11-year period for the conventionally tilled plots of Ghidey and Alberts (1996). For these storms for continuous corn, WEPP overestimated runoff by 3 percent and underestimated soil loss by 13 percent. For continuous soybeans, WEPP overestimated runoff by 11 percent and soil loss by 28 percent. As shown in Figure 4, WEPP provided good predictions of soil loss for these large storms over a considerable range of storm sizes. But, there were some predictions, two for corn and two for soybeans, that were outside the confidence intervals computed using Equation (3). In three of the four cases, soil loss was overpredicted. For one storm, both plot soil losses were overpredicted. WEPP's event based soil loss predictions are outside the area of application of the USLE technology.

Bjorneberg *et al.* (1999) evaluated WEPP by comparing measured and predicted infiltration, runoff, and soil erosion on furrow irrigated plots on the Portneuf soil near Kimberly, Idaho (Figure 5). Predicted soil loss values shown in Figure 5 were from WEPP runs made using calibrated parameters for hydraulic conductivity, critical shear and rill erodibility, based on a small portion of the study area. As shown in Figure 5, soil loss predictions were outside the 95 percent confidence interval for four of the 14 comparisons. Data shown are for annual soil loss, the results of six irrigations in one year and five irrigations in another year.

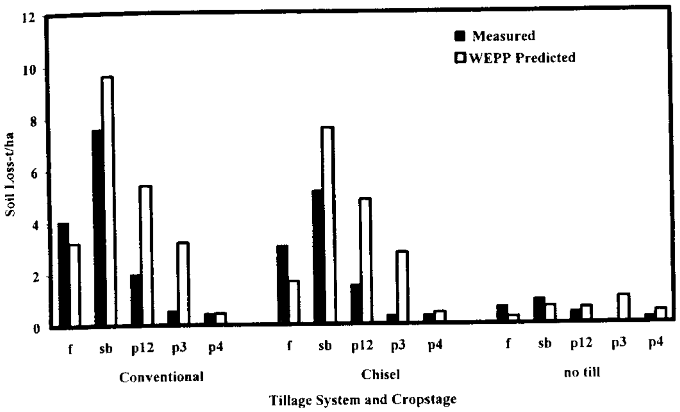


Figure 3. Average Annual Soil Loss by Crop stage for Continuous Corn and Continuous Soybeans With Three Tillage Systems on a Midwest Claypan Soil (data scaled from Figure 9 in Ghidey and Alberts, 1996).

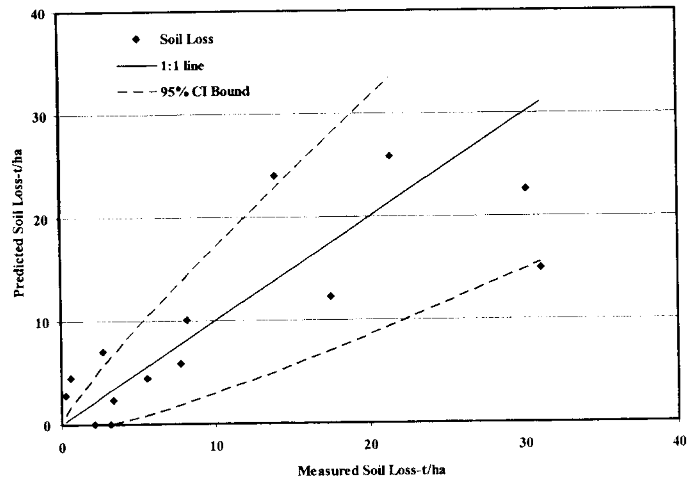
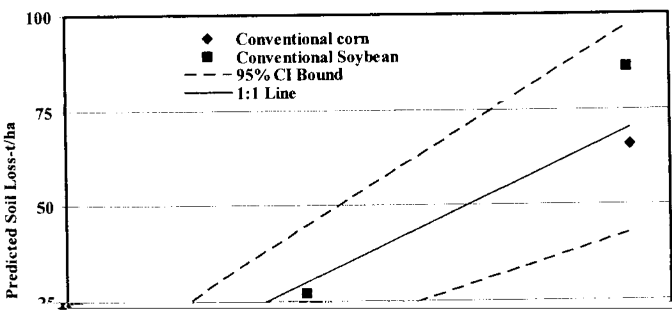


Figure 5. Measured and WEPP Predicted Soil Loss for Furrow Irrigated Plots (Bjorneberg *et al.*, 1999).



Bjorneberg *et al.* (1999) found that the WEPP defined values for rill erodibility and critical shear were much greater than the calibrated values that were used in this study. In fact, the recommended critical shear measured on that soil under rainfall and flow addition conditions (Elliot *et al.*, 1990) was much larger than hydraulic shears occurring in this study. Bjorneberg *et al.* (1999) recommended that WEPP not be used for furrow irrigation estimates

Span 6 were acceptable, while for Span 3, they were unacceptable. The differences between the soil loss rates for the two spans were quite significant, as were runoff rates. This is attributed to soil differences under the spans. The WEPP baseline effective hydraulic conductivity was set at a higher level than the computed baseline value to more nearly reflect runoff rates from the irrigation.

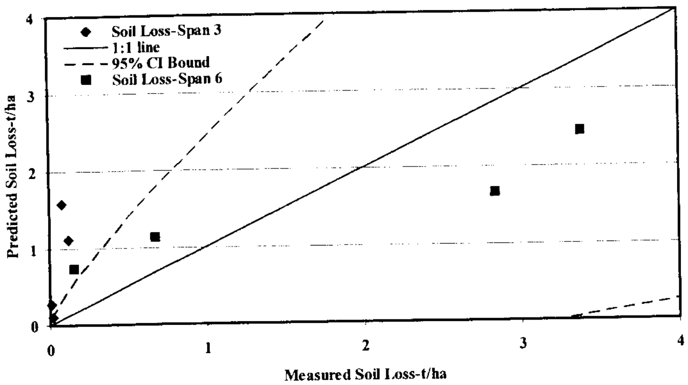


Figure 6. Measured and WEPP Predicted Soil Loss for Center Pivot Irrigation (from Kincaid and Lehrsch, 2001). Note that lower bound is less than zero for measured soil loss less than 3.2 t/ha.

It is significant that the erodibility value used for the center pivot irrigation was that computed for the Portneuf soil, and was apparently reasonably satisfactory. Yet, it was clearly unsatisfactory for the Bjorneberg *et al.* (1999) study, lending support to the recommendation that erodibility parameters must be better defined for furrow irrigation.

Elliot (2004) reported on a study by Elliot and Foltz (2001) where measured and predicted soil loss was compared for forest roads and disturbed forest hillslopes. An interface developed by the U.S. Department of Agriculture Forest Service (USDA-FS) was used with the WEPP model to make average annual predictions for a specific site, while measured soil loss was for specific periods of time and climate. Results presented by Elliot were redrawn and are shown in Figure 7 for a disturbed forest hillslope, while results for a forest road are shown in Figure 8. In another study, the USDA-FS interfaces and WEPP performed better on rangeland than the RUSLE model (Elliot, 2001).

While the comparisons of Elliot are less conclusive because the measured and predicted soil losses and sediment delivery use different climate, they do show that measured and predicted values for the disturbed hillslope fall within the 95 percent confidence bounds. For the USDA-FS roads (Figure 8), about half the observations fall outside the 95 percent confidence bounds. Clearly, WEPP reasonably estimated the nearly 40 times differences between disturbed forests and forest roads soil loss.

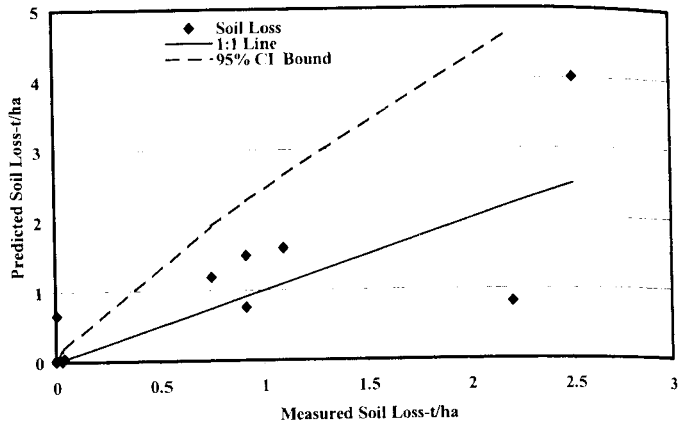


Figure 7. Measured and WEPP Predicted Soil Loss From Disturbed Forest Hillslope (after Elliot, 2004). Note that lower bound is less than zero for measured soil loss less than 3.2 t/ha.

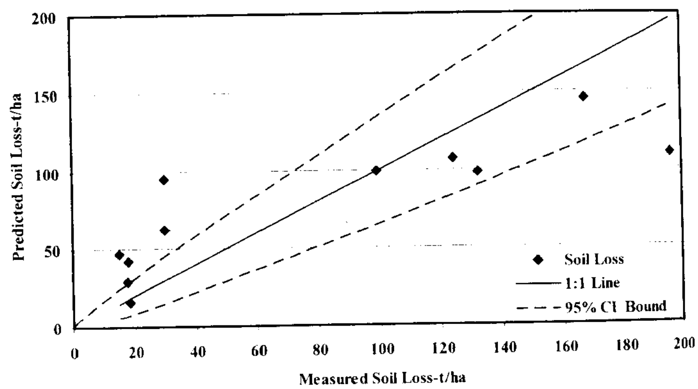


Figure 8. Measured and WEPP Predicted Soil Loss for Forest Roads (after Elliot, 2004).

WEPP TESTING ON WATERSHEDS

Measured data from 15 small (0.34 to 5.14 ha) watersheds (Table 3) at six U.S. locations were compared to runoff and sediment yield estimates using WEPP (Liu *et al.*, 1997). The average period of record for the data was nine years. All storms having surface runoff were used except those occurring during the winter when measured data were not collected. Average annual runoff ranged from a measured low of about 2 mm/yr to a maximum of over 400 mm/yr.

TABLE 3. Total Runoff and Sediment Yields for Small Watershed Studies (from Liu *et al.*, 1997).

Watershed	Total Runoff (mm) for Selected Events		Sediment Yield (t/ha) for Selected Events		Number of Years of Record	Total Number of Selected Events	Outside 95% CI
	Measured	Predicted	Measured	Predicted			
Chickasha C5, Oklahoma	320	309	4.27	3.81	4	34	No
Coshocton 109, Ohio	25	26	1.99	1.02	11	4	No
Coshocton 130, Ohio	49	30	0.036	1.11	7	6	Yes
Coshocton 191, Ohio	20	20	0.055	0.035	11	3	No
Holly Springs 1, Mississippi	3,409	2,820	64.7	153.7	8	237	Yes
Holly Springs 2, Mississippi	3,576	2,658	65.9	121.8	8	241	Yes
Holly Springs 3, Mississippi	2,858	2,600	94.0	141.6	8	241	Yes
Riesel W-12, Texas	833	860	15.77	9.61	6	117	No
Riesel W-13, Texas	879	920	10.38	8.05	6	83	No
Tifton Z, Georgia	403	332	6.67	8.31	8	46	No
Watkinsville P-1, Georgia	596	567	53.9	67.6	11	33	No
Watkinsville P-2, Georgia	377	359	17.40	18.18	3	21	No
Watkinsville P-3, Georgia	518	614	9.74	8.51	11	35	No
Watkinsville P-4, Georgia	529	541	5.96	7.50	10	36	No

Sediment yield ranged from about 0.007 t/ha/yr to over 8 t/ha/yr. Soils ranged from a silty clay to a sandy loam and management included conventional and no-till, as well as meadow. These six sites represent tremendous diversity. The total sediment yield over the period of record for the individual sites is shown graphically in Figure 9, along with the best fit linear line, a 1:1 line, and the upper and lower 95 percent confidence lines computed using Equation (3).

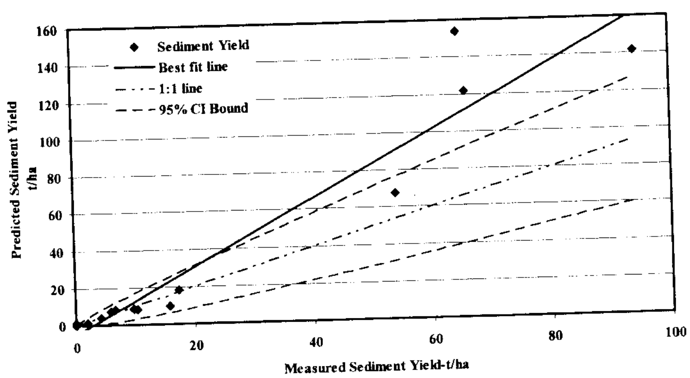


Figure.9. Measured and WEPP Predicted Sediment Yield From 14 Small Watersheds (data from Liu *et al.*, 1997).

The linear regression analysis comparing measured and predicted sediment yield indicated that the slope of the relationship between measured and predicted sediment yield was significantly different than one, while the intercept was not significantly different than zero. When the data points that were outside the 95 percent confidence interval lines were removed from the regression, the slope of the relationship was much lower, but still significantly greater than one. However, when the Watkinsville P1 watershed was removed (even though it was within the 95 percent confidence interval), the linear regression yielded a slope that was not significantly different than one and an intercept that was not significantly different than zero.

Data points outside the lower and upper confidence bounds merit special attention. These watersheds included all the Holly Springs watersheds, and one of three at Coshocton. Liu *et al.* (1997) indicated that there were two problems with the application of WEPP to the Holly Springs watershed. First, the silage routines in WEPP predicted removal of much more of the biomass than actually occurred, which would be expected to lead to an overprediction of sediment yield. Second, the growth of biomass weeds and grass after harvest was not modeled, even though it is well within the capabilities of WEPP. This would also lead to higher sediment yield predictions.

The three Coshocton watersheds produced small amounts of sediment. Additionally, the number of events was very low, an average of less than one per year. Two of the three watersheds at Coshocton, either with a continuous corn rotation using no tillage or with a corn, soybean, wheat, and meadow rotation, had good agreement between predicted and measured runoff and sediment loss. The third watershed was in meadow, which would be expected to have a lower sediment delivery rate than watersheds in no-till corn or a corn, soybean, wheat, and meadow rotation, yet it had the greatest predicted sediment delivery rate. This raises questions about how the meadow was modeled. Some differences could be due to the fact that the data collection period for the meadow watershed was different than for the watersheds having no-till corn or a corn, soybean, wheat, and meadow rotation.

The comparisons described here were for total sediment delivery over the period of record. Additional comparisons could have been shown using the published data for average annual or average event sediment delivery. The USLE and RUSLE cannot be used for watershed sediment delivery, an area of application of WEPP.

SUMMARY AND CONCLUSIONS

Over a very wide range of conditions, WEPP performed about as good as replicated small plots and about as good as USLE and RUSLE where comparisons were made. This is a major finding, for WEPP was developed from basic relationships constructed similarly to how one would build a building – piece by piece – using the attributes of the pieces and the best understanding of the linkages between the pieces so that the model would replicate the real world. WEPP was not calibrated, nor were locally derived parameters based on measurements used. When the results using WEPP are compared to results using USLE and RUSLE, which are based on locally derived parameters and developed from the data set on which they were tested, and WEPP does as well there is a very strong indication that in uncalibrated comparisons, WEPP will perform very well as compared to USLE and RUSLE technology. Tiwari *et al.* (2000) essentially indicated this when they stated there was a need for improvement in parameter estimation for WEPP. Tiwari *et al.* (2000) also strongly indicated that the comparisons with USLE and RUSLE were biased in the USLE's and RUSLE's favor.

Comparisons have been made using a number of techniques. A new technique, based on experimental variability, developed by Nearing and coworkers (Nearing, 2000; Nearing *et al.*, 1999), was used in this paper to evaluate WEPP for a very wide range of applications. Generally, the technique was able to ascertain where the model may have performed poorly, and to indicate where improvements in application or parameterization are needed. Additionally, the technique also revealed where apparent differences were not of concern. In particular, large percentage errors at low erosion rates are frequently of no consequence, but rather may be within the differences expected in replicates. The information developed using this technique was different than information developed using other techniques, but the results did not contradict, but rather tended to support, results obtained using other techniques for model evaluation. The new technique, based on measurements of replicate variability, clearly shows that expectations of models must be realistic.

There are a few notable improvements that need to be made to WEPP before it is applied to certain situations. The estimation of soil erodibility parameters for furrow irrigation needs to be improved, as it is obvious that those from the rainfall simulation experiment simply did not work for the furrow irrigation study reported in the literature. Another finding was that plant growth and residue occurrence and fate must be reasonably modeled if good results are to be achieved.

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