Reply to Foster et al. Discussion of "Application of the Universal Soil Loss Equation to Rangelands on a Per-storm Basis", by Trieste and Gifford in Journal of Range Management 33:66-70, 1980.

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We appreciate the in-house defense of the Universal Soil Loss Equation (USLE) by Foster et al. Unfortunately, their paper is far from convincing. It fails to acknowledge the premise under which we carried out the study and which is clearly stated at the beginning of the paper and, secondly, it is filled with material that to the casual reader appears to be proven fact when in fact it simply represents "truth" through personal opinion. Adequate evaluation of the USLE on rangelands would seem to border on the impossible, or so Foster et al. would have us to believe. If criticism does materialize, then plots used are too long or too short, too wide or not wide enough, or the P, C, K, or R factors have not been correctly evaluated, or a 22-year rainfall cycle has not been experienced, or, if a rainfall simulator is used, the drop size is wrong or terminal velocities were not properly considered or any one of a dozen other things. We believe this to be a serious problem, and unless adequately resolved, practicing field hydrologists may be grossly deceived through use of an erosion-predicting tool (reli-gion?) that is insufficient even for rangeland planning purposes.

Applicability of Small Plots

Foster et al. state: "Trieste and Gifford assumed that the USLE applied to their data. . . . The validity of their analysis depends on the validity of this assumption which, unfortunately, they did not assess." We did not feel it necessary to demonstrate the USLE applied to our data but simply to state our initial assumptions. We agree that the USLE lumps sheet and rill erosion together, and we were very careful to indicate "This study pertains to sheet erosion only and all computations were done on a per-storm basis."

The 2,805 plots utilized present, as outlined in our paper, a wide range of conditions in many different rangeland-plant communities and on a variety of mining sites. Assuming the average simulated storm approximated perhaps a 25-year storm, then our data represent perhaps 70,125 plot years of record. Given our initial assumption(s), the precision (repeatability) can be easily tested although the accuracy (actual amount) may be questioned. The large number of plots used in the statistical analysis is sufficient reason to support this assumption. And if the equation can't handle sheet erosion in natural rangeland plant communities, then can it handle sheet and rill erosion together? Quite frankly, given the difference between agricultural fields and rangeland plant communities, we tend to lean, at least for the present, toward indicators

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generated from data gathered under natural conditions.

As for Foster's et al. suggestion that the USLE does not apply to single storms and that we did not consider the natural distribution of rainfall events and antecedent moisture conditions, we can only suggest once again that they check our study objectives and initial assumptions. Our data provided an excellent opportunity to examine many variables and the equation was unable to handle them in natural plant communities. This finding is entirely consistent with recommendations offered for use with the USLE. The point, however, is that erosion on many rangelands sites is dominated by only one or two storms per year and in these instances the application of the USLE, based on the results of our work, may not be realistic. In short, we disagree strongly with the statement from Foster et al. that ". . . neither absolute nor relative values from small plots can, in general, be reliably applied to the USLE." We have, for example, less problem (by far) in rationalizing the use of small plots than we do in determining C and K factors using conventional methodology. It is of note that Foster et al. can provide no evidence of their small plot criticism since, as they state, "Apparently, no one has evaluated the minimum slope length to which the USLE applies. We *believe* (emphasis added) that the USLE probably does not apply to slope lengths shorter than 25 feet. . . ."

Rainfall Erosivity (R) Factor

Foster et al. state: "Rainfall intensity during a storm generally varies and is not consistent as it was in some, if not most, of the rainfall simulator tests of Trieste and Gifford. The EI parameter of the USLE could work well for variable intensity natural storms but not for constant intensity simulated storms." Of the 2,805 plots analyzed in this study, 1,917 represent data from Rocky Mountain infiltrometer plots. Rainfall intensity from the Rocky Mountain infiltrometer is anything but constant, and that is the reason rainfall is carefully measured on each plot and why kinetic energy is computed for six different time intervals at which intensity was measured. Our results indicate it made no difference whether rainfall was constant or not in performance of the USLE in natural plant communities. However, where constant rainfall was applied on mining spoils, and was accounted for as given in our paper, the USLE performed very well. To the extent that our equation for computing total kinetic energy for the Rocky Mountain infiltrometer (Case 1) may have caused some confusion, the equation may be rewritten as follows:

$$E = \sum_{i=1}^5 [(916 + 331 \log_{10} X_1) (X_1 * T_i)]$$

where:

E = total kinetic energy for the simulated storm in foot-tons per acre

X_1 = weighted average rainfall intensity of the five time intervals that make up the 28-minute rainfall simulation period

X_i = rainfall intensity for a specific 5-minute period (in/hr)

T_i = time interval (hours)

Foster et al. state that their equation (2) should be used for calculating total kinetic energy. Kinetic energy (E) is in units of foot-tons/acre. Kinetic energy from Wischmeier and Smith's equation, $Y = 916 + 331 \log_{10} X$, is in units of foot-tons/acre-inch. Since E is in units of foot-tons/acre, then foot-tons/acre-inch * inches equals foot-tons/acre. In our equation, $X * T = \text{inches (inches/hour * hour = inches)}$, which is needed for the dimensions to equate to foot-tons/acre. If X and T, as defined by Foster et al., equal rainfall intensity and volume, respectively, then $X * T$ would equal inches/hour * acre-inch, or acre-inch²/hr. We fail to see how this leads to anything productive.

As for using equation 4 of Foster et al., we did some trial calculations using this equation and results were similar to values obtained with equation 3. After due deliberation, we decided to use equation 3 so as to be consistent with techniques used in the USLE and to avoid confusion or undue interpretation. Our procedure in the computation of storm EI values was from information sent to us by George Foster in September, 1976.

Meyer (1965), as referred to in our paper, has shown that adjustments in raindrop energy can be made. The value of 3.7 mm for a mean drop diameter of natural rainfall wasn't used as "the mean drop diameter" for natural rainfall, but instead was used simply because the mean drop diameter from the Rocky Mountain infiltrometer is about 3.7 mm. Since we are calculating relative erosivity between natural and simulated rainfall using Meyer's technique, the same drop diameter was used throughout the calculations. As recently pointed out by Mutchler and McGregor (1979), we know very little about natural raindrop size distributions, and this is especially true in the western United States. In some cases, adjustments for raindrop energy may not even be necessary (Barnett and Dooley 1972). However, even if the adjustments are in error, they would be the same on all plots for the same rainfall simulator, and relative evaluations can be made and precision tested for.

The paragraph of Foster et al. which begins: "Including other factors like runoff in the USLE erosivity factor, improves soil loss estimates, but not greatly," provokes an interesting question. If runoff doesn't improve soil loss estimates much, they why the problem with small plots? Foster et al. state elsewhere that "Such plots are too short for significant rill erosion to occur or for runoff to accumulate to influence sediment transport. . . ." Obviously, as pointed out elsewhere, additional research is needed to clarify such statements. This same confusing element is also evident in Foster's et al. brief discussion of the soil erodibility (K) factor.

Soil Erodibility (K) Factor

We not only didn't find a correlation of erosion with the soil erodibility factor K, but for everything else also. The lack of correlation with the K factor is not a surprise to us, not because of plot size, but because of the definition of K (Wischmeier and Smith 1978). The concept, as applied to rangelands, is indeed questionable.

We suggest, if different values (in this case for the USLE) are derived using a variety of techniques, it is time to examine the techniques in greater detail so they may be related to one another through reliable methodologies. Where rainfall simulators are used there will always be compromise, even when large plots are utilized. The relatively complex and expensive equipment as (for example) described by Foster et al. (1979) is not suited to extensive use on rangelands. Even modification of the Colorado State Uni-

versity (see Smith 1979) rainfall simulator for field use borders on unrealistic expectations in terms of what actually is accomplished in the field due to time, water, and equipment demands. Small plot efforts on both a research and applied hydrology scale are here to stay, and it is hoped that such things as the Rainfall Simulator Workshop held in Tucson in 1979 will stimulate increased funding and study of this obvious fact.

Slope Length (L) Factor Slope Steepness (S) Factor Cover-Management (C) Factor

The L factor in our power equation should be $L^{-0.99}$.

Foster's et al. discussion of the cover-management (C) factor is primarily an exercise in academic gymnastics. Wischmeier and Smith (1978) state that C factors for rangelands have not been derived by direct comparison of measured soil loss rates. The very low R^2 value associated with our multiple regression equation indicates that discussion of the equation or individual factors within the question is not warranted. The factors in the equation were not analyzed separately but rather exponents were derived from multiple regression optimization with all variables together as they interact with one another. It wasn't the intent of our paper to try and explain the meaning of exponents in the multiple regression equation, but, instead to present the results for the reader's interest. We welcome the interpretation by Foster et al., but it is important to realize that their statements are their own conclusions and the statements are not in any sense arguments against our results.

As for selection of our C values, the source was *Erosion Control During Highway Construction*, Vol. II, Utah Water Research Laboratory, Utah State University, 1976. The range in C was not small, but varied from about .05 to about .45. Foster et al. states: "Their result of a negative exponent for C would suggest that USLE C factors are meaningless." We would like to emphasize that the statement may be true as there is no evidence from rangelands to indicate that the C factor, as expressed in the USLE, adequately describes the impact of this very important variable.

General Comments

Foster et al. state: "The conclusions reached by Trieste and Gifford apply more to the use of small plots and simulated rainfall to study erosion on rangeland than to the applicability of the USLE to rangeland." This statement is strictly opinion and we challenge Foster et al. to validate the predictability of the USLE on rangelands before making such biased statements.

Literature Cited

- Barnett, A.P., and A.E. Dooley. 1972. Erosion potential of natural and simulated rainfall compared. *Trans. Amer. Soc. Agr. Eng.* 15:1112-1114.
- Foster, G.R., F.P. Eppert, and L.D. Meyer. 1979. A programmable rainfall simulator for field plots. *In: Proc. Rainfall Simulator Workshop, Tucson, Arizona, March 7-9:45-59.*
- Mutchler, C.K., and K.C. McGregor. 1979. Geographical differences in rainfall. *In: Proc. Rainfall Simulator Workshop, Tucson, Arizona, March 7-9:8-16.*
- Smith, R.E. 1979. Current rainfall simulators and simulator activities at Ft. Collins, Colorado. *In: Proc. Rainfall Simulator Workshop, Tucson, Arizona, March 7-9:163-165.*
- Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall erosion losses—a guide to conservation planning. U.S. Dep. Agr. Agr. Handk. 537:58 p.