LA-UR -84-1399

CONF-840744--1

LA-UR--84-1399

DE84 011365

TITLE: PREDICTION OF SOIL LOSS WITH THE CREAMS MODEL

AUTHOR(S): Naomi M. Becker

SUBMITTED TO: American Society of Civil Engineers Irrigation and Drainage Division Specialty Conference, July 24-26, 1984, Flagstaff, AZ

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

PREDICTION OF SOIL LOSS WITH THE CREAMS MODEL

BY

NAOMI M. BECKER A.M. ASCE*

ABSTRACT: Variations in soil loss as a function of certain land use and land management practices were investigated on a small watershed in the Texas Panhandle using CREAMS, a recently developed computer model capable of simulating dynamic rainfall, runoff, and erosion processes over the time-frame of decades. Simulations of different curve numbers, three types of cropping, and varying crop yield and plowing practices were made to determine the sensitivity of soil loss to these parameters. Comparisons were made to actual in-field measurements of soil loss on experimental plots.

INTRODUCTION

Techniques for calculating soil loss over the landscape, particularly farmland, have been available and updated over the last 40 years. The most popular method, the Universal Soil Loss Equation (USLE), uses a relatively simple regression equation to calculate average annual soil losses (8). In instances where soil losses from individual or coupled storm events are to be examined, or location of erosion and deposition areas are of interest, or study of erosion from the channel components of the watershed is desired, then a physically based mathematical model is needed to simulate the rainfall and subsequent erosion process. One such model is CREAMS, a field-scale model for chemicals, runoff and erosion from agricultural management systems recently developed by the US Department of Agriculture (USDA) (4). This model can be used as a tool to study the effects of different hydrologic, land use, and land management factors on soil loss.

The purpose of this paper is twofold. First, to present the sensitivity of the model to a few particular variables as they affect soil loss. Second, to compare results from model predictions to in-field measurements of soil loss.

---

* Hydrologist, Los Alamos National Laboratory, Los Alamos, NM 87545.

The Setting

Model simulations were performed on a subbasin located within a watershed on the US Department of Energy's Pantex Plant and at the USDA Research Laboratory at Bushland near Amarillo in the Texas Panhandle (Fig 1). This area is characterized by closed drainage into shallow lake basins (playas), which are usually dry. Average annual precipitation is about 20 inches, of which 75% occurs between April and September, primarily associated with thunderstorm activity. Mean annual Class A pan evaporation is about 95 inches (2), and the mean monthly temperature at Amarillo is 57°F (7).

The topography is characterized by relatively flat uplands intermittently drained by shallow playas. On site, the upland area

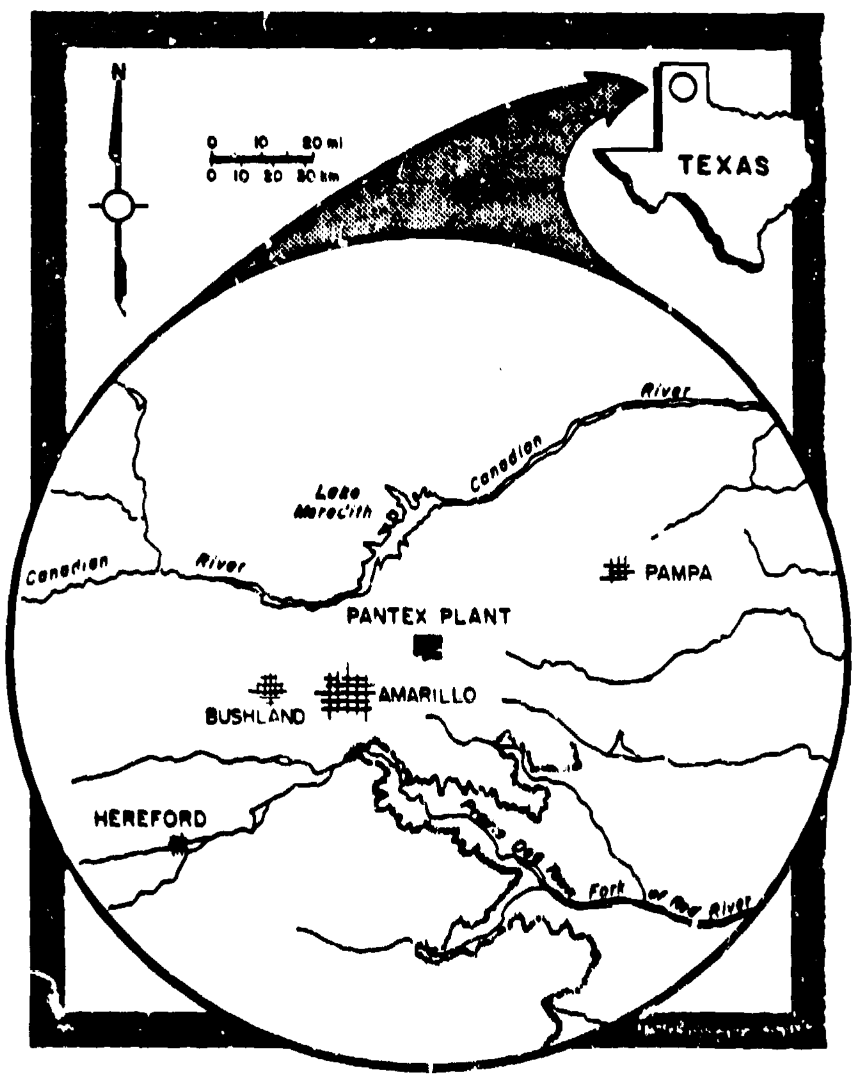

Fig. 1. Location of the Pantex Plant and USDA Research Laboratory at Bushland, TX.

soils belong to the Pullman clay loam series, which is a grayish-brown clay loam having low permeability and a dark brown clay subsoil.

The subbasin at Pantex drains primarily agricultural land. Topographically, it is composed of long, relatively flat slopes into a playa; these slopes steepen in the vicinity of a channel drainage, which is not plowed or planted over, and in the vicinity of the playa itself. The watershed at Bushland is a uniform grade terrace.

Data

Measurements of mean monthly temperature and solar radiation, and leaf area indices (LAI) for wheat and sorghum were obtained from the US Department of Agriculture Southern Region Conservation and Production Research Laboratory at Bushland, Texas, about 20 miles west of the Pantex subbasin (Fig 1).* Leaf area index data for native grasses were obtained from Knight (3) and adjusted to the Panhandle climate. Soil properties of the Pullman silty clay loam were obtained from Taylor (5).

MODEL SENSITIVITY

Simulations were made at Pantex to examine the model's sensitivity to the runoff curve number, different land uses, and land management practices. Rainfall data run from 1961 through 1965 produced a continuous record of runoff and soil erosion during that period, and provides the basis for the following discussions.

Runoff Curve Number

The runoff curve number, a parameter developed by the Soil Conservation Service, is a measure of the soil's runoff potential. The curve number is determined by the soil type, land use, and land treatment.

The subbasin was assumed to be planted with a crop of winter wheat, moldboard plowed, with fair (residue about 2600 lb) production,

---

* Unpublished data supplied by Mr. Ron Davis of the US Department of Agriculture Southern Region Conservation and Production Research Laboratory, Bushland, TX, March 8, 1982.

during the 5 year simulation period. Only one crop per year is planted. After harvest, the residue may be left on the ground or plowed under, and the land surface remains in that condition until the next planting.

The effect of varying curve number on this setting is shown in Fig 2. There is a rapid increase in annual soil loss when the curve number exceeds 80; small changes in curve number above that value will result in very large changes in soil loss. The amount of soil loss will, of course, also depend upon variables such as site-specific climatic conditions, soil types, and cropping.

Land Use

How land use schemes affect soil loss was investigated through simulation of a crop of winter wheat, a crop of grain sorghum, and a native grasses cover.

Those parameters that reflect differences in land use include the leaf area index, curve number, C-factor, and Manning's n (a roughness coefficient). Curve numbers varied between 80 and 90. The leaf area index measures the plant's leaf area through a ratio of the amount of

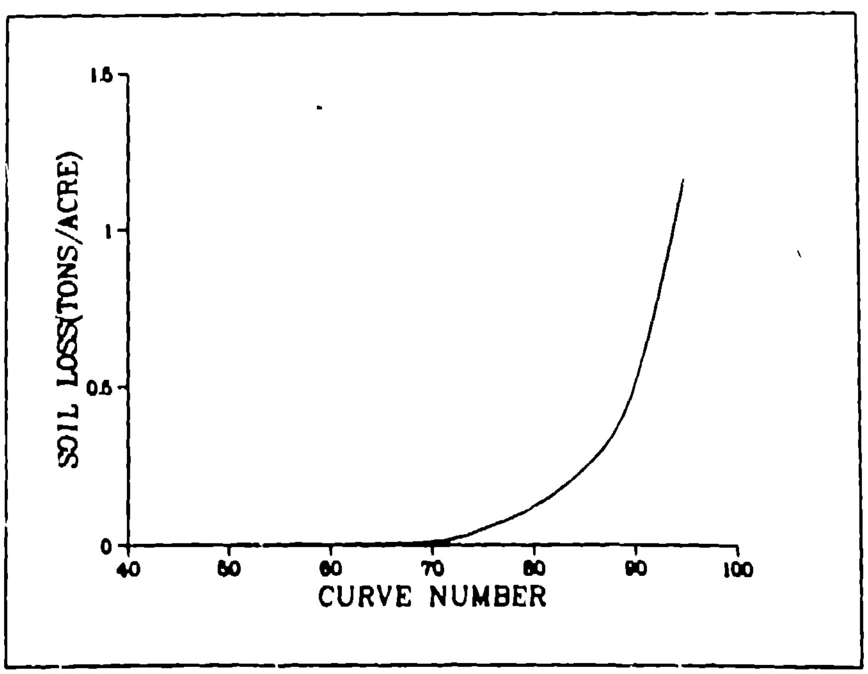

Fig. 2. Variation of Annual Soil Loss with Curve Number.

of leaf area to the amount of ground surface area. The C-factor is a ratio between soil loss from land under particular crop conditions to soil loss from land under clean-tilled continuous fallow. Manning's n accounts for both soil and cover roughness. For simulation of a winter wheat crop, planting occurred in the fall, and harvest during June. It was assumed that the production was fair, that it was moldboard plowed, and that the residue was left lying on the field. When a grain sorghum crop was simulated, assumed planting took place in May or June and harvest occurred in September or October. It was also assumed that production was fair (2600 lbs residue), that it was moldboard plowed, and that the residue remained on the field. Native grasses in that region are short grasses, primarily blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides) (6).

The grain sorghum crop cover produced the largest soil loss, 2.0 tons/acre annually, while the wheat produced the smallest soil loss, 0.4 tons/acre annually. Native grasses produced an annual soil loss of 0.6 and 1.0 tons/acre for 50% and 30% cover, respectively. It was originally thought that estimated runoff volumes would differ between different land uses, and that this would account for the differences in soil loss. There was in fact a relatively small difference in the runoff volumes for the different land uses.

Land Management Practices

The effect of differing plowing practices on the amount of soil loss was investigated. Two types were simulated: 1) moldboard plowing, which inverts the soil to almost completely burying the residue, and 2) chisel plowing, which cuts a narrow trace and leaves most of the residue intact. Simulated soil loss from the moldboard-plowed acreage was about 30% greater than from the chisel-plowed acreage; average soil loss of 0.44 ton/acre for moldboard compared to 0.31 ton/acre for chisel.

Of additional interest was the effect of crop production on soil loss. Production amount is classified as high, good, fair, and poor, depending on the amount of residue (the dry weight per acre after winter loss and reductions by grazing or partial removal). High production corresponds to a residue weight of 4500 lb; good, to 3400 lb; fair, to 2600 lb; and poor, to 2000 lb.

The simulated effect on soil loss by varying production is not great. There was a 7% decrease in simulated soil loss between a poor production wheat crop and a high production crop from 0.45 to 0.42 tons/acre.

COMPARISON WITH MEASURED SOIL LOSS

Values of soil loss predicted by the CREAMS model on the Bushland watershed were compared with measured values at the US Department of Agriculture Southern Region Conservation and Production Research Laboratory at Bushland, Texas.*

Onsite soil losses were compared for 1978, a year soil loss data were available. The measured annual soil losses were 2.67 and 2.75 tons/acre for sorghum and wheat, respectively. Predicted soil losses on the Bushland watershed were 1.7 and 1.2 tons/acre, respectively.

DISCUSSION

Model Sensitivity

Soil losses predicted by CREAMS are highly sensitive to curve number, particularly when the curve number exceeds about 80. This indicates that, for a D soil, or other fairly impervious surfaces, care should be taken in selecting a curve number. In the runoff curve number selection process there should be made some attempt to match the curve number and predicted runoff with known runoff values if at all possible.

Soil losses were also found to be sensitive to the type of cropping or cover. The sorghum crop produced the highest soil loss, and the wheat, the lowest. Runoff volumes alone did not account for these differences. What appears to be of importance is the plant's development stage of leaves during the period of greatest rainfall

---

* Unpublished data supplied by Mr. O.R. Jones of the USDA Southern Region Conservation and Production Research Laboratory, Bushland, TX, January 9,1984.

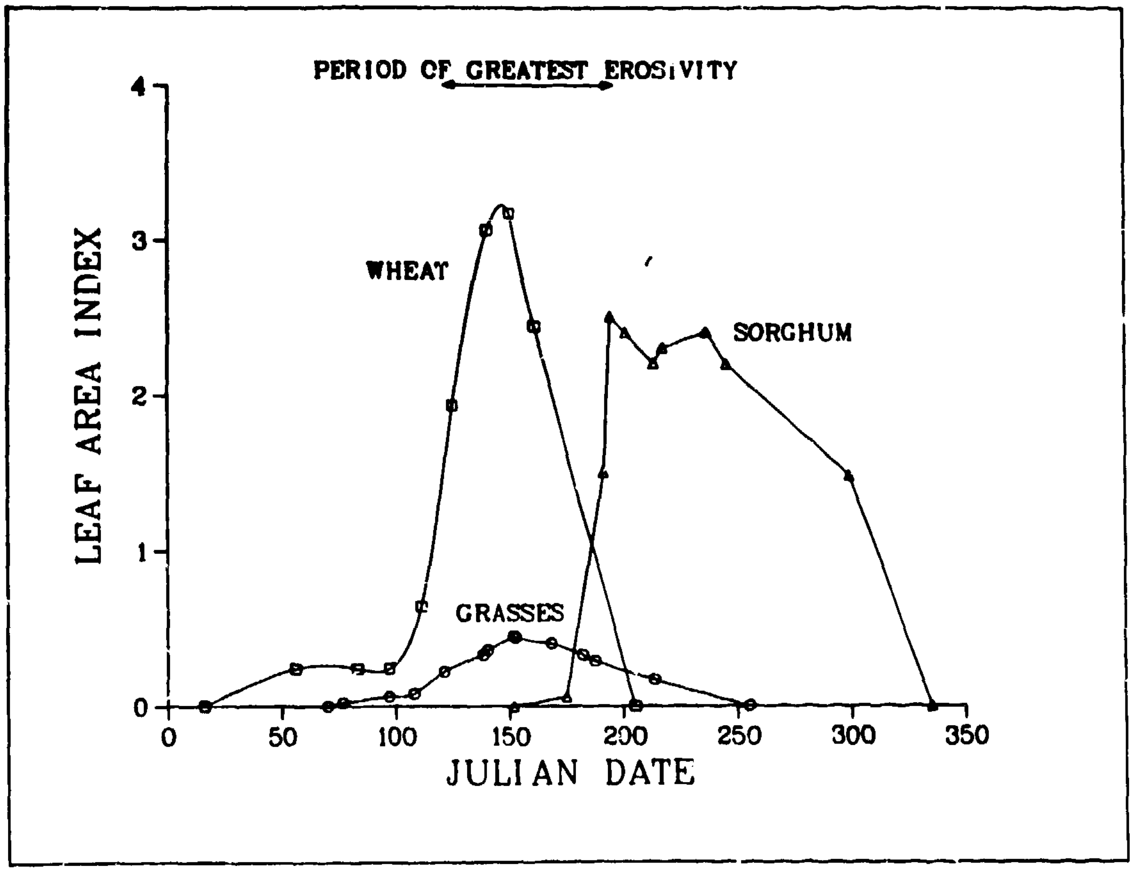

Fig. 3. Measured Seasonal Variation in Leaf Area Index for Native Grasses, Winter Wheat, and Grain Sorghum.

erosivity, Fig 3. Although the Amarillo area receives the greatest portion of its annual rainfall during the months of April though August, the period of greatest erosivity from rainfall lies between May 1 and July 15 (8). During this period the grasses are approaching their maximum growth height and the wheat, its maturity. Sorghum, on the other hand, is at the stage where the field has been plowed, the seed has been planted, and only small, young plants cover the field. Therefore, the sorghum crop is more susceptible to erosion because the soil is not protected from rainfall and runoff erosion by plant canopy, as it is for wheat or native grasses. The Leaf Area Index will affect the value of the C-factor through the growing season, which is used to predict soil loss. Other differences in soil loss may be attributed to such factors as land management practices, plant density, and the type of rooting system.

Land Management Practices

Simulated soil loss was found to be sensitive to the type of plowing practice; chisel plowing produced 30% less soil loss than moldboard plowing for the same watershed, curve number, crop, precipitation, and runoff. It is believed that this difference is due to the amount of soil exposed to erosion elements by the plow. The moldboard plow will upturn nearly all the soil, whereas the chisel plow overturns only a narrow path for the seed. In the model the remaining area was covered with residue, which provided an armoring effect on the soil against erosion.

The amount of production did not have a large effect on soil loss. A high production crop of wheat, which produces a larger volume (and weight) of residue, had soil losses only 7% less than a poor production crop. Residue in itself is important for its role in soil armoring, but apparently greater volumes of residue will not greatly diminish soil loss.

Measured vs. Predicted Soil Losses

It is of concern that the predicted soil loss amounts were about half as much smaller than the measured soil loss. Demonstrated examples exist where CREAMS has provided good agreement regarding soil loss in a similar field situation (1).

The year tested was unusual in that only two storms produced nearly all the runoff, and one of those storms was the largest ever recorded.* Because, in the model, the peak runoff rate and erosivity index is not a function of rainfall intensity, this may lead to inaccuracies in soil loss prediction if the storms are either quite high or low in rainfall intensity. In addition, two storms alone do not constitute a representative sample population. Many years of data should be simulated to achieve representative results (data of this nature were not available).

*Oral communication from Mr. O. R. Jones, USDA Southern Region Conservation and Production Research Laboratory, Bushland, TX.

ACKNOWLEDGEMENTS

The author wishes to thank George Foster, USDA-ARS National Soil Erosion Laboratory, Lafayette, IN, for his many helpful comments and suggestions, O. R. Jones, and Ron Davis, USDA Southern Region Conservation and Production Research Laboratory, Bushland, TX, for generously supplying field data and measurements.

REFERENCES

(1) G.R. Foster and V.A. Ferreira, "Deposition in Uniform Grade Terrace Channels," Proceedings of ASAE Conference on Crop Production with Conservation in the 80's," American Society of Agricultural Engineers 1981, pp.185-197.

(2) M. A. Kohler, T. J. Nordenson, and D. R. Baker, "Evaporation Maps for the United States," US Department of Commerce Weather Bureau Technical Paper, No. 37, 1959.

(3) D. H. Knight, "Leaf Area Dynamics of a Shortgrass Prairie in Colorado," Ecology 54(4), 1973, pp. 891-896.

(4) W. G. Knisel (ed).,"CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems," US Department of Agriculture, Conservation Research Report, No. 26, May 1980.

(5) H. M. Taylor, C. E. Van Doren, C. L. Godfrey, and J. R. Coover, "Soils of the Southwestern Great Plains Field Station," Texas A&M University, Texas Agricultural Experiment Station Publication MP-669, June 1963.

(6) P. W. Unger and F. B. Pringle, "Pullman Soils: Distribution, Importance, Variability, and Management," Texas Agricultural Experiment Station report B-1572, September 1981.

(7) US Department of Commerce, "Local Climatological Data Annual Summary with Comparative Data, 1980, Amarillo, Texas," National Oceanic and Atmospheric Administration National Climatic Center, Asheville, NC, 1981.

(8) W. H. Wischmeier and D. D. Smith, "Predicting Rainfall Erosion Losses - A Guide to Conservation Planning," US Department of Agriculture, Agriculture Handbook No. 537, 1978.