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Effects of Land-Use Conversion on Water Runoff and Soil Erosion

Abstract

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Converting grassland on either 2.2 or 5.5 percent sloping loamy or "hardland" soils in eastern Colorado to cropland in an alternate winter wheat-fallow rotation increased water runoff and soil erosion. The conversion increased water runoff from the 5.5 but not from the 2.2 percent slopes. The differences in plant population, presumably associated with soil temperature under different exposures, confounded the effect of slope on runoff. Average annual runoff over a 10-year period was 1.1 inches.

Annual soil losses were correlated with runoff and were 5 times as great from cropland as from grassland on 5.5. percent slopes. Soil losses were 1.8 times as great from fallow as from wheat plots. On 2.2 percent slopes annual soil losses from cropland were 1.8 times the losses from grassland. However, the highest annual soil loss was only 2.7 tons per acre from the fallow plot on 5.5 percent slope. Soil erosion by water was within the acceptable range of 1 to 5 tons per acre which was considerably less than that predicted by the Universal Soil Loss Equation.

KEYWORDS: hydrology, runoff, soil loss, precipitation, winter wheat, fallow, grassland, slope, soil water storage

Contents

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Effects of Land-Use Conversion On Water Runoff and Soil Erosion

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Introduction

Erosion is one of the primary factors in the degradation of the Nation's soil resources. In Colorado 2 million acres of cropland are eroding at rates higher than the USDA's Soil Conservation Service (SCS) acceptable rate of 1 to 5 tons per acre per year, depending on soil type (5).[2] Erosion by water on Colorado croplands is responsible for the annual loss of 27.4 million tons of soil with the greatest losses from sheet and rill erosion.

Colorado's cropland totaled 7.27 million acres in 1982 (3). Almost 50 percent was in winter wheat production in a wheat-fallow rotation, while a similar number of acres were in summer fallow to store enough soil water for wheat production the following year. The erosion potential is higher on fallowed land than on cropped land unless adequate surface crop residues are maintained throughout the summer fallow period. The amount of crop residue produced on dryland in eastern Colorado is often limited by frequent periods of drought.

The area planted to crops continues to increase, and most of the increase comes from land that had been range, forest, pasture or wetlands. The SCS reported that since 1979, in Colorado alone, about 390,000 acres of native sod have been converted to additional cropland (4). Much of this land has very limited crop production potential because the area is arid with shallow soils and undulating topography. Consequently, the conversion of land from native sod to cultivated cropland has reduced surface cover and increased the potential for water erosion and sedimentation in streams and reservoirs.

The degree of water erosion resulting from conversion of grassland to cultivated cropland varies with soil type, topography, tillage system, and rainfall characteristics (2). This report presents research results on the conversion of loamy or "hardland" soils in eastern Colorado from grass to cropland.

Experimental Procedure

The project was conducted over a 10-year period beginning in 1963 following a year of establishment. Water runoff and soil erosion were monitored from grass, winter wheat and summer fallow plots under natural rainfall conditions.

Site Description

The site for the runoff and erosion study was established in 1962 on a hillside at the Central Great Plains Research Station near Akron, Colo. The area is part of knob that was cultivated and because of it's droughtiness was proned to wind and water erosion. This area was seeded to a mixture of grasses in 1958, 1960, and 1961 in an effort to curtail erosion. Switchgrass, blue grama grass, crested wheatgrass, intermediate wheatgrass, and alfalfa survived after the three seeding attempts, but stands were sparse because of drought during establishment. Hillside slopes varied from nearly level to 5.5 percent with northeast to southeast phasing aspects.

Soil Description

The three principal soil series were delineated: Colby fine sandy loam,

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2/Numbers in parentheses refer to literature citations.

Rago loam and Weld loam soils. The Colby series is of the fine-silty mixed (calcareous) mesic, Ustic Torriorthents (13). This soil is formed from wind blown deposits of very fine sand on the uplands (10) and is highly susceptible to blowing and drifting when cultivated. The Rago soils are of the fine, montmorillonitic, mesic, Pachic Argiustoll group. They are loamy and very smooth at the surface. They have a clay loam at the 4- to 8-inch depth that restricts downward movement of water; therefore, the runoff potential is slightly greater than that for the Colby series.

The Weld soils are of the fine, montmorillonitic, mesic, Aridic Paleustoll group. They are similar to the Rago series but have a thicker A horizon and lower organic matter content. Both the Weld and Rago soils belong to the B hydrologic group indicating that they are more susceptible to water erosion and less susceptible to wind erosion than are the Colby soils (15).

These soils, which constitute most of the farmland in the area, lend themselves to the production of a number of crops and allow for diversification and economic stability in agriculture. They are better suited to small grains but will produce corn and sorghum if precipitation is favorable.

Methods and Materials

Runoff plots were 200 feet long and 120 feet wide with border ridges of soil constructed on four sides to a settled height of one foot to divert runoff from outside areas. Three plots were oriented on slopes averaging 5.5 percent with northeast aspect and three on slopes averaging 2.2 percent with southeast aspect. On each slope one plot was maintained in mixed grasses while two were cultivated in an alternate winter wheat-fallow rotation.

Entrance boxes with 2-foot H-flumes and FW-1 runoff recorders were installed at the lower end of each plot to measure storm runoff. Coshocton sediment sampling wheels were installed below each flume to intercept an aliquant portion of the runoff water and divert it to a holding tank. The runoff water in the tank was thoroughly agitated as three 1-quart subsamples were collected. These subsamples were weighed, dried and weighed again to determine volume of water and sediment concentration (1).

Both standard and recording rain gauges were used throughout the experimental site. Storm amounts and intensities were determined for each rainfall event from April 1 to September 30 each year.

The year of 1962 was one of treatment establishment. The two cultivated plots on each slope were one-way plowed and disked in April of 1962. Plots to be fallowed received 1,500 lb/acre straw which was crimped in the surface soil to help control erosion. The plots were then tilled in mid June and early September with rodweeder to control undesirable vegetation. Winter wheat was planted on September 6, 1962, at 30 pounds per acre with a deep-shoe drill in 14-inch rows. Planting was done on the contour to minimize runoff and erosion.

The plots planned for cropping the first year had 1,300 lb/acre of straw applied and crimped in the soil surface following the initial disking operation. They were again tilled in June with rodweeder and planted to millet at about 18 lbs/acre with grass drill. The millet was harvested in early September with combine. Millet was grown only the first year to initiate the cropping phase of the rotation. Thereafter, winter wheat was the principle crop grown on plots following 14 months of fallow.

The period of fallow began with winter wheat harvest which was done by handclipping two 14-inch rows of wheat, eight feet long, on nine sites within each plot. Straw and grain yields were determined from these samples. A field combine was later used to harvest the remainder of the crop. Two to four weeks after harvest, the wheat plots were undercut to a depth of about four inches with V-blade to kill growing weeds and grass when they persisted, otherwise standing wheat stubble was left untouched to trap snow during the winter and early spring periods.

At the onset of weed and/or volunteer wheat growth in fallow plots the next spring, the V-blade was used to undercut the plots, and if precipitation during the late spring and early summer was abundant, causing excessive growth of the undesirable vegetation, the fallow plots were disked rather than undercut. Depending upon the frequency and amount of rainfall during the rest of the fallow period, plots were bladed or rodweeded 2-4 more times before planting winter wheat around September 10. Herbicides were never used on fallow or growing wheat to control weeds.

The mixed grass plots were left untouched except for harvesting which was accomplished by handclipping the grass in a 3- x 3-foot quadrant at nine sites within each plot. The grass samples were then oven-dried at 70°C and weighed to calculate the dry matter yields. The frequency of grass harvest varied from one to three times a year depending again on the precipitation. Above normal precipitation throughout the growing season resulted in three grass harvests while below normal precipitation resulted in only one harvest. Following hand sampling, the remainder of the mixed grasses was windrowed, baled, and removed from the plots.

Surface residues were collected from 3- x 3-foot quadrants from nine sites within each fallow plot. Timing and frequency of these samplings during the fallow period varied from year to year, but always just before a necessary tillage operation. The samples were processed according to standardized procedure (16).

Soil water in the mixed grass plots was measured by core sampling soil in one-foot increments to a depth of five feet at nine sites per plot. The samples were weighed wet, dried at 104°C, and weighed again. These data were used to calculate soil water content on the percent dry weight basis. The samples were taken at the first onset of grass growth in the spring and at each harvest of mixed grasses. Similar soil water samplings were taken in winter wheat plots at planting and harvesting of winter wheat.

Results

Rainfall Characteristics

The annual precipitation for the study period averaged 15 inches or 1.5 inches below the long-term mean, and was highly variable in amount, areal distribution, and timeliness. Figure 1 shows the annual distribution of mean weekly precipitation for the 10 years beginning in 1963. The week-to-week variation in rainfall was largest during midsummer. A 5-week moving average to show the general trend and mean weekly runoff also were graphed. More than 70 percent of the annual precipitation and 90 percent of annual runoff occurred from April through August. The period of greatest rainfall and runoff was in June.

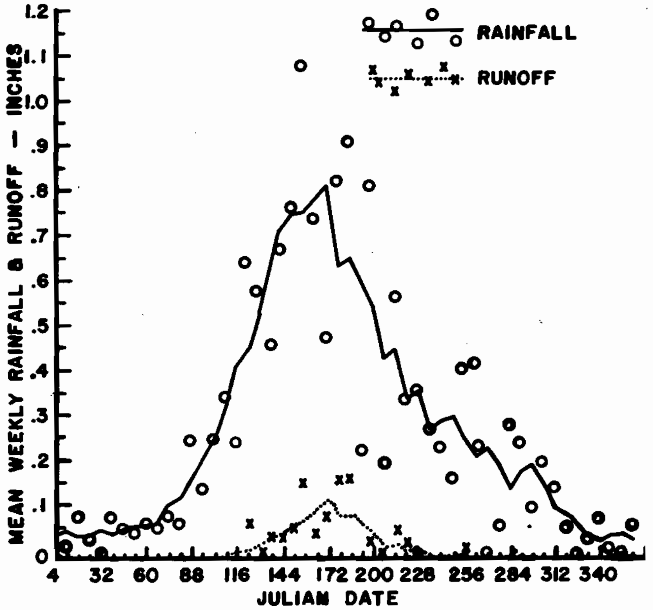

Figure 1.--Weekly precipitation and runoff, 10-year average.

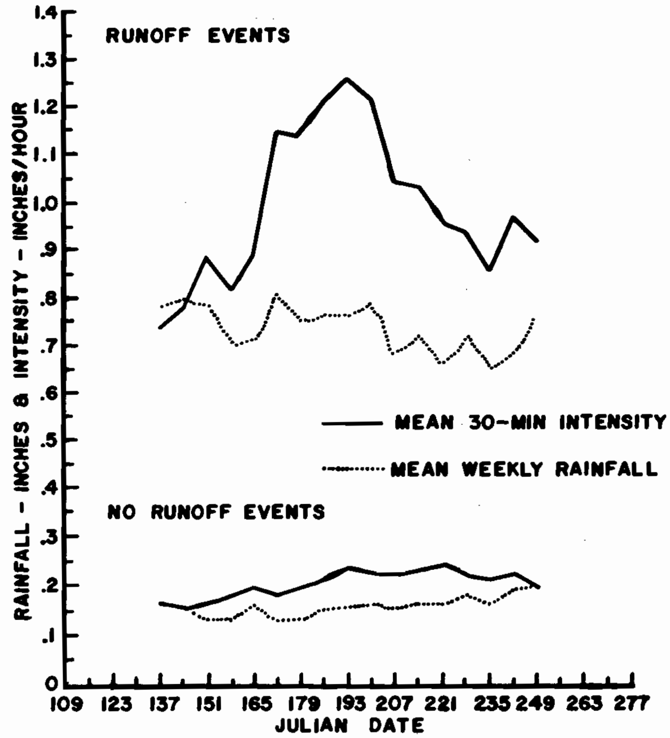

Figure 2.--Weekly rainfall and maximum 30-minute intensities of storms producing runoff, 10-year average.

The rainfall events were grouped into those producing runoff and those not producing runoff. The mean weekly storm amounts and maximum 30-minute intensities are plotted in Figure 2 for the weeks of May 17 through September 6. For storms producing runoff, mean weekly precipitation varied from 0.65 to 0.80 inch. However, the storms' average maximum 30-minute intensities increased during June to a maximum of about 1.26 inches per hour in July before decreasing. For storms yielding no runoff during this same period of the year, amounts averaged less than 0.2 inch and maximum 30-minute intensities were less than 0.25 inch per hour. There was little variation throughout the growing season period.

During the 10 years, 70 rainfall events yielded measurable amounts of runoff. Maximum 30-minute intensities exceeded 3.00 inches per hour in only one of these storms, and 2.00 inches per hour in five storms, and 1.00 inch per hour in 28 storms. Of the runoff-producing storms, 50 percent had maximum 30-minute intensities of less than one inch per hour.

The SCS engineering handbook (12) classifies rainfall events into three Antecedent Moisture Conditions (AMC) as an index of watershed wetness. The 5-day antecedent rainfall amounts were used to determine the AMC for the dormant and growing seasons. Since all runoff-producing storms occurred during the growing season, the 5-day antecedent rainfall was used to analyze storm types. Distribution of the 70 runoff-producing storms among the AMC categories with their respective 5-day antecedent rainfall amounts were as follows: 56 storms (80%) as Type I with less than 1.4 inches; 8 storms (11%) as Type II with 1.4-2.1 inches; and 6 storms (9%) as Type III with more than 2.1 inches. Most of the annual runoff occurred with a Type I condition which normally has low runoff potential because the soils are considered dry enough to be tilled; however, rainfall intensities and amounts were great enough to produce runoff. The low frequency of high intensity rainfall events is one reason why runoff and water erosion are less severe in the western than in the eastern portion of the Great Plains Region.

A measure of the erosion potential or energy of a storm was developed by Wischmeir and Smith (17). The erosion index (EI) is the product of total kinetic energy of the storm and its maximum 30-minute intensity. An EI-value was determined for each storm event during the 10-year study. The storm EI-values were totaled for each month and summarized in Table 1. The maximum monthly EI-values for a given year equals the R-value that is used in the USLE to predict annual soil losses for any specific practice. These R-values ranged from 21.1 to 123.6 and averaged 82.2 for the 10-year period. This average R-value agrees with the R-value of 91 published for Akron, Colo., area by Wischmeir and Smith (18).

Soil Water Availability

Unfavorable distribution and amounts of precipitation, rather than soil fertility, have limited crop production on these soils. When soil slopes are greater than 2 percent, efficient use of the precipitation becomes critical because of the runoff potential. Soil water storage is lower on these slopes than on flatter slopes tilled by conventional means.

Table 2 presents the net gain or loss of water per foot in a 5-foot soil profile; percent of the fallow period precipitation stored in the profile; and the percent of it lost to runoff, evapotranspiration, and deep percolation. The values are 9-year averages for the fallow period that began with winter wheat harvest around July 23 and ended 14 months later with winter wheat planting around September 10. The water storage period for grass began with the last clipping, usually around August 11, and ended about 8 months later with the onset of new grass growth around April 6 each year. The precipitation during these periods averaged 17.8 and 4.9 inches, respectively.

Water content at 15 bars for these soils averaged 1.27 inches per foot or 6.34 inches in 5 feet. At wheat harvest, the residual water content in five feet averaged 6.9 and 6.5 inches on the 2.2 and 5.4 percent slopes, respectively. The wheat plots normally did not receive any fall tillage unless weed growth in stubble was evident. Water storage on wheat fallow plots averaged 2.6 and 3.4 inches, which was 14.7 to 19.2 percent of the precipitation received during the fallow period. More than 75 percent of the precipitation was lost to evapotranspiration by undesirable vegetation and deep percolation, while 5 to 8 percent of it was lost to runoff.

In grass plots, the residual soil water in 5 feet averaged 5.6 and 5.3 inches at the last clipping of grass on 2.2 and 5.5 percent slopes, respectively. This was below the 15-bar tension level for these soils and with the hot, dry temperatures in August, the grass and alfalfa made little, if any, growth during the remainder of the regular growing season.

Soil water storage in the grass-alfalfa plots was 1.3 inches in 5 feet, and 85.5 percent was in the top 2 feet. The storage was about 25.9 percent of the precipitation which averaged 4.9 inches, mostly as sleet and snow. The runoff losses of 1.8 percent occurred in late August following the last cutting of the hay crop. The portion of precipitation that was not accounted for as either storage in the root zone or runoff was assumed lost to evaporation, transpiration, and deep percolation. These losses amounted to more than 70 percent of the precipitation on the grass-alfalfa plots. The losses were mostly in evaporation, as the soils were very dry and plants were under severe moisture stress.

Soil water storage in wheat-fallowed soils increased as land slopes decreased. Fallow efficiency, which is the percent of precipitation stored in the root zone over a specified period of time, averaged 14.7 percent on the 5.5 percent slope, and 19.2 percent on the 2.2 percent slope. Fallow efficiencies of 26 and 33 percent were reported for 1 and 0 percent slopes, respectively, in a bench terrace study on wheat-fallow with conventional tillage (11). In 1979, research showed that fallow efficiencies as high as 50 percent now are possible with minimum or no-till system (7,8).

Available growing season water supplies for winter wheat and grass-alfalfa production are presented in Table 3. Available soil water is the water in excess of the 15-bar tension values of 1.27 inches per foot. For winter wheat, the available soil water at planting time averaged only 2.7 inches in 5 feet on the 5.5 percent slope and 4.2 inches on the 2.2 percent slope. Maximum available water-holding capacity of these soils is about 12 inches in 5 feet; therefore, the profile was filled to 22-33 percent ot its water-holding capacity. Available soil water was even more limiting for the grass-alfala crop, where only 1.2 to 1.9 inches was available at start of growing season.

Average growing season precipitation was 11.8 inches for winter wheat and 7.3 inches for the grass-alfalfa. Of this amount, 9-12 percent was lost in runoff from the wheat plots; the higher losses were from the steeper slopes. The grass-alfalfa crop was more effective in controlling growing season runoff and losses were only 3 to 4 percent. Total available water supplies were about 14 and 7 percent greater for wheat and grass, respectively, on the 2.2 percent slope than on the 5.5 percent slope.

The low available water supplies limited winter wheat yields to about half of normal yields with conventional tillage on flatter slopes (11). The differences in yield of winter wheat grain and total dry matter that were associated with slope were related to differences in available water supplies. Because flat slopes allow less runoff and better opportunity for water infiltration than steep slopes, crops utilized the available water more efficiently. Water-use efficiency by winter wheat was 14.4 percent greater on the 2.2 than on the 5.5 percent slope. On the grass plots, available water also was greater on the 2.2 than the 5.5 percent slopes, but the crop was not better on the flatter slope. Grass-alfalfa plant population was greater on the steeper slope with a northeast facing aspect than on the flatter slope with a southeast facing aspect--presumably because the cooler soil temperatures favored establishment. The total dry matter yields of hay were 21.5 percent greater on the 5.5 than on the 2.2 percent slope.

The crop residue production from winter wheat generally exceeded one ton per acre at harvest and provided good protection from water and wind erosion throughout the fall and winter. The surface residue was drastically reduced by the first few tillage operations in the late spring. Figure 3 illustrates the amounts of wheat residue available during the fallow year. The surface residues, which are substantially reduced by periodic stubble mulch tillage, were only 600 pounds per acre, about 30 percent of the original amount, by the middle of May, when the runoff season begins. That amount was only half the surface residue necessary to control erosion by wind and water (9). By planting time, residue was less than 200 pounds per acre. Thus, the potential for soil erosion was high because of the low amounts of residue cover.

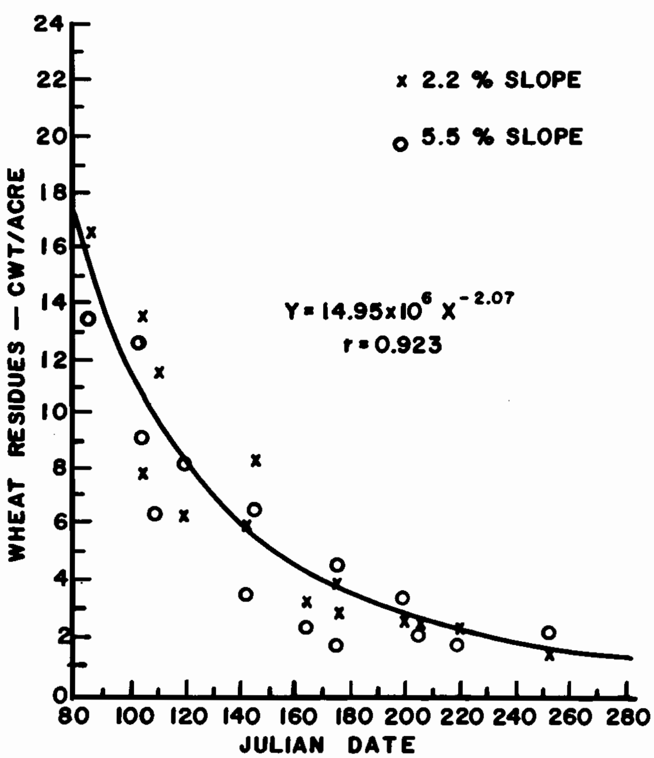

Figure 3.--Decrease in residue as a function of time.

Annual Runoff

Annual plot runoff ranged from none to 4.7 inches for the 10 years and averaged 1.2 and 1.1 inches from the 5.5 and 2.2 percent slopes, respectively (Table 4). The amount of vegetative cover on the slopes tended to reduce differences in runoff due to effect of slope. For example, grass yields averaging 800 pounds of dry matter per acre provided less than 50 percent cover on the 2.2 percent slopes while 960 pounds of dry matter per acre provided 75-80 percent cover on the 5.5 percent slopes. The difference in plant population was the primary reason that the average annual runoff was 50 percent greater from grass on 2.2 percent slope (1.25 in.) than from the 5.5 percent slope (0.85 in.).

On the 5.5 percent slope, average annual runoff was almost twice as high from wheat as from grass. Fallow increased annual runoff only about 25 percent over that from grass. On the 2.2 percent slope average annual runoff was equal from wheat and grass, while runoff from fallow was 44 percent less. Destroying the grass cover increased runoff from the 5.5 but not from the 2.2 percent slope. The accumulative runoff (Fig. 4) illustrates the effects of crop and slope on the annual distribution of runoff. A 5-week moving average of mean weekly runoff amounts was used to smooth out the accumulative curves. The runoff season began about the second week in April. Runoff from wheat plots was highest early in the season when plants were small and very little residue was present on the surface. Runoff was lower in fallow than in grass or wheat plots except for the grass plot on the 5.5 percent slope. The runoff season peaked around the third week in June, and more than 90 percent of the annual runoff had occurred by the third week of August.

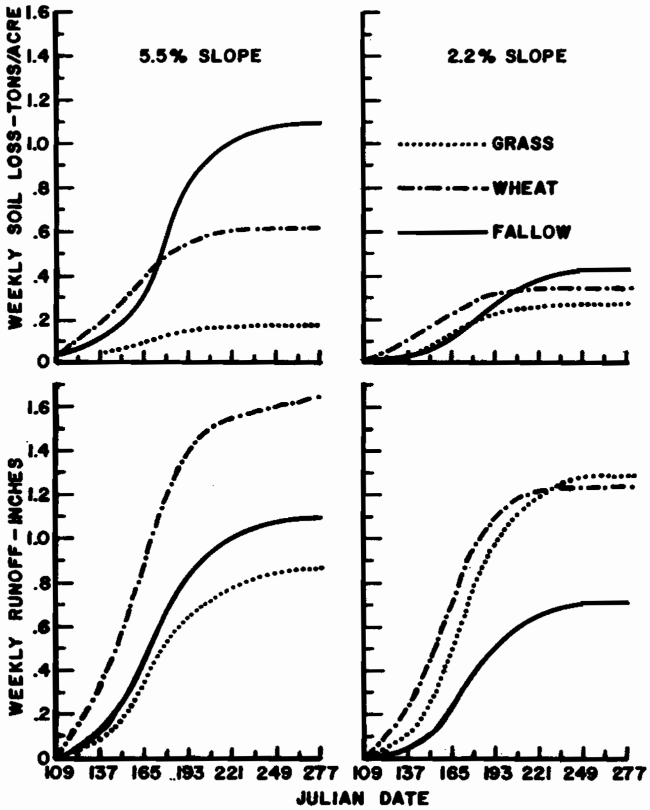

Figure 4.--Accumulative weekly runoff and soil loss for various land uses and slopes, 10-year average.

The rainfall and runoff values of individual plots were used to determine the S-value in the SCS formula for estimating direct runoff from rainfall (12): $Q=(P-0.2S)^2/(P+0.8S)$, where Q is direct runoff in inches; P is storm rainfall in inches; and S is the maximum potential difference between P and Q in inches, at time of storm's beginning. Data from all runoff-producing storms were used to calculate an average S-value. The S-value was then used to calculate the runoff curve number for predicting runoff for a given set of conditions. This system of curve numbering was developed from the equation: $CN=1,000/(10+S)$, where CN is curve number. These values, with the multiple correlation coefficients, are summarized in Table 5. A curve number was generated for each runoff-producing event. The number of events varied from 59 for the fallow plot on the 2.2 percent slope to 82 for the wheat plot on the 5.5 percent slope. The coefficient of variation of curve numbers varied from 7.4 percent for the grass plots to 9.7 percent for the wheat plots. The variation was smallest for plots that were not disturbed by tillage, for example, the grass plots.

The runoff curve numbers for grass were similar to the published numbers (12). Those for wheat (87-88) were somewhat higher than the handbook values (73-74), while those for fallow (84-87) were lower (86-91). The stand of wheat was thin most years because of drought. Because the thin stands intercepted little rainfall, the surface soil was puddled and sealed early in the growing season and rates of runoff were higher than they would have been with adequate crop cover. The periodic tillage of the fallow plots dried out the surface soils and enhanced surface water storage. The infrequency of runoff-producing rainfall also decreased runoff.

Soil Loss

Annual soil losses summarized in Table 6, never approached the SCS maximum tolerable limit of 5 tons per acre per year (15). The maximum annual erosion was 2.7 tons per acre in 1967 from the fallow plot on 5.5 percent slopes. The average annual soil losses from grass were 0.13 and 0.25 tons per acre from the 5.5 and 2.2 percent slopes, respectively. The amounts were related to the amount of runoff. When the grass on 5.5 percent slopes was converted to a wheat-fallow rotation, annual erosion increased more than 500 percent. The annual soil loss from fallow plots was 78 percent greater than that from wheat plots on the steeper slopes. Converting grass to winter wheat production on the 2.2 percent slope increased annual soil erosion 51 percent. Therefore, the land-use conversion increased soil erosion less on the 2.2 than on the 5.5 percent slope.

The accumulated soil losses for the 10-year period (Figure 4) indicate the times during the year that the runoff and soil losses occurred. Early in the season soil losses from wheat plots exceeded those from other plots, but as the crop matured and provided more cover, the losses were substantially reduced. Early in the season soil losses were less from fallow than from wheat plots, but losses increased in fallow plots as periodic tillage destroyed the residues. Erosion was greater on fallow than from wheat plots by mid-June on the 5.5 percent slope and by mid-July on the 2.2 percent slope. The effect of slope on soil losses was greater for wheat and fallow than for grass.

The average weekly runoff intensity, in inches of runoff per inch of rainfall, and sediment concentration, in tons per acre-inch, are shown in Figure 5. Sediment concentration did not necessarily vary with runoff intensity. The sediment concentration from grass on both slopes was highest early in the growing season and diminished with increasing crop cover. The freezing-thawing action during winter and early spring loosens the surface soil particles, making them more susceptible to erosion. Only after the surface soil was compacted by the early season rainfall did the sediment concentration appear to vary with runoff intensity.

The situation was similar on wheat plots. Sediment concentration and runoff intensity were highest early in the growing season because of the minimal surface cover and soil particles loosened by the winter freezing-thawing action. As the wheat matured, both sediment concentration and runoff intensity decreased. After wheat was harvested and the cover removed sediment, concentration increased slightly. In years when tillage was performed in August following wheat harvest, sediment concentration increased.

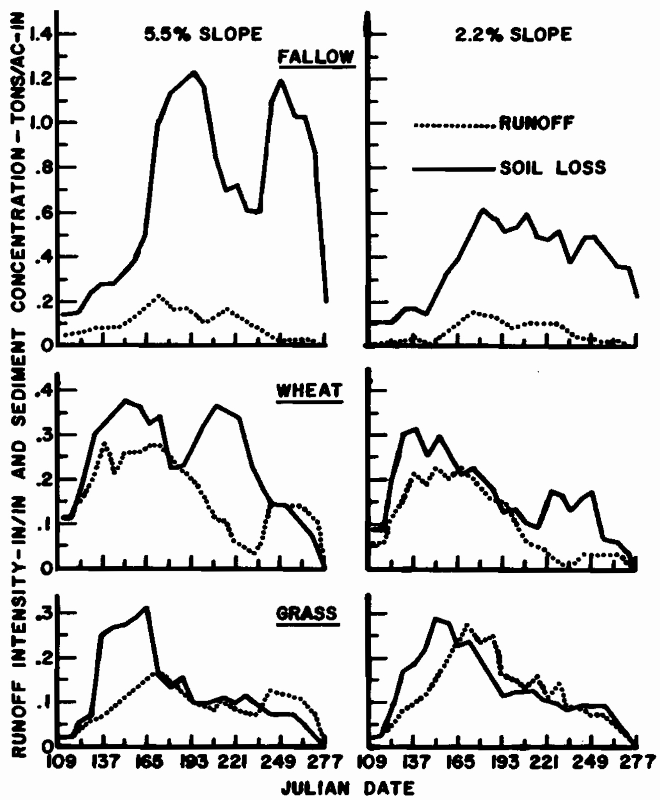

Figure 5.--Runoff intensity and soil loss concentration at different dates during the runoff season, 10-year av.

Sediment concentration in runoff from fallow plots was not related to runoff intensity but to the gradual deterioration of the surface residue by periodic tillage. The sediment concentrations were low early in the fallow season and as surface residues were destroyed by tillage increased rapidly. There were two noticeable periods of elevated sediment concentrations on the 5.5 percent slopes. The first was in June when most of the fallowed lands were tilled. The sediment content then decreased as the soil surface was compacted by raindrop impact. The fallow soils were usually tilled once more in August before wheat planting in early September; this tillage significantly increased the sediment concentration in runoff. The effect of tillage on fallow plots was less evident on 2.2 than on 5.5 percent slopes.

Multiple linear regression analysis was used to determine the relationship between the rainfall-runoff characteristics and the soil erosion. The number of runoff events used in these analyses varied from 49 for fallow on 2.2 percent slope to 64 for wheat on the 5.5 percent slope. With soil erosion as the dependent variable, simple correlations were determined for rainfall, runoff, and the EI factor with each as the independent variable. All the correlations were significant at the 5 percent level. Coefficients were highest for the runoff-erosion relationship and varied from 0.622 for wheat to 0.893 for grass. Coefficients were next highest for the EI-erosion correlation and varied from 0.458 for wheat to 0.832 for grass. Coefficients were lowest for the rainfall-erosion correlation and varied from 0.357 to 0.471.

Discussion

The conversion of established grassland to winter wheat production increased runoff from the 5.5 but not from the 2.2 percent slope. The land-use conversion increased soil erosion on both slopes and the increase was highly significant on the steeper slope. Nevertheless, the average annual soil losses were well below the maximum allowable level of 5 tons per acre per year established by the SCS (15); and the highest annual soil loss in any given year was only 2.7 tons per acre from fallow land on the 5.5 percent slopes.

Annual soil losses predicted by the Universal Soil Loss Equation (18) were considerably greater than the present experimental values, particularly those for the fallow-wheat rotation. The experimental and predicted annual soil losses are summarized for each treatment in Table 7. The erosivity factors used for the prediction were those recommended by the SCS for the eastern Colorado area (14,15). The rainfall-runoff erosion index (EI) was calculated from rainfall intensity data collected annually on the experimental site. The EI-value agrees closely with that assigned by the SCS for this area. The crop cover and management values were estimated for the average amount of plant canopy and residue cover on the plots. The other factors were designated for the soils and topography within each plot.

One primary reason that the measured soil losses were lower than predicted losses was the dryness of the soils. As discussed earlier, about 80 percent of the runoff-producing storms occurred when the AMC was Type 1, and soils were normally dry enough to be tilled and absorbed most of the rainfall before runoff began. The mean annual R-value for the runoff-producing storms was 65.4, but the mean R-values of storms yielding runoff in the Types II and III categories were only 7.7 and 2.8, respectively. The probability of two high intensity storms within 5 days is very low. Because high intensity storms were infrequent, the surface soils were depleted of water by the growing vegetation and periodic tillage.

The annual runoff and soil losses from wheat-fallow were measured from plots in conventional tillage. On this station, research showed that minimum or no-till systems of fallow can almost eliminate runoff and soil losses from plots on slopes of less than 2 percent. At Sidney, Nebr., no-till reduced soil losses on 4 percent slopes to 20 pounds per acre from a simulated rainfall of 3 inches per hour (6). Although the need for terracing such slopes probably would not be eliminated, the use of no-till systems could enable farmers to increase the interval between terraces and thus substantially reduce their cost per acre of terrace construction, without increasing soil losses from water erosion.

Literature Cited

1. Brakensick, D. L., H. B. Osborn and W. J. Rawls. 1979. Field Manual for Research in Agricultural Hydrology. U.S. Department of Agriculture, Agric. Handbook 224, 550 p.

2. Browning, G. M. 1977. Soil erosion: prediction and control. In Developments that led to the universal soil loss equation: an historical review, p. 3-5. Soil Conserv. Soc. of Am. Special Publ. No. 21, 393 p.

3. Colorado Department of Agriculture. 1983. Colorado Agricultural Statistics, Colorado Crop and Livestock Reporting Service, Denver, Colorado. Bull. 1-83, 94 p.

4. Colorado Rural Electric Association. 1981. Conservation challenge (guest editorial). Colo. Country Life 29:4-5.

5. Colorado State Soil Conservation Board. 1981. Conservation in Colorado, a program for present and future resource needs. Colo. Dept. of Natural Res., Denver, Colorado. 24 p.

6. Dickey,, E. C., C. R. Fenster, J. M. Laflen, and R. H. Mickelson. 1983. Effects of tillage on soil erosion in a wheat-fallow rotation. Trans. of the Am. Soc. of Agric. Eng. 26:814-820.

7. Greb, B. W. 1979. Reducing drought effects on croplands in the West-Central Great Plains. U.S. Dept. of Agric. Information Bull. 420, 31 p.

8. Greb, B. W. and D. E. Smika. 1979. Technology and wheat yields in the Central Great Plains - Experiment Station Advance. Jour. of Soil & Water Conserv. 34:264-268.

9. Greb, B. W., D. E. Smika, N. P. Woodruff and C. J. Whitfield. 1974. Summer fallow in the Central Great Plains. In Summer Fallow in the Western United States, Ch. 4, p. 51-85. U.S. Dept. of Agric., Conserv. Res. Rep. 17, 160 p.

10. Knobel, E. W., L. A. Brown, D. Hodgell, and others. 1947. Soil Survey of the Akron Area, Colorado. U.S. Dept. of Agric., Series 1938, No. 14, 80 p.

11. Mickelson, R. H. 1982. Hard red winter wheat production on conservation bench terraces. Soil Sci. Soc. of Am. Journ. 46:107-112.

12. U. S. Department of Agriculture, Soil Conservation Service. 1964. SCS National Engineering Handbook, Part 1 Watershed Planning, Section 4 Hydrology. Washington, D.C.

13. ______________ Soil Conservation Service. 1972. Soil series of the United States, Puerto Rico, and the Virgin Islands: their taxonomic classification. U.S. Dept. of Agric. Supplement to Agric. Handbook 436.

14. ______________ Soil Conservation Service. 1984. A guide for predicting soil loss from water erosion in Colorado. Colorado Soil Conserv. Tech. Note No. 50, 22 p.

15. ______________ Soil Conservation Service. 1979. Soils of Colorado, erosion factors and hydrologic groups. U.S. Government Printing Office. 68 p.

16. Whitfield, C. J., J. J. Bond, E. Burnett, and others., 1962. A standardized procedure for residue sampling, a committee report. USDA-ARS Series 41-68, 9 p.

17. Wischmeir, W. H. and D. D. Smith. 1958. Rainfall energy and its relationship to soil loss. Trans. of the Amer. Geo. Union 39(3):385-391.

18. ______________ and D. D. Smith. 1978. Predicting rainfall erosion losses - guide to conservation planning. U.S. Dept. of Agric., Agric. Handbook 537, 58 p.

Table 1 - Monthly EI and annual R values for the storm events at the Central Great Plains Research Station, Akron, Colorado, 1963-72

Year	Monthly EI Values							R-Values 1/
	April	May	June	July	Aug.	Sept.	Oct.	
1963	---	---	2.9	59.3	20.7	21.2	2.9	107.0
1964	1.7	4.6	68.3	3.9	14.0	---	---	92.5
1965	---	47.9	30.3	30.1	13.7	.4	1.2	123.6
1966	.7	4.5	57.8	5.2	14.1	10.3	---	92.5
1967	---	29.7	64.2	28.7	---	---	---	122.5
1968	---	6.9	---	46.5	28.6	---	---	81.9
1969	---	22.2	15.8	20.1	---	---	---	58.1
1970	1.3	8.8	9.1	1.9	---	---	---	21.1
1971	.8	.9	6.1	11.8	14.7	.5	---	34.9
1972	---	8.4	4.1	66.8	8.6	---	---	87.9
Mean	.5	13.4	25.9	27.4	11.4	3.2	.4	82.2

1/ The rainfall and runoff factor as the number of rainfall-erosion index units (EI) expressed as 100 foot-ton inch per acre-hour (1).

Table 2 - Soil water storage on wheat-fallow and over-winter on grass-alfalfa, 9-year average

Crop and Slope (%)	Soil depth (ft.) 0-1	1-2	2-3	3-4	4-5	Total	Fallow 1/ efficiency (%)	Runoff loss (%)	Other 2/ losses(%)
	Net gain in soil water (in)								
Fallow									
5.5	0.45	0.80	0.67	0.40	0.29	2.61	14.7	7.8	77.4
2.2	.63	1.14	.89	.51	.25	3.42	19.2	4.8	76.0
Grass									
5.5	.64	.37	.19	.12	.07	1.39	28.2	1.8	70.0
2.2	.87	.30	.06	.04	-.11	1.16	23.5	1.8	74.7

1/ Percent of precipitation stored in the root zone over a 14-month period of fallow for winter wheat and 8-month, over-winter period for grass.

2/ Evaporation, transpiration, and deep percolation losses not attributable to runoff or root zone water storage.

Table 3 - Mean available growing-season water supplies, crop yields, and water-use efficiency for winter wheat and grass-alfalfa for the 10-year period beginning in 1963

Crop and Slope (%)	Available soil water (in)	Runoff (in)	Water-Use (in)	Grain yield (lb/acre)	Total dry matter (lb/acre)	Water-use 1/ efficiency (lb/acre-in)
Wheat						
5.5	2.67	1.43	12.32	870	2,660	216
2.2	4.15	1.11	13.53	1,030	3,340	247
Grass						
5.5	1.24	.24	3.51	---	960	274
2.2	1.91	.33	3.57	---	790	224

1/ Pounds of dry matter produced per inch of water used.

Table 4 - Annual runoff for various land-uses and slopes

Year	Annual precip. (in)	5-Month rainfall (in)	Runoff (in)			
			Grass	Wheat	Fallow	Average
			5.5 % slope			
1963	15.35	12.54	1.70	2.15	1.61	1.82
1964	12.13	8.54	1.27	1.18	1.07	1.17
1965	22.20	18.85	1.33	4.73	.84	2.30
1966	14.87	12.35	1.26	1.13	1.95	1.45
1967	19.70	17.12	1.39	2.23	1.58	1.73
1968	13.06	10.69	.47	.54	1.02	.68
1969	15.12	10.35	.55	2.94	1.35	1.61
1970	10.34	6.96	.00	.22	.48	.23
1971	13.55	8.65	.00	.13	.06	.06
1972	15.20	11.39	.53	1.11	.66	.77
Mean	15.15	11.74	.85	1.64	1.06	1.18
			2.2 % slope			
1963	15.35	12.54	2.89	1.31	1.28	1.83
1964	12.13	8.54	1.57	.63	.84	1.01
1965	22.20	18.85	2.19	4.53	.69	2.41
1966	14.87	12.35	1.53	.96	.69	1.06
1967	19.70	17.12	1.75	1.95	.95	1.55
1968	13.06	10.69	.75	.16	.93	.61
1969	15.12	10.35	.70	1.86	.54	1.03
1970	10.34	6.96	.01	.39	.18	.19
1971	13.55	8.65	.01	.00	.01	.01
1972	15.20	11.39	1.14	.65	.89	.89
Mean	15.15	11.74	1.25	1.24	.70	1.07

Table 5 - Runoff curve numbers for different crops as determined from actual runoff measurements

Crop and Slope (%)	Runoff curve no.	Coefficient of variation (%)	Multiple correlation coefficient
Grass			
5.5	84	8.2	0.745
2.2	85	7.4	.822
Wheat			
5.5	88	8.9	.686
2.2	87	9.7	.639
Fallow			
5.5	87	8.4	.686
2.2	84	8.4	.642

Table 6 - Annual plot erosion for various land uses and slopes

Year	Soil erosion (tons/acre) Grass	Wheat	Fallow	Average
			5.5 % slope	
1963	0.31	0.61	1.77	0.90
1964	.35	.60	.53	.49
1965	.12	1.31	.32	.58
1966	.21	.78	1.16	.72
1967	.13	.27	2.71	1.04
1968	.05	.19	.95	.40
1969	.05	1.46	1.66	1.06
1970	.00	.08	.17	.08
1971	.00	.03	.05	.03
1972	.12	.55	1.20	.62
Mean	.13	.59	1.05	.59
			2.2 % slope	
1963	.67	.42	.77	.62
1964	.51	.22	.55	.43
1965	.47	1.31	.10	.63
1966	.32	.21	.34	.29
1967	.17	.14	.60	.31
1968	.08	.05	.63	.26
1969	.05	.65	.56	.42
1970	.00	.22	.15	.12
1971	.00	.00	.04	.01
1972	.22	.18	.42	.27
Mean	.25	.34	.42	.34

Table 7 - Annual soil losses from water erosion as predicted from the USLE with local erosivity factors and actual 10-year average experimental values

Crop and Slope (%)	USLE factors 1/					Soil loss (ton/acre/year)	
	R	K	LS	C	P	Predicted A	Actual A
Grass							
5.5	82	0.32	0.90	0.04	1.00	0.945	0.134
2.2	82	.32	.22	.07	1.00	.404	.250
Wheat							
5.5	82	.30	.81	.16	.50	1.594	.588
2.2	82	.31	.29	.15	.50	.553	.340
Fallow							
5.5	82	.30	.81	.53	.50	5.280	1.052
2.2	82	.31	.29	.47	.50	1.732	.415

1/ A = RKLSCP, where
A = computed soil loss in tons/acre/year,
R = rainfall-runoff erosion index,
K = soil erodibility factor,
LS = slope length-steepness factor,
C = cover and management factor, and
P = support practice factor.

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