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PRINCIPLES OF SOIL EROSION CONTROL: RANGELANDS

by

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The control of erosion on rangeland is certainly not an easy problem for the land manager/environmentalist. The reason the land is probably being used as range is because of some limitation in the resource base such as poor soil (shallow or mineral deficiency), excessive slope (and corresponding high erosion hazard), limited precipitation and in turn, limited soil protection by vegetation. A further significant factor in the erosion control problem on rangelands involves the low economic value on a unit basis of such land which limits the options for investments in many types of treatments which have been found to be effective on cultivated land. And finally, the erosion on rangeland includes that from both wind and water so that both contribute to the loss of the precious soil base.

Having spent most of my career working with water erosion problems on rangeland, I hope to emphasize water erosion on rangelands while recognizing that the same forces and processes are involved with wind erosion, the transport medium being the major difference.

Erosion and sedimentation by water involve processes of detachment, transport and deposition of soil particles. The major forces are from raindrop impact and water flowing over the land surface. The factors affecting erosion can be expressed in equation form as:

$$Er = f\ (Cl,\ Sp,\ To,\ SS,\ M) \qquad (1)$$

where Er = erosion; f = function of ( ); Cl = climate; Sp = soil properties; To = topography; SS = soil surface condition including vegetation; and M = human activities. A fairly detailed treatment of the theoretical aspects of each of these factors was presented by Renard and Foster (1983) and Foster (1982). Neither time or space permit repeating such material here. Rather I want to discuss what is being done regarding two approaches to estimate upland erosion by water, namely a revision of the Universal Soil Loss Equation ,USLE, (Wischmeier and Smith, 1965 & 1978) and the Water Erosion Prediction Project, WEPP, a technology intended to replace the USLE.

Although it is now over 20 years since the original USLE handbook was published, the technology has been available and widely used in USDA for almost four decades. The USLE is an expression of the functional relationship shown in equation 1. Developed from extensive field experimentation, the USLE involves six terms, the product of which furnishes an estimate of the average annual erosion from a field area.

$$A = R\ K\ L\ S\ C\ P \qquad (2)$$

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where A = computed soil loss per unit area; R = a rainfall and runoff factor; K = soil erodibility factor; L & S = topographic terms representing slope length and steepness; C = cover-management factor; and P = support practice factor.

Unfortunately, this technology was developed from experiments performed on cultivated areas although the technology has been extended to most other land use conditions (Renard and Foster, 1985). In the current revision of the USLE, perhaps the most significant change occurs in the method used to determine a value of the cover-management factor, C. A subfactor approach is used, as proposed by Wischmeier, 1975, Mutchler et al., 1982 and Laflen et al., 1985. The factor C is expressed as

$$C = LU * CC * SC * SR \quad (3)$$

where LU is a land use subfactor, CC is a canopy subfactor, RC is a surface cover subfactor and SR is a surface roughness subfactor. Each of these subfactors in turn is also expressed by an equation so that a value can be computed for any specific situation. The equations contain the variables recognized to greatly influence erosion and vary according to land use and management practices.

The individual subfactor values presently proposed for rangeland are as follows:

$$LU = 0.40 * \exp(-0.012 * RS) \quad (4)$$

where RS is the live roots and buried residue in the upper 100mm of soil (kg per ha per mm of depth). This number is not exactly easily obtained so a scheme has been developed to estimate the value from annual above ground biomass estimates.

$$RS = BIO * n * e/100 \quad (5)$$

Where BIO is the annual above ground biomass estimate (kg per ha), e is the ratio of below ground biomass to above ground biomass and n is the ratio of biomass in the upper 100mm of soil to the total below ground biomass. Tables are being prepared of reported typical values of n and e by vegetation type (e.g. grass, brush, tree, etc.) and climatic region in addition to the effects of grazing and other man induced activity.

$$CC = 1 - FC * \exp(-0.34*H) \quad (6)$$

where FC is the fraction of the land surface beneath canopy and H is the height (m) that raindrops fall after impacting the canopy.

$$SC = \exp(-4.0*M) \quad (7)$$

where M is the fraction of the surface covered by nonerodible material (e.g. living and dead plant material, rock and large gravel). This factor has been observed to be extremely important, especially where erosion pavement, cryptogams, or other nonerodible items can be expected to protect bare soil from the erosive forces of raindrops or flowing water or both.

$$SR = \exp(-0.026 (RB - 6)(1 - \exp[-.035*RS])) \quad (8)$$

where RB is a random roughness (mm) expressed as the standard deviation of surface elevations from a plane and is intended to reflect any tillage consequence or other roughness forms. Illustrations are being provided of typical values which might aid users in selecting values representing their condition. These solutions as well as those for the other factors have been programmed for speedy solution in a user friendly way on a personal computer.

Other factors in the USLE are also to undergo some changes. For example, the R-factor data base which in Agriculture Handbook 537, was so inadequate for the western U.S. will be expanded to include almost 1000 stations. Unfortunately, the analysis will not be concluded in time for the current revision (a special supplement will be produced) and the snowmelt problem will still remain inadequately addressed.

Slope length and steepness (LS) for rangeland has been investigated extensively by McCool and Foster (personal communication) using some research models and new field data. The nonlinear LS versus erosion relationship presented in Agriculture Handbook 537 will be replaced with tables/algorithms for rangelands (and other land uses) reflecting the estimated intensity of rill to interrill erosion and the presence of erosion associated with thawing soil. The soil erodibility value, K, as presented in the nomograph in Agriculture Handbook 537 is being left unchanged.

Finally, the supporting practices factor, P, has never specifically been adapted to mechanical practices like ripping, root plowing, contouring and chaining on rangelands. These practices affect erosion by wind and water in several ways but perhaps most importantly by removal (usually temporarily) of surface cover. That effect is and should be considered in the cover-management factor. The mechanical practice effects on the P-factor involve the rate, amount and direction of runoff as well as the hydraulic forces that the flowing water exerts on soil. A table of P-factor values for six common mechanical practices used on rangelands, was developed by incorporating an estimate of the surface disturbance, duration of effectiveness of the disturbance and the runoff reduction into a physically based simulation model, CREAMS (Knisel, 1980) and simulations performed for different slope steepness.

WATER EROSION PREDICTION PROJECT

The USDA WEPP activity is now well underway under the leadership of Dr. George R. Foster at the ARS National Soil Erosion Laboratory in W. Lafayette, IN. He is assisted by a core team distributed around the country and representing the Agricultural Research Service, Soil Conservation Service and Forest Service in USDA and the Bureau of Land Management in USDI. Contrary to the empirically based USLE, the new technology will be based on fundamental hydrologic, erosion, soil, and crop sciences and is intended to replace the USLE. The technology, based on solutions with a personal computer, will consider the basic erosion processes of detachment, transport, and deposition of soil particles by rainfall and runoff. Thus, the technology will include simulation of climate, hydrology, erosion, tillage, crop growth and management practices and require consideration of topographic conditions when applied to areas larger than a simple hillside slope element.

Planning for the field validation to provide the a priori parameter values needed to perform computations is well along. The initial field testing on the rangelands of the western U.S. include about 20 locations/soils from 11 different states. A rotating boom rainfall simulator will be used for the field experiments. Similar plans for the cultivated croplands of the US include simulation on over 30 soils. A working version of the model is anticipated for use by 1992 although it is recognized that ongoing experiments and validation will be required for sometime into the future.

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