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# Erosion on Range and Forest Lands: Impacts of Land Use and Management Practices

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Range and forestlands account for about 53 percent of the nonfederal lands included in the 1982 National Resources Inventory (NRI) and are estimated to produce 28 percent of the total annual soil loss. Thus, even though this soil loss is less serious than that of intensively cultivated lands, it is an important part of the U.S. soil erosion problem that needs to be addressed. In some areas, the damage occurring to range and, to a much lesser extent, forestlands is the primary resource concern.

This study used the 1982 NRI data to test ways to address the following policy questions:

- How much could future land use decisions affect the soil erosion problem on range and forestlands? For example, if the range and forestland identified as potential cropland were all converted to this use, how would the remaining range and forest be affected? Would the conversion of the best lands leave the remainder significantly more erosion-prone, in terms of the average quality of the resource base?
- What impact will improved range management and timber stand practices have on soil erosion? These practices are generally promoted on the basis of their benefits to the grass or trees, and for improved productivity, but what about the effects on soil erosion? Can areas be identified where more effective range conservation or farm forestry programs can yield important secondary benefits for erosion control?
- Improved targeting of conservation programs has been a much-touted benefit of the broad area information provided by the NRI. How can the 1982 inventory be used to improve targeting on range and forestlands?

To address these policy questions, the study first evaluated the NRI data and tested different analytical methods for effectively using them. In so doing, the following questions were raised:

- How much additional value can be gained from using the Major Land Resource Area (MLRA) data versus state-level or national data? Can substate distinctions be made that will be helpful to conservation policymakers?
- At what point does the data contain too few sample points to be reliable?
- Can a separation of the physical data from the management data in the Universal Soil Loss Equation (USLE) give some insight into the potential for improving erosion conditions through changing management? In the USLE, this would mean letting the RKLS (rainfall, soil erodibility, length of slope, and steepness of slope) indicate the physical condition and using the C (cover) and P (conservation practices) factors to indicate management.

Since the P factor is unity (1) on range and forestland, the C factor becomes the major determinant of the difference between potential erosion (RKLS) and observed erosion (USLE). On rangelands, wind erosion may be more important than sheet and rill erosion in some areas, so the data recorded for the Wind Erosion Equation (WEE) come into play. On forestland, wind erosion can be ignored.

The analysis was conducted in two sections--six MLRAs were chosen for range evaluation and six others for the forestland study. In addition, two state summaries were prepared for both forest and range. (Detailed tables on the characteristics of the areas studied are available from the author.)

A microcomputer spreadsheet program evaluated key characteristics of the MLRA data as a means of helping select MLRAs where certain range and forest factors would be significant. The areas were chosen for a combination of characteristics, including geographic area, percentage of land indicating a particular problem, and total size of the range or forestland resource in the area. Once analytical tables were designed and MLRAs chosen, the Agricultural Research Service (ARS) Soil and Water Management Research Unit at the University of Minnesota did the necessary programming to generate the data tables. The information was transferred to a microcomputer using a spreadsheet program, which allowed manipulation of the



basic data. All tables in this paper are the product of the author's computer, not the ARS computer at Minnesota.

Two important caveats about the results for the sample MLRAs and the states need to be mentioned. First, these tables can be easily duplicated by the Minnesota computer or any other mainframe that will run the NRI tapes, but some reprogramming is necessary. Second, the final results of the two methods will not be identical. The Minnesota tables are generated by taking the individual point data and computing weighted averages based on the values at each point. The microcomputer calculations are made by manipulating the weighted average values themselves. Although the results are very similar, they are not identical, and analysts who reproduce this methodology on a mainframe computer using the point data will find minor discrepancies in the results for these sample MLRAs. The methodology, however, should work equally well using either method.

Even though the point sample data are invaluable for certain analytical techniques, much can be learned from the national, state, and MLRA summary data published by the Soil Conservation Service (SCS), without resorting to expensive use of the sample point data. An ordinary microcomputer can aid in ranking MLRAs on the basis of problems or features that are helpful, for example, in evaluating the targeting potential of national programs.

Soil erosion problems can be identified from the tables in this paper and many inferences drawn from them that will be of use to national policymakers. The benefits of changing land use and applying conservation practices are fairly easy to estimate, if certain critical assumptions can be made. But such assumptions need further discussion and agreement within the professional community if they are to provide the basis for future policy research using the NRI data.

## RANGELAND

### General Findings

Nonfederal rangelands comprise 405.9 million acres, with only about 136 million, or 33.5 percent, rated in the 1982 NRI as adequately protected. Soil erosion was estimated to be at or below the soil loss tolerance limit (T value) on 336 million acres, or 82.8 percent. Erosion rates between T and 2T were associated with 26 million acres (6.4 percent), while almost 44 million acres (10.8 percent) were suffering soil erosion in excess of 2T. Average soil losses on these highly eroding rangelands were estimated at 20.3 tons/acre/year.

The average annual erosion rate on U.S. rangelands is estimated to be about 1.5 tons/acre/year from wind erosion and 1.4 tons/acre/year from sheet and rill erosion. But this 2.9 tons/acre/year average does not reflect some critically eroding areas, which seem to be associated with MLRAs where wind erosion rates are high. In some areas, over 85 percent of the soil loss due to wind erosion is concentrated on less than 1 percent of the land.

That fact alone would seem to provide a strong argument for targeting conservation efforts to those lands. Care must be taken in arriving at that conclusion, however, because much of that soil loss may not be treatable, according to SCS judgments made during the NRI sampling process. A rough estimate of the amount of treatable land can be made from the NRI, however, and this should be highly valuable in designing program targeting efforts.

Range improvements yield significant erosion reductions, even on lands where current erosion problems are not rated as serious. Thus, efforts to improve range conditions through grazing management or to improve or reestablish improved stands of forage are likely to yield significant erosion control benefits in addition to increased grazing, wildlife, and watershed values.

Point sample data from six MLRAs (10, 30, 43, 67, 77, and 81) and from Idaho and Texas were summarized to seek answers to the following questions:

- If the rangeland that was identified as potential cropland were developed, would the remaining rangeland be significantly changed in terms of erosion characteristics? What kind of a conservation problem would exist on the remaining rangeland, assuming it was used at the same intensity and with the same management that it now receives?
- How much erosion control benefit could be achieved by improving the condition of the range forage by the equivalent of one condition class?
- How much erosion control benefit could be achieved by carrying out the forage improvements indicated as needed in the NRI?



- How useful are the 1982 NRI data in identifying areas where it would be beneficial to target range conservation efforts?

## Conversion of Rangeland to Cropland

Insights into these questions are relatively easy to obtain from the 1982 NRI data. Table 1 is a summary of data generated by the University of Minnesota, in which weighted averages for total potential erosion (RKLS), total actual sheet and rill erosion (USLE), and total actual wind erosion were calculated for rangeland in each MLRA and in the two states considered. The rangeland point samples with potential for conversion to cropland were then subtracted from the rangeland totals. The result is the erosion characteristics of the rangeland that would remain if the areas with high and medium potential as cropland were actually converted to that new use.

With the percentage increases in total erosion running from 0 to almost 15 percent, it seems clear that there would be very different soil erosion impacts in different regions if the rangeland that could be cropland were converted. The methodology used here seems useful in portraying those regional differences. Although actual range productivity would be difficult, if not impossible, to assess from the NRI data, some of the rangeland characteristics of the land judged to have high and medium potential for conversion to cropland can be evaluated.

Table 2 shows the rangeland conditions of total rangeland, range with cropland potential, and total rangeland minus potential cropland on the sample MLRAs and states. By comparing (with a chi-square test) the condition class distribution found on all rangeland with that found for rangelands that could be cropland, it can be established whether the potential cropland would be taken disproportionately from one or another range condition. This could lead to policy conclusions about the potential damage to the rangeland resource that might occur should the conversions actually take place.

Interesting differences arose among the sample MLRAs and states. In MLRAs 10 and 43, as well as in Idaho, potential cropland would be taken disproportionately from land now listed as in poor range condition. Thus, cropland conversions in this area would have less of an

**TABLE 1 Potential and Actual Erosion of Rangeland in Selected MLRAs and States with Percentage Increase of Potential Cropland Converted**

| Erosion on Rangeland (Tons/Acre) | MLRA 10 | 30 | 43 | 67 | 77 | 81 | Idaho | Texas |
|---|---|---|---|---|---|---|---|---|
| Average potential erosion (RKLS) | | | | | | | | |
| All rangeland | 21.84 | 2.93 | 44.32 | 14.69 | 9.57 | 24.85 | 36.57 | 19.91 |
| Potential cropland | 16.65 | 0.96 | 11.15 | 7.44 | 5.48 | 7.92 | 13.60 | 13.04 |
| Rangeland without potential cropland | 22.09 | 3.07 | 45.82 | 16.54 | 10.49 | 25.89 | 38.42 | 21.07 |
| Average actual sheet/rill erosion (USLE) | | | | | | | | |
| All rangeland | 1.45 | 0.59 | 1.31 | 1.21 | 0.81 | 1.59 | 0.55 | 1.21 |
| Potential cropland | 0.93 | 0.21 | 0.23 | 0.53 | 0.39 | 0.37 | 0.31 | 0.59 |
| Rangeland without potential cropland | 1.47 | .62 | 1.36 | 1.38 | 0.90 | 1.67 | 0.57 | 1.32 |
| Average actual wind erosion (WEE) | | | | | | | | |
| All rangeland | .00 | 41.27 | .00 | 0.40 | 3.67 | 0.13 | 0.04 | 0.65 |
| Potential cropland | .00 | 6.88 | .00 | 0.99 | 1.40 | 0.01 | 0.11 | 0.19 |
| Rangeland without potential cropland | .00 | 43.76 | .00 | 0.24 | 4.19 | 0.13 | 0.03 | 0.72 |
| Average total erosion (USLE + WEE) | | | | | | | | |
| All rangeland | 1.45 | 41.86 | 1.31 | 1.60 | 4.48 | 1.72 | 0.59 | 1.86 |
| Potential cropland | 0.93 | 7.09 | 0.23 | 1.53 | 1.80 | 0.37 | 0.43 | 0.78 |
| Rangeland without potential cropland | 1.47 | 44.38 | 1.36 | 1.62 | 5.09 | 1.80 | 0.60 | 2.04 |
| If potential cropland were converted: | | | | | | | | |
| Percent increase in RKLS | 1.14 | 4.78 | 3.38 | 12.59 | 9.61 | 4.19 | 5.06 | 5.83 |
| Percent increase in USLE | 1.38 | 5.08 | 3.82 | 14.05 | 11.11 | 5.03 | 3.64 | 9.09 |
| Percent increase in WEE | .00 | 6.03 | .00 | -40.00 | 14.17 | 0.00 | -25.00 | 10.77 |
| Percent increase in USLE + WEE | 1.38 | 6.02 | 3.82 | 01.25 | 13.62 | 4.65 | 1.69 | 9.68 |

SOURCE: Derived from 1982 NRI.



**TABLE 2 Percentage of Rangeland, Selected MLRAs and States in Various Forage Conditions and with Conservation Needs**

| Rangeland Conditions | MLRA 10 | 30 | 43 | 67 | 77 | 81 | Idaho | Texas |
|---|---|---|---|---|---|---|---|---|
| Excellent condition class | | | | | | | | |
| All rangeland | 2.72 | 8.35 | 7.46 | 1.33 | 0.60 | 0.56 | 5.10 | 0.51 |
| Potential cropland | .00 | 5.37 | 2.60 | 1.87 | 0.63 | 0.44 | 0.37 | 0.52 |
| Rangeland without potential cropland | 2.84 | 8.70 | 7.67 | 1.19 | 0.60 | 0.56 | 5.40 | 0.51 |
| Good condition class | | | | | | | | |
| All rangeland | 20.14 | 20.45 | 32.30 | 30.53 | 30.58 | 7.26 | 34.55 | 14.53 |
| Potential cropland | 5.00 | 39.69[a] | 26.79 | 29.51 | 38.10 | 4.75 | 28.57 | 14.54 |
| Rangeland without potential cropland | 20.81 | 18.19 | 32.54 | 30.80 | 28.90 | 7.42 | 34.93 | 14.52 |
| Fair condition class | | | | | | | | |
| All rangeland | 34.21 | 47.08 | 45.88 | 58.50 | 57.76 | 73.56 | 40.53 | 57.42 |
| Potential cropland | 29.11 | 45.15 | 46.13 | 59.21 | 48.96 | 85.23 | 36.45 | 56.52 |
| Rangeland without potential cropland | 34.43 | 47.31 | 45.87 | 58.32 | 59.71 | 72.85 | 40.79 | 57.57 |
| Poor condition class | | | | | | | | |
| All rangeland | 42.92 | 24.12 | 14.35 | 9.63 | 11.06 | 18.62 | 19.83 | 27.54 |
| Potential cropland | 65.89[a] | 9.79 | 24.49[a] | 9.41 | 12.30 | 9.57 | 34.61[a] | 28.42 |
| Rangeland without potential cropland | 41.92 | 25.81 | 13.93 | 9.69 | 10.79 | 19.17 | 18.88 | 27.39 |
| Adequately protected | | | | | | | | |
| All rangeland | 15.17 | 19.56 | 30.65 | 33.97 | 35.87 | 15.73 | 22.35 | 22.84 |
| Potential cropland | 11.73 | 42.48 | 36.08 | 41.07 | 46.15 | 24.81 | 24.60 | 29.16 |
| Rangeland without potential cropland | 14.64 | 16.69 | 29.08 | 25.61 | 27.37 | 14.29 | 20.52 | 18.63 |
| Needs forage improvement | | | | | | | | |
| All rangeland | 43.07 | 8.94 | 32.86 | 26.17 | 35.92 | 65.30 | 39.60 | 51.56 |
| Potential cropland | 55.72 | 5.22 | 20.55 | 28.88 | 30.61 | 67.02 | 38.52 | 46.12 |
| Rangeland without potential cropland | 40.54 | 8.59 | 31.97 | 20.29 | 30.29 | 61.42 | 36.74 | 44.90 |
| Needs forage reestablishment | | | | | | | | |
| All rangeland | 14.29 | 2.77 | 4.25 | 2.25 | 3.80 | 9.43 | 11.36 | 13.65 |
| Potential cropland | 26.24 | .00 | 11.22 | 2.46 | 4.96 | 5.35 | 27.85 | 17.28 |
| Rangeland without potential cropland | 13.10 | 2.77 | 3.77 | 1.75 | 2.88 | 9.12 | 9.29 | 11.15 |

[a]Significant at the 95 percent level.

SOURCE: Derived from 1982 NRI.

effect on the average quality of the remaining rangeland than might be the case in MLRA 30, where there appears to be a tendency for potential cropland to be in good range condition. In MLRA 67 and in Texas, the condition of the land shown as potential cropland is almost identical to the average condition of the total range resource. In MLRAs 77 and 81, the potential cropland seems to fall somewhat disproportionately in the good and fair condition categories, but the differences are not significant at the 95 percent level.

In all but MLRA 10, it appears that the potential cropland would be disproportionately drawn from rangeland that is now adequately protected. In MLRA 10, potential cropland would come disproportionately from lands needing forage improvement or reestablishment, which seems consistent with the fact that these same lands were rated as being in poor range condition.

## Erosion Control Potential in Range Management

Range conservationists promote improved range management for many reasons, including soil conservation. Ranchers are primarily interested in the potential for improved forage production through management changes. Thus, most of the literature promoting range conservation focuses on the potential improvements in grazing values that can be gained by improving range conditions. But policymakers must look at range conservation programs to determine the overall public benefits. If significant reductions in soil erosion are part of the benefits, range programs have one more bargaining point as they compete for national and state funds.

The 1982 NRI offers an excellent opportunity to estimate the soil erosion control that might result from improvements in the forage condition on rangelands. The methodology is relatively straightforward. Table 3 summarizes the NRI point sample data for MLRA 77, as an example, to calculate the acreage in each rangeland condition class, plus the weighted average of the factors. Similarly, Table 4 addresses wind erosion. These were easily converted into estimates of current soil loss in tons. (Tables 3 and 4 are in 100 tons because the acreage figures were generated in 100-acre units.)

At this point, some assumptions were made. If the rangeland that is now in good condition was improved to



TABLE 3 Estimated Sheet and Rill Erosion Reduction in MLRA 77 from Improving the Condition of Perennial Range Vegetation by One Condition Class

| Rangeland Condition Class | Acreage (100 Acres) | Weighted Average | | | | Soil Loss (100 Tons) | Improved C Factor | Potential Erosion Reduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | RKLS | C | P | USLE | | | (100 Tons) | Percent |
| Excellent | 835 | 7.50 | .087 | 1 | .70 | 545 | .09 | 0 | .00 |
| Good | 42,238 | 9.40 | .064 | 1 | .64 | 25,410 | .06 | 0 | .00 |
| Fair | 79,783 | 10.00 | .084 | 1 | .90 | 67,018 | .06 | 15,957 | 23.81 |
| Poor | 15,283 | 7.80 | .106 | 1 | .82 | 12,636 | .08 | 2,623 | 20.75 |
| Annual range | -- | -- | -- | -- | -- | 0 | -- | 0 | -- |
| Not applicable | 622 | 4.50 | .100 | 1 | .42 | 280 | .100 | 0 | .00 |
| Not rangeland | -- | -- | -- | -- | -- | 0 | -- | 0 | -- |
| Total | 138,761 | | | | | 105,889 | | 18,579 | 17.55 |

SOURCE: Derived from 1982 NRI.

TABLE 4 Estimated Wind Erosion Reduction in MLRA 77 from Improving the Condition of Perennial Range Vegetation by One Condition Class

| Weighted Average WEE | Soil Loss (100 Tons) | Improved WEE | Potential Erosion Reduction (100 Tons) | |
|---|---|---|---|---|
| | | | (100 Tons) | Percent |
| .00 | 0 | .00 | 0 | .00 |
| 2.75 | 116,155 | .00 | 116,155 | 100.00 |
| 3.20 | 255,306 | 2.75 | 35,902 | 14.06 |
| 8.89 | 135,866 | 3.20 | 86,960 | 64.00 |
| 0 | 0 | .00 | 0 | .00 |
| 4.06 | 2,525 | 4.06 | 0 | .00 |
| Total | 509,851 | | 239,017 | 46.88 |
| Total wind + sheet and rill erosion | 615,740 | | 257,596 | 41.84 |

SOURCE: Derived from 1982 NRI.

excellent condition, the weighted average C factor associated with excellent condition in that MLRA should also be achieved. Similarly, a move from fair to good condition should improve the C factor accordingly, as would a move from poor to fair condition. This would work very well, except where the weighted average C factor is actually lower (indicating better cover conditions) on the poorer condition range.

In MLRA 77, for example, the C factor on good condition range is lower than that recorded on excellent condition range. When that occurs, a shift from good to excellent condition is not assumed to be accompanied by an increase in C factor, so the C factor now existing on the good condition rangeland was used.

The column labeled "Improved C Factor" thus takes either the C factor of the next higher condition class or the existing C factor, whichever is lower. It was a relatively simple task, then, to multiply the improved C factor by the RKLS for the land in question and to



estimate the potential erosion reduction that might be achieved from moving up one condition class (and simultaneously achieving the new C factor).

Wind erosion requires a slightly different methodology, since only the WEE final estimate, not the individual equation factors, are contained in the NRI point data. So it was assumed that the achievement of an improved rangeland condition class would result in the same WEE estimate as already experienced by other lands in that higher class in the MLRA (see Table 4). An exception was made where the WEE was not inversely related to range condition class, in which case it was assumed that improving range condition would not induce more wind erosion, but that the WEE would remain the same.

Table 5 shows a summary of the results obtained in the six MLRAs and two states tested with this method. On the basis of this sample, it appears that the erosion control benefits of range improvement might be significant--causing a drop of approximately 31 percent in combined wind and water erosion on rangelands. The potential benefits vary widely, however, so analysis of the NRI data could be very useful in identifying both the regions where potential benefits might be the highest, as well as the type of erosion (wind or water) that might be most affected by improved range management.

An interesting variation of this method tested the Resource Conservation Act (RCA) goal currently being proposed by SCS--to raise the condition of poor and fair rangelands to good condition. Table 6 shows how this might affect erosion. The methodology followed was exactly the same as for Tables 3, 4, and 5, but both excellent and good condition ranges were left unchanged, while poor and fair condition ranges were adjusted so that the C factor and WEE products either equaled the current C and WEE associated with good condition land or were unchanged if they were already in a less erosion-prone condition.

The effect of achieving this goal would be somewhat different than that of achieving a one-class improvement across the board. For the MLRAs tested, the total soil erosion reduction would be slightly less (dropping from 30.74 to 27.95 percent). The major difference appears to be that the RCA goal might be slightly more effective in reducing sheet and rill erosion, and slightly less effective in reducing wind erosion. In some MLRAs (10, for example) the RCA goal seems to hold more promise for erosion control, while in others (77, for example) it

TABLE 5 Estimated Erosion Reduction from Improving the Condition of Perennial Range Vegetation by One Condition Class, Selected MLRAs and States (Percentages)

| Erosion Type | MLRA 10 | 30 | 43 | 67 | 77 | 81 | Idaho | Texas | Average |
|---|---|---|---|---|---|---|---|---|---|
| Sheet and rill erosion | 29.25 | 2.31 | 20.18 | 22.04 | 17.55 | 43.83 | 15.74 | 39.72 | 23.83 |
| Wind erosion | .00 | 23.22 | .00 | 77.59 | 46.88 | 26.32 | 75.67 | 34.20 | 35.49 |
| Total erosion | 29.25 | 22.85 | 20.18 | 34.52 | 41.84 | 42.56 | 18.44 | 36.29 | 30.74 |

SOURCE: Derived from 1982 NRI.

TABLE 6 Estimated Erosion Reduction from Improving Range in Poor and Fair Condition to Good Condition, Selected MLRAs and States (Percentages)

| Erosion Type | MLRA 10 | 30 | 43 | 67 | 77 | 81 | Idaho | Texas | Average |
|---|---|---|---|---|---|---|---|---|---|
| Sheet and rill erosion | 46.30 | .00 | 15.78 | 17.44 | 19.80 | 51.87 | 7.32 | 46.92 | 25.68 |
| Wind erosion | .00 | 23.59 | .00 | 82.23 | 25.45 | 16.37 | 80.81 | 29.08 | 32.19 |
| Total erosion | 46.30 | 23.17 | 15.78 | 17.62 | 24.48 | 49.30 | 11.09 | 35.83 | 27.95 |

SOURCE: Derived from 1982 NRI.



seems to hold considerably less. This may argue for a more flexible goal-setting process, done on a statewide, rather than national, basis.

## Erosion Control Potential in Rangeland Improvement Practices

The NRI data can also be used to estimate the potential erosion control benefits of applying the conservation practices listed as needed on rangelands. To estimate the soil loss reductions that might be achieved, the point data on acres needing various treatments, by MLRA, were used to prepare a table containing the weighted averages of the RKLS, USLE, and WEE factors. (The C factor is also needed. In the tables generated for this paper, it was not obtained by summing from the point samples, so it had to be deduced by dividing the weighted average of USLE by the weighted average of RKLS.)

For each treatment need, it was assumed that applying the needed treatment would achieve a C factor equal to that of the adequately treated land in the MLRA or state. Therefore, the new erosion level was calculated by multiplying the best attainable C factor by the existing RKLS, and the percent erosion reduction was calculated.

Table 7 summarizes the findings for all six MLRAs and for Idaho and Texas. In looking at this table, it is important to realize that the percentage erosion reductions apply only to those acres shown as needing each individual treatment; they are not applicable to the entire range resource of the area in question.

One MLRA, however, has enough unusual characteristics to raise questions about whether this methodology should be attempted there without considerable further investigation. In MLRA 30, the Sonoran Desert, there are very high wind erosion rates shown on much of the rangeland. USLE estimates are very low, as would be expected with the very low R factor (rainfall) involved. Nearly half the land and 65 percent of the soil loss in MLRA 30 are rated as unfeasible to treat.

What is even more perplexing, however, is that the weighted annual average wind erosion is over 10 tons/acre/year on land that has been rated as adequately protected. This raises questions about the accuracy of the Wind Erosion Equation as it applies to those desert conditions, or about the judgment of the field people in determining adequate protection, or both. With almost 1 million

TABLE 7 Estimated Erosion Reduction from Applying Needed Conservation Treatments on Rangelands, Selected MLRAs and States (Percentages)

| Conservation Treatment | MLRA 10 | 30 | 43 | 67 | 77 | 81 | Idaho | Texas |
|---|---|---|---|---|---|---|---|---|
| Erosion control | 73.63 | 79.1 | 81.95 | 55.32 | 92.37 | 81.01 | 74.92 | 86.05 |
| Forage protection only | 42.31 | .00 | 59.83 | 36.77 | 83.89 | 66.07 | 32.95 | 67.21 |
| Improvement without brush | 67.14 | 88.05 | 67.9 | 34.04 | 78.79 | 70.94 | 53.69 | 75.39 |
| Improvement with brush | 76.48 | 87.49 | 70.88 | 58.05 | 52.66 | 68.12 | 48.99 | 65.68 |
| Reestablish without brush | 77.84 | 53.57 | 75.21 | 93.20 | 92.04 | 74.11 | 65.50 | 78.92 |
| Reestablish with brush | 85.15 | 1.91 | 20.18 | 71.42 | 32.79 | 82.63 | 73.85 | 73.94 |
| Treatment unfeasible | | | | | | | | |
| Percent land | 9.12 | 48.66 | 3.82 | .38 | 1.1 | 2.26 | 5.82 | 2.67 |
| Percent erosion | 4.66 | 65.34 | 21.75 | 1.93 | 4.38 | 7.67 | 6.29 | 16.33 |

SOURCE: Derived from 1982 NRI.



acres in the sample category, the problem does not appear to be caused by a few renegade sample points, so additional checking or explanation seems in order.

## Using the 1982 NRI Data to Target Range Conservation Programs

A great deal of the soil erosion problem is concentrated on a small percentage of the land, which has been cited in recent USDA efforts to target soil conservation programs toward those lands where technical assistance, cost-sharing, or other forms of conservation incentive can produce the greatest reduction in soil loss per federal dollar. As in 1977, the 1982 NRI confirms this pattern. Point data for the sample MLRAs and states were aggregated according to ranges of actual soil loss, as indicated by the USLE and WEE results, and a weighted average soil loss was generated for each aggregation. Multiplying this weighted average by the acreage in the category gave total tons of soil loss, which enabled cumulative percentages for both acreage and soil loss to be generated.

Table 8 shows the results of this method for sheet and rill erosion in MLRA 43, and Table 9 provides wind erosion data from MLRA 77. In both these examples, a good case can be made for targeting soil conservation work on rangelands. In MLRA 43, about half the sheet and rill erosion is occurring on only about 5 percent of the land--those areas that are eroding at rates of 5 tons/acre/year or higher. In MLRA 77, 96 percent of the wind erosion is occurring on only about 20 percent of the land--areas eroding at rates of 2 tons/acre/year or higher. MLRA 30, the Sonoran Desert, demonstrated a somewhat different distribution, as might be expected, with 62 percent of the land suffering no wind erosion at all, while 16 percent was losing almost 85 percent of the total soil loss attributed to wind erosion n the MLRA.

That would be a strong case for targeting, but it should be tempered by remembering that 49 percent of the land and 65 percent of the soil loss was rated as unfeasible to treat in this MLRA. This no doubt means that natural geologic erosion rates are high and that USDA program targeting would have little, if any, effect.

(For the tests run in this assessment, the University of Minnesota ran the special computer program that counts the number of point samples in each segment of each

TABLE 8 Estimated Sheet and Rill Erosion on Rangeland, MLRA 43

| Actual Erosion (USLE) | Acreage (100 Acres) | Cumulative Percent of Acreage | Weighted Average Sheet/Rill Erosion | Soil Loss (100 Tons) | Cumulative Percent of Erosion |
|---|---|---|---|---|---|
| 0--<1 | 50,624 | 73.85 | 0.25 | 12,656 | 14.05 |
| 1--<2 | 8,060 | 85.61 | 1.45 | 11,687 | 27.02 |
| 2--<3 | 3,738 | 91.06 | 2.50 | 9,345 | 37.40 |
| 3--<4 | 1,353 | 93.04 | 3.42 | 4,627 | 42.53 |
| 4--<5 | 1,106 | 94.65 | 4.40 | 4,866 | 47.94 |
| 5--<6 | 479 | 95.35 | 5.50 | 2,635 | 50.86 |
| 6--<7 | 610 | 96.24 | 6.45 | 3,935 | 55.23 |
| 7--<8 | 275 | 96.64 | 7.27 | 1,999 | 57.45 |
| 8--<9 | 111 | 96.80 | 8.72 | 968 | 58.52 |
| 9--<10 | 185 | 97.07 | 9.47 | 1,752 | 60.47 |
| 10--<11 | 83 | 97.19 | 10.39 | 862 | 61.43 |
| 11--<12 | 124 | 97.37 | 11.33 | 1,405 | 62.99 |
| 12--<13 | 129 | 97.56 | 12.28 | 1,584 | 64.74 |
| 13--<14 | 948 | 98.95 | 13.33 | 12,637 | 78.77 |
| 14--<15 | 0 | 98.95 | | 0 | 78.77 |
| 15--<20 | 372 | 99.49 | 16.85 | 6,268 | 85.73 |
| 20--<25 | 25 | 99.52 | 23.00 | 575 | 86.37 |
| 25--<30 | 5 | 99.53 | 29.36 | 147 | 86.53 |
| 30--<50 | 294 | 99.96 | 36.37 | 10,693 | 98.40 |
| 50--<75 | 27 | 100.00 | 53.28 | 1,439 | 100.00 |
| 75--<100 | 0 | 100.00 | | 0 | 100.00 |
| 100 & up | 0 | 100.00 | | 0 | 100.00 |
| Total | 68,548 | | | 90,079 | |

SOURCE: Derived from 1982 NRI.

category in the tables. In the MLRAs and states chosen, the rangeland acreages were fairly large, so the lack of point samples to ensure data accuracy did not seem to present a problem. Even the smaller acreage divisions were the result of 5 to 10 sample points, and the assumption is that anything represented by four or more points is a statistically reliable number for these purposes. One exception was in the soil erosion groupings used for MLRAs 43 and 77, where some of the categories lacked adequate point data. One way to get around this problem, with little apparent loss of utility to the analysis, would be to group the erosion levels in broader groups. For rangeland, it would appear that groupings of less than 1 ton/acre/year, 1 to 2, 2 to 5, 5 to 10, 10 to 25, 25 to 50, and over 50 would be adequate for most evaluations and would ensure that adequate point samples existed in each category so that statistical reliability could be maintained.)

Several additional evaluations could make this analysis more relevant:



- Sample point data could be summarized to aggregate only those points rated as feasible to treat, which would be a much more logical basis for comparing different MLRAs to see where targeting would be the most productive.
- NRI data were collected on the trends in rangeland condition (up, even, or down) and the estimated grazing level at the time of the sampling (not grazed, presently deferred, properly used, or excessively used). The point data were summarized according to these factors, and associated RKLS, C, P, USLE, and WEE weighted averages obtained. It would be interesting to correlate the C factors obtained under proper grazing use with those associated with excessive use to yield an estimate of the erosion-prevention value of promoting proper grazing use on rangeland.
- Comparisons with the individual soil characteristics contained in Soils-5 can be made to separate the sample point data by total soil erosion rates compared with the soil loss tolerance limit. There was not enough time to do this, but a computer run could be designed to separate the acreage shown as needing the various

TABLE 9 Estimated Wind Erosion on Rangeland, MLRA 77

| Actual Erosion (WEE) | Acreage (100 Acres) | Cumulative Percent of Acreage | Weighted Average Wind Erosion | Soil Loss (100 Tons) | Cumulative Percent Erosion |
|---|---|---|---|---|---|
| 0--<1 | 103,293 | 74.44 | 0.08 | 8,263 | 1.62 |
| 1--<2 | 8,974 | 80.91 | 1.41 | 12,653 | 4.10 |
| 2--<3 | 6,277 | 85.43 | 2.49 | 15,630 | 7.17 |
| 3--<4 | 2,239 | 87.04 | 3.36 | 7,523 | 8.65 |
| 4--<5 | 1,967 | 88.46 | 4.44 | 8,733 | 10.36 |
| 5--<6 | 1,373 | 89.45 | 5.38 | 7,387 | 11.81 |
| 6--<7 | 1,596 | 90.60 | 6.48 | 10,342 | 13.84 |
| 7--<8 | 919 | 91.26 | 7.48 | 6,874 | 15.19 |
| 8--<9 | 441 | 91.58 | 8.43 | 3,718 | 15.92 |
| 9--<10 | 695 | 92.08 | 9.47 | 6,582 | 17.21 |
| 10--<11 | 310 | 92.31 | 10.52 | 3,261 | 17.85 |
| 11--<12 | 535 | 92.69 | 11.46 | 6,131 | 19.05 |
| 12--<13 | 868 | 93.32 | 12.48 | 10,833 | 21.18 |
| 13--<14 | 503 | 93.68 | 13.48 | 6,780 | 22.51 |
| 14--<15 | 466 | 94.01 | 14.75 | 6,874 | 23.86 |
| 15--<20 | 1,667 | 95.22 | 16.76 | 27,939 | 29.34 |
| 20--<25 | 1,610 | 96.38 | 21.81 | 35,114 | 36.23 |
| 25--<30 | 1,246 | 97.27 | 27.53 | 34,302 | 42.96 |
| 30--<50 | 1,721 | 98.51 | 38.54 | 66,327 | 55.98 |
| 50--<75 | 543 | 98.91 | 58.13 | 31,565 | 62.17 |
| 75--<100 | 446 | 99.23 | 86.29 | 38,485 | 69.73 |
| 100 & up | 1,072 | 100.00 | 143.91 | 154,272 | 100.00 |
| Total | 138,761 | | | 509,588 | |

SOURCE: Derived from 1982 NRI.

conservation treatments into three categories: land eroding at less than T, land eroding at T to 2T, and land eroding at over 2T. Such a table would be useful in assessing where the application of these conservation measures could help treat the most vulnerable rangeland soils.

## FORESTLAND

### General Findings

The 1982 NRI identified 393.7 million acres of non-federal forestland, some 26 percent of the total non-federal estate. About 37 percent of this land was adequately protected, with timber stand treatment needed on most of the rest. Soil erosion rates at or below the established T value were found on 94 percent of the forestland, with another 9.8 million acres (2.5 percent) eroding at levels between T and 2T and 13.6 million acres (3.5 percent) eroding at over 2T. Clearly, soil erosion is not a serious problem on most forestland.

Where erosion exists, however, it can be intense, because forestlands are generally steeper than more intensively used lands, with topsoils that are often thin and vulnerable to damage. Consequently, even though the average annual erosion rate on forestlands is just under 1 ton/acre/year, there are places where erosion control is badly needed.

Much of the accelerated erosion on forestland is associated with the grazing of livestock, and the division of the NRI statistics into grazed and ungrazed forestland helps assess this important difference. Soil erosion, on the national average, is about four times more severe on grazed forestland than on ungrazed. In some MLRAs (126, for example), grazed forestland is very erosion-prone, with RKLS factors in the 400 to 600 range. Such land is so steep and susceptible to erosion that removing livestock may be the best (or only) way to treat the erosion problem.

In contrast to the findings on rangeland, most soil erosion on forestlands can be treated. Even where erosion rates were highest, the sample NRI data tested suggest that very little of the problem is not feasible to treat, and the application of needed forest management and timber stand improvement practices appears to have the potential of reducing soil erosion by one-third to three-fourths.



Point sample data from six MLRAs (1, 15, 105, 115, 126, and 133B) and from Georgia and Michigan were summarized to consider the following questions:

- If potential cropland were developed, would the average quality of the remaining forestland be significantly changed in terms of erosion characteristics or timber productivity?
- How much erosion control benefit could be achieved by carrying out the erosion control and timber stand improvements shown in the NRI as needed?
- How can the 1982 NRI be used to improve understanding of the nation's nonindustrial private forestlands, which offer a significant challenge to forestry programs in many agencies and organizations?

### Conversion of Forestland to Cropland

A great deal of excellent forestland has been lost to crop production in recent years, and more may be lost in the future. One question that can be evaluated easily with the NRI data deals with the impact of future conversion on the soil erosion problem of remaining forestland.

Point sample data were summarized by grazed and ungrazed forestland, and a weighted average developed for both RKLS and USLE. The points shown as having high or medium potential for conversion to cropland were identified, and similar weighted averages developed for them, thus providing an estimate of the erosion characteristics on the remaining forestland should those lands actually be converted. Table 10 summarizes the results from the six MLRAs and two states tested.

Several things are evident from this table. First, in most areas and on both grazed and ungrazed forest, the comparative RKLS factors show that the land with potential for cropland is much less erosion-prone than the average for all forestland. Removing the better land is going to leave the remaining forest somewhat more erosion-prone, on the average, than before. There is significant variation among MLRAs and states on this, however. In MLRA 15, for example, the effect would be negligible, while in MLRA 115, farmland conversion could leave the remaining forestland as much as 10 percent more erosion-prone than it is today. If that occurred, a region where forestland might not appear to have a soil erosion problem today might indeed have such a problem in the future.

TABLE 10 Potential and Actual Erosion of Forestland in Selected MLRAS and States, with Percentage Increase of Potential Cropland Converted

| Average Erosion on Forestland (Tons/Acre) | MLRA 1 | 15 | 105 | 115 | 126 | 133B | Georgia | Michigan |
|---|---|---|---|---|---|---|---|---|
| Potential erosion (RKLS) | | | | | | | | |
| All ungrazed forestland | 288.11 | 181.23 | 373.83 | 269.99 | 474.85 | 39.40 | 94.02 | 16.21 |
| Potential cropland | 72.94 | 109.65 | 98.71 | 53.98 | 154.95 | 21.40 | 30.32 | 6.47 |
| Ungrazed forestland without potential cropland | 309.58 | 183.12 | 402.21 | 299.38 | 500.00 | 40.49 | 104.91 | 17.37 |
| Actual sheet/rill erosion (USLE) | | | | | | | | |
| All ungrazed forestland | 2.73 | 8.64 | 0.99 | 1.59 | 1.50 | 0.38 | 0.23 | 0.14 |
| Potential cropland | 0.08 | 6.88 | 0.37 | 0.25 | 0.25 | 0.15 | 0.08 | 0.13 |
| Ungrazed forestland without potential cropland | 2.99 | 8.69 | 1.06 | 1.77 | 1.60 | 0.40 | 0.25 | 0.14 |
| Potential erosion (RKLS) | | | | | | | | |
| All grazed forestland | 239.10 | 135.46 | 452.67 | 326.96 | 555.40 | 47.47 | 119.03 | 18.83 |
| Potential cropland | 13.33 | 91.80 | 137.52 | 100.13 | 163.87 | 23.11 | 53.22 | 7.61 |
| Grazed forestland without potential cropland | 248.85 | 135.80 | 486.68 | 354.81 | 583.94 | 50.55 | 133.44 | 25.78 |
| Actual sheet/rill erosion (USLE) | | | | | | | | |
| All grazed forestland | 3.07 | 7.49 | 5.10 | 13.04 | 7.65 | 0.99 | 0.73 | 0.62 |
| Potential cropland | 0.04 | 4.69 | 1.72 | 3.11 | 1.68 | 0.41 | 0.30 | 0.10 |
| Grazed forestland without potential cropland | 3.20 | 7.51 | 5.46 | 14.25 | 8.09 | 1.06 | 0.83 | 0.93 |
| If potential cropland were converted: | | | | | | | | |
| Ungrazed forestland | | | | | | | | |
| Percent increase in RKLS | 7.45 | 1.04 | 7.59 | 10.89 | 5.30 | 2.77 | 11.58 | 7.16 |
| Percent increase in USLE | 9.52 | 0.58 | 7.07 | 11.32 | 6.67 | 5.26 | 8.70 | 0.00 |
| Grazed forestland | | | | | | | | |
| Percent increase in RKLS | 4.08 | 0.25 | 7.51 | 8.52 | 5.14 | 6.49 | 12.11 | 36.91 |
| Percent increase in USLE | 4.23 | 0.27 | 7.06 | 9.28 | 5.75 | 7.07 | 13.70 | 50.00 |

SOURCE: Derived from 1982 NRI.

One interesting aspect of the 1982 NRI was the attempt to identify general forest types during the sampling. This provides an opportunity to look at the kinds of forests that seem most susceptible to continued conversion to cropland. Table 11 shows the distribution of the general forest types within the test areas, and Table 12 indicates the percentage of each type in each test area that might be converted to cropland.

It is not uncommon in these sample areas for 10 to 25 percent of a given forest type to be rated as having potential for conversion to cropland. Just what impact this would have on the forest products industry in those regions is beyond the scope of this study, but it would appear that several policy inferences could be made from these data, particularly if they were analyzed on a state-by-state basis, using MLRA data, within each state to identify regional impact potentials. In the samples from the central and eastern regions, the large acreages of oak-hickory forest that might be converted to cropland seem to hold the largest potential impact.

Another way to use the NRI in looking at potential land use impacts is to summarize the effects of potential cropland conversion on the remaining forest resource as indicated by the current canopy cover of the forestland most likely to be converted. This gives some idea of the size and value of the forest stands on those lands. Tables 13 and 14 are calculated in exactly the same manner as the two preceding tables, with the acreage figures aggregated according to estimated forest canopy cover. As can be seen, most of the potential cropland has canopy covers of less than 50 percent, and, in many areas, one-quarter to one-third is associated with a canopy cover of less than 25 percent. In some areas, the distribution is almost equally split among the canopy cover categories. Of interest is MLRA 1, where most of the forest has a canopy cover of over 50 percent, and almost 11 percent of that forestland is rated as having potential for conversion to cropland.

The NRI forestland data also captured information about the size of trees, separating those with a diameter at breast height (DBH) of over 5 inches from the smaller trees. On areas with average DBH of less than 5 inches, a stocking rate was estimated. Those factors were not correlated with conversion potential in this analysis, but that could be done if it were seen as potentially useful.



TABLE 11 General Forest Types in Selected MLRAs and States (100 Acres)

| General Forest Type | MLRA 1 | 15 | 105 | 115 | 126 | 133B | Georgia | Michigan |
|---|---|---|---|---|---|---|---|---|
| Jack pine | | | 835 | 216 | 1,942 | | 184 | 16,928 |
| Spruce/fir | | | 67 | | 51 | | 12[a] | 24,916 |
| Loblolly/slash pine | | | | | 12[a] | 6,794 | 43,050 | |
| Loblolly/shortleaf pine | | | 9[a] | 173 | 2,176 | 71,543 | 45,891 | 10[a] |
| Oak/pine | | | 256 | 822 | 1,953 | 80,718 | 64,422 | 3,280 |
| Oak/hickory | | 10[a] | 25,556 | 28,685 | 57,269 | 20,940 | 42,184 | 16,309 |
| Oak/gum/cypress | | | | 694 | 59 | 11,040 | 16,896 | |
| Elm/ash/cottonwood | | | 1,846 | 4,053 | 1,729 | 558 | 413 | 13,463 |
| Maple/beech/birch | | | 860 | 197 | 6,281 | | 59[a] | 40,484 |
| Aspen birch | | | 1,073 | 19[a] | 353 | | | 35,462 |
| Low production type | | 8[a] | 11[a] | 25[a] | 2,042 | 48[a] | 131 | |
| Nonstocked | 1,609 | 67[a] | 199 | 309 | 1,126 | 5,938 | 5,594 | 2,727 |
| Douglas fir | 33,831 | 226 | | | | | | 18[a] |
| Ponderosa pine | | 670 | | | | | | |
| Fir/spruce | 175 | | | | | | | |
| Hemlock/sitka spruce | 12,707 | | | | | | | |
| Lodgepole pine | 155 | | | | | | | |
| Redwood | 26[a] | 308 | | | | | | |
| Hardwoods | 9,602 | 16,591 | | 12[a] | | | | |
| Other conifers | | 32[a] | | | | | | |
| Savanna | | 10,167 | | | | | | |
| Total | 58,105 | 28,079 | 30,712 | 35,205 | 74,993 | 197,579 | 218,836 | 153,597 |

[a]Data cells of dubious statistical value—four sample points or fewer.

SOURCE: Derived from 1982 NRI.

TABLE 12 Percentage of Land by General Forest Types, with Potential for Conversion to Cropland, Selected MLRAs and States[a]

| General Forest Type | MLRA 1 | 15 | 105 | 115 | 126 | 133B | Georgia | Michigan |
|---|---|---|---|---|---|---|---|---|
| Jack pine | | | 6.47 | | 14.37 | | | 8.69 |
| Spruce/fir | | | | | | | | 4.16 |
| Loblolly/slash pine | | | | | | 20.36 | 25.43 | |
| Loblolly/shortleaf pine | | | | | 12.64 | 5.56 | 12.46 | |
| Oak/pine | | | 12.89 | 3.16 | 6.71 | 6.43 | 14.71 | 6.59 |
| Oak/hickory | | | 9.14 | 10.04 | 6.54 | 8.62 | 9.69 | 14.92 |
| Oak/gus/cypress | | | | 33.00 | | 3.30 | 1.78 | |
| Elm/ash/cottonwood | | | 11.97 | 18.33 | 9.66 | 19.35 | | 16.62 |
| Maple/beech/birch | | | 18.49 | 41.62 | 10.51 | | | 10.74 |
| Aspen birch | | | 8.39 | | 7.65 | | | 13.54 |
| Low production type | | | | | 4.75 | | | |
| Nonstocked | | | | 37.22 | 3.29 | 15.96 | 28.10 | 16.72 |
| Douglas fir | 6.90 | | | | | | | |
| Ponderosa pine | | 16.12 | | | | | | |
| Fir/spruce | | | | | | | | |
| Hemlock/sitka spruce | 18.60 | | | | | | | |
| Lodgepole pine | | | | | | | | |
| Redwood | | | | | | | | |
| Hardwoods | 5.41 | 1.28 | | | | | | |
| Other conifers | | | | | | | | |
| Savanna | | 0.90 | | | | | | |
| Total | 9.02 | 1.46 | 9.47 | 11.78 | 7.24 | 6.99 | 14.68 | 11.09 |

[a]Percentages only calculated where the acreage of a given general forest type with potential for conversion to cropland was 2,500 acres or more. Smaller acreages were discarded as having too few sample points for statistical reliability.

SOURCE: Derived from 1982 NRI.



TABLE 13 Forest Canopy Cover in Selected MLRAs and States (100 Acres)

| Estimated Canopy Cover (Percent) | MLRA 1 | 15 | 105 | 115 | 126 | 133B | Georgia | Michigan |
|---|---|---|---|---|---|---|---|---|
| 0--9 | 6,755 | 10,004 | 878 | 481 | 1,323 | 12,217 | 13,520 | 7,461 |
| 10--25 | 6,300 | 4,422 | 1,315 | 1,435 | 3,520 | 11,091 | 11,438 | 11,331 |
| 26--55 | 8,583 | 5,417 | 4,501 | 6,892 | 11,669 | 40,277 | 36,888 | 30,562 |
| 56--100 | 36,467 | 8,236 | 24,018 | 26,397 | 58,481 | 133,994 | 156,990 | 104,243 |
| Total | 58,105 | 28,079 | 30,712 | 35,205 | 74,993 | 197,579 | 218,836 | 153,597 |

SOURCE: Derived from 1982 NRI.

TABLE 14 Percentage of Land, by Forest Canopy Cover, That Has Potential for Conversion to Croplano, Selected MLRAs and States

| Estimated Canopy Cover (Percent) | MLRA 1 | 15 | 105 | 115 | 126 | 133B | Georgia | Michigan |
|---|---|---|---|---|---|---|---|---|
| 0--9 | 5.67 | 1.21 | 10.48 | 22.04 | 9.45 | 6.21 | 18.56 | 15.69 |
| 10--25 | 4.49 | 1.11 | 5.48 | 13.52 | 10.14 | 8.16 | 23.01 | 13.81 |
| 26--55 | 7.18 | 1.59 | 11.60 | 13.31 | 7.12 | 7.20 | 17.24 | 12.12 |
| 56--100 | 10.86 | 1.88 | 9.25 | 11.10 | 7.04 | 6.89 | 13.14 | 10.16 |
| Total | 9.02 | 1.46 | 9.47 | 11.78 | 7.24 | 6.99 | 14.68 | 11.09 |

SOURCE: Derived from 1982 NRI.



## Erosion Reduction Potential in Conservation Treatment on Forestlands

In assessing the potential for erosion reduction associated with the application of conservation practices, the NRI point sample data were summarized to develop a weighted average for the RKLS and C factors associated with the various treatment categories for each sample area. The P factor was left out of the tables because it is unity (1) in all cases, and the wind erosion (WEE) was ignored because it was 0 in virtually all cases. It was assumed that the application of the needed treatment would result either in a C (cover) factor similar to that of land adequately protected in the same area, or in the maintenance of the existing C factor, whichever was lower. The analysis was done separately for grazed and ungrazed forestlands. (Detailed tables with the results of this analysis for the six MLRAs and the two states are available from the author.)

Several conclusions emerged. Forestland that is adequately treated has very low soil erosion rates, and the treatment of forestland identified as needing erosion control, if that treatment could achieve good forest cover, has the potential of reducing erosion on those lands by 60 to 90 percent.

Even timber stand improvement, however, may be associated with significant soil erosion reductions (in terms of percentage) if the assumptions are correct. Reductions in the range of 50 percent are not uncommon if an improved cover condition equivalent to that experienced on adequately protected land in the region can be achieved as part of the timber stand work. Since most of the work on improving timber crops includes some attention to roads, trails, and other openings in the forest, this may be achievable.

On the national level, about 9 percent of the forestland needs timber establishment and reinforcement, 42 percent needs timber stand improvement, and 2 percent needs timber crop improvement. If significant progress on these treatment needs could be made, soil erosion on the nation's forests would be virtually nonexistent.

To get at the soil erosion problem, however, conservation programs need only target about 3 to 5 percent of the forestlands in most areas. The 1982 NRI data provide excellent information for locating the general region and size of the areas that need to be targeted, and they give good guidance as to whether the program could be enhanced by attention to timber stand improvement practices or whether it would be best to simply concentrate on erosion control efforts. It should be noted that SCS field staff were instructed to identify land that needed grazing eliminated in order to control erosion as land "needing erosion control." Thus, some of the land in the category of grazed forestland can be assumed to be land where livestock grazing is incompatible with the resource situation. Just how much of the grazed forest is in this condition cannot be determined from the NRI data, however.

### Using the 1982 NRI to Evaluate Forestry Program Potential

As the first national statistical sample to include detailed forestry information, the 1982 NRI is of definite interest to the forestry policy community. Although industrial and nonfederal publicly owned forestlands are not separable from nonindustrial privately owned lands, it appears that the data can be of considerable value when used in conjunction with other sources of forest information.

A caveat is necessary, however, based on indicators from the limited sample data reviewed to date. The SCS technicians who were filling out the sample point data for the NRI were not all foresters, and this was a first attempt, so the data on specific forest types and even on general forest types may be somewhat suspect. In this limited analysis, many data cells were encountered where the acreage suggested only one or two points in the entire MLRA.

In assessing the size of the trees on the sample site (DBH) and the stocking rate, the field technician was supposed to list the DBH in inches if it was over 5, to estimate the stocking rate (poor, moderate, full, or nonstock) if the DBH was under 5 inches. In our test MLRAs, there were many samples where neither a DBH nor a stocking rate was recorded. Those points were counted, and from them, a rough estimate of an error rate can be determined.

Whether all of these problems are errors or simply anomolies could not be ascertained, but it was clear that there were reasons to use the forest data with caution. As analyses continue, however, the errors will probably come to light, and the SCS will be able to improve techniques in forestry monitoring on a future NRI. Both the



1982 data and any future versions should be very carefully analyzed, and checked against other data, for value in providing background information and guidance to the nation's state and private forestry programs.

One conclusion could be drawn from this review, however. The forestland data are probably not too important in most states as a source of information on soil erosion and the effects of various conservation treatments. Soil erosion is simply not much of a problem on most forestlands.

This is not to say, however, that the NRI data cannot be of considerable value in the analysis of forestry policy. Tests to develop analytical techniques for evaluating the general forest type, canopy cover, and stand size information should be conducted to test the value of the MLRA and statewide estimates as indicators of the potential workload for forestry programs on nonfederal lands. It appears possible, from this limited review of the data, to use this information as one basis for identifying the forest opportunities of the nation and for drawing some conclusions about where the payoff of targeted forestry programs would be highest.

## GENERAL CONCLUSIONS

If the primary goal of conservation programs is the reduction of soil erosion, the point source data contained in the NRI data files can be very helpful in analyzing the areas where targeting effort might be most promising. In addition, particularly for rangeland, they can be used to give some approximations of the returns that might be associated with different targeting schemes.

If four sample points are considered useful criteria for selecting those data elements that have adequate statistical reliability, there seems to be little problem in utilizing the data base where acreages of range and forestland are fairly large. In MLRAs where these acreages are fairly small, however, statistical reliability will be a significant problem. One response would be to add a line on every table generated that would be labeled "all other" or something similar, where the sample units containing less than four sample points could be aggregated. Such a category would allow each table to accurately add the acreages in the MLRA and to keep the internal percentages accurate without misleading the analyst by indicating small amounts of a condition that may or may not exist.

The use of MLRA data rather than state data when using the SCS summary tables seems fully justified. In both forest and rangeland, the MLRA data would lead to different, and more accurately targeted, policy decisions than the statewide averages would. In the rangeland analysis, for example, both MLRA 10 and 43 are located partially in Idaho, and both 77 and 81 are located mainly in Texas.

In both cases, however, the MLRA data were different from each other and from the state data. Thus, it would appear that most of the analyses that would be most useful for program managers could be run as a state analysis using those portions of the MLRA within the state. In many cases, this would lead to rather small areas, and increased problems with statistical reliability, but the use of the "all other" category suggested above should help that situation.

In performing national program and policy tests, where each MLRA can be used in whole for evaluation, it seems clear that MLRA data will be far more useful, particularly when working with the SCS-generated summaries.

Finally, while there are many ways in which the point data are invaluable for research purposes, there are also very useful interpretations that can be made from the summary data provided by SCS. In selecting the MLRAs for this study, a common microcomputer and spreadsheet program was employed to develop useful information quickly.

The method was straightforward. A spreadsheet template was prepared containing the MLRA numbers in the first column. It could then be used to enter such data as total range acres, acres needing various types of conservation treatment, or any other factor in adjoining columns. The spreadsheet was programmed to calculate the national totals by adding each column. If that matched the total provided by the SCS summary, the entries were assumed correct; if not, errors were located and corrected.

With the raw numbers entered, other columns on the spreadsheet could be programmed to calculate percentages or any other necessary calculation. The particular spreadsheet program used (SuperCalc2) was also capable of rearranging the entries in ascending or descending order very rapidly. In this way, the MLRAs could be ranked according to any acreage or percentage characteristics. Through the use of this increasingly common tool, a number of comparative tables were generated in a very short time (see Table 15), and MLRAs could be chosen for

TABLE 15 Rangeland Characteristics as Shown in the 1982 NRI, Ranked by Total Acres of Range in MLRA (1,000 Acres)

| Rank | MLRA | Total Acres | Adequately Protected | | Needs Erosion Control | | Needs Re-Establishment | |
|---|---|---|---|---|---|---|---|---|
| | | | Acres | Percent | Acres | Percent | Acres | Percent |
| 1 | 42 | 24,374.9 | 7,412.0 | 30.41 | 2,110.6 | 8.66 | 268.9 | 1.10 |
| 2 | 78 | 21,303.9 | 6,986.3 | 32.79 | 765.3 | 3.59 | 408.2 | 1.92 |
| 3 | 81 | 21,244.8 | 3,341.4 | 15.73 | 239.0 | 1.12 | 437.3 | 2.06 |
| 4 | 58A | 16,794.2 | 7,169.2 | 42.69 | 220.9 | 1.32 | 123.5 | 0.74 |
| 5 | 70 | 15,307.4 | 4,715.9 | 30.81 | 2,477.1 | 16.18 | 162.2 | 1.06 |
| 6 | 77 | 13,876.1 | 4,977.0 | 35.87 | 1,945.8 | 14.02 | 288.5 | 2.08 |
| 7 | 35 | 13,672.0 | 3,010.6 | 22.02 | 832.8 | 6.09 | 1,020.6 | 7.46 |
| 8 | 65 | 11,389.3 | 8,416.8 | 73.90 | 33.3 | 0.29 | 195.7 | 1.72 |
| 9 | 67 | 9,963.2 | 3,384.5 | 33.97 | 1,261.8 | 12.66 | 196.9 | 1.98 |
| 10 | 34 | 9,773.0 | 2,368.6 | 24.24 | 381.9 | 3.91 | 91.7 | 0.94 |

SOURCE: Derived from 1982 NRI.

study on the basis of known characteristics and rankings for selected criteria.

Analyses of this kind can use the data from the SCS summaries on an ordinary office microcomputer to develop information that is likely to be adequate for a wide variety of policy and program planning needs, as well as giving useful insights that can be helpful in public information programs. While this will not always satisfy the precision requirements of researchers, it is both inexpensive and efficient, and should not be overlooked as an opportunity that is available, for the first time, with the 1982 NRI.

## Discussion

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This is a most thorough and thought-provoking summary and analysis of the 1982 National Resources Inventory (NRI) survey for erosion from range and forestland. The assessments contained in Sampson's paper suggest additional analyses and summaries that would be worthwhile and supportive of Soil Conservation Service (SCS) targeting efforts.

The Society for Range Management (SRM) has gone on record as being opposed to use of the Universal Soil Loss Equation (USLE). The group (Schuster, 1984) contends that "until technology is developed to replace it...the USLE is inapplicable for assessing the resources on rangelands." The SRM further "encourages the U.S. Department of Agriculture (USDA) to adopt proven and acceptable techniques for evaluating vegetation as a more accurate and earlier indication of degradation of the total rangeland resource." Such statements have done a real disservice to the USLE, which was never intended to assess anything but the erosion that would be expected over a relatively long time.

Use of the USLE in the 1982 NRI evaluation and its analysis by papers such as this one are valid applications of the USLE for targeting the use of resources--dollars and personnel. The question that remains is whether the USLE has received sufficient verification and validation for use on rangeland.

Some of the earliest measurements of soil erosion were made by A. W. Sampson (Sampson and Weyl, 1918), assisted by L. H. Weyl, E. V. Storm, and C. L. Forsling, on



overgrazed rangelands in central Utah. These studies, and research by Chapline (1929), illustrated how overgrazing allowed erosion to reduce soil fertility and waterholding capacity. Unfortunately, erosion research on rangeland languished from the time of these early efforts until the 1970s. Concern for the ecological health of rangeland grew with general concern for the environment that developed during the late 1960s and 1970s. Excessive erosion was again recognized as being detrimental to rangelands as well as other agricultural lands. Consequently, current management plans for rangelands frequently contain analyses on how management alternatives would affect erosion. Since research has provided little information on erosion associated with rangeland activities, technology from other geographic areas was adapted to estimate erosion on rangeland. In particular, the USLE, which has been used successfully on cropland since the early 1960s, was adopted to estimate erosion on rangeland.

Had computer technology been available in the 1940s, current erosion prediction methods might look more like the theory contained in Ellison's classic paper (1947) than like the empirical form of the USLE. The USLE and its predecessors were very much structured to be "user friendly," because by the early 1950s erosion equations were accepted by the USDA-SCS as a tool for tailoring erosion control practices to the needs of specific fields and farms. Unfortunately, during this period no comparable erosion research program on rangelands in the western United States was conducted, and thus recent efforts to develop erosion methods for rangelands have not had an extensive data base on which to draw.

Although the USLE was being applied on a limited basis prior to its 1965 release in Agriculture Handbook 282 (Wischmeier and Smith, 1965), the SCS and other agencies soon switched from the regional agronomic planning concepts for erosion abatement to the USLE, and by the mid-1970s there was an interest in using the technology on western rangelands. Thus, requests were made for a "best estimate" approach for the cover-management factor [Wischmeier then developed Table 10 in Agriculture Handbook 537 (Wischmeier and Smith, 1978)] until such time that research could provide data for a similar table or an alternative.

Table 1 presents a list of some of the material that has appeared in the scientific literature over the past few years regarding application of the USLE to range

TABLE 1 Research Evaluating USLE Performance on Rangelands

| Reference | Area of Work | Comments |
|---|---|---|
| Renard et al., 1974 | Arizona | Used small watersheds; significant channel erosion |
| Renard and Simanton, 1975 | Arizona, New Mexico | Explored estimation of erosion factor |
| Osborn et al., 1976 | Arizona, New Mexico | Showed importance of stone surface cover |
| Simanton et al., 1977 | Arizona | Showed effect of root plowing and reseeding on erosion control |
| Verma et al., 1977 | Arizona | Measured erosion from disturbed and natural plots with artificial or simulated rainfall |
| Johnson et al., 1980 | Idaho | Used canopy and ground cover to compute potential erosion for sagebrush control |
| Renard, 1980 | Arizona | Compared numerous sediment yield formulae |
| Simanton et al., 1980 | Arizona | Applied to small watersheds on storm basis |
| Trieste and Gifford, 1980 | Utah | Used small plots with rainfall simulator; suggested USLE did not apply well to rangelands |
| Foster et al., 1981 | Utah | Discussed applicability of USLE to rangelands |
| Dissmeyer, 1982 | New Mexico | Used subfactor approach in evaluating C (cover) on rangeland |
| Hart, 1982 | Utah | Measured erosion on sagebrush plots with a rainfall simulator |



TABLE 1 (Continued)

| Reference | Area of Work | Comments |
|---|---|---|
| McCool, 1982 | Washington | Theoretical analysis of slope length-steepness factor |
| Renard and Stone, 1982 | Arizona | Correlation of USLE estimates with stock pond yields |
| Simanton and Renard, 1982 | Arizona, New Mexico | Evaluated erosivity of air-mass thunderstorms |
| Williams, 1982 | Texas, Oklahoma, Iowa, New Mexico | Estimated sediment yield from mixed cover watersheds with modified USLE |
| Trott and Singer, 1983 | California | USLE soil erodibility factor should consider soil mineralogy |
| Hart, 1984 | Utah | Fair agreement of USLE with simulated rainfall data; slope factor needs adjustment |
| Simanton et al., 1984 | Arizona | Measured erosion reduction caused by stone surface cover |
| Smith et al., 1984 | Texas, Oklahoma | Sediment yield estimates with modified USLE, on watersheds less than 122 hectares and on watersheds with mixed land uses |
| Tracy et al., 1984 | Arizona | Measured drop-size distribution of air-mass thunderstorms for use in evaluating erosivity |
| Johnson et al., 1984 | Idaho, Nevada | Used rainfall simulator and found interpretation of C on ungrazed areas needed refinement |

conditions. Despite this considerable attention, many problems remain unresolved, although analysts are getting much closer to being comfortable with this technology.

Two years ago, the Bureau of Land Management asked a number of Agricultural Research Service (ARS) and university researchers to develop a handbook for the application of the USLE on rangelands. The response to this request made several issues apparent: (1) A major effort was needed to improve the evaluation of C, the cover-management factor; (2) this improvement could best be accomplished by using a subfactor approach for evaluating C; (3) there are problems in assessing the orographic effects of precipitation in the form of rain and snow on EI, the storm kinetic energy times maximum 30-minute intensity; (4) snowmelt is a problem in estimating erosion; (5) frozen soils and the freeze/thaw cycles that occur frequently on rangeland represent a special problem; and (6) slope length and steepness are often greater than that encountered on cultivated cropland.

Time does not permit treatment of all of these problems. Rather, a discussion of the subfactor approach for evaluation of C will be presented. The procedure is very similar to that presented by Dissmeyer (1982) and Dissmeyer and Foster (1981) for forestland in the southeastern United States and now used elsewhere. The cover-management factor for rangeland is given as (J. M. Laflen, USDA-ARS, Ames, Iowa, personal communication, 1984):

$$C = (PLU)(PC)(SC)(SR), \qquad (1)$$

where PLU is a prior land use subfactor, PC is a plant canopy subfactor, SC is a surface cover subfactor, and SR is a surface roughness subfactor. The individual subfactors can be obtained as follows:

$$PLU = 0.45\ EXP(-.012\ RS), \qquad (2)$$

where RS is the mass of roots and residue (kilograms/hectare/millimeter of depth) in the surface 100 millimeters of soil. At present, there are no adjustments in this subfactor to account for differences in grazing intensity. However, the coefficient 0.45 does express the long-term consolidation effects occurring on rangeland due to grazing. Other grazing effects, such as reduced



canopy cover, different surface cover, or roughness changes, are reflected in other subfactors.

If the rangeland is tilled, the PLU is assumed to follow this relationship for 7 years:

$$PLU = (1 - 0.08\ Y)\ EXP(-.012\ RS). \qquad (3)$$

The relationship of plant canopy to soil erosion was taken from Wischmeier and Smith (1978) and given as:

$$PC = 1 - FC(EXP - 0.34\ H), \qquad (4)$$

where FC is the fraction of the land surface covered by canopy and H is the average canopy height (meters).

Surface cover creates small dams where runoff is temporarily ponded and eroded sediment may be deposited. The surface cover factor is expressed as:

$$SC = EXP(-3.5\ M), \qquad (5)$$

where M is the fraction of the land surface covered by nonerodible material such as litter, rock, and growing vegetation.

Surface roughness influences soil erosion by reducing runoff volume and velocity, and by ponding surface runoff to cause deposition. The roughness of a surface is expressed as the standard deviation among heights along the soil surface perpendicular to the slope. The algorithm used to compute the subfactor is:

$$SR = EXP[-.026(RB - 6)(1 - EXP(-.035\ RS))], \qquad (6)$$

where RB is surface roughness and RS is as defined earlier. Tables and pictures for estimating RB are given in the document to assist the user in selecting the appropriate value for the condition being considered.

Of concern is how much changes in the USLE parameters resulting from new USLE information might affect the rangeland summaries in the NRI. Because the research is unlikely to be completed until after the targeting objectives of the Resource Conservation Act process are in effect using the 1982 NRI data, perhaps the answer will never be known. It does seem likely that confidence in the numbers obtained would be improved and that professional societies like the SRM will be more amenable to working on the rangeland resource problem. Likewise, the USLE technology used for the 1982 NRI is based on fundamental concepts and, as such, should provide reasonable planning/inventory data on water erosion.

## SOIL LOSS TOLERANCES

Sampson's paper refers to 83 percent of the rangeland with estimated soil loss at or below the soil loss tolerance limit (T value). Furthermore, 6.4 percent of the area had loss rates between T and 2T, and 10.8 percent had soil erosion in excess of 2T. Presumably a T value for rangeland of 5 tons/acre/year was used. Is there sufficient information on soil formation processes on rangeland to establish T values? Soil morphologists have noted that many of the soils on Walnut Gulch in southeastern Arizona are not soil (based on their experience in more humid areas) but rather partly weathered parent geologic material. Thus, given the dry conditions, low organic matter, and other factors, soil loss may not be affordable (in a noneconomic sense). But geologic erosion has always been taking place in such areas. The question, then, is how significant current erosion is relative to geologic erosion. In fact, in many rangeland areas, erosion from the rill/interrill areas is not the major sediment source. It is the material coming from headcuts, arroyo entrenching, channel degrading and widening, or other sources that is the major contributor to the downstream sediment yield. Thus, unless land management alters the runoff distribution, downstream sedimentation may not be rectified. And this is not even a part of the assessment of the NRI.

The wind erosion estimates in the section on rangeland of this paper are very interesting. Like the USLE, the Wind Erosion Equation has certainly had minimal testing on western rangelands, with the exception of some work in Texas and New Mexico. The wind erosion problem specifically cited in Table 1 for MLRA 30 is an interesting one. The area, on both sides of the lower Colorado River near the U.S.-Mexico border, is quite arid and contains many sand dunes and an extreme shortage of vegetation in the nonirrigated condition. Further, desert pavements are quite common in the area. Were allowances for the gravel on the soil surface made? The I value (soil erodibility) selected was probably based on soil texture determined without considering the gravel. Dr. Leon Lyles, director of the ARS Wind Erosion Laboratory at Manhattan, Kansas, has stated that the gravel should be



considered in the textural evaluation and thus in the I value that might be selected (personal communication, 1984). Adequate protection with vegetation treatments is extremely difficult in such areas when moisture is so limiting.

## REFERENCES

Chapline, W. R. 1929. Erosion on rangeland. J. Am. Soc. Agron. 21:423-429.

Dissmeyer, G. E. 1982. Report on application of the USLE to desert brush and rangeland conditions. Pp. 214-225 in Proc. of Workshop on Estimating Erosion and Sediment Yields on Rangelands. ARM-W-26. Washington, D.C.: USDA Agricultural Research Service.

Dissmeyer, G. E., and G. R. Foster. 1981. Estimating the cover-management factor (C) in the Universal Soil Loss Equation for forest conditions. J. Soil Water Conserv. 36:235-240.

Ellison, W. D. 1947. Soil erosion studies. Agric. Engineer. 28:145-146, 197-201, 245-248, 297-300, 349-351, 402-405, 442-444.

Foster, G. R., J. R. Simanton, K. G. Renard, L. J. Lane, and H. B. Osborn. 1981. Viewpoint: Application of the USLE to rangelands on a per-storm basis. J. Range Manage. 34:161-166.

Hart, G. E. 1982. A test of the USLE on bare and sagebrush plots in Utah. Pp. 101-105 in Proc. of Workshop on Estimating Erosion and Sediment Yield on Rangelands. ARM-W-26. Washington, D.C.: USDA Agricultural Research Service.

Hart, G. E. 1984. Erosion from simulated rainfall on mountain rangeland in Utah. J. Soil Water Conserv. 39:330-334.

McCool, D. K. 1982. Effects of slope length and steepness on soil erosion from rangelands. Pp. 73-95 in Proc. of Workshop on Estimating Erosion and Sediment Yield on Rangelands. ARM-W-26. Washington, D.C.: USDA Agricultural Research Service.

Johnson, C. W., G. A. Schumaker, and J. P. Smith. 1980. Effects of grazing and sagebrush control on potential erosion. J. Range Manage. 33(6):451-454.

Johnson, C. W., M. R. Savabi, and S. A. Loomis. 1984. Rangeland erosion measurements for the USLE. Trans. ASAE 127:1313-1320.

Osborn, H. B., J. R. Simanton, and K. G. Renard. 1976. Use of the Universal Soil Loss Equation in the semiarid Southwest. Pp. 41-49 in Soil Erosion: Prediction and Control. Special Pub. 21. Ankeny, Iowa: Soil Conservation Society of America.

Renard, K. G. 1980. Estimating erosion and sediment yields from rangelands. Pp. 164-175 in Proc. of Am. Soc. Civil Engineers Symp. on Watershed Management. Boise, Idaho: American Society of Civil Engineers.

Renard, K. G., and J. R. Simanton. 1975. Thunderstorm precipitation effects on the rainfall-erosion index of the Universal Soil Loss Equation. Hydrol. Water Res. Ariz. Southwest 5:47-55.

Renard, K. G., and J. J. Stone. 1982. Sediment yield from small arid rangeland watersheds. Pp. 129-144 in Proc. of Workshop on Estimating Erosion and Sediment Yield on Rangelands. ARM-W-26. Washington, D.C.: USDA Agricultural Research Service.

Renard, K. G., J. R. Simanton, and H. B. Osborn. 1974. Applicability of the Universal Soil Loss Equation to semiarid rangeland conditions in the Southwest. Hydrol. Water Res. Ariz. Southwest 4:18-32.

Sampson, A. W., and L. H. Weyl. 1918. Range Preservation and Its Relation to Erosion Control on Western Grazing Lands. U.S. Department of Agriculture Bulletin No. 675. Washington, D.C.: U.S. Government Printing Office.

Schuster, J. L. 1984. Position statements by SRM. Rangelands 6(3):139-140.

Simanton, J. R., and K. G. Renard. 1982. The USLE rainfall factor for southwestern U.S. rangelands. Pp. 50-62 in Proc. of Workshop on Estimating Erosion and Sediment Yield on Rangelands. ARM-W-26. Washington, D.C.: USDA Agricultural Research Service.

Simanton, J. R., H. B. Osborn, and K. G. Renard. 1977. Effects of brush to grass conversion on the hydrology and erosion of a semiarid southwestern rangeland watershed. Hydrol. Water Res. Ariz. Southwest 7:249-256.

Simanton, J. R., H. B. Osborn, and K. G. Renard. 1980. Application of the USLE to southwestern rangelands. Hydrol. Water Res. Ariz. Southwest 10:213-220.

Simanton, J. R., E. Rawitz, and E. D. Shirley. 1984. The effects of rock fragments on erosion of semiarid rangeland soils. Pp. 65-72 in Erosion and Productivity of Soils Containing Rock Fragments. Special Pub. 13. Madison, Wis.: Soil Science Society of America.





Smith, S. J., J. R. Williams, R. G. Menzel, and G. A. Coleman. 1984. Prediction of sediment yield from southern plains grasslands with the modified Universal Soil Loss Equation. J. Range Manage. 37(4):295-297.

Tracy, F. C., K. G. Renard, and M. M. Fogel. 1984. Rainfall energy characteristics for southeastern Arizona. Pp. 559-566 in Water--Today and Tomorrow. Proc. of Am. Soc. Civil Engineers Irrig. and Drain. Div. Specialty Conference July 24-26, Flagstaff, Arizona.

Trieste, D. J., and G. F. Gifford. 1980. Application of the Universal Soil Loss Equation to rangelands on a per-storm basis. J. Range Manage. 33(1):66-70.

Trott, K. G., and M. J. Singer. 1983. Relative erodibility of 20 California range and forest soils. Soil Sci. Soc. Am. J. 47:753-759.

Verma, T. K., J. L. Thames, and J. E. Mills. 1977. Soil erosion and sediment control on the reclaimed coal mine lands of the semiarid Southwest. Hydrol. Water Res. Ariz. Southwest 7:41-47.

Williams, J. R. 1982. Testing the modified Universal Soil Loss Equation. Pp. 157-165 in Proc. of Workshop on Estimating Erosion and Sediment Yield on Rangelands. ARM-W-26. Washington, D.C.: USDA Agricultural Research Service.

Wischmeier, W. H., and D. D. Smith. 1965. Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains--Guide for Selection of Practices for Soil and Water Conservation. Agriculture Handbook No. 282. Washington, D.C.: U.S. Government Printing Office.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting Rainfall-Erosion Losses--A Guide to Conservation Planning. Agriculture Handbook No. 537. Washington, D.C.: U.S. Government Printing Office.