Chapter 6
Erosion Prediction on Range and Grazing Lands: A Current Perspective

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Introduction

Rangelands cover almost half the earth's land surface (Williams et al. 1968). Much of this rangeland occurs in arid and semiarid regions (Branson et al. 1981) and exhibits wide variations in plant height, distribution, canopy, and ground surface cover (Tuller 1982). The spatial and temporal patterns of vegetation, ground cover, and rock outcrops which make rangelands so visually appealing, are the very attributes that make developing management plans for sustainable ecosystems extremely difficult. Vegetation has been found to be the primary factor influencing the spatial and temporal variability of surface runoff and interrill erosion (detachment of soil by raindrops) of soil on semi-arid rangelands (Blackburn et al. 1992). Plant and litter variables influence infiltration and the basic erosion process of soil detachment by raindrops and runoff, sediment transport, and sediment deposition by influencing the hydraulic roughness, organic matter content, bulk density, aggregate stability, surface crusting, porosity, and structure of the soil (Blackburn et al. 1982, 1992, Laflen et al. 1985). Canopy cover has the most affect on interrill erosion whereas ground surface cover affects runoff velocity and hence runoff shear stress and detachment by overland flow (rill erosion) (Tiscareno-Lopez et al. 1992). Thus, an understanding of the variation in spatial patterns of vegetation and soil attributes across the landscape is essential for understanding and predicting the interrelations of infiltration, surface runoff, and soil erosion as related to management of the landscape.

History of Erosion Prediction

The evaluation of the relation of surface runoff and water- induced soil erosion in the Unites States dates to the early part of this century. Research evaluating soil erosion on range and forest lands was initiated in 1912 in the Manti National

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Forest in Utah on two 4.05-hectare plots (Sampson and Weyl 1918). Early research on rangelands demonstrated how overgrazing reduces the soil's water-holding capacity leading to soil erosion and lowered soil fertility (Chapline 1929). Soil erosion on rangelands was recognized as a serious problem at both local and national scales in the 1920's (Bennett and Chapline 1928).

Improperly applied grazing management practices may significantly decrease infiltration rates, increase runoff rates, and accelerate erosion rates on rangelands (Renner 1936, Llacos 1962, Rauzi and Fly 1968, Aldon and Garcia 1973, Hanson et al. 1978, Blackburn et al. 1982, Thurow et al. 1986, Weltz and Wood 1986a&b). However, numerous studies have indicated that proper grazing management practices have similar infiltration, surface runoff, and soil loss characteristics as ungrazed landscapes (Blackburn et al. 1982, Weltz and Wood 1986a&b, and Thurow et al. 1986 and 1988). Grazing management practices influence soil erosion on rangelands because of their effect on plant distribution, biodiversity, canopy and ground cover, and soil properties (Gifford and Hawkins 1978, Blackburn et al. 1982, Johnson and Blackburn 1989, Blackburn et al. 1992).

In 1929, Congress appropriated money for soil erosion research by the United States Department of Agriculture (USDA), and ten experimental stations were established across the United States at: Clarinda, Iowa; Hays, Kansas; Bethnay, Missouri; Statesville, North Carolina; Guthrie, Oklahoma; Zanesville, Ohio; Temple and Tyler, Texas; Pullman, Washington; and LaCrosse, Wisconsin. By 1935, soil erosion was considered a national menace and a serious problem on over one-half of the United States (Weaver and Noll 1935).

The study of the influences of land-use and management practices on soil erosion from natural rainfall on soil erosion plots was initiated in Missouri in 1917 (Duley and Miller 1923, Miller 1929, Miller and Krusekopf 1932, Woodruff 1987). These early erosion plots were 27.68 m long by 1.83 m wide (0.0051 ha). The techniques that Miller and his associates developed were adapted and employed at the other USDA research locations, although the size of the plots was decreased to 22.1 m long by 1.83 m wide (0.0041 ha). The runoff and erosion for each storm was usually caught in a large tank, often with no time-rate information collected to determine sediment concentration or peak flow rate (Meyer 1981). Although a common experimental design was followed, the treatments were seldomly randomized or replicated and the data were of little use outside the local area (Meyer 1981). However, this information did provide the core database to begin developing statistical and mathematical methods of estimating soil erosion.

The basis of mathematical equations to estimate soil erosion can be traced to the work of Cook (1936), who identified three major variables: 1) the susceptibility of soil to erosion, 2) the potential erosivity of rainfall and runoff, and 3) the protection offered by vegetation. Zingg (1940) evaluated the effects of length of slope (L) and slope steepness (S) on soil erosion and proposed the following equation:

$$A = C\ S^{1.4}\ L^{0.6}$$

where C is a constant of variation and A is total soil loss per unit area. The following year Smith (1941) included the influences of vegetation and supporting farming practices (i.e., type, depth, frequency, and direction of tillage) and recommended that soil loss be calculated as:

$$A = C\ S^{1.4}\ L^{0.6}\ P$$

where the C-factor included effects of weather and soil as well as cropping systems.

Smith and Whitt (1948) proposed the "rational" equation to estimate soil erosion:

$$A = C\ S\ L\ K\ P$$

where C was the average annual soil loss for a specific site for a specific crop rotation on a 3% slope, 27.45 m long slope, farmed up and down the slope and the other terms were non dimensional representing slope (S), length (L), soil group (K) and a supporting practice (P).

Universal Soil Loss Equation (USLE) model

During the 1950's and 60's factors for crop rotation, management, and rainfall for the United States east of the 104th meridian were added (Smith 1958, Wischmeier 1959, Wischmeier 1960) to equations for estimating soil loss from upland areas. The resulting Universal Soil Loss Equation (USLE) was completed and released by Wischmeier and Smith (1965). The USLE was later revised to include methods of estimating soil loss on rangelands and for cropland areas west of the 104th meridian (Wischmeier and Smith 1978). The USLE groups the physical and land management factors that influence soil erosion into six factors. The USLE is defined as:

$$A = R\,K\,L\,S\,C\,P$$

where:

- A is a computed soil loss per unit area in tons/acre,
- R is a rainfall and runoff factor and was based on 22 years of climate records with units of hundreds of ft * ton f * in * acre^{-1} * yr^{-1}
- K is a soil erodibility factor based on a slope length of 22.1 m and a uniformly sloping 9% surface in continuously clean-tilled fallow with units ton * acre * h [hundreds of acre ft * ton f * in]$^{-1}$
- L is a slope length factor determined as the ratio of soil loss from the field slope length to that of a 22.1 m length under identical conditions rather than actual slope length and is unitless,
- S is a slope steepness factor determined as the ratio of soil loss from the field slope to that from a 9% slope otherwise under identical conditions and is unitless,
- C is a cover and management factor determined as the ratio of soil loss from an area with specified cover and management practices to that of continuous fallow and is unitless, and
- P is a support practice factor determined as the ratio of soil loss with conservation practices to straight-row tillage parallel with the slope and is unitless.

The USLE is the most widely known and used method for estimating soil erosion and has been adapted for use in numerous countries around the world (Singh et al. 1981, Lane et al. 1992). With foreign application of the USLE, conversion to SI units is necessary. Conversion factors for A, R, and K between U.S. customary units and SI units are given by Foster et al. (1981). The USLE was statistically derived from over 10,000 plot years of data (Meyer 1981). The USLE was designed to estimate sheet and rill erosion in the various parts of a watershed, but was not designed to address soil deposition and channel or gully erosion.

Modifications to the USLE

Renard et al. (1974) modified the USLE to address soil loss from small rangeland watersheds in the Southwest. They added a term (Ec) to the USLE to account for channel erosion. Williams (1975) modified the USLE to predict individual storm-sediment yield from watersheds. A sediment-routing technique was developed that allowed sediment yield to be routed from small watersheds through large watersheds. Williams (1975) replaced the rainfall/runoff (R) factor with a term that combined storm- runoff volume (Q in acre-feet) and peak runoff rate (qp in cubic-feet per second). The modified USLE (MUSLE) is defined as:

$$A = 95\,(Q\,qp)^{0.56}\,K\,L\,S\,C\,P$$

where the other terms are as defined in the USLE. Replacing the R factor increased accuracy in sediment prediction and allowed the USLE to be used on single storm events (Williams 1977).

Limitations with the USLE

The USLE is an empirical model that does not separate factors that influence soil erosion, such as plant growth, decomposition, infiltration, runoff, soil detachment, or soil transport. The applicability and accuracy of the USLE on rangelands has generated considerable attention (Blackburn 1980, Trieste and Gifford 1980, Foster et al. 1981, Renard 1984). The potential for improving estimates of soil erosion on rangelands with USLE is limited because of its restrictive structure, reliance on an empirical database, and lack of temporal adjustments on rangelands for factors of soil erodibility "K", cover "C", and management practice "P".

Slope length limits for applicability of the USLE have not been precisely defined. Foster et al. (1981) suggested that a minimum slope length to which the USLE applies is approximately 5 m. The upper limit is even less clearly defined (Foster 1982). The USLE slope length is defined as the distance from the origin of overland flow to the point where runoff reaches a well defined channel or to where slope steepness decreases enough for deposition to occur (Wischmeier and Smith 1978). A defined waterway or channel is not always obvious on rangelands, especially if the area is not eroding (Foster 1982). Thus, selection of a typical slope length value involves judgement which results in different values by different users when the USLE is applied on the same site (Foster 1982).

Dissmeyer and Foster (1980) proposed that slope length seldom exceeded 150 m on either forests or rangelands.

The spatial variability of rainfall in the western United States from air-mass thunderstorms is well documented (Osborn and Renard 1969). The variability in total rainfall and rainfall intensity on rangeland watersheds can lead to significant errors in estimating soil loss. Renard and Simanton (1975) reported that for a single thunderstorm on the USDA-ARS Walnut Gulch Experimental Watershed near Tombstone, Arizona, rainfall varied between 25 mm and 50 mm within 3 km. Because the R factor is based on the maximum 30-minute rainfall intensity, the variation in the R factor is magnified and ranged from 30 to 100 units over the 3 km distance. On rangelands, Renard and Simanton (1975) concluded that extrapolating the R factor for more than 1.4 km from a rain gauge may lead to serious error in estimating erosion with the USLE. They concluded that additional work is needed to facilitate estimating the R factor from precipitation data in most areas of the Southwest where thunderstorms dominate rainfall.

Simanton and Renard (1985), using rainfall simulation studies on three semiarid rangeland soils that had been cleared of vegetation, reported that soil erodibility was not constant and continued to increase throughout the four-year study. Nearing et al. (1988), however reported that soil erodibility was not constant and decreased with time following tillage. Thus a study on rangeland and cropland was conducted over much of the United States to estimate soil erodibility values (Laflen et al. 1991). Analysis indicated that actual soil erodibility values bear little quantitative resemblance to the USLE soil erodibility values.

Johnson and Gordon (1988) working on sagebrush dominated rangelands on the USDA-ARS Reynolds Creek Experimental Watershed near Boise, ID, reported that the combination of K and C factors in estimating soil loss from rainfall simulation plots resulted in approximately eight times more soil loss from interspace areas than from shrub dominated areas. Actual measured soil loss from interspace areas were 10 times that from sagebrush (*Artemisia* spp.) areas, seven times more than decadent sagebrush areas, and five times greater than horsebrush (*Tetradymia canescens* DC.) dominated areas. USLE technology for estimating the C and K factors on rangelands has no mechanism for incorporating information on spatial variability of soil loss into the existing structure of the USLE.

Pacific Southwest Interagency Committee Method (PSIAC)

The method developed by the Water Management Committee of Pacific Southwest Interagency Committee (PSIAC 1968) was intended for broad planning rather than for specific project formulation where more intensive investigations were required (Renard 1980). This method was intended for areas larger than 25 km^2. Nine factors were recommended for consideration in determining the sediment yield classification of a watershed. The factors are: 1) geology; 2) soils; 3) climate; 4) runoff; 5) topography; 6) ground cover; 7) land use; 8) upland erosion; and 9) channel/sediment transport. Each factor is assigned a numerical value from a rating chart. Numerical values for each factor range from 25 to minus 10. Summing the rating chart values for the nine factors defines a sediment rating classification, which can be converted to a average annual sediment yield.

Johnson and Gebhart (1982) used the PSIAC methodology to estimate sediment yield from three subwatersheds within the USDA-ARS Reynolds Creek Experimental Watershed near Boise, ID. They developed regression equations to predict each of the values to represent the subfactors within the PSIAC method. Average annual predicted sediment yields were within 15 % of measured values. They concluded that more research was necessary to determine if the fitted relationships developed in this study were applicable to other rangeland watersheds.

Current Technology

Chemical Runoff and Erosion From Agricultural Management Systems (CREAMS) Model

During the 1970' s a new approach to estimating soil erosion and the impact of agricultural practices on off-site water quality was initiated by the USDA-Agricultural Research Service (ARS) to replace the regression type equation approach of Dendy and Bolton (1976), Flaxman (1972), and Renard (1982). The ARS started developing process-based continuous simulation models to address the needs of natural resource planners in the USDA-Soil Conservation Service. This was in response to legislation passed by Congress (i.e., Resource Conservation ACT of 1977 and National Renewable Resource Planning ACT of1974). The CREAMS model (Knisel 1980) was developed as a tool to evaluate the relative effects of agricultural practices on pollutants in surface runoff and in soil water within the root zone (Lane et al. 1992).

The main governing equation in the CREAMS model for both overland flow and the channel elements is the steady-state continuity equation for sediment transport (Foster et al. 1981). The erosion component utilizes the storm erosivity index from the USLE model (EI_{30}) and peak runoff rate to compute an average sediment concentration for each runoff event. Soil erosion is estimated for both raindrop induced erosion (interrill erosion) with a modification of the USLE and for soil erosion induced by flowing water (rill erosion) (Foster et al. 1977). The CREAMS model also accounts for the effect of non-eroding (plow-pans) soil layers and for backwater effects caused by impoundment terraces (Laflen et al. 1972, 1978).

Erosion Production Impact Calculator (EPIC) Model

Accurate estimates of future soil productivity are essential in planning and decision-making processes to provide for sustainable ecosystems on rangelands. Soil erosion reduces soil productivity, but the relation between the two is not well defined. Until this relationship is adequately defined, management strategies to maximize long-term ecosystem stability will be difficult to develop (Sharpley and Williams 1990).

To address the Soil and Water Resource Conservation Act, a method of assessing the effect of long-term (>100 years) soil erosion on agricultural productivity was needed. In 1981 a National ARS erosion/productivity modeling team was formed. The model that was developed (EPIC) consists of (a) physically based components for simulating soil erosion, plant growth, and related processes, and (b) economic components for assessing the cost of erosion and for determining optimal management alternatives. The model was successfully utilized for the 1985 Resource Conservation Assessment (Sharpley and Williams 1990).

The present plant-growth component of the EPIC plant-growth model does not contain a rangeland option, but a pasture grass option can be calibrated to reflect some rangeland conditions (Cooley et al. 1990). When model parameters were calibrated to mean observed forage yields, the simulated and observed hydrologic variables were similar for a sagebrush site in Idaho (Cooley et al. 1990). However, the seasonal dynamics of observed and predicted values for individual years did not correspond (Cooley et al. 1990). Parameterization of the plant growth parameters for rangeland are circuitous. Cooley et al. 1990 parameterized a low sagebrush *(Artemisia arbuscula* Nutt.*)* by selecting the pastureland grasses option and harvesting with N fertilizer to represent the recycling of N removed by grazing. Limitations of the EPIC model are the lack of a plant-growth submodel that accounts for shrub and tree growth, recruitment of new plant species, and competition between grasses and woody plants, and parameterization of the plant-growth routine is limited to a single species.

Kinematic Runoff and Erosion (KINEROS) Model

Woolhiser et al. (1990) developed KINEROS, a distributed, rainfall (event-oriented), physically based model describing the processes of surface runoff and erosion from small watersheds. The KINEROS model is a distributed model that can represent spatial differences in a watershed through the use of cascading planes and channels. Each plane or channel is uniquely controlled with initial conditions and does address spatially varied precipitation and interception losses by vegetation. The vegetation and ground surface conditions for rangelands are represented by a hydraulic roughness term. Because KINEROS is event based, it does not address soil water redistribution, lateral subsurface flow of water, evapotranspiration, or plant growth and root distribution.

KINEROS is event based and does not consider interactions between vegetation, ground cover, land use, and management practices. KINEROS is not useful for developing grazing management plans. Future models for developing grazing management plans must address the large temporal variability in plant growth induced by climate from one season or year to the next, or spatial variability induced by land use practices (i.e., continuous vs rotational grazing or complete protection from grazing).

Revised Universal Soil Loss Equation (RUSLE) Model

Efforts to upgrade the USLE were precipitated by the recognition that the USLE needed to be improved to incorporate the advances in erosion science since its release in 1978. The development of the Revised Universal Soil Loss Equation (RUSLE) was initiated in April, 1985. RUSLE 1.04 is available to users in a computerized form (Lane et al. 1992); however the USDA-Natural Resources Conservation Service has not officially adopted this version. The RUSLE model is still restricted to the simple linear form of the USLE by using the by-product of the six factors, but each of the factors is calculated from subfactors and each factor has been improved to reflect current knowledge of erosion science.

The original procedure that was used to extrapolate the R-factor values for the western United States has proven to be a poor estimator (Lane et al. 1992). The new R-factor for RUSLE was based on over 1000 National Weather Station rain gauges. The new methodology has increased R values up to seven fold. The R-factor has been adjusted to account for soil erosion on partially frozen soils and on soils with ponded water where the erosivity of raindrop impact is reduced.

The K-factor now accounts for seasonally varying erodibilities, highest values are in the spring and values are lowest in mid-autumn following rain compaction. The S and L factors have been modified for slopes greater than 20% and generate soil loss values considerably less than does the USLE values although these new algorithms have yet to be verified with experimental data (Lane et al. 1992). The P-factor has been the least defined of all factors for rangelands. In RUSLE, the P-factors for several mechanical renovation techniques have been incorporated and require the user to estimate the random roughness and the reduction in runoff as a result of the treatment.

For both crop and rangelands, the most important term within RUSLE is the C-factor. The C-factor is the one term that land management practices can directly affect. The C-factor can vary from near 0 (for a dense grass area with no exposed bare soil) to 1.5 for freshly tilled and bedded soil. The C-factor for rangelands currently does not change over the simulation period. The RUSLE model computes the C-factor for croplands by 15 day increments. The C-factor for rangelands is estimated as:

$$C = CC \,.\, SC \,.\, SR. \, Bioeff \,.\, 0.45$$

where:

CC	Canopy cover subfactor,
SC	Soil cover subfactor,
SR	Surface roughness subfactor, and
Bioeff	Bioefficiency coefficient

Each of these subfactors in turn is expressed by an equation so that a value can be computed for most situations on rangelands.

Only a brief description of factors involved in the calculation of these subfactors is discussed here. For a complete description of the subfactor equations see Weltz et al. (1987), Renard and Simanton (1990), and Renard et al. 1991. The canopy cover subfactor is related to the fractional cover of the soil surface provided by above-ground plant biomass and the height that raindrops fall after leaving the plant and impacting the soil surface. The soil surface cover subfactor is related to the fractional cover of the soil surface that is covered by non-eroding material (basal area of plants, rocks, and organic litter). The surface roughness factor is based on the random roughness of the soil surface and the root biomass in the upper 100 mm of the soil. The bioefficiency subfactor is based on above ground biomass and a community bioefficiency coefficient which represents latent variables respective to various rangeland community types.

New Technology

Water Erosion Prediction Project (WEPP) Model

Farm Bill legislation of 1985 and 1990 has had a significant impact on the importance placed on the estimation of soil loss. These legislation packages required farmers to control erosion below critical levels and to develop farm management plans in order to be eligible to participate in cost share and other government-sponsored farm programs (Cohen et al. 1991). The Water Erosion Prediction Project (WEPP) was initiated in 1985 to address the needs of action agencies for new and improved methods of estimating soil erosion from farm, forest, and rangeland. The objective of WEPP was to replace the USLE and RUSLE erosion models with a new generation water erosion prediction technology (Foster and Lane 1987, Lane and Nearing 1989, Laflen et al. 1991, Lane et al. 1992).

The Water Erosion Prediction Project is a process-based erosion simulation model that operates on a daily time step. This allows the incorporation of temporal changes in soil erodibility, management practices, above and below-ground biomass, litter biomass, plant height, and canopy and ground cover in the prediction of soil erosion on rangelands. The WEPP simulation model is designed to be applicable on all U.S. rangelands and grazinglands (pastures, woodlands, alpine meadows, etc.). Linear and nonlinear slope segments and multiple soil series and plant communities within a hillslope can be represented with the model Fig.. 6-1). The WEPP model is intended to apply to all situations where water erosion occurs, including that resulting from rainfall, snowmelt, irrigation, and ephemeral gullies. On rangelands these ephemeral gullies or concentrated flow channels range in size from one to two meters in width and one meter in depth (Ascough 1993). Stream-bank sidewall sloughing, head cutting in gullies, or wave action induced soil erosion are not addressed by the WEPP model.

WEPP Hillslope Model

The rangeland component of the hillslope model can be divided into seven conceptual components: climate, topography, soils, hydrology, erosion, management, and plant growth and decomposition. Criteria used in the development of the rangeland component were:

1. the model must be process based and function on a daily time step,
2. the model should be based on easily obtainable or easily predictable climatic input,
3. the model must predict plant variables needed by the infiltration, hydrologic routing, and erosion components,
4. the model should run from easily obtainable plant parameters that reflect variability in climate, soil texture and mineralogy, and management practices, and
5. the model must run from databases that are easily updated and maintained over the next 25 years.

Plant growth is simulated as a function of temperature, solar radiation, and soil water content. The soil-water balance is updated as a function of daily evapotranspiration, precipitation, runoff, and drainage (Fig. 6-2). The physical resources that are most easily manipulated by the land manager are the amounts, distributions, and kinds of vegetation. It is the interactions of vegetation and surface cover with runoff that determine soil erosion and deposition across the landscape (Fig. 6-3). The growth rate of above-ground biomass for range-plant communities is simulated by using a potential-growth curve, which is defined with either a unimodal or a bimodal distribution of plant growth (Alberts et al. 1989, Weltz and Arsland 1990).

The potential-growth-curve represents the aggregate total production for the plant community. The flexibility of the potential-growth-curve permits description of either a warm or cool-season plant community or a combination of the two communities. Plant parameters calculated by daily simulation include canopy height and cover, above-ground standing biomass, plant density, leaf area index, litter mass and cover, basal plant cover, rock and cryptogam cover, total ground cover, root biomass, and root distribution with depth.

Climate inputs required by the model are minimum and maximum daily temperatures (C°), daily precipitation (mm), precipitation duration (hr) and intensity (mm/hr), relative humidity (%), wind speed (kph) and direction, and total daily solar radiation (ly). Daily temperatures are used to initiate growth, induce dormancy in plants, and simulate the effect of frozen soils on runoff and the erosion process. Historical data or data stochastically generate by CLIGEN (Nicks and Lane 1989), a weather generator that has been parameterized to yield a weather sequence for nearly 1000 stations in the United States, can be utilized.

The WEPP model provides four management options within the rangeland component: grazing, fire, herbicide application, and complete protection. The user can define the type, severity, and timing of the management activity to be simulated. A hillslope within the WEPP model can be subdivided as many as ten overland flow planes (Fig. 6-1) and each overland flow plane can represent a different soil type, vegetation community, or management activity. Multiple hillslopes can be defined to comprise a watershed. This versatility allows the user to represent a wide range of management practices.

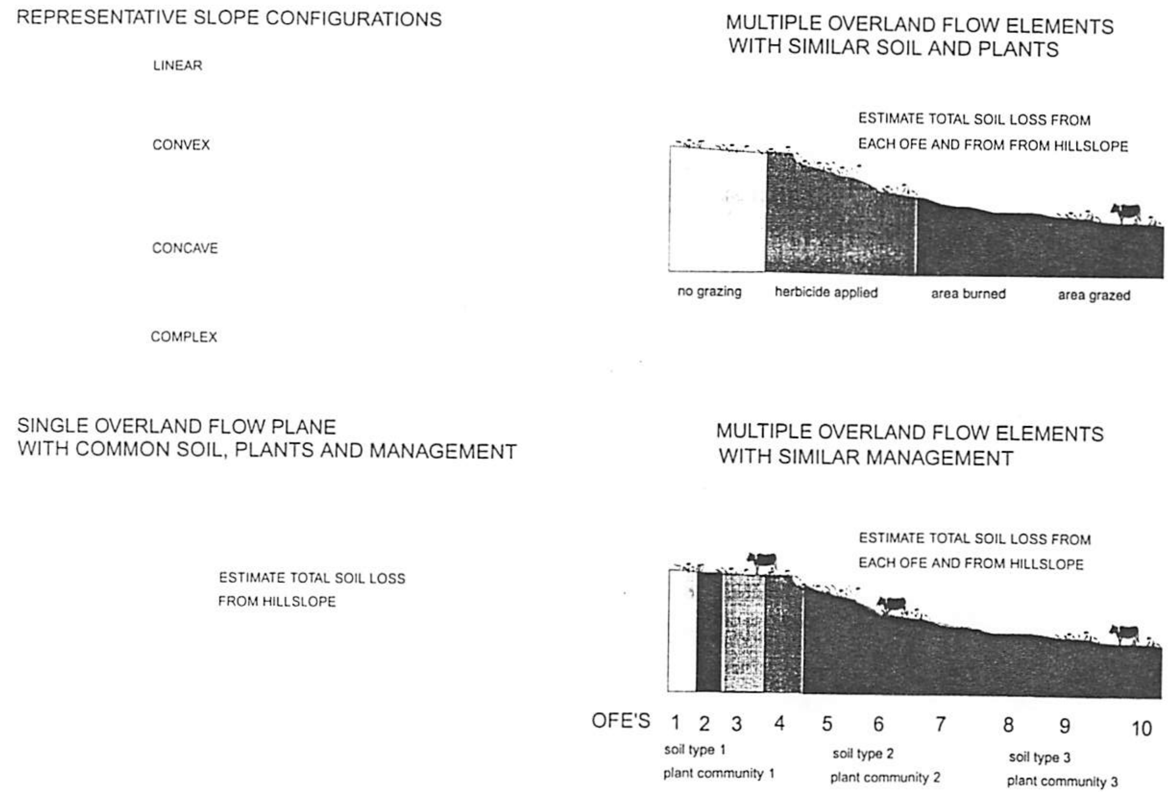

Fig. 6-1. Example of potential slope shapes and number of overland flow planes (OFE's) the WEPP model can represent on a single hillslope. Each OFE (maximum of 10) can be defined with a different soil series, plant community, or management practice.

The grazing option allows for as many as ten rotations of livestock within a year on each overland flow plane and livestock can be rotated from one hillslope to a separate hillslope or within a hillslope. The user can control the weight and number of animals to represent either domestic livestock (cattle, goats, or sheep) or wildlife (elk, deer, or horses).

The effect of grazing is represented by removal of standing biomass with a corresponding reduction of canopy and basal plant cover. Grazing increases transfer of standing dead biomass to litter, and increases the bulk density of the soil. Trampling by livestock alters the hydraulic roughness of the soil surface through the interaction of the amount and type of ground cover and significantly affects the predicted soil loss (Warren et al. 1986, Weltz and Wood 1989).

WEPP Watershed Model

The watershed option of the WEPP model will estimate soil loss and deposition from one or more hillslopes within a watershed (Fig. 6-4). WEPP computes sediment delivery from small watersheds and computes sediment transport, deposition and detachment in small channels and impoundments within the watershed. This includes erosion in ephemeral gullies and channels, but not classical gullies. The watershed model will expand the hillslope conservation planning applications to small agricultural and natural resource watersheds. The natural resource planner will be able to evaluate resource management systems with regards to: 1) productivity maintenance by controlling erosion to a tolerable rate on a watershed; 2) identify zones of soil loss and soil deposition on the hillslope, within permanent channels, and ephemeral gullies; and 3) predict excessive off-site sediment yield that may result in decreased water quality (Foster and Lane 1987, Ascough et al. 1993). The watershed model can be utilized within the confines of project planning to: 1) determine watershed erosion control measures and their distribution over a project area to meet specific project objectives; 2) improve estimates of sedimentation of livestock ponds; 3) improve estimates of effectiveness of implementing grazing systems on soil loss reduction; and 4) improved estimates of soil loss from mine reclamation activities.

Elliot et al. (1993) evaluated the watershed model on two reclaimed mine watersheds in Ohio. They compared observed runoff and sediment yield to model simulated values. They concluded that suitable model parameters could be developed for surface mine conditions and that the most sensitive parameter affecting sediment yields was saturated hydraulic conductivity.

Constraints of the WEPP Watershed Model

The WEPP watershed model is limited to "field size" areas. For rangelands this area is estimated to be approximately 800 ha (Foster and Lane 1987). The major constraint on size of area the model is applicable on, is the influence of the assumption of uniform rainfall within the watershed version of the model. The watershed model will not apply to: 1) headcut erosion; 2) sloughing of gully side-walls; 3) effect of springs or seepage on soil erosion; 4) perennial stream channels; and 5) areas where partial-area hydrology dominate (Foster and Lane 1987).

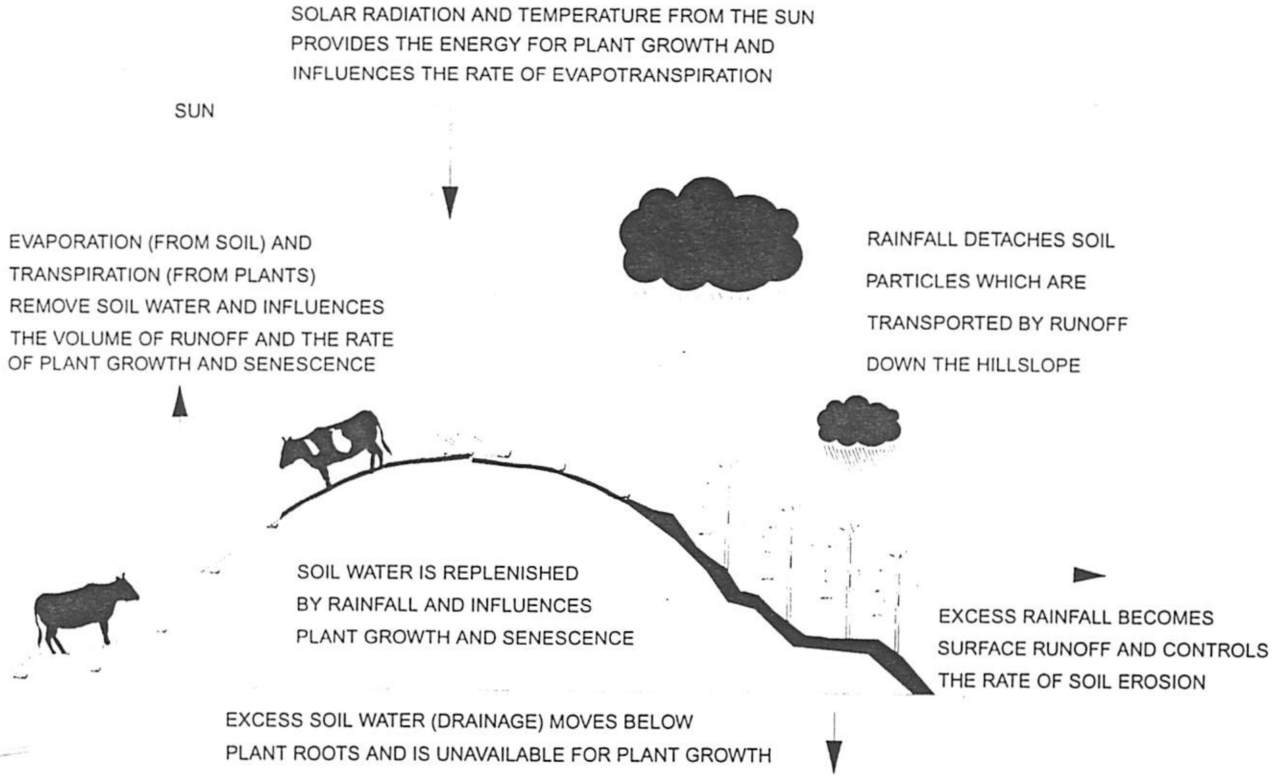

Fig. 6-2. Diagram of climatic impact and soil water balance.

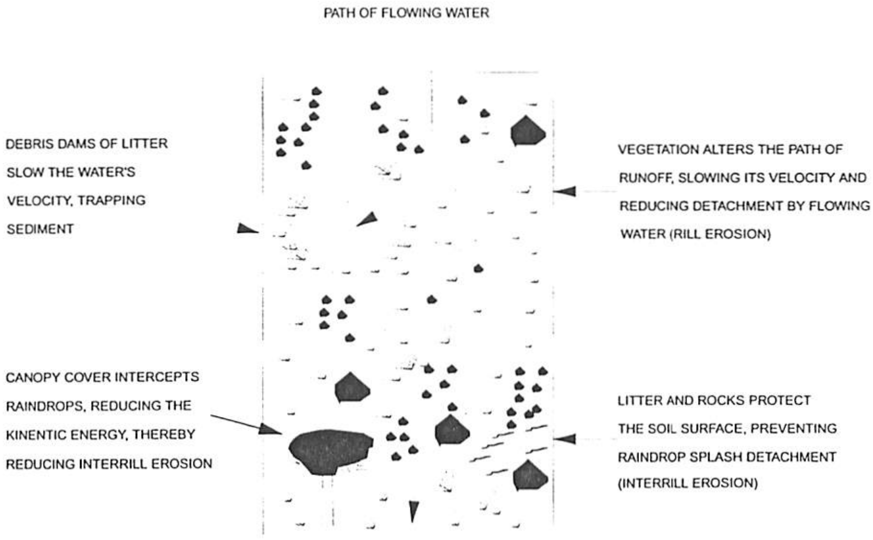

Fig. 6-3. Influence of vegetation and surface cover on soil erosion.

Future Research Needs

The movement from soil erosion models like USLE to modern erosion-prediction technology requires computers to implement the erosion models (CREAMS, EPIC, KINEROS, RUSLE and WEPP). These models require new data and may possibly require new methods for data collection, storage, and retrieval by federal action agencies. The WEPP and RUSLE models require several new baseline biological inputs including; plant height and density, canopy diameter, above-ground standing and litter biomass, rock cover, cryptogam cover, random roughness, and root biomass that previously have not been collected routinely by federal agencies.

Currently, vegetation properties are estimated with line-intercept or belt-transect methods (Canfield 1941, Eberhardt 1978), the point-intercept method (Levy and Madden 1933), or by sampling quadrats (Mueller-Dombois and Ellenberg 1974). These methods involve measuring vegetation properties along randomly determined strips, lines, belts, or quadrats across the landscape. These methods are expensive and labor intensive, and the areas sampled are usually inadequate for assessing large scale or landscape characteristics. The degree of accuracy required for the field measurement of vegetation parameters is an important consideration when embarking on data collection for various hydrologic and erosion simulation models. Time and labor are expensive resources and it is important to use these resources efficiently.

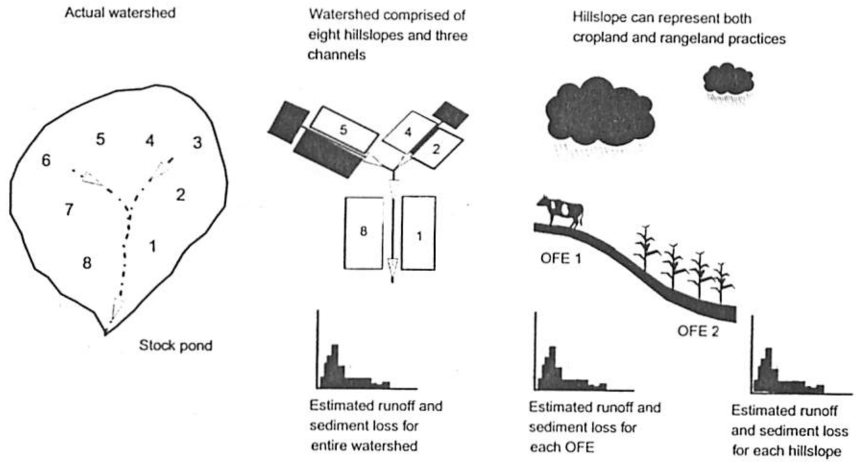

Fig. 6-4. Example of how a watershed can be represented with the WEPP model to predict runoff and soil erosion. Each hillslope within the watershed can be defined with 10 overland flow planes (OFE) to reflect differences in soils, plant community, or management as illustrated in Figure 1.

Current methods of estimating soil loss and surface runoff assume uniform distributions of vegetation and surface cover across the landscape. The RUSLE and WEPP models assume that litter and rocks are equally distributed in the rill and interrill areas. The WEPP model also assumes that plants and cryptogams are limited to interrill areas. Techniques to describe the distributions of vegetation and the rates of change in both spatial and temporal scales of plant species, plant canopy, and surface cover are required before significant improvements can be developed at either the field or watershed scale to predict surface runoff and soil erosion.

Remotely-sensed spectral, thermal, microwave, and airborne laser altimeter measurements provide indirect means of deriving geophysical quantities required as inputs over a range of spatial scales to hydrologic models. Satellite measurements provide information on topography, vegetation cover, plant height and spacing, soil water content, snow depth, soil erosion, precipitation, and evapotranspiration (Engman and Gurney 1991). There is a need to understand the limitations, accuracies and efficiencies of vegetation, ground-cover, and digital-elevation data acquired by remote-sensing as a tool to parameterize hydrologic and erosion simulation models.

National relational databases that contain climate, soils, topography, land-use, management-practice, and vegetation data are required to implement the new generation of erosion-simulation models. These natural resource databases will allow for the new erosion technology to be applied uniformly across all user groups at the local, county, state, and national levels and avoid duplication of effort and time in collecting and maintaining separate databases and thus better serve the American farmer and rancher.

Technology for modeling runoff and soil loss has greatly improved, but improvements in model accuracy are often lost in the techniques used to estimate model parameters. Improvements in model parameter estimation techniques and our understanding of the interactions between vegetation, soil, and grazing-practice induced temporal and spatial variability are needed before the full potential of our hydrologic and erosion modeling capabilities are achieved.

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