Soil Addition to an Eroded Slope

L. E. Cowell and E. de Jong
Dept. Soil Science, University of Saskatchewan, Saskatoon

ABSTRACT

Soil was added at depths of 5, 10 and 15 cm to the eroded slope of a waterway in a farm field. Spring wheat yields were monitored over a three year period after soil addition. In the first and third year of the study, the added soil depths were split into unfertilized and fertilized (70 kg N ha^{-1} + 30 kg P_2O_5 ha^{-1}) treatments. Large yield increases were measured due to soil addition in the second and third year of the study, but only to the 5 cm depth. Examination of the data did not consistently indicate a main soil factor to cause the yield increase. Rather, it was probably the combined improvement of soil fertility and physical qualities which resulted in higher yields.

INTRODUCTION

Wind and water erosion has caused a rapid decline in the quality of many western Canadian prairie soils over the past century. Loss of topsoil results in a direct loss of soil nutrients and may also reduce crop yield due to soil structural problems and reduced water holding capacity. The relative impact of the deterioration of soil fertility and soil physical properties depends on the original topsoil and subsoil characteristics, and the extent of erosion. If a soil profile with good subsoil structural characteristics is eroded, the soil fertility will become the main limit to crop yield. Additions of fertilizer nutrients will often be sufficient to restore productive capacity of this type of eroded soil. In contrast, erosion of topsoil to expose a poor quality subsoil (e.g. a solonetzic profile) will cause a sharp reduction in potential crop yield. Restoration of soil quality is very difficult in this case, and a permanent reduction of potential crop yield occurs. These scenarios have been recognized and reviewed for a diversity of soils (Langdale and Shrader, 1982; Pierce et al, 1983; P.F.R.A., 1983)

Numerous studies have examined the importance of topsoil depth and erosion by either scalping topsoil to simulate erosion, or by adding topsoil to an eroded area. Both approaches have limitations. Scalping removes the entire topsoil whereas wind and water selectively remove the most erodible portion of the topsoil. Addition of topsoil assumes that the added soil is of the same quality of the eroded soil.

In a topsoil scalping study in Montana, crop yields were reduced by 9, 28 and 45% over 3 of 5 study years when 6, 12 and 18 cm of topsoil was removed (Tanaka and Aase, 1989). Application of nitrogen and phosphorus fertilizer to the eroded areas fully restored crop production in comparison to unfertilized, noneroded areas. During the other two years, when available water limited yield, the erosion treatments did not affect yield. A similar study in Alberta also showed fertilizer addition could completely restore yields of crops grown on artificially eroded soil except where erosion was very severe (Dormaar et al, 1986).

Data from a topsoil addition trial in Nebraska suggests crop yields were limited by both soil fertility and structural quality (Mielke and Schepper, 1986). A recent field experiment in Saskatchewan compared wheat yields over two years after additions of 5, 10, and 15 cm of topsoil from lower slopes to eroded upper slopes (Verity and Anderson, 1990). Replicated additions of fertilizer according to soil testing recommendations were added to a similar knoll in the same field. The addition of only 5 cm of topsoil sharply increased wheat yields in both years of the experiment. Fertilizer addition increased yield in only one year. It appeared that soil fertility was not the only factor limiting yield in the eroded soil.

Identification of the factors which limit crop yield on eroded soils is necessary for agronomists to provide recommendations to farmers for management and improvement of these soils. If fertility is the main limiting factor, additions of fertilizer nutrients will remedy the problem. If structural problems have developed with erosion, long-term changes in field management may be required. For example, the farmer may choose to incorporate additional crop residue, apply barnyard manure, or seed the eroded area to a permanent grass cover. In either case, attention to the sensitive areas in a field will limit the spread of erosion to larger areas.

SITE DESCRIPTION

The study site was the eroded slope of a waterway in a farm field near Saskatoon. This site has been described elsewhere as part of the 'Floral Basin' (Martz, 1986; de Jong and Martz, 1989). These previous studies affirmed that substantial erosion has occurred within the basin, with over 90% of the basin showing average net losses of soil at rates of 4 to 20 t/ha/yr, with only the upland depressions and the main channel receiving soil. The soil addition plots were set out on the south face of the main channel in the basin, near the border of the cultivated field and the grassed portion of the channel. The slope at this point along the channel is about 7%, and includes a convex and a concave face. Substantial deposits of water and wind eroded soil have accumulated in the channel and along a fenceline that cross the grassed channel. These areas served as a ready source of soil for the experiment, with the advantage that this soil was accumulated from eroded parts of the basin.

The soil in the vicinity of the plots is mapped as an Elstow loam. Soil profiles were described along transects before soil addition. Profile descriptions are available elsewhere (Cowell and de Jong, 1990). In general, the soil profile graded from a tilled Regosol on the upper part of the slope to a grass covered, deep Chernozem with an Ah horizon of 20 cm and a solum depth of 40 cm at the bottom of the channel.

MATERIALS AND METHODS

In preparation to move the soil from the bottom of the channel, the grass was sprayed with glyphosate and disked two weeks later. The soil was moved in October of 1989. A road scraper hauled soil from the depositional areas and placed it on the upper part of the slope. The plot area was restricted to the apparently eroded part of the slope and not the crest nor toe slope positions. A road grader leveled and packed the soil in the plots. Each plot measured 4 by 20 m. Soil depths were measured after grading, and subsamples were collected for analysis. The intended soils depths were 0, 5, 10, and 15 cm. The actual depths were 0, 6±0.9, 11.5±1.2, and 15.6±0.8 cm. The plots were tilled once after establishment.

The plots were set out in a RCB design with 3 blocks. The trial was maintained and harvested each year for 3 years (1990 to 1992). Spring wheat was used as the test crop. In the first and third crop year after plot establishment, the plots were divided into fertilized and unfertilized subplots. The fertilized treatments received 80 kg N/ha as urea and 30 kg P_2O_5/ha as ammonium phosphate. The phosphorus fertilizer was placed in the seed-row, and the nitrogen fertilizer was side-banded at seeding. In the second year, no fertilizer was applied, and the crop was harvested in the portion of the plot which received no fertilizer in the first year. Each year of crop yield data was compared separately within ANOVA tables to establish significant F values.

RESULTS

Available Soil Nutrients

The soil added to the plots had a fairly high available nutrient content (Table 1). In addition, mineralization of the grass residue which was added with the soil may have contributed to the available nutrient pool.

Table 1. Characteristics of topsoil added to the plots.

NO_3-N (ppm)	11
Available P (ppm)	25
Available K (ppm)	323
pH	7.7
Conductivity (ms/cm)	1.1

Available soil N and P was measured in soil collected before seeding each year (Table 2). According to general fertilizer recommendations for cereal crops, both N and P were sufficient in the first year. Available P in the 0-cm treatment may have been deficient in the second year. Both N and P appeared deficient for the third crop year.

Table 2. Available soil N and P in plots, measured before seeding or fertilization.

	Available nutrients (kg/ha)	
Depth of soil added (cm)	NO3-N (0-60 cm)	P (0-15 cm)
	First Year (1990)	
0	194	42
	Second Year (1991)	
0	125	28
5	143	36
10	176	51
15	211	63
	Third Year (1992)	
0	36	18
5	100	25
10	160	48
15	276	65

Crop Yield

There was no significant response to either added soil or fertilizer in the first crop year. A total of 193 mm of growing season precipitation was received, which is near the long-term average for the area. The overall grain yield was 1782 kg/ha, with a harvest index of 0.38 (Table 3).

Table 3. Grain and straw yield in the first crop year (1990).

Depth of soil added (cm)	Yield (kg/ha) Grain	Straw
0	1747	2857
5	1777	2787
10	1775	2941
15	1856	3079

Excellent growing conditions in the second crop year, with 325 mm of precipitation, produced grain yields well over 2000 kg/ha for most treatments. Topsoil additions sharply increased crop yield (Table 4). No fertilizer treatments were added to the plots in the second year. Most of the benefit from increased topsoil thickness occurred with the first 5 cm of topsoil, which increased grain yield by 62% over the control yield. The grain yield for the 15 cm topsoil addition was 83% higher than the control yield.

Table 4. Grain and straw yield in the second crop year (1991). Yield values followed by the same letter are not significantly different (Fisher PLSD for p = 0.10)

Depth of soil added (cm)	Yield (kg/ha) Grain	Straw
0	1332a	3118a
5	2160b	5235b
10	2399bc	6068c
15	2438c	6423c

Adequate and timely rainfall (145 mm) and cool temperatures during the third growing season produced good grain yields, with an average harvest index of 0.51. The fertilizer treatments were again added to the topsoil treatments in the third year of the experiment. However, a significant response to fertilizer was not detected; the overall fertilized grain yield was 2305 kg/ha, compared to 2241 kg/ha for the unfertilized yield. The topsoil additions did increase grain yield (Table 5). Grain yield increased 18% with 5 cm of soil addition, but further increments of topsoil thickness had little effect.

Table 5. Grain and straw yield in the third.crop year (1992). Yield values followed by the same letter are not significantly different (Fisher PLSD for p = 0.10)

Depth of soil added (cm)	Yield (kg/ha) Grain	Straw
0	1967a	3616a
5	2315b	4406b
10	2460b	4970b
15	2351b	4779b

DISCUSSION

Although topsoil addition had no effect on crop yield in the first year, crop yield was much higher in subsequent years where topsoil had been added to the eroded slope. The first 5 cm of topsoil addition had the greatest effect on crop yield. Further topsoil additions increased crop yield slightly in the second crop year, but not the in the third year.

The data does not conclusively indicate the main soil factor which caused yield increase. The soil tests indicated both N and P deficiencies in the control plots. Available soil N and P increased with thicker topsoil additions; this was most evident in the third crop year. However, N and P fertilizer additions in the first and third crop year did not detectably increase crop yield. It is unlikely that other nutrients limited yield. Potassium and sulphur are typically highly available in this type of soil. Zinc has been indicated as a possibly deficient micronutrient in eroded soil, but large responses to zinc have not been demonstrated for Chernozemic soils in Saskatchewan, except in conjunction with very high rates of P fertilizer.

Soil physical properties, including water holding capacity, may have contributed to higher crop yield. There were no severe subsoil constraints noted in sampling transects prior to adding the topsoil. Available soil water was not accounted for in all years. In the spring of the third year, total soil moisture to 60 cm totalled 13.5 cm in the control plot, and 15.9 cm where 15 cm of topsoil had been added. This may have partly accounted for the 384 kg/ha higher grain yield in the 15 cm topsoil treatment compared to the control plots. However, the lack of yield response in the first crop year seems to question any physical benefit due to the added topsoil.

CONCLUSIONS

The addition of 5 cm of topsoil onto an eroded slope sharply increased crop yields in a three year field experiment. Further increments in topsoil thickness had much less effect on crop yield.

It is likely the combined effects of better nutrition, improved water holding capacity, and a better rooting environment for plant growth combined to improve crop yield. These benefits proved difficult to replace with simple additions of N and P fertilizer. These results underscore the importance of topsoil quality, both in terms of fertility and physical quality.

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