Measured and Simulated Productivity of Eroded Soils

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Soil erosion can result in reduced soil productivity and crop yields. Yield reductions of 34 percent to 40 percent were observed on soils of the Piedmont in 1940 (Adams, 1940). Similar observations were made by Frye et al. (1982) on silty soils in Kentucky, by Langdale et al. (1979) on clayey Piedmont soils in Georgia, and by Buntley and Bell (1976) on silty soils in Tennessee. The amount of data on the effects of erosion on yield is limited because it is often difficult to obtain randomized statistical field plot design (Langdale and Shrader, 1982). Langdale et al. (1979) found that the complex nature of erosion caused considerable variability in studies using standard statistical design.

Surface thickness and clay content are the primary indicators of erosion on the soils of the Southeastern United States (Langdale et al., 1979). These characteristics combined with nutrient availability greatly influence productivity.

The Erosion-Productivity Impact Calculator model is a comprehensive model developed for application to erosion-productivity problems (Williams et al., 1984). EPIC can be used to predict current-year crop yields using actual measured input variables, such as climate, or long-term simulations using various management strategies.

The purpose of this research was to conduct an extensive on-farm study to determine the effects of past erosion on corn and soybean yields in the Coastal Plain and cotton in the Tennessee Valley regions. In addition, future yields were simulated for moderately and slightly eroded phases of major soils using the EPIC model.

Farm fields in the Alabama Coastal Plain and Tennessee Valley regions were selected for study. Crops included corn and soybeans in the Coastal Plain from 1981 through 1984 and cotton in the Tennessee Valley from 1982 through 1984. These fields were in map units of the Dothan series in the Coastal Plain (fine-loamy, siliceous, thermic, Plinthic Paleudults) and Decatur in the Tennessee Valley (clayey, kaolinitic, thermic, Rhodic Paleudults). These soils are major cropland soils in these two land resource areas. Each field was under uniform management and planted to a single crop and variety using conventional tillage. Each field had at least two levels of erosion, slight and moderate. In most fields, plots were located on single uniform slopes ranging from 3 percent to 5 percent.

Two plots were located in each field. One was a slightly eroded area and the other was moderately eroded. Each plot was made up of three replicates. Soil data, such as surface soil thickness, color, texture, and slope, were collected from each replicate. Samples of the surface soil and subsoil were collected for P, Ca, Mg, pH, free iron oxides, organic matter, and particle size analyses.

Yields were obtained for each replicate from row segments adjacent to each boring where samples were taken and measurements made. Yield data were analyzed using analysis of variance of completely randomized design. Each field was analyzed as an individual test because of variation in soils, rainfall patterns, and cultural practices between fields.

The cropping condition assumed in the EPIC simulation was a corn-wheat-soybean rotation under conventional tillage in the Coastal Plain and continuous cotton in the Tennessee Valley. Fertilizer rates and applications were according to soil test recommendations (Cope et al., 1981). Initial soil conditions were obtained from averages of slightly and moderately eroded Dothan and Decatur from farmer-operated fields. Properties of these soils used for this study are given in Table 1. Climatic data for the Dothan soils were obtained from records in Henry County, Alabama (Wiregrass Experimental Substation), and from Belle Mina, Alabama (Tennessee Valley Experimental Substation).

Results

Yields

Average yields and percent yield reduction for all years and crops are given in Table 2. In general, differences in soybean and cotton yields between years reflect seasonal rainfall differences. Severe drought stress caused cotton yields to be reduced by half in 1983. The effect of moisture stress on corn and soybean yields was not as great as on cotton. The percent yield reduction of corn and soybean on moderately eroded soils relative to slightly eroded yields was highest in 1983, the driest year. The average percent yield reduction for 1981-1984 on moderately eroded Dothan soils was 24 percent for corn, 41 percent for soybeans, and 28 percent for cotton (1982-1984) on moderately eroded Decatur soils in the Tennessee Valley.

Soil Properties

Regression analysis, means, and standard deviations were used to evaluate soil properties relative to yield differences between slightly and moderately eroded areas within fields. The analysis indicated that surface thickness, surface and subsurface clay content, free iron oxides, organic matter, and surface layer phosphorus content were most frequently related to yield differences

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TABLE 1. SOME SOIL INPUT DATA USED IN EPIC SIMULATION. PROPERTIES OF BT HORIZONS BELOW THE BT1 WERE CONSIDERED THE SAME FOR BOTH SLIGHT AND MODERATE EROSION CLASSES OF EACH SOIL

Horizon	Depth	Sand	Silt	Bulk Density	pH	Organic Matter	P	Field Cap
	cm	%	%	t/m-3		%	kg/ha	m/m
				Dothan, slightly eroded, 3% slopes				
Ap	0-25	77.4	15.4	1.70	5.9	1.2	59	0.15
Btl	25-41	54.7	13.7	1.68	5.2	0.6	—	0.24
				Dothan, moderately eroded, 4.5% slopes				
Ap	0-14	71	14	1.75	5.7	1.0	17	0.15
Btl	14-30	57	13	1.68	5.0	0.4	—	0.25
				Decatur, slightly eroded, 3% slopes				
Ap	0-18	16	58	1.45	6.2	1.14	52	0.16
Btl	18-46	13	53	1.50	5.1	0.53	—	0.17
				Decatur, moderately eroded, 4% slopes				
Ap	0-11	13	52	1.45	6.0	1.07	31	0.19
Btl	11-39	9	47	1.50	5.1	0.45	—	0.20

between eroded areas within fields (Tables 3 and 4). All of these properties have previously been related to erosion effects (Langdale et al., 1979; Frye et al., 1982; National Soil Erosion-Soil Productivity Research Planning Committee, 1981). Surface soil thickness and percent clay in the surface and subsurface horizons were best correlated with yield differences. Moderately eroded areas with low yields had thin surface layers (Ap), with high clay contents and abrupt boundaries to relatively clayey Bt subsurface horizons. These moderately eroded areas are easily detected in the field by trained soil scientists.

EPIC Simulation

The EPIC output of interest for this study is the initial yield difference between slightly and moderately eroded initial conditions of these soils and the long-term yield differences between erosion levels. Ten-year averages are given in Table 5. The simulated results show reduced yields on initially eroded soils; however, the difference between slight and moderate yields are less than ob-

TABLE 2. YIELDS AND PERCENT YIELD REDUCTION OF CORN, SOYBEAN AND COTTON ON SLIGHTLY AND MODERATELY ERODED SOILS

Soil Series	Crop	Year	Erosion Level: Slight	Erosion Level: Moderate	Yield Reduction
			kg/ha	kg/ha	%
Dothan	Soybean	1981	2787	1817	35
		1982	2661	1788	33
		1983	2285	1142	50
		1984	1004	564	44
	Corn	1981	4704	3432	27
		1982	5096	4124	19
		1983	5559	3700	33
		1984	3889	3261	16
Decatur	Cotton	1982	3340	2583	23
		1983	1388	883	36
		1984	3416	2734	20

TABLE 3. SURFACE SOIL CHARACTERISTICS AND CORRELATIONS OBTAINED BY MULTIPLE REGRESSION ANALYSIS

	Clay	Free Iron Oxides	P	pH	Organic Matter	Yield
				(r^2)		
Surface Thickness	0.57	0.45	0.50	0.22	0.12	0.61
Clay	1.00	0.58	0.42	0.36	0.32	0.48
Free Iron Oxides	—	1.00	0.54	0.10	0.48	0.44
P	—	—	1.00	0.34	0.10	0.28
pH	—	—	—	1.00	0.15	0.17
Organic Matter	—	—	—	—	1.00	0.31

TABLE 4. SELECTED SOIL PROPERTIES OF TWO SLIGHTLY AND MODERATELY ERODED SOILS IN THE COASTAL PLAIN (DOTHAN) AND TENNESSEE VALLEY (DECATUR) REGIONS OF ALABAMA

	Erosion Class	Series			
		Dothan		Decatur	
		Mean	SD	Mean	SD
Surface	Slight	25	2	18	2
(cm)	Moderate	14	2	11	2
% Clay					
Ap	Slight	8	3	26	6
	Moderate	15	4	35	6
Btl	Slight	21	7	34	6
	Moderate	30	5	44	8
% Free Iron					
Ap	Slight	1.27	0.26	2.81	1.12
	Moderate	1.75	0.55	3.85	1.41
Btl	Slight	2.46	0.60	3.85	1.60
	Moderate	3.37	0.85	4.28	1.49
% OM					
Ap	Slight	1.19	0.36	1.14	0.37
	Moderate	1.01	0.23	1.07	0.32
Btl	Slight	0.58	0.41	0.53	0.08
	Moderate	0.14	0.09	0.47	0.10
Phosphorus	Slight	59.00	29.00	52.00	21.00
kg/ha	Moderate	17.00	12.00	31.00	17.00

tained from on-farm plots. EPIC predictions agreed with on-farm results in that yield reductions caused by erosion were greatest for soybeans and least for cotton. Simulated yields of all crops were within the range of yields actually measured.

Long-term simulated productivity of corn and soybean indicates essentially no decline in yields. However, yield difference between initially slightly and moderately eroded conditions became less, reversing for corn and being equal for soybean the last 10 years of simulation. EPIC output indicated that moisture stress days were most closely related to both yield differences between erosion levels and that differences between years were due to effects from the climatic sequence predicted by EPIC's weather routine. The results are given in Figures 1 and 2. The simulated greater rate of yield decline for initially slightly eroded Dothan soils is expected since subsurface soil material is not favorable for productivity and loss of favorable topsoil is critical. On moderately eroded soil, further erosion will probably cause little loss of productivity. A 10-year simulation of cotton yields showed higher yields on slightly eroded areas throughout the period (Figure 3). As with corn and soybeans, moisture stress is the factor causing yield differences between erosion levels and between years.

EPIC simulation using data from eroded and slightly eroded soils from on-farm studies in Alabama predicted small yield differences between erosion levels. If the soil fertility status is maintained, moisture stress is the yield-limiting factor. As slightly eroded areas continue to erode under conventional tillage, yields approach those of soils that are now moderately eroded.

TABLE 5. TEN-YEAR EPIC SIMULATION, CONTINUOUS COTTON, CORN AND SOYBEANS

Soil	Crop	Erosion Class		Yield Reduction
		Slight	Moderate	
		T/ha	T/ha	%
Dothan	Corn	4.16	3.71	11
	Soybean	2.14	1.83	13
Decatur	Cotton	2.82	2.63	7

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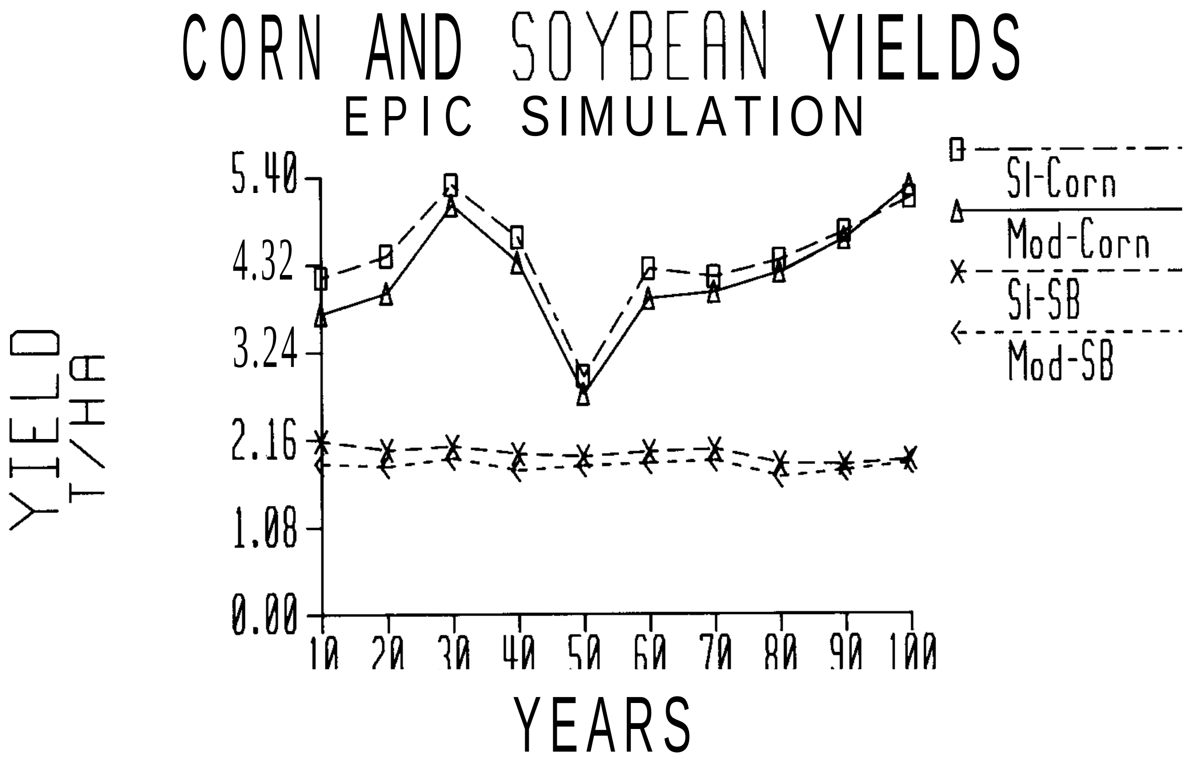

Figure **1.** Corn and soybean yields simulated by EPIC for Dothan soils in South Alabama (Sl—Slight erosion, Mod—Moderate erosion, SB—Soybean).

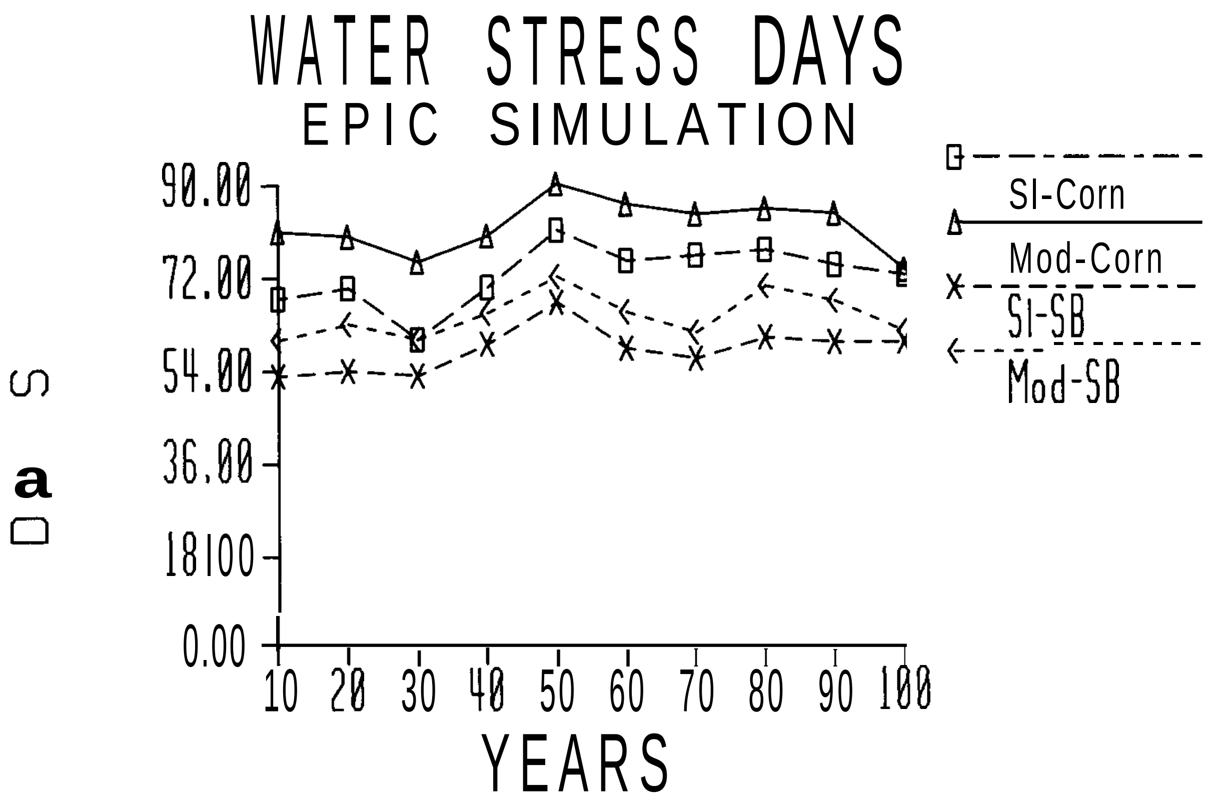

Figure 2. Corn and soybean (SB) water stress days simulated by EPIC for a slightly (Sl) and moderately (Mod) eroded Dothan soil in South Alabama.

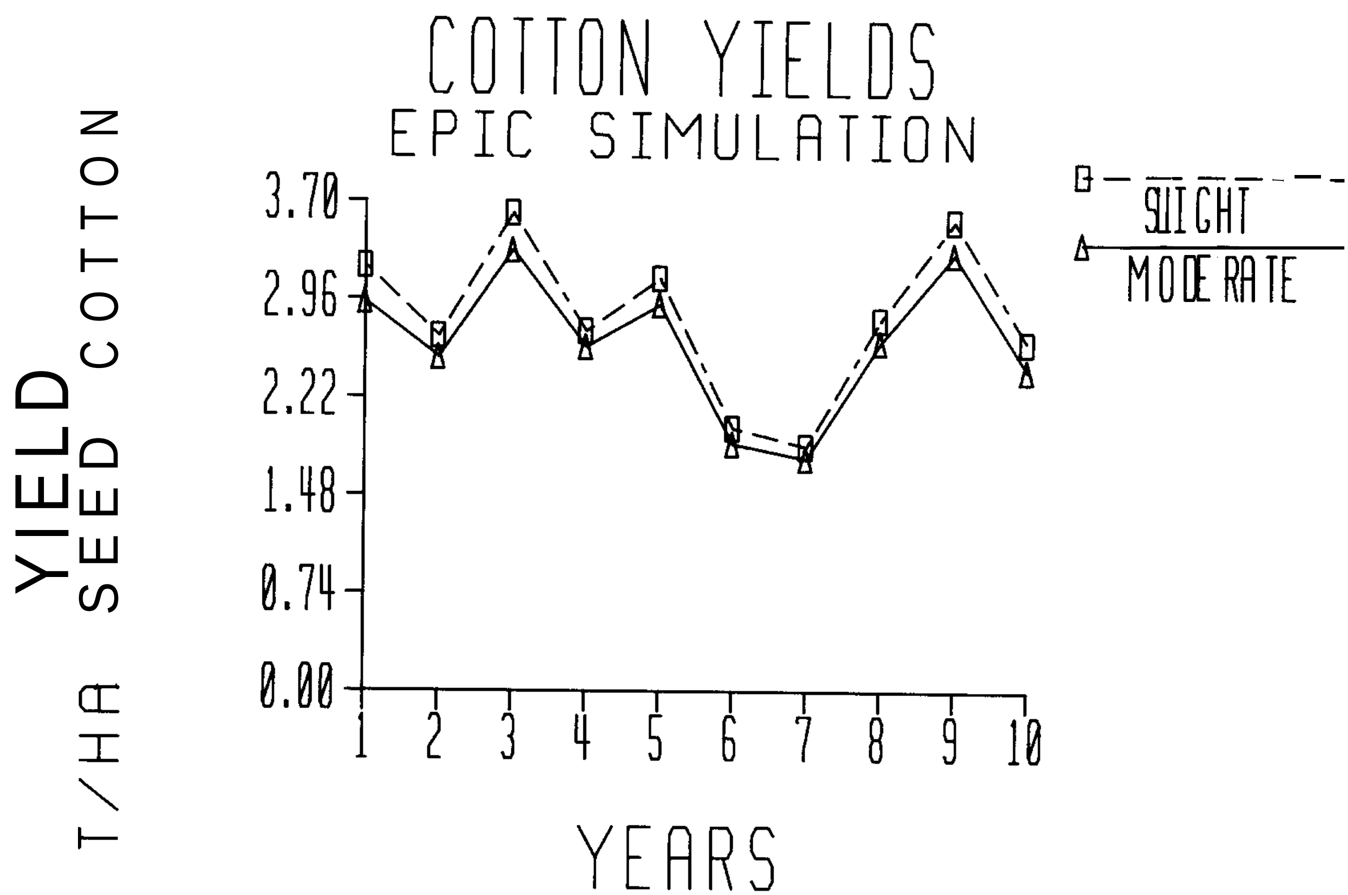

Figure 3. Cotton yields simulated by EPIC for a slightly and moderately eroded Decatur soil in North Alabama.