CONSERVATION TILLAGE SYSTEMS AND THEIR CONTROL OF WATER EROSION IN THE SOUTHERN PIEDMONT[1]

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INTRODUCTION

Soil erosion has been considered a serious hazard to row crop production on sloping cultivated Piedmont lands since the early 1930's. Soil erosion induced by conventional tillage causes soil management problems. In the 1940's Adams (1) observed yield reduction of 34 to 40% for row crops (cotton and corn) on Southern Piedmont soils (Capability Class IV land) where the top 15 cm (6 inches) had been eroded by water. Langdale et al. (5) recently observed a similar 40% corn yield reduction, even though modern fertilizers, herbicides, and improved varieties have increased corn yields more than 100% in the past 30 years.

Sediment from soil erosion has recently been identified as our most serious pollutant (8), and it serves as a carrier of agrichemicals. In the Southern Piedmont the source of most farm-transported sediment is conventionally tilled, row cropped land (3). Barnett and Hendrickson (2) demonstrated the hazards of continuous tilling cotton for 20 years. Their annual soil losses from runoff plots ranged from 11 to 119 metric tons/ha (5 to 53 tons/acre) on Capability Class III land. They concluded that summer thunderstorms account for 25% of the annual rainfall and cause 56% of the annual runoff as well as 86% of the annual soil loss. Willis and Evans (13) estimated a current monetary value of $59.00/ha ($24.00/acre) for the major nutrients (N, P, and K) contained in the generally accepted natural soil loss of 11.2 metric tons/ha/yr (5.0 tons/acre/yr).

This paper describes the effects of recent conservation tillage procedures on runoff and sediment transport from rainfall simulator plots and small upland watersheds at the Southern Piedmont Conservation Research Center. Both plots and watersheds were located primarily on eroded Cecil sandy loam soil *(Typic Hapludults)* with slopes ranging from 3 to 7% (9). Tillage and cropping sequences used on these research sites are given in Table 1. Summer annuals, either soybeans *(Glycine max* L. Merr.) or grain sorghum *(Sorghum vulgare* Pers.) followed small grain-barley *(Hordeum vulgare* L.) or rye *(Secale cereale* L.), which provided a mulch upon harvest.

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Table 1. Tillage treatments, cropping sequence, slope, ana crop row orientation on rainfall simulator plots and watersheds.

Tillage*	Crop Sequence	Slope	Row Orientation
		%	
	Rainfall Simulator Plots		
CT/NT	Comb. Rye/Soybean	6	Contour
CT/NT plus	Grazed + Comb. Rye/Soybean	6	Slope
	Conservation Watershed (Terraced)		
CT/CT	Plowed down Rye/Soybean	1 - 3	Contour
NT/NT	Combined Barley/Grain Sorghum	1 - 3	Contour
	Nonconservation Watershed (Nonterraced)		
CT	Fallow/Soybean	2 - 7	Contour
NT/NT	Comb. Barley/Grain Sorghum	2 - 7	Slope

* CT = conventional till; NT = no-till; NT plus = no-till plus.

Rainfall Simulator Plots

All rainfall simulator tests (7) were performed on 6% slopes with an average K value of 0.25. Simulated rainfall was applied in 12.7-cm increments at a constant rate of 6.4 cm/hour (erosion index, EI, = 174 metric tons-m/ha). Unless otherwise specified, total rye residues averaged approximately 2.5 metric tons/ha with plot lengths of 10.7 m. The standard 6-cm fluted coulter (no-till) and no-till plus (10, 11), as well as conventional tillage treatments, were imposed'on plots. The no-till plus implement utilizes a spring-loaded fluted coulter, a 5.0-cm wide chisel, and a slot filler tine (10, 11). This reduced tillage treatment was in-row chiseled 20 cm deep.

Conservation Watershed

One Southern Piedmont Conservation Research Center watershed is located on 3.0% sloping land with parallel terraces (25.6 m apart) and bisecting grass waterways behind flumes (12). This watershed was 1.26 ha in size and referred to as P-3. Three consecutive years of conventionally-tilled soybeans with fall-planted rye (green manuring) were grown (October 1972 to October 1975) on this watershed (Table 1). Three consecutive years (October 1975 to October 1978) of continuous double crop no-tilling of barley and grain sorghum followed.

Nonconservation Watershed

Another Southern Piedmont Conservation Research Center watershed, P-1 , is located on 2.0 to 7.0% sloping land without terraces or grass waterways (6). This 2.71-ha watershed was planted to soybeans using conventional tillage methods for two consecutive years. The watershed was fallowed between November and April each year. Rows were oriented approximately parallel to ground contours. After harvesting the second soybean crop, a 0.28-ha grassed waterway 11 m wide was established before no-till double cropping barley and grain sorghum continuously for two consecutive years. Rows of both of these crops were oriented up- and downhill to permit herbicide application parallel to the grass waterway.

DISCUSSION

Rainfall Simulator Plots

Cumulative runoff response to tillage during low antecedent soil moisture is presented in Fig. 1. Excessive runoff (72%) associated with the tilled-fallow plots shows how vulnerable clean till soil is to natural high-intensity storms (2). With crop residue mulch (standing rye stubble plus combine residues) no-till practices created surface conditions that reduced runoff volume (56%). The combined effect of chiseling 20 cm deep (no-till plus) and a rye residue mulch almost eliminated runoff (5%)when antecedent soil moisture was low. However, runoff data in Fig. 2 and Table 2 suggest that "in-row chiseling" associated with the no-till plus treatment diminishes in importance as soil water, slope length, and soybean canopy increase. Slope length is probably the most important parameter, because the chances are remote for high-intensity rainstorms occurring when antecedent soil moisture is high after soybean canopy development in double crop systems (6). For the no-till plus treatment in-row chiseling did not affect runoff after canopy development under high antecedent soil moisture and rye residues. The interactive effects of rye residue quantity and soybean canopy development did not appear to alter runoff values for no-till treatment (Table 3).

Table 2. Runoff and sediment losses from rainfall simulator plots planted to soybeans with the no-till plus* system and from tilled fallow at low and high antecedent soil moisture.

Slope Length, m	Rye Stubble		3/4 Canopy		Tilled	
	Low**	High	Low	High	Low	High
			Runoff, %			
10.7	4.2	36.7	19.2	62.0	71.5	87.5
21.4	12.9	67.4	43.8	80.8	85.0	91.8
			Sediment, metric tons/ha			
10.7	0.05	0.40	0.09	0.22	36.3	39.2
21.4	0.29	0.72	0.11	0.18	50.1	39.4

* The no-till plus treatment utilized a fluted coulter and in-row chiseling (20 cm deep on Cecil scl soil with 6.0% slope.)

** Antecedent soil moisture was considered low during initial rainfall simulator runs, which began at average soil moisture. Antecedent soil moisture was considered high during the second runs made within 24 hours on wet soil.

Table 3. Runoff and sediment losses from low antecedent soil moisture plots planted to soybeans with the no-till system in varying quantities of rye mulch.

Canopy	Rye Residue, metric tons/ha			
	2.46**	3.02	3.58	4.70
	Runoff, %			
Rye Stubble	57.1	57.6	57.6	54.2
Half-Canopy	57.7	58.6	59.7	51.4
Full-Canopy	58.2	52.2	56.6	58.1
	Sediment, metric tons/ha			
Rye Stubble	0.11	0.09	0.07	0.07
Half-Canopy	0.11	0.09	0.09	0.09
Full-Canopy	0.05	0.07	0.05	0.09

* The no-till treatment utilized a 6-cm fluted coulter without additional tillage.

** Standing rye stubble only.

Both of the reduced tillage treatments provided adequate soil erosion control for soybean production on Southern Piedmont soils (Fig. 3, Tables 2 and 3). Rows may even be oriented up- and downhill on slopes of <6% and slope lengths <20 m. Harrold and Edwards (4) effectively controlled soil erosion during a 100-year frequency storm on a 21% sloping watershed with no-till corn. The sediment loss (-40 metric tons/ha) associated with the tilled-fallow treatment in Fig. 3 approximates the average annual sediment values of Southern Piedmont watersheds with similar slopes (6). Since the simulated rainfall represented approximately one-third of the annual rainfall energy, this shows the obvious importance of residue mulches for controlling erosion. Although sediment yield values reported for the no-till treatment are small (Table 3), differences associated with rye residue quantity and soybean canopy are large enough to change C-values (Fig. 4) of the universal soil-loss equation (14).

Conservation Watershed

Hydrologic data representing the conservation watershed are presented in Table 4 and Fig. 5. We concluded that tillage and residue management provided the only real difference in runoff and soil erosion. Although runoff (12%) and soil erosion (2.8 metric tons/ha/yr) were controlled within respectable limits during the tillage period with conservation practices, no-tillage double crop management reduced runoff and erosion slightly more than 50 and 90% respectively. Even on a per unit erosion index (EI), the soil erosion reduction is still near 90%. Average annual rainfall was not highly different (123.3 vs 118.5 cm) between tillage periods. During the no-till period, approximately 80% of the runoff occurred during seasons 3 and 4 (Table 4). This was a period of minimum ground cover at the pre-tiller small grain stage.

Table 4. Hydrologic parameters associated with tillage on a conservation watershed.

Season*	Rainfall	Erosion Index	Runoff Events	Runoff	Sediment
	cm	metric tons-m/ha	no.	cm	metric tons/ha
		Tillage Period			
1 (May-Jul)	33.6	289	4	4.2	2.06
2 (Aug-Oct)	21.7	107	2	1.3	0.25
3 (Nov-Jan)	30.3	142	4	2.8	0.11
4 (Feb-Apr)	37.7	201	5	6.4	0.39
Avg. Annual Mean	123.3	739	15	14.7	2.81
		No-Till Period			
1 (May-Jul)	30.4	122	1	0.5	0.02
2 (Aug-Oct)	30.1	188	3	0.8	0.01
3 (Nov-Jan)	34.0	105	5	3.3	0.11
4 (Feb-Apr)	24.0	62	1	1.7	0.05
Avg. Annual Mean	118.5	477	10	6.3	0.19

Most of the runoff during the tillage period occurred during seasons 1 and 4. However, slightly more than 70% of all soil erosion occurred during season 1 of the tillage period (Table 4). Sediment yield data is expressed on a monthly basis in Fig. 5 to emphasize the erosion hazard during season 1 with conventional tillage practices.

Nonconservation Watershed

Hydrologic data are given in Table 5. Except for extremes during the tillage period, data trends were similar to those of the conservation watershed. During the tillage period, soil erosion was a disaster (22.2 metric tons/ha). Cumulative monthly sediment yields are given in Fig. 6 to show how closely high energy rainfall coincides with single cropped, conventional tilled soybeans. Sixty percent of the annual runoff and 85% of the soil erosion occurred during this season. During the no-tillage period, similar percentages of all runoff and soil erosion occurred in season 4. Flume-measured runoff and sediment were reduced 2.5- and 194-fold by continuous no-tilling. These wide differences clearly suggested that no-till systems may be used in the Southern Piedmont with strategically located grass waterways to minimize runoff and sediment transport on slopes up to 7%. Results during the tillage period on this watershed were analogous to those observed on most current conventionally-tilled farms in the Southern Piedmont.

Table 5. Hydrologic parameters associated with conventional and no-till nonconservation watersheds.

Season	Rainfall	Erosion Index	Runoff Events	Runoff	Sediment
	cm	metric tons-m/ha	no.	cm	metric tons/ha
		Tillage Period			
1 (May-Jul)	38.1	389	10	13.3	22.22
2 (Aug-Oct)	20.2	115	4	2.3	0.86
3 (Nov-Jan)	37.0	115	6	2.0	0.51
4 (Feb-Apr)	32.3	138	6	4.5	2.67
Avg. Annual Mean	127.6	757	26	22.1	26.26
		No-Till Period			
1 (May-Jul)	32.5	262	3	1.5	0.02
2 (Aug-Oct)	20.5	119	2	0.1	0.01
3 (Nov-Jan)	27.3	63	3	0.5	0.01
4 (Feb-Apr)	43.5	172	8	6.6	0.10
Avg. Annual Mean	123.8	616	16	8.7	0.14

CONCLUSIONS

Reduced tillage is essential for effective control of runoff and soil erosion during high energy rainfall probability months (May - July) on >3.0% sloping row crop land in the Southern Piedmont. All of the reduced tillage procedures used adequately controlled soil erosion from rainfall simulator plots and watersheds. The no-till plus treatment reduced runoff to 20% (average for low and high antecedent soil moisture rainfall simulator runs on 10.7-m slope lengths) which is a precedent in conservation tillage. In double cropped-reduced tillage systems, slope length was extremely important, whereas average percent slope and crop canopy or residue quantity were only mildly important in runoff control. If continuous reduced tillage systems are used, crop rows may be oriented up- and downhill with an occasional properly-located grass waterway.

REFERENCES

1. Adams, William E. 1949. Loss of topsoil reduced crop yield. J. Soil and Water Cons. 4:130.

2. Barnett, A. P., and B. H. Hendrickson. 1960. Erosion on Piedmont soils. J. Soil and Water Cons. 26:31-34.

3. Carreker, J. R., S. R. Wilkinson, A. P. Barnett, and J. E. Box, Jr. 1977. Soil and water management systems for sloping lands. U.S. Dep. Agr. ARS-S-160. 76 pp.

4. Harrold, L. L., and W. M. Edwards. 1972. A severe rainstorm test of no-till corn. J. Soil and Water Cons. 27:30.

5. Langdale, G. W., J. E. Box, Jr., R. A. Leonard, A. P. Barnett, and W. G. Fleming. 1979. Corn yield reduction on eroded Southern Piedmont soils. J. Soil and Water Cons. *(In review)*

6. Langdale, G. W., A. P. Barnett, R. A. Leonard, and W. G. Fleming. 1979. Reduction of soil erosion by the no-till system in the Southern Piedmont. Trans. ASAE *(Accepted for publication in early 1979)*

7. Meyer, L. D., and D. L. McCune. 1958. Rainfall simulator for runoff plots. Agr. Eng. 39:644-648.

8. Minimum Tillage. 1975. A preliminary technology assessment. U. S. Dep. Agr. Office of Planning and Evaluation. 34 pp.

9. Perkins, H. F., and F. T. Ritchie, Jr. 1968. Physical features of Georgia. J. Soil and Water Cons. 23:97-100.

10. Pitts, Nadine S. 1978. New design for no-till planter. Soil Cons. (USDA) 43(9) 9-11.

11. Reardon, J. C. 1978. Plant nutrient losses in runoff under simulated rainfall using various ground covers. M.S. Thesis, University of Georgia.

12. Smith, C. N., R. A. Leonard, G. W. Langdale, and G. W. Bailey. 1978. Transport of agricultural chemicals from upland Piedmont watersheds. U.S. Environmental Protection Agency, Athens, GA and U.S. Department of Agriculture, Watkinsville, GA. Final Report on Interagency Agreement No. D6-0381. Pub. No. EPA-600/3-78-056. 364 pp.

13. Willis, W. O., and C. E. Evans. 1977. Our soil is valuable. J. Soil and Water Cons. 32:258-259.

14. Wischmeier, W. H., and D. D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agric. Handbook No. 282, USDA, U.S. Government Printing Office, Washington, DC. 47 pp.

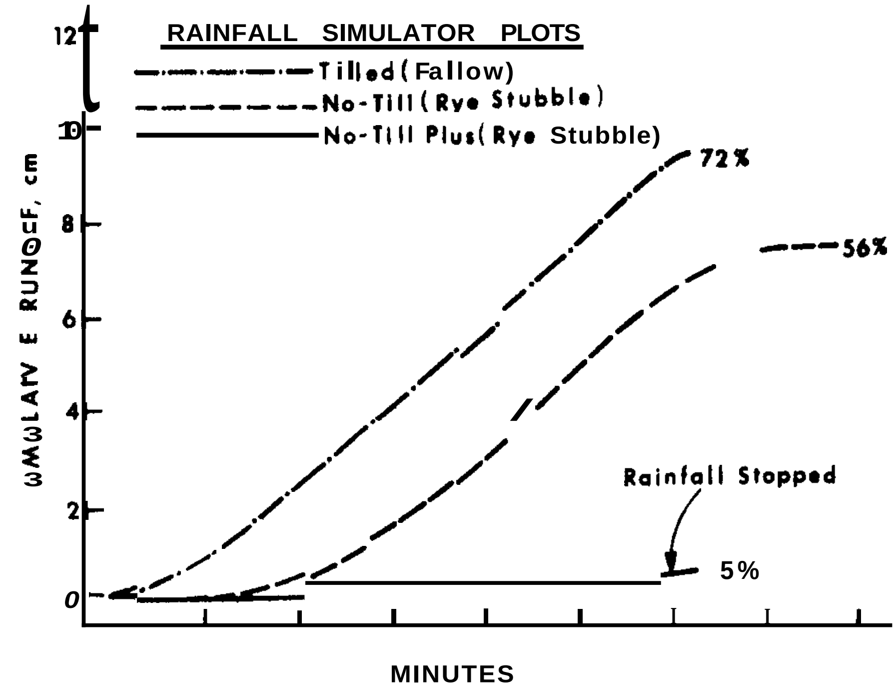

Fig. 1. Simulated runoff response to tillage associated with low antecedent soil moisture.

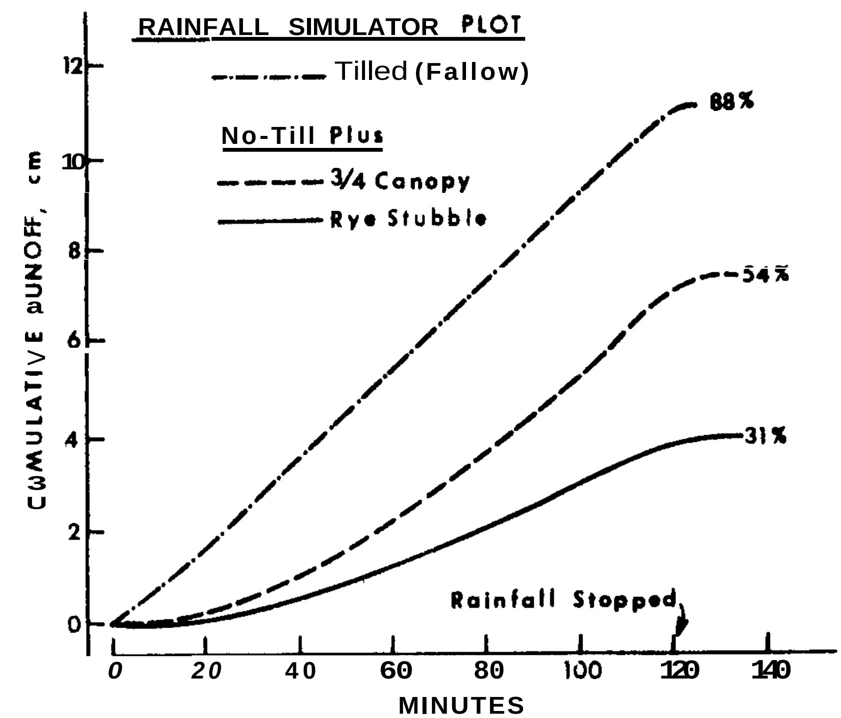

Fig. 2. Simulated runoff response to tillage associated with high antecedent soil moisture.

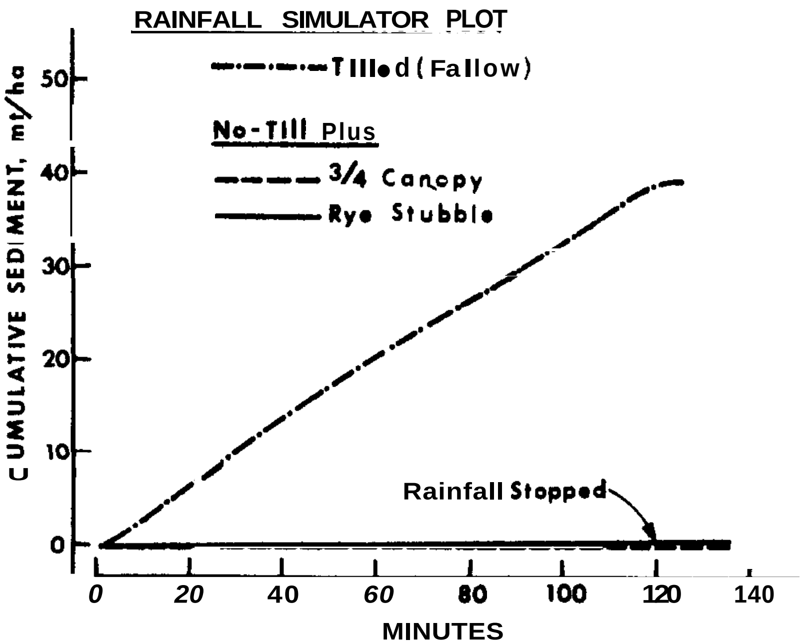

Fig. 3. Simulated soil loss associated with tillage and high antecedent soil moisture.

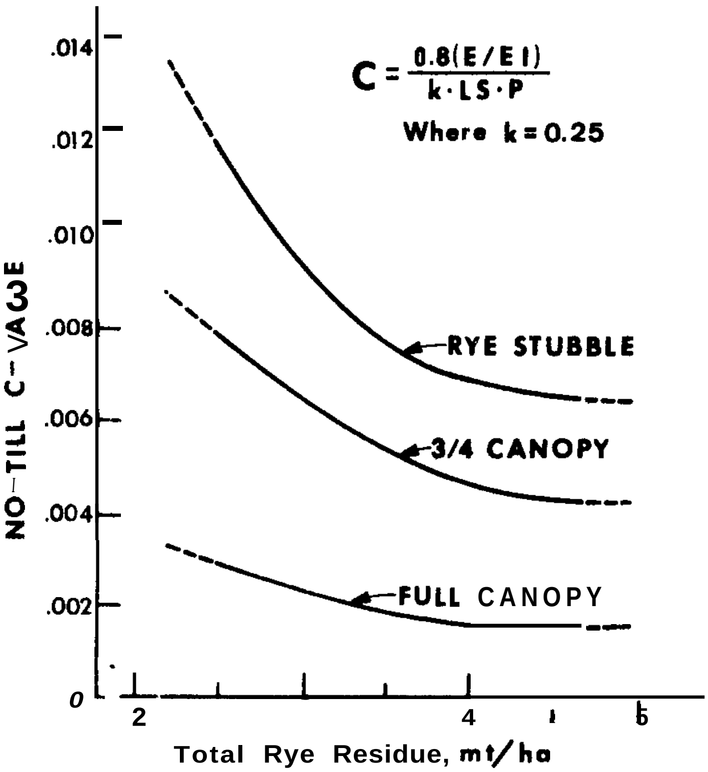

Fig. 4. Cover management factor "C" relation to no-till soybean canopy and rye residue on rainfall simulator plots.

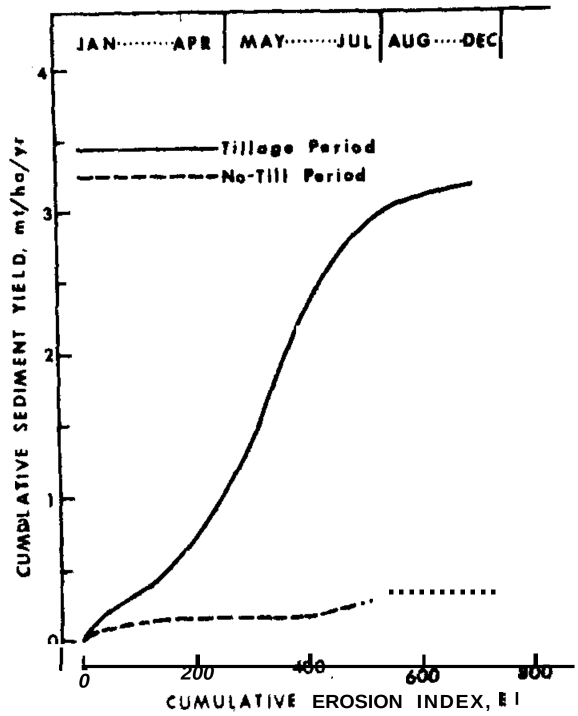

Fig. 5. Average annual cumulative erosion index (EI) relation to average annual cumulative sediment yield on the conservation watershed.

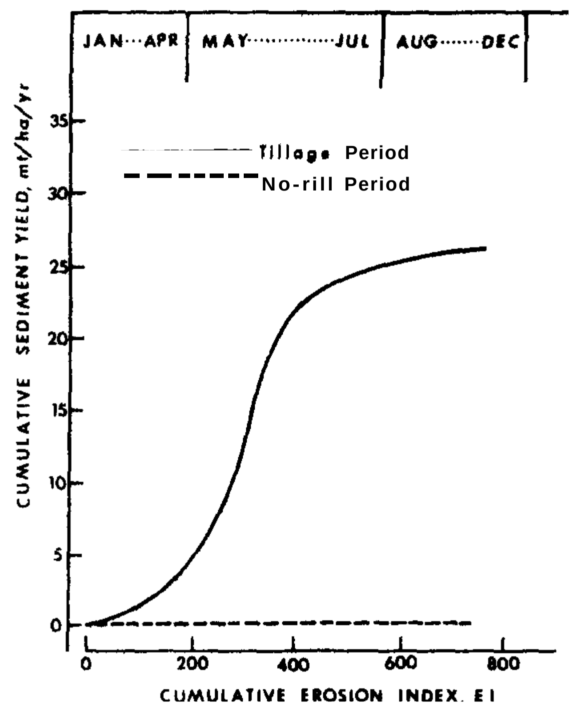

Fig. 6. Average annual cumulative erosion index (EI) relation to average annual cumulative sediment yield on the nonconservation watershed.