Viewpoint

Soil Erosion Effects on Productivity in Rangeland Environments; Where is the Research?

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Abstract

The importance of erosion on rangelands has been recognized for many years. However, the impact of erosion on site productivity (choose your own index of productivity) has not been quantified to any extent for any rangeland plant—soil complex in the western United States. It is hoped that researchers over the next few years will shift their efforts to this neglected yet very important information void.

While some studies have been conducted on land under agricultural use relative to how its productivity is impacted by erosion, complimentary research type work has not been undertaken relative to rangeland. Soil productivity is the capacity of a soil, in its normal environment, to produce a particular plant or sequence of plants under a specified management system (Soil Sci. Soc. Amer. 1975). In most rangeland situations productivity is generally expressed in terms of yields, which reflect the ability to produce.

The National Soil Erosion-Soil Productivity Research Planning Committee (1981) has recently provided a research perspective for erosion-productivity research on agricultural lands. Their discussion of the erosion-productivity problem is in part applicable also to rangelands. Appropriate excerpts are given below.

The erosion-productivity problem:

> One of the most dangerous characteristics of the erosion-productivity problem is its difficulty of detection. . .Erosion reduces productivity so slowly that the reduction may not be recognized until land is no longer economically suitable for growing crops. . .
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> The difficulty of detecting productivity losses is compounded by the nonlinear nature of the erosion process. Erosion generally increases future runoff because of reduced infiltration. Increased runoff reduces available soil water, thus plant growth. Of course, less plant growth means less residue. Less vegetation and residue provide less cover, which increases erosion. Because water erosion strongly relates to runoff. . . , increased runoff also leads to increased erosion. The process thus advances exponentially, and reversing it may quickly become economically impossible if it is not detected and controlled properly. . .

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> Still another characteristic of the erosion-productivity problem is the difficulty of restoring the productivity of severely eroded soils. Restoration is generally difficult and costly because subsoil conditions often inhibit. . .growth. . .These conditions include poor aeration, low organic matter, lack of exchangeable or soluble nutrients and calcium carbonate, high soluble aluminum, gravel, and high density (strength). Although productivity can be partly restored by adding organic material and fertilizer, such additions may not be economical. For example, eroded rangeland is particularly difficult to restore because fertilization usually is not economical in low-rainfall areas. . .

Ways erosion reduces productivity:

> Erosion reduces productivity first and foremost through loss of plant-available soil water capacity. Lower soil water capacity subjects (plants) to more frequent and severe water stress. Plant-available soil water may be reduced by changing the water-holding characteristics of the root zone or by reducing the depth of the root zone. Erosion reduces root-zone depth if subsoils are toxic to roots or have high strength or poor aeration that retards root growth. The water-holding characteristics of the root zone are almost always changed when topsoil is removed because topsoil usually has a higher plant-available water capacity than subsoil.
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> Erosion also reduces productivity by contributing to plant-nutrient losses. Eroded soil particles carry attached nutrients from fields into streams and lakes. Because subsoils generally contain fewer plant nutrients than topsoils, . . .fertilizer is needed to maintain. . .production.
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> A third way erosion reduces productivity is by degrading soil structure. Degradation of soil structure increases soil erodibility, surface sealing, and crusting. . .Surface sealing and crusting reduce seedling emergence and infiltration. Reduced infiltration provides less opportunity for soil water storage.
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> Erosion also reduces productivity through nonuniform removal of soil within a field. Erosion does not occur uniformly across a field mainly because of the runoff flow network and nonuniform topography. Selecting a management strategy to maximize production is nearly impossible in fields with various degrees of erosion. When fields are (treated) as units, fertilizer is normally applied uniformly over the field. If erosion is nonuniform, the application rate is more appropriate for some areas than others (optimal production is impossible for all areas).
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> The effect on herbicide use is similar. Because herbicides interact with soils, their performance varies with soil organic matter content, pH, and cation exchange capacity. In a nonuniformly eroded field one rate of herbicide application may kill weeds and damage the crop in one part of the field but not effectively control weeds in another part of the field. . .
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> . . .Nonuniform erosion also affects tillage effectiveness and causes inconsistent seedbeds that produce poor stands and variable emergence. . .

Erosion studies, both under natural rainfall on small plots or watersheds or under simulated rainfall using mostly small plots, have been conducted in a number of rangeland situations. Examples include Osborn (1950), Meeuwig (1960, 1970), Wright et al. (1976), Hanson et al. (1978), Marston (1952), Blackburn and Skau (1974), Gifford and Skau (1967), Orr (1970), Williams et al. (1969), and Rich (1961), to name a few. Gifford (in press) has recently compiled a listing of most of the relevant erosion-related studies on rangelands. None of these, however, relate erosion to productivity.

Cooperrider and Hendricks (1937) found that cover density on rangeland in New Mexico was a function of erosion. As erosion increased from a "normal" rate to an "excessive" rate, cover density decreased from 35% to 13%. They also discussed some of the nutrient deficiencies associated with eroded soils, but these deficiences were not correlated with productivity.

Lyons and Gifford (1980a, b) looked at incremental soil depths on two pinyon-juniper sites in Utah in terms of infiltration rates, potential sediment losses, chemical water quality, plant production, transpiration ratios, and nitrogen-mineralization rates. Responses of these variables often changed significantly as a function of soil depth. In general, plant production and nitrogen mineralization rates decreased with "loss" of surface soils. Transpiration ratios increased significantly. Infiltration rates and sediment losses were not particularly affected, but phosphorus concentrations in runoff waters were increased somewhat. Results of similar studies are not available for comparative purposes.

Wight and Siddoway (1982) discussed the problems associated with developing soil loss tolerances for rangelands and indicated that the relationships between productivity and soil loss are only vaguely understood.

Conclusions

At the present time it is impossible to evaluate the impacts on productivity of differential rates of erosion on western rangelands. The National Soil Erosion-Soil Productivity Research Planning Committee advocates strongly the development of mathematical models and field experiments to support the models as a way to facilitate studying soil erosion-soil productivity relationships. Components of the model(s) should include hydrology, erosion-sedimentation, nutrient cycling, crop growth, tillage, and animal uptake for rangeland and pasture. However, given the state-of-the-art of erosion-productivity relationships on rangelands, *any* research on the topic would be useful. This is especially true for field studies (which may be designed around specific model-input requirements). Funding levels will have to be increased to accommodate this research because erosion-productivity studies are time-consuming and expensive. Concomitantly, scientific and public concern for productivity-related erosion impacts on western rangelands must be intensified. Without more vociferous concern, the necessary funding levels will never materialize.

Literature Cited

Blackburn, W.H., and C.M. Skau. 1974. Infiltration rates and sediment production of selected plant communities in Nevada. J. Range Manage. 27:476-480.

Cooperrider, C.K., and B.A. Hendricks. 1937. Soil erosion and stream flow on range and forest lands of the upper Rio Grande watershed in relation to land resources and human welfare. USDA Tech Bull. No. 567.

Gifford, B.G. (In press). Vegetation allocation for meeting site requirements—one viewpoint. Westview Press (for Nat. Acad. Sci.)

Gifford, G.F., and C.M. Shau. 1967. Influence of various rangeland cultural treatments on runoff and sediment production from the big sage type, Eastgate Basin, Nevada. *In:* Proc. 3rd Amer. Water Resour. Conf., San Franscisco, Calif., Nov. 8-10:137-148.

Hanson, C.L., A.R. Kahlman, and J.K. Lewis. 1978. Effect of grazing intensity and range condition on hydrology of western South Dakota ranges. South Dakota Agr. Exp. Sta. Bull. 647: 54 p.

Lyons, S.M., and G.F. Gifford. 1980a. Impact of incremental surface soil depths on infiltration rates, potential sediment losses, and chemical water quality. J. Range Manage. 33:186-189.

Lyons, S.M., and G.F. Gifford. 1980b. Impact of incremental surface soil depths on plant production, transpiration ratios, and nitrogen mineralization rates. J. Range Manage. 33:189-196.

Marston, R.B. 1952. Ground cover requirements for summer storm runoff control on aspen sites in northern Utah. J. Forest. 50:303-207.

Meeuwig, R.O. 1960. Watersheds A and B—a study of surface runoff and erosion in the subalpine zone of central Utah. J. Forest 58:556-560.

Meeuwig, R.O. 1970. Sheet erosion on intermountain summer ranges. USDA FS Res. Paper INT-85: 25 p.

National Soil Erosion-Soil Productivity Research Planning Committee. 1981. Soil erosion effects on soil productivity: A research perspective. J. Soil and Water Conserv. 36:82-90.

Orr, H.K. 1970. Runoff and erosion control by seeded and native vegetation on a forest burn, Black Hills, South Dakota. USDA FS. Res. Paper RM-60: 12 p.

Osborn, B. 1950. Range cover tames the raindrop. A summary of range cover evaluations, 1949. Soil Conservation Service, Ft. Worth, Texas. 92 p.

Rich, L.R. 1961. Surface runoff and erosion in the lower chaparral zone, Arizona. USDA FS, Rocky Mt. Forest and Range Exp. Sta. Pap. No. 66:35 p.

Soil Science Society of America. 1975. Glossary of soil science terms. Madison, Wisc.

Wight, J.R., and F.H. Siddoway. 1982. Determinents of soil loss tolerance for rangelands. *In:* Amer. Soc. Agron. Special Publ. 45:67-74.

Williams, G., G.F. Gifford, and G.B. Coltharp. 1969. Infiltrometer studies on treated vs. untreated pinyon-juniper sites in central Utah. J. Range Manage. 22:110-114.

Wright, H.A., F.M. Churchill, and W.C. Stevens. 1976. Effect of prescribed burning on sediment, water yield and water quality from dozed juniper lands in central Texas. J. Range Manage. 29:294-298.