RECLAMATION AND CROP GROWTH IN A DRASTICALLY DISTURBED PRIME FARMLAND SOIL IN THE MISSISSIPPI DELTA[1]

by

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Abstract. A prime farmland soil of the Alligator series (Vertic Haplaquept) was disturbed to a depth of 3.5 m to simulate surface mining. The spoil was replaced in five segregation treatments ranging from morphological restoration to complete mixing. Soybeans were grown in eight replications of each soil handling treatment under optimum fertility levels for three years. Soybean grain yields for three diverse growing seasons showed no statistical differences for any of the five soil segregation treatments. However, all the soil treatments increased soybean yields significantly ($p = 0.05$) and ranged from 50.8 to 64.2% above the yields of the undisturbed plots. Increased yields in the disturbed prime farmland soil are attributed to improved aeration, porosity and water holding relationships.

Additional Key Words: prime farmland restoration, Mississippi.

Introduction

About 22 percent of the estimated 22.5 billion short tons of strippable, near-surface lignite reserves in the Gulf Coast region is located in Mississippi (Hossner and O'Shay, 1985). Large areas in Mississippi were leased for potential lignite mining in recent years and mining plans were developed. Fertile prime farmlands comprised large areas of the leased lands. Detailed research on the effects of surface mining on the clayey, montmorillonitic, prime farmland soils of the Southern Mississippi Valley Alluvium (Delta) region had not been previously addressed, nor had a data base been established. This study was a cooperative effort with the Phillips Coal Company to determine the effects of drastic disturbance on productivity of a representative prime farmland soil of large proportionate extent in a potential lignite surface mining area in the Mississippi Delta.

Methods and Materials

Location

The study site was located in the northeast part of Quitman County, MS about 1.6 km northwest of the town of Sledge and 4.8 km east of the Coldwater River. The area has a humid, temperate climate with 220-260 freeze-free days and about 1200 mm precipitation. It was located about 51 m above mean sea level. Soil temperatures were in the thermic regime (15-22° C). The area was level with a slope of 0-1%. The site had been in row crops for the past 20 years, and it was in soybeans at the initiation of this study.

Soil

The soil at the study site was an Alligator clay which comprises significant acreage in the region. It was classified as very fine, montmorillonitic, acid, thermic, Vertic Haplaquept. These soils are poorly drained with gray, clayey A and B horizons. They are sticky and plastic when wet and firm when dry, and they have very slow permeability. The soils are locally referred to as gumbo soils. The high content of expansive montmorillonitic clay produces exten-

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sive shrinking and swelling which produce cracks in the summer that commonly attain widths of 8 to 10 cm.

Experimental Model

The model designed for the study consisted of a split plot design where whole plot treatments were two methods of land preparation (flat and hipped), and where subplot treatments were five soil segregation methods. Four plots (46.6 m long, 6.1 m wide, and 3.5 m deep) were spaced over the 3.3 ha parcel of Alligator clay soil which was leased for the study. Each subplot was 3.9 m wide by 6.1 m long to accommodate 4-row equipment on 0.9 m centers. The soil segregation treatments were as follows:

Control (C) - The control consisted of an unexcavated subplot in the same soil.

Treatment 1 (T1) - The A and B horizons were removed separately, segregated and replaced to a depth of 1.2 m in the same morphological position existing prior to disturbance over mixed materials. Total depth of cut was 3.5 m.

Treatment 2 (T2) - The A and B horizons were removed to a depth of 1.2 m, mixed and replaced over mixed materials. Total depth of cut was 3.5 m.

Treatment 3 (T3) - The A and B horizons were removed separately to a depth of 0.61 m, segregated and replaced in the same morphological position over mixed materials. Total depth of cut was 3.5 m.

Treatment 4 (T4) - Loamy material occurring at depths of 1.5 to 3.5 m was segregated and replaced to a depth of 1.2 m over mixed materials. Total depth of cut was 3.5 m.

Treatment 5 (T5) - The total cut was randomly mixed to a depth of 3.5 m.

Plot Construction

The plots were constructed by dragline with a 1.1 m^3 bucket and a small bulldozer in September and October, 1980. Plots were excavated to a depth of 3.5 m where the water table was encountered. The A and B horizons, and deeper loamy strata occurring at depths of 1.5 to 3.5 m were removed separately and segregated. The soil materials were replaced by dragline and allowed to overwinter before planting. Subplots were limed to bring them to similar pH levels according to soil tests.

Plot Preparation and Planting

1981 Season. Plant macronutrients (0-20-20) were applied at the rate of 224 kg/ha. Fritted micronutrients were applied at the rate of 224 kg/ha. Treflan (Trade name of Elanco Company), a pre-emergence herbicide, was applied for grass control. The fertilizer and herbicide were incorporated with a tiller. The tiller was also used to hip rows on half of the subplots. Bedford variety soybeans (*Glycine max* L.) were planted May 13, 1981. The seeds were inoculated with rhizobium and treated with molybdenum. Plants were thinned by hand after the stand was established to provide a uniform plant population of 19 to 25 plants per m of row length. Subplots were cultivated twice with a tiller during the growing season. Soybeans were harvested October 8 and threshed in a stationary rasp-type thresher.

1982 Season. Plant macronutrients (0-20-20) were applied at the rate of 224 kg/ha. Fritted micronutrients were applied at the rate of 156 kg/ha. Treflan was applied for grass control. The fertilizer and herbicide were incorporated with a tiller which was also used to hip rows on half of the subplots. Bedford variety soybeans were planted May 21, 1982. The seeds were inoculated with rhizobium and treated with molybdenum prior to planting. Subplots were cultivated twice with a tiller during the growing season. Soybeans were harvested October 26-27, 1982.

1983 Season. Fertilizer (0-24-24) was applied at the rate of 224 kg/ha and incorporated with a tiller which was used to hip rows on half of the subplots. Bedford variety soybeans were planted May 30, 1983. Seeds were inoculated with rhizobium and treated with molybdenum prior to planting. Subplots were cultivated twice with a tiller during the growing season. Soybeans were harvested October 27-28, 1983.

Yields and Statistical Analyses

Harvested soybeans were sieved to remove foreign matter. Seed moisture content was determined with a a Burrows moisture computer (Model 700) using 250 g of soybeans. Yields were expressed on the basis of 13% moisture level. Data were analyzed using the Rummage II-General Purpose Models Program, and a Univac 1100 computer.

Soil Analyses

Soil morphology at the study site was characterized in detail from excavated pits and auger holes prior to plot construction, and by auger samples after construction. Representative soil samples from major horizons were collected for laboratory characterization. Samples were air-dried and sieved to remove coarse fragments (> 2 mm). Particle size distribution was determined by the hydrometer method (Day, 1965) and sieving. Clay and silt fractions were separated by sieving and centrifugal sedimentation. They were analyzed via X-ray diffraction with a Norelco Geiger counter spectrometer using Cu K α radiation and a Ni filter.

Exchangeable cations were extracted in 1N neutral NH_4OAC and determined by atomic absorption spectrophotometry. Extractible acidity was determined by the barium chloride-triethanolamine method (Peech, 1965). Organic matter was determined by digestion in chromic acid (Allison, 1935). Exchangeable aluminum was determined by the methods of Yuan (1965). Soil pH was measured in water and in 1<u>N</u> KCl using a 1:1 soil-to-liquid ratio.

Soil bulk density was determined by the undisturbed core method (Blake, 1965).

Results and Discussion

Soil Properties

Soil structural development was generally confined to the surface cultivated horizon (Ap) and the upper part of the Bg subsoil horizon (Table 1). The soil was massive below these depths. Slickenslides which indicate shrinking-swelling actions in the soil were confined to the Ap and Bg horizons.

Table 1. Morphological Description of Representative Soil Pedon of Research Plots.

Horizon	Depth (cm)	Description
Ap	0-27	Gray (10YR 6/1) clay; weak fine granular structure; firm; plastic, sticky; few fine roots; strongly acid; abrupt smooth boundary.
Bg1	27-40	Gray (10YR 5/1) clay, common medium distinct yellowish brown (10YR 5/4) mottles; moderate medium angular blocky structure; very firm; plastic; common cracks ranging to 3 cm width that contain Ap material; strongly acid; gradual wavy boundary.
Bg2	40-160	Gray (10YR 5/1) clay; common medium distinct yellowish brown (10YR 5/4) mottles; massive parting to moderate medium angular blocky structure; firm; plastic; common medium slickenslides; slightly acid; gradual wavy boundary.
Cg	160-212	Gray (10YR 5/1) silty clay; few fine distinct light yellowish brown (10YR 6/4) mottles; massive; firm, plastic; few, fine white concretions; mildly alkaline; gradual wavy boundary.
2Cg1	212-300	Stratified gray (10YR 5/1) and yellowish brown (10YR 5/4) sandy loam with pockets of clay and loam; massive; slightly firm; common medium white firm detritus; mildly alkaline; gradual irregular boundary.
2Cg2	300-350	Stratified gray (10YR 5/1); olive gray (5Y 4/2), yellowish brown (10YR 5/4) clay loam with few fine distinct brownish yellow (10YR 6/8) mottles; massive; slightly firm; common white detritus; mildly alkaline.

Clay contents in the surface horizon (Ap) ranged from 65 to 48% over the study area with less than 20% sand and 30% silt. Sand and silt contents increased at depths below 120 cm. The upper clayey horizons were underlain by stratified loamy materials at depths below 166 cm. Representative soil particle size distribution of major horizons of the study site is presented in Table 2.

Table 2. Representative Soil Particle Size Distribution of Major Horizons Before Plot Construction.

Depth	Sand	Silt	Clay	Texture
cm		%		
0-37	9.1	25.7	65.2	Clay
37-155	25.0	27.9	52.6	Clay
155-232	36.6	24.3	39.1	Clay loam
232-325	70.4	17.1	10.5	Sandy loam

The soil was strongly acid in the upper sola before liming (Table 3). Extractible acidity decreased with depth. Cation exchange capacities were highest in the upper horizons reflecting the high content of montmorillonitic clay. Organic matter contents ranged from 2 to 3% and decreased rapidly below the surface horizon. High levels of exchangeable Ca and Mg occurred throughout the regolith (Table 4).

Table 3. Soil Chemical Characteristics of Representative Pedon Before Plot Construction.

Depth	pH	Organic Matter	Acidity	CEC*
cm		%	--cmol (+) kg^{-1}--	
0-27	5.2	2.5	10.6	40.7
27-40	5.1	0.6	7.3	37.3
40-160	6.1	0.5	3.9	49.3
160-212	7.5	0.1	1.4	40.1
212-350	7.7	0.1	1.8	27.9

*Cation Exchange Capacity

Table 4. Exchangeable Cations of Representative Pedons Before Plot Construction.

Depth	Ca	Mg	K	Na
cm		cmol (+) kg^{-1}		
0-27	20.2	8.7	0.8	0.4
27-40	16.6	11.7	0.6	1.1
40-160	27.4	13.7	0.5	3.7
160-212	18.6	15.8	0.5	3.8
212-350	16.8	8.0	0.5	0.9

The clay fractions were dominantly montmorillonite with lesser amounts of kaolinite, illite and vermiculite. Sand and silt fractions were dominantly siliceous with appreciable feldspar and mica contents. The white concretions or detritus present in the deeper loamy materials were comprised dominantly of dolomite.

Soil bulk density levels of the surface horizons ranged from 1.38 to 1.56 mg/m^3 before plot construction. Values decreased and were erratic for several months after construction which reflected the increase in macropores and temporal change. Bulk density values exhibited seasonal variations with lowest values occurring in the wetter winter months. Surface bulk density increased slightly after three cropping seasons (Table 5) as structural stability was approached. No compaction problems occurred. Highest values were in the T4 (loamy materials) and T5 (total mix) treatments which contained less clay, and more sand + silt than the other soil handling treatments.

Table 5. Soil Bulk Density of the Surface Horizon For Three Years After Plot Construction.

Treatment	Years After Construction 1	2	3
	---------mg/m³---------		
Control	1.13	1.20	1.28
T1	1.10	1.15	1.32
T2	1.20	1.17	1.24
T3	1.15	1.15	1.35
T4	1.29	1.24	1.43
T5	1.23	1.29	1.43

Plant Growth and Yields

Soybean plants in the soil handling treatment subplots germinated quicker than plants in control subplots. Plants in the soil handling treatments tended to be taller, and they had deeper, better developed root systems. The flat subplots generally had taller plants earlier in the season than did the hipped subplots. However, plants on the hipped subplots tended to attain similar heights as flat treatment plots as the growing season progressed. Bloom and pod-set periods were similar for the control and all treatments.

1981 Season. Meterological conditions during the growing season posed a severe test of the ability of the disturbed soil materials to support soybean plant growth. Although 270 mm of rain fell in May, the plants were too young to utilize much of the moisture. During the remainder of the growing season, monthly rainfall averaged about 50 mm. Ambient temperatures exceeded 37° C on numerous occasions resulting in soil temperatures exceeding 38° C in some of the subplots during August. Soil moisture in the surface horizons was low during the critical flowering and pod-set period of July 9-August 12.

The 1981 mean yields are presented in Table 6. All soil handling treatments in both flat and hipped methods of land preparation had significantly ($P = .05$) higher yields than the undisturbed control plots. There were no significant differences in yield between each of the soil handling treatments, nor was there a significant difference between flat and hipped land preparation treatments (Table 7). The mean yields of the soil handling treatments were about double the mean yields of the control subplots. No interaction among soil handling treatments was discernible. Yields in the control plots were similar to the average county soybean yields.

Table 6. Mean Soybean Yields and Statistical Relationships For Soil Handling Treatments, 1981 Season.

Treatment	Mean Yields
	kg/ha
T1	2,157 b
T2	2,271 b
T3	2,338 b
T4	2,593 b
T5	2,278 b
Control	1,176 a

($P = 0.05$)

Table 7. Mean Soybean Yields of Flat and Hipped Treatments and Statistical Relationships, 1981 Season.

Land Preparation Method	Mean Yields
	kg/ha
Flat	2,244 a
Hipped	2,029 a

($P = 0.05$)

1982 Season. Adequate rainfall and moderate temperatures during the growing season were conducive for high yields. August had 211 mm of precipitation which occurred during the critical bloom and pod-filling stages. Plants were generally shorter on the control subplots throughout the season. The 1982 soybean yields for all soil handling treatments were significantly higher ($P = 0.05$) than yields of the non-disturbed Alligator soil under similar levels of fertility, management, and growing conditions (Table 8). There were no significant differences in yield between each of the soil handling treatment subplots nor was there a significant difference between the flat and hipped land preparation treatments (Table 9). Less difference was noted in yields of the two land preparation methods in 1982 than occurred in the 1981 growing season. Average county yields were very similar to control subplot yields.

Table 8. Mean Soybean Yields and Statistical Relationships for Soil Handling Treatments, 1982 Season.

Treatment	Mean Yields
	kg/ha
T1	2,768 b
T2	2,674 b
T3	2,755 b
T4	2,701 b
T5	2,903 b
Control	2,345 a

($P = 0.05$)

Table 9. Mean Soybean Yields of Flat and Hipped Treatments and Statistical Relationships, 1982 Season.

Land Preparation Method	Mean Yields
	kg/ha
Flat	2,741 a
Hipped	2,640 a

($P = 0.05$)

1983 Season. Hot, dry weather during the bloom and pod-set period caused severe plant stress. The plots received less than 12.5 mm of precipitation during the month of August. High soil temperatures, low rainfall and soil moisture combined to promote poor pod set and development. The mean yields for the soil handling treatments were more than double that of the control plots (Table 10). The large yield differences were very impressive considering the severe drought during the growing season and the designation of 1983 as a crop disaster year for the study area. All the soil handling treatments in both flat and hipped methods of land preparation had significantly higher yields (P = 0.05) than undisturbed control subplots. There were no significant yield differences between each soil handling treatment, nor was there a significant difference between flat and hipped land preparation methods (Table 11). Control subplot yields were very similar to average county yields.

Table 10. Mean Soybean Yields and Statistical Relationships for Soil Handling Treatments, 1983 Season.

Treatment	Mean Yields
	kg/ha
T1	1,216 b
T2	1,176 b
T3	1,169 b
T4	1,337 b
T5	1,223 b
Control	537 a

(P = 0.05)

Table 11. Mean Soybean Yields of Flat and Hipped Treatments and Statistical Relationships, 1983 Season.

Land Preparation Method	Mean Yields
	kg/ha
Flat	1,135 a
Hipped	1,081 a

(P = 0.05)

Three Year Yield Relationships. Results of the three year study which had diverse climatic conditions are very decisive. All soil handling treatments increased soybean yields significantly (P = 0.05) from 50.8 to 64.2% above the yields of the undisturbed control plots. (Table 12). Yields of the control plots were very similar to local average yields of Quitman County. There were no significant differences between flat and hipped soil preparation treatments (Table 13).

Table 12. Mean Soybean Yields for the 1981, 1982 and 1983 Seasons and the Statistical Relationships.

Treatment	Mean Yields
	kg/ha
T1	2,157 b
T2	2,036 b
T3	2,089 b
T4	2,217 b
T5	2,130 b
Control	1,350 a

(P = 0.05)

Table 13. Mean Soybean Grain Yields of Flat and Hipped Land Preparation Treatment for the 1981, 1982 and 1983 seasons.

Land Preparation Methods	Mean Yields
	kg/ha
Flat	2,076 a
Hipped	1,915 a

(P = 0.05)

Conclusions

All soil handling treatments evaluated increased soybean yields significantly (P = 0.05) above yields of the non-disturbed Alligator soil under similar levels of fertility and management over three diverse growing seasons. Large yield increases resulted from drastic disturbance of the prime farmland soil in tests to simulate surface mining. There were no differences among the five soil handling treatments which ranged from morphological restoration to a total mix. One treatment was statistically as effective as another. No soil toxicities or adverse physical or chemical conditions resulted from the soil handling treatments. The increased yields are attributed to improved aeration, porosity and water relationships resulting from the drastic disturbance.

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