This paper was peer-reviewed for scientific content.
Pages 266-271. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds). 2001. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

Effects of Erosion and Manure Applications on Corn Production

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ABSTRACT

Soil erosion has been a problem in agriculture since ancient times. The main impact of erosion on the soil is a loss of soil productivity because of decreased capacities in soil biological, chemical, and physical properties. A study was initiated 14 yr ago (1985) to investigate the effects of soil erosion on soil productivity and corn production in southwest Wisconsin, USA. Three levels of erosion (slight, moderate, and severe) were identified based on the depth of topsoil above a red clay residuum (2Bt horizon) on a Dubuque silt-loam soil. Manure applications to half of the plots were started in 1988 to evaluate manure effect on soil physical properties of eroded soils. Differences in corn (*Zea mays* L.) yields as a result of soil erosion level have been small, but in general yields decreased with increasing erosion level. In addition, it appears that some of the yield differences between erosion levels are weather related. Manure effects on corn yields are dependent on erosion level, but these effects are not consistent. Nevertheless, grain yields appear to be generally greater in manured subplots. Based on data collected to date, manure has had little effect on corn yields; however, plant heights have been found to increase with manure applications. We suspect that manure applications will have a long-term effect on soil physical properties, mainly on water retention. Tensiometric data collected during the 1997 growing season revealed greater water retention at 30 cm on the manured subplots. Differences in water retention were less noticeable below 30 cm. Wetting front in the manured subplots appears to move faster than in no manure subplots. This effect is more noticeable with increasing erosion level. However, this faster movement of the wetting front in manured subplots could indicate that manure applications may increase the potential of contaminant leaching to groundwater.

INTRODUCTION

A soil erosion productivity study site was established 14 yr (1985) ago at the Univ. of Wisconsin Agricultural Research Station at Lancaster, Wis., USA. The plots are located on a Dubuque soil (fine-silty, mixed, mesic, Typic Hapludalfs), with three levels of erosion: slight, moderate, and severe. After 4 yr of research, it was shown that the main impact of erosion on corn (*Zea mays* L.) yield is attributed to a reduction in the water holding capacity of Dubuque soil (Andraski and Lowery, 1992). Other researchers have shown that crop yields are generally reduced by erosion (Frye et al., 1982; Olson and Carmer, 1990; Chengere and Lal, 1995; Shaffer et al., 1995). However, similar and greater yields have been reported in eroded areas when compared to uneroded soils. This largely reflects weather differences between years, especially rainfall (Swan et al., 1987). Soil erosion not only reduces corn grain but total biomass (stover) yields are also reduced, and it has been found that soil erosion delays crop emergence, reduces plant height, and creates an uneven plant population (Lindstrom et al., 1986; Olson and Carmer, 1990; Schumacher et al., 1994).

Application of manure has been reported to over time improve soil aggregation, reduce bulk density, and increase soil water retention and hydraulic conductivity (Chaney and Swift, 1986a,b; Mbagwu, 1989; Droogers and Bouma, 1996). This is mainly caused by an increase in organic matter content. Increased crop yields have been reported with manure applications to eroded land, but similar yield increases have been found with commercial fertilizers (Larney and Janzen, 1996). Therefore, application of animal manure should have other benefits such as amelioration of the negative effects of erosion on soil physical properties and crop production. Application of manure to eroded soil has been shown to increase wheat yields, which has been attributed to improved soil physical properties (Dormaar et al., 1988; Larney and Janzen, 1996). For this reason, we propose the use of animal manure as an ameliorating amendment for eroded soils. Thus, the objective of this study is to determine if the water storage and crop production capacity of an eroded soil can improve by increasing its organic matter content with animal waste.

MATERIALS AND METHODS

This study was conducted in the driftless region of southwestern Wisconsin, at the Lancaster Agricultural Research Station of the Univ. of Wisconsin-Madison (42º52' N, 90º42' W). Soil in the research site is a Dubuque silt loam, formed in loess underlain by a red clay residuum with a sub-angular blocky structure (Glocker, 1966). The site is 90 by 45 m and is located on a southwest-facing slope (10 to 14%). In 1985, three levels of past erosion (slight, moderate, and severe) were identified based on the depth to the red clay residuum (2Bt2 horizon) (Table 1) (Andraski and Lowery, 1992). The erosion levels were determined utilizing the criteria established by the Natural Resources Conservation Service [former Soil Conservation Service] were: Class 1 (slight erosion level) defined as a loss of <25% of the original A horizon or of the uppermost 20 cm if the original A horizon was <20cm thick; Class 2 (moderate erosion level) is were a loss of between 25 and 75% of the

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original A horizon has occurred or of the uppermost 20 cm if the original A horizon was <20 cm thick; and Class 3 (sever erosion level) is a loss of >75% of the original A horizon or of the uppermost 20 cm if the original A horizon was <20 cm thick (Soil Survey Staff, 1981). Depth to the red clay residuum in the research area ranges from 0.45 to 0.95 m.

Alfalfa (*Medicago sativa* L.) was planted on this site for 5 yr prior to this study. Since 1984, the site has been under continuous corn. Tillage operations include chisel plowing in the fall and disking in spring. Anhydrous ammonia was used as preplant N fertilizer, and an NPK fertilizer was applied at planting (Table 2). Weeds and insects were controlled as needed with herbicides and insecticides, respectively.

Three replicate plots of 13.7 by 7.3 m were established for each erosion level at the beginning of the study. The effects of different levels of past erosion on corn production and soil physical properties were evaluated exclusively at this site from 1985 to 1987. In fall 1987, each plot was split in half across the slope creating two subplots per plot. Cattle manure slurry was injected in the bottom half of each plot (downslope subplots). The liquid animal manure was injected in fall and spring of each year from 1988 to 1991. However, because of a lack of rapid response, starting in 1992 fall applications of solid manure at higher rates were used until 1998 (Touray, 1994). The solid cattle manure has been incorporated into the soil in the fall of each year by chisel plowing. Anhydrous ammonia applications were reduced in those subplots receiving manure to compensate for the N applied with manure (Table 2). The NPK fertilizer applied at planting was the same for unmanured and manured subplots.

In summer 1998, soil core samples were taken for water retention determination. Samples were taken using a bulk density soil core (7.6 cm diam. by 7.6 cm length) sampler to a depth of 45 cm in 15-cm increments; they were analyzed in the laboratory using a hanging water column apparatus (McGuire and Lowery, 1992).

Corn was harvested by hand for grain yield measurements on the two center rows of the four-row subplots. Data were analyzed using analysis of variance (ANOVA) using the generalized linear model (GLM) and means calculated using the means procedure in Statistical Analysis Systems (SAS) software (SAS Institute, 1989).

RESULTS AND DISCUSSION

The effect of erosion level on corn production was analyzed with data collected since 1985. From 1988 until present, yield data from the subplots that received no manure were used to assess the effects of erosion at different levels on corn production. Corn grain yield trends due to erosion level were hard to depict, especially since year-to-year trends between erosion levels vary. Not surprisingly, year effects were highly significant. The lowest-yielding year was 1988, with an average yield of 2.8 Mg ha^{-1}, and the highest-yielding year was 1994, with an average yield of 15.1 Mg ha^{-1} (Table 3). The 14-yr corn grain yield average for non-manure subplots was 10.7 Mg ha^{-1}. Overall, the slight erosion level was the greatest yielding (11.0 Mg ha^{-1}), but it was not significantly different than the severe erosion level (10.6 Mg ha^{-1}). However, grain yields were significantly different between slight (11.0 Mg ha^{-1}) and moderate (10.5 Mg ha^{-1}) erosion levels, but differences in 14-yr grain average between moderate and severe erosion levels were not significant. These differences in yields between soils at different erosion stages can be mainly attributed to differences in soil physical properties from the erosion process (Frye et al., 1982; Olson and Nizeyimana, 1988 Andraski and Lowery, 1992; Fahnestock et al., 1995).

Cattle manure additions since 1988 have had a significant effect on corn grain yields when all erosion levels are grouped together. When averaged over all erosion levels, observed mean corn grain yields since 1989 were significantly greater in subplots receiving cattle manure than in subplots receiving only commercial fertilizer, 10.9 and 10.5 Mg ha^{-1}, respectively. However, when observing each erosion level separately manure application did not always increased corn grain yields (Table 4). Significance because of manure additions in corn production was only observed in the slight erosion level. It appears that cattle manure may need to be applied for a longer period of time in order to observe a statistically significant increase on the production capacity of moderately and severely eroded soils receiving manure. Nevertheless, manure applications appear so far to have a moderate positive effect on corn production.

Table 1. Horizon depth and textural classification for three erosion levels of a Dubuque silt loam soil in 1985 (adapted from Andraski and Lowery, 1992).

Erosion level	Soil horizon	Avgerage depth	Textural class	Sand content	Clay content
		cm		-------- %	--------
Slight	Ap	0 - 36	silt loam	5	13
	Bt	36 - 95	silty clay loam	2	32
	2Bt	95 -> 113	silty clay	5	54
Moderate	Ap	0 - 20	silt loam	6	16
	Bt	20 - 74	silty clay loam	2	29
	2Bt	74 -> 99	silty clay	3	45
Severe	Ap	0 - 17	silt loam	5	17
	Bt	17 - 45	silty clay loam	3	33
	2Bt	45 - 79	silty clay	4	40

Table 2. Planting day, seeding, fertilizer and manure rates since 1985 at the Lancaster Research Station. Numbers in parenthesis refer to the NPK fertilizer used. (n/a - not available).

Agronomic practice		1985	1986	1987	1988	1989	1990	1991
Planting date		May 2	May 2	May 1	May 4	May 3	May 8	May 2
Seeding rate (seed ha^{-1})		74,100	74,100	75,335	77,805	72,865	73,359	77,774
Starter fertilizer (kg ha^{-1})		224	224	258	280	224	224	224
		(6-24-24)	(6-24-24)	(6-24-24)	(6-24-24)	(6-24-24)	(6-24-24)	(6-24-24)
Anhydrous	no manure	224	224	280	280	n/a	224	224
ammonia (kg ha^{-1})	manure					n/a	134	112
Manure loading rate (Mg ha^{-1})					7.5	10.8	16.7	27.4
Available N in manure (kg ha^{-1})					115	179	252	537
Planting date		May 5	May 14	May 3	May 16	May 1	May 15	May 21
Seeding rate (seed ha^{-1})		76,045	76,045	76,045	76,076	79,012	76,543	79,040
Starter fertilizer (kg ha^{-1})		224	224	213	224	163	163	163
		(6-24-24)	(6-24-24)	(8-32-17)	(8-32-17)	(8-32-17)	(8-32-17)	(8-32-17)
Anhydrous	no manure	224	179	179	179	202	179	179
ammonia (kg ha^{-1})	manure	134	90	90	90	101	90	90
Manure loading rate (Mg ha^{-1})		14	n/a	19.8	10	n/a	11.9	13
Available N in manure (kg ha^{-1})		85	n/a	128	95	n/a	106	77

Table 3. Mean corn grain yields for each erosion level. Values reported at 15% moisture. Standard deviation in parenthesis.

	Corn Grain Yield		
Erosion Level	Slight	Moderate	Severe
-- Year --	---------------- Mg ha-1 ----------------		
1985	10.5 (0.8)	10.3 (0.7)	9.8 (0.5)
1986	12.2 (0.4)	11.3 (0.3)	12.1 (0.2)
1987	12.8 (0.1)	12.2 (0.3)	11.8 (0.7)
1988	3.0 (0.1)	2.6 (0.5)	2.8 (0.3)
1989	9.0 (0.3)	9.4 (1.3)	8.6 (0.6)
1990	10.7 (1.4)	10.5 (0.6)	11.9 (0.7)
1991	11.9 (1.8)	11.8 (0.2)	12.1 (1.7)
1992	13.4 (1.0)	11.1 (2.8)	13.2 (0.5)
1993	9.6 (0.8)	10.5 (1.4)	10.8 (1.0)
1994	15.8 (1.4)	14.3 (0.7)	15.2 (1.0)
1995	11.4 (0.9)	12.0 (0.9)	11.9 (0.5)
1996	11.2 (0.9)	8.9 (0.2)	8.5 (1.7)
1997	11.7 (2.4)	11.9 (0.1)	10.0 (1.7)
1998	11.1 (1.3)	9.8 (0.8)	10.5 (1.1)

Table 4. Mean corn grain yield for unmanured and manured subplots at each erosion level. Values reported at 15% moisture. Standard deviation in parenthesis.

	Mean Corn Grain Yield					
Erosion Level	Slight		Moderate		Severe	
Year	no manure	manure	no manure	manure	no manure	manure
	----------------------------- Mg ha^{-1} -----------------------------					
1988	3.0 (0.1)	3.1 (0.4)	2.6 (0.5)	3.1 (0.2)	2.8 (0.3)	2.7 (0.3)
1989	9.0 (0.3)	9.5 (0.3)	9.4 (1.3)	9.4 (0.7)	8.6 (0.6)	8.6 (0.3)
1990	10.7 (1.4)	11.3 (1.5)	10.5 (0.6)	11.2 (1.3)	11.9 (0.7)	11.2 (0.1)
1991	11.9 (1.8)	12.1 (1.4)	11.8 (0.2)	10.6 (0.5)	12.1 (1.7)	11.6 (1.1)
1992	13.4 (1.0)	15.5 (0.3)	11.1 (2.8)	12.5 (1.6)	13.2 (0.5)	14.4 (0.9)
1993	9.6 (0.8)	8.2 (3.1)	10.5 (1.4)	9.0 (1.6)	10.8 (1.0)	7.3 (1.5)
1994	15.7 (1.4)	17.4 (1.3)	14.3 (0.7)	14.3 (0.3)	15.2 (1.0)	15.5 (0.9)
1995	11.4 (0.9)	11.8 (1.3)	12.0 (0.9)	12.0 (0.9)	11.9 (0.5)	11.9 (1.2)
1996	11.2 (0.9)	12.1 (0.8)	8.9 (0.2)	10.0 (0.6)	8.5 (1.7)	10.7 (0.4)
1997	11.7 (2.4)	11.5 (1.5)	11.9 (0.1)	10.5 (0.7)	10.0 (1.7)	10.7 (1.1)
1998	11.1 (1.3)	14.0 (0.8)	9.8 (0.8)	13.4 (1.2)	10.5 (1.1)	11.3 (1.0)

Table 5. Mean corn plant heights for the 1997 and 1998 growing seasons. Standard deviation is shown in parenthesis. (DAP – days after planting).

Mean Corn Plant Height - 1997 Growing Season

	Erosion Level					
	Slight		Moderate		Severe	
DAP	no manure	manure	no manure	manure	no manure	manure
	meters					
46	0.92 (0.09)	1.11 (0.15)	1.01 (0.08)	1.12 (0.07)	1.03 (0.08)	1.18 (0.09)
56	1.41 (0.07)	1.69 (0.14)	1.48 (0.09)	1.68 (0.12)	1.52 (0.09)	1.69 (0.11)
63	1.94 (0.09)	2.17 (0.13)	1.91 (0.11)	2.11 (0.09)	1.90 (0.13)	2.09 (0.13)
74	2.42 (0.12)	2.60 (0.17)	2.40 (0.13)	2.59 (0.12)	2.44 (0.14)	2.64 (0.18)

Mean Corn Plant Height - 1998 Growing Season

	Erosion Level					
	Slight		Moderate		Severe	
DAP	no manure	manure	no manure	manure	no manure	manure
	meters					
40	0.85 (0.07)	0.93 (0.08)	0.85 (0.07)	0.97 (0.05)	0.92 (0.09)	0.92 (0.07)
49	1.41 (0.13)	1.47 (0.16)	1.44 (0.14)	1.58 (0.10)	1.47 (0.11)	1.56 (0.12)
56	2.00 (0.09)	2.04 (0.24)	2.02 (0.09)	2.13 (0.15)	2.05 (0.11)	2.01 (0.18)
63	2.36 (0.13)	2.55 (0.15)	2.35 (0.15)	2.43 (0.23)	2.30 (0.21)	2.50 (0.07)
70	2.66 (0.12)	2.77 (0.18)	2.58 (0.19)	2.74 (0.23)	2.55 (0.12)	2.72 (0.22)

Table 6. Mean dry stover yields for each erosion level. Standard deviation is shown in parenthesis.

	Mean Dry Stover Yield		
Erosion Level	Slight	Moderate	Severe
Year	$Mg\ ha^{-1}$		
1985	7.0 (0.6)	7.3 (0.8)	6.8 (0.8)
1986	8.0 (0.3)	7.2 (0.4)	8.2 (1.5)
1987	9.7 (0.7)	8.0 (1.2)	8.9 (1.0)
1989	5.2 (0.3)	5.3 (1.0)	5.1 (0.1)
1992	7.4 (0.6)	6.4 (0.8)	7.0 (0.7)
1993	6.5 (1.2)	6.0 (0.2)	6.0 (0.6)
1994	8.8 (1.7)	8.2 (0.2)	8.6 (0.6)
1997	8.7 (1.1)	8.7 (1.2)	7.0 (2.1)
1998	8.7 (0.6)	8.9 (1.6)	9.1 (1.2)

Early in the growing season, average plant heights in subplots not receiving manure were greater with increasing erosion level, but later in the season differences were less noticeable. Nonetheless, manure applications increased corn plant heights for the three erosion levels (Table 5).

Response of stover yields to erosion level was similar to that of grain yields. A large variability from year-to-year was observed (Table 6). Average stover yield for all erosion levels combined was 7.5 Mg ha^{-1}. Manure applications usually increased stover yields (Table 7). Average stover yields were significantly different for unmanured and manured subplots, 7.3 and 8.0 Mg ha^{-1}, respectively.

Tensiometric data collected during the 1997 growing season revealed greater water retention at 30 cm on the manured subplots (Fig. 1). Similar trends of increasing water retention in manured soils were observed for all erosion levels. However, as pointed out by Andraski and Lowery (1992), the water present in the soil may not be plant-extractable. In addition, by studying the rate of change in matric potential at different depth it appears that the wetting fronts in the manured subplots move faster than in unmanured subplots. This effect is more noticeable with increasing erosion level. Nevertheless, this may increase the potential for contaminant leaching.

Differences in water retention as a function of erosion level from 0 to 200 cm of H_2O were not readily noticeable (Table 8). However, manure additions did have an impact on water retention. Water retention increased at all depths with manure applications with exception of 0 cm of H_2O at 30-45 cm depth. However, this was more apparent from the 0-15 cm depth, especially on the slightly eroded plots.

Table 7. Mean dry stover yields for unmanured and manured subplots at each erosion level. Standard deviation shown in parenthesis.

	Mean Dry Stover Yield					
	Erosion Level					
	Slight		Moderate		Severe	
Year	no manure	manure	no manure	manure	no manure	manure
	---------- $Mg\ ha^{-1}$ ----------					
1989	5.2 (0.3)	5.2 (0.3)	5.3 (1.0)	5.6 (0.3)	5.1 (0.1)	5.9 (0.4)
1992	7.4 (0.6)	7.9 (1.2)	6.4 (0.8)	7.6 (1.7)	7.0 (0.7)	6.8 (1.0)
1993	6.5 (1.2)	5.7 (0.3)	6.0 (0.2)	6.3 (0.9)	6.0 (0.6)	4.7 (1.7)
1994	8.8 (1.7)	10.6 (1.0)	8.2 (0.2)	9.8 (0.7)	8.6 (0.6)	8.4 (1.5)
1997	8.7 (1.1)	8.6 (1.1)	8.7 (1.2)	9.6 (1.5)	7.0 (2.1)	9.4 (0.7)
1998	8.7 (0.6)	11.7 (1.7)	8.9 (1.6)	10.5 (0.3)	9.1 (1.2)	9.3 (1.2)

Table 8. Water retention at three different depths for unmanured and manured subplotsat each erosion level. Water content on a volume basis. Standard deviation.

	Water Retention					
	Erosion Level					
	Slight		Moderate		Severe	
Tension (cm H_2O)	no manure	manure	no manure	manure	no manure	manure
(0 - 15 cm)						
0	0.50 (0.01)	0.57 (0.04)	0.50 (0.05)	0.54 (0.04)	0.51 (0.03)	0.55 (0.05)
200	0.35 (0.01)	0.41 (0.04)	0.35 (0.02)	0.37 (0.06)	0.37 (0.02)	0.38 (0.06)
(15 - 30 cm)						
0	0.46 (0.01)	0.48 (0.02)	0.45 (0.02)	0.45 (0.02)	0.47 (0.02)	0.48 (0.02)
200	0.33 (0.02)	0.35 (0.03)	0.33 (0.01)	0.35 (0.01)	0.34 (0.02)	0.35 (0.03)
(30 - 45 cm)						
0	0.50 (0.02)	0.47 (0.02)	0.46 (0.02)	0.45 (0.02)	0.49 (0.01)	0.45 (0.01)
200	0.32 (0.02)	0.34 (0.01)	0.34 (0.02)	0.35 (0.01)	0.32 (0.02)	0.35 (0.01)

SUMMARY

Changes in soil physical properties, hydraulic properties in particular, from long-term manure applications to eroded soil seem to have helped to increase corn grain and stover yields. Although weather factors play a crucial role, these changes have been more noticeable in recent years. Humus formation in the soil is a long-term process. Therefore, a considerable period of time must pass for animal manure additions to have a marked impact on crop production of an eroded soil. For this reason, it is extremely important to minimize erosion in the first place and maintain the productivity potential of soil.

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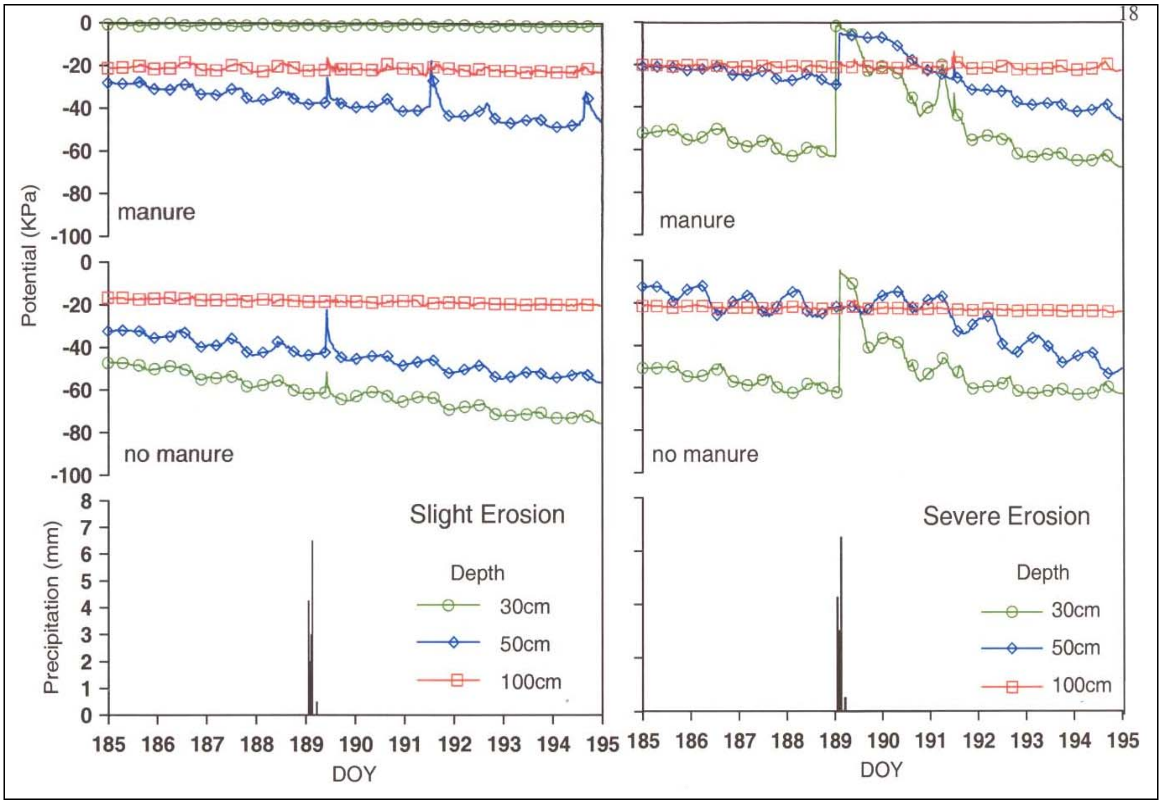

Figure 1. Tensiometric data for slight and severe erosion levels for a ten day period (early June) for the growing season of 1997. (DOY – day of the year).

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