COMPACTION MEASUREMENT METHODS

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Abstract

Current reclamation practices include a variety of methods to reconstruct soils. The methods of excavation, transportation, and placement can affect the physical properties of the reconstructed soil. This is a major factor affecting crop performance. The relationship of compacted subsoils and poor crop performance has been identified, and deep tillage is used when compaction is suspected. Illinois researchers have investigated several methods to detect and quantify soil physical problems. Experience has shown that soil strength, as collected with the deep profile penetrometer, is the most efficient and reliable measure for reconstructed soils. A three dimensional view of the soil can be rapidly generated when this information is collected with a GPS database. Some mine operators are currently using soil strength to more efficiently prescribe the deep tillage, where needed, at the proper depths.

Introduction

Current reclamation practices include a variety of methods to reconstruct soils. The methods of excavation, transportation, and placement can affect the physical properties of the reconstructed soil. This is a major factor affecting crop performance (Jansen et al. 1985). The relationship of compacted subsoils and poor crop performance has been identified with deep tillage to relieve subsoil compaction and improve productivity, becoming an accepted practice in the industry. Deep tillage is commonly used in Illinois as the final step in the reclamation process for row-crop acres. The yield effects of tillage depth, reclamation methods, and time have been studied (Dunker et al. 1995; Hooks et al. 1992). In general, it has been concluded that productivity success is directly related to the physical condition of the soil or the level and extent of compaction. In the early years of Illinois reclamation research, it became apparent that, in addition to long-term yield testing, a more efficient method for evaluation of these soils was needed. Several parameters were considered and have been tested in varying degrees. A discussion considering advantages and limitations is presented in this paper.

Parameters Considered

Crop Performance

Annual crop yields have been measured since 1978 by Illinois researchers on various test plots and whole fields. Differences in yields are most dramatic in years of high moisture stress. In years of little stress, moderate, if any, yield differences can be measured. Hence, yield tests over several years are necessary to reliably detect a minesoil problem. Figure 1 illustrates this with yield differences between years within treatment sometimes greater than the differences between the compacted (Scraper) and a favorable (Wheel-Conveyor) minesoil.

Whole field yield comparisons (grain elevator weight ticket measurement) are easily tabulated but are only useful for a field to field comparison. Specific within field problem areas cannot be identified. GPS and yield monitors can be used to gather more specific information. Crop performance evaluations are subject to weather variability, and tests over time are required. Even then, it can be difficult to determine if yield differences are due to a soil problem, a management error, or a weather anomaly.

Visible Differences

Those who have been involved with monitoring crops during the growing season over time can attest to the fact that treatment or soil differences are easily detectable by plant moisture stress symptoms.

Signs of stress may occur for a long period of time or only a few days depending on the year. Symptoms may not be present in the early morning hours but are observable at midday. After long periods of stress, the symptoms remain through the night and are present in the morning. The plant response to soil differences is easily detected by

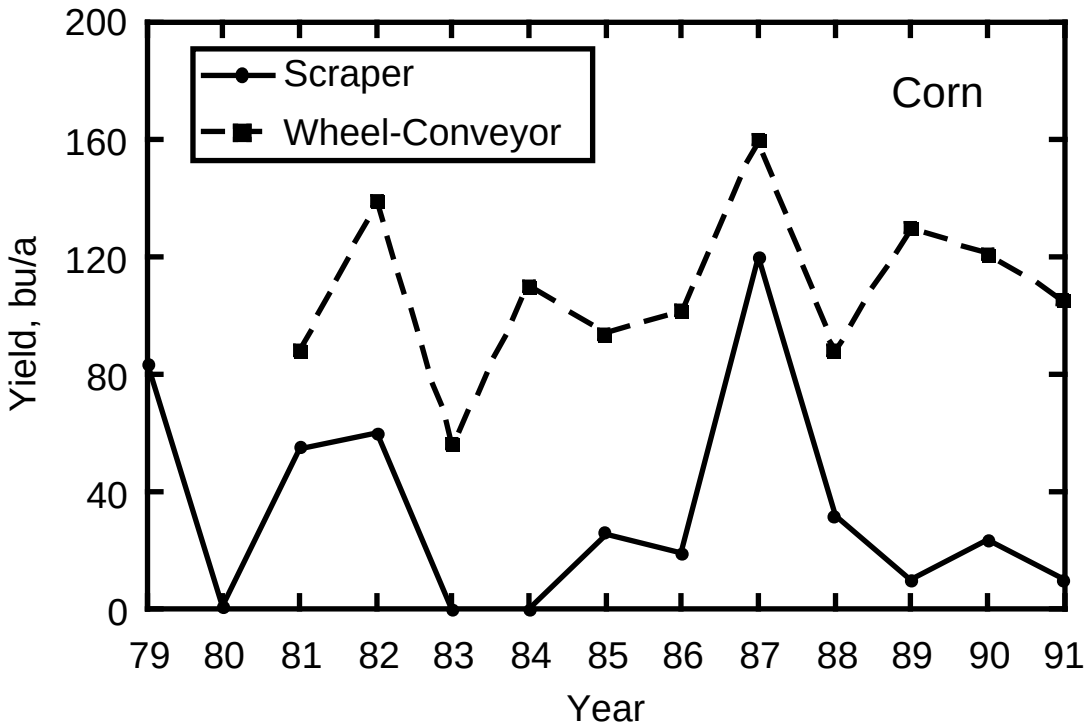

Figure 1. 1979 to 1991 Corn Yields: Compacted and Noncompacted Minesoils.

those who frequent the fields but it is difficult to quantify. The year, the time of year, and the time of day are critical to capture these observable differences. Well-timed visual and infrared aerial photography has been used by researchers for this purpose. Through digitization, this information can be quantified. Though costly and time consuming, differences can be measured and compared statistically. Canopy temperatures also were measured with a hand-held infrared thermometer (Thompson et al. 1984). This also generated measurable differences, but again the timing and the year were critical. With considerable effort and critical timing, observable differences can be measured. The quantification of visible differences is possible but it is impractical for the mine operator.

Soil Characteristics

A constant rate penetrometer was developed to serve the need to quantify physical properties of reconstructed soils (Hooks and Jansen 1986). Thompson (1987) studied the relationship of bulk density and soil strength to corn root length density on reclaimed soils. That study concluded that while both bulk density and soil strength correlated well with corn root length density, soil strength data was easier to collect in the numbers required to accurately assess reconstructed soils. Bulk density sampling by the core method is questionable on reclaimed soils, especially deep tilled soils. In some cases, there is a resultant fluff in the soil that may be as much as 20 inches. With this dramatic increase in macroporosity, percolation increases and the subsoil can be easily compressed. Another possibility is that the tillage shatters the subsoil but large peds of compacted material remain with large fissures and macropores between them. Some minesoils with bulk density levels higher than acceptable for natural soils are productive. Bulk density has proven to be an unreliable test across several minesoils. Figure 2 shows that there is a lack of correlation between bulk density and yield across several depths of tillage. The correlation of soil strength and yield from the same data set is significant (Figure 3).

The reliability of in situ soil strength measurements has been questioned (Mulqueen et al. 1977). Mulqueen also acknowledged the ease of sampling and suggested the measurement of moisture content. Perumpal (1983) presented a summary of many studies with the cone penetrometer. These studies relate the effects of moisture content, density, texture, and even organic matter to cone index. It appears that it is generally accepted that soil

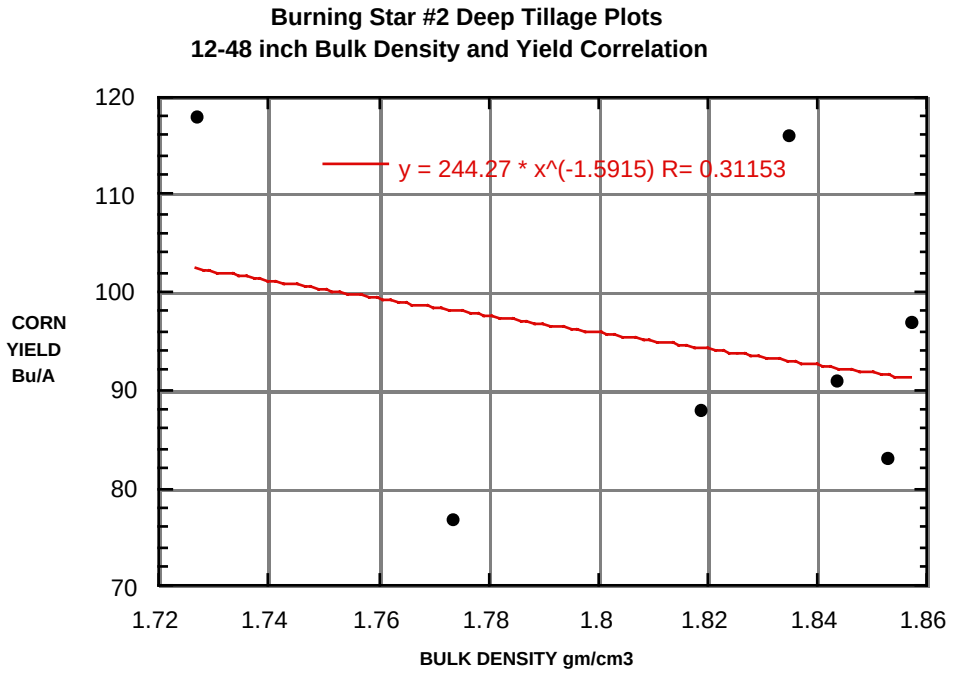

Figure 2. Subsoil Bulk Density vs 10 Year Corn Yield Means.

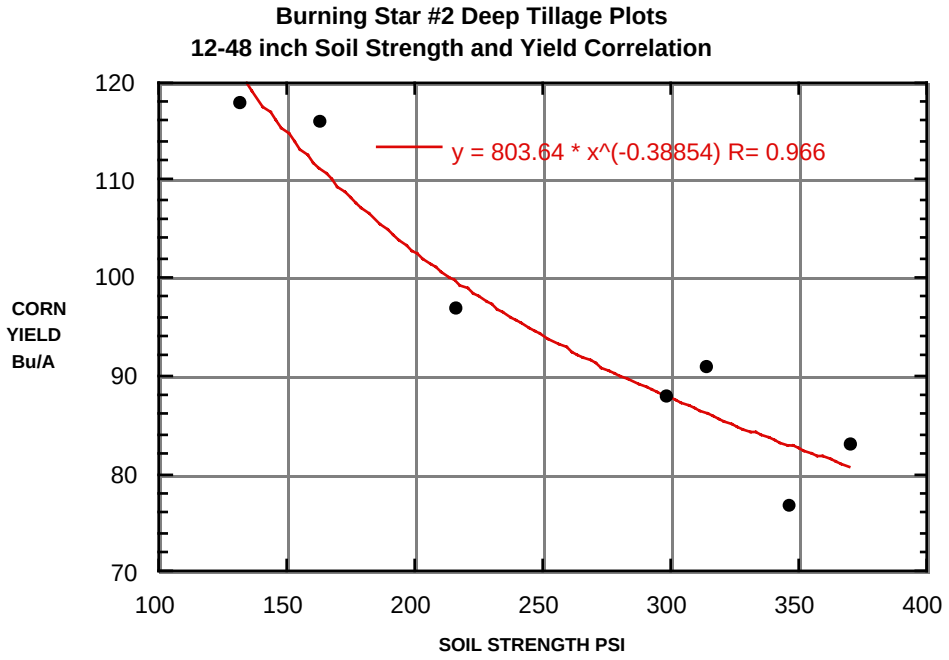

Figure 3. Subsoil Soil Strength vs 10 Year Corn Yield Means.

strength measurements are most reliable at or near field capacity. From an engineering or physical approach, soil strength is a true value that should be predictable with given values of moisture content, texture, density, etc. In this study, soil strength is approached as a relative value that is a composite of the effects of moisture content, texture,

density, etc. Moisture content is a major factor in soil strength when it is well below field capacity. However, when the data is collected in the spring, when soils are the most uniformly moist, minor differences in soil moisture between treatments are considered to be a reflection of the soil/environment interaction and a valid part of the composite value "soil strength."

Minesoil productivity is related to the level and extent of compaction. Soil strength can determine the level of compaction in PSI, which can be related to plant root penetration. Soil strengths above 300 PSI are highly restrictive to root growth and are an indication that a soil physical problem exists. The depth to a root limiting zone also can be determined, which relates to the available soil volume favorable for plant growth. When combined with a ground position database (GPS or surveyed) a three dimensional view of the reconstructed soil can be generated. This allows the identification of critical compaction levels, their extent, location, and depth in a field. The data is collected in real time with the computer and data acquisition system. Minimal effort and data manipulation is required to generate a three dimensional field compaction map. Figure 4 is an example for a 24 acre field on topsoil over wheel spoil. Depth "slices" were generated with 6 inch segment means. The west half of this field was deep tilled to 32 inches and the east half was not tilled. The 12 to 18 inch segment is just below the topsoil and indicates that the west side is uniformly favorable for plant root growth with PSI levels below 300. The east side is highly compacted and few roots will penetrate below this depth. The 24 to 30 inch segment indicates a similar distribution of compaction but excessive levels still exist on the east side. The 36 to 42 inch segment is below the depth of excessive compaction with fairly uniform PSI levels at 300 or less. This is below the depth of tillage on the west side and is typical of wheel construction with compaction below the topsoil to the depth affected by spoil grading. Compaction can be efficiently managed with this information that indicates the east half of the field is a problem area needing tillage to a depth not exceeding 36 inches.

Summary

Soil strength as measured with the deep profile penetrometer has proven to be the most efficient and useful parameter for the detection and evaluation of compaction.

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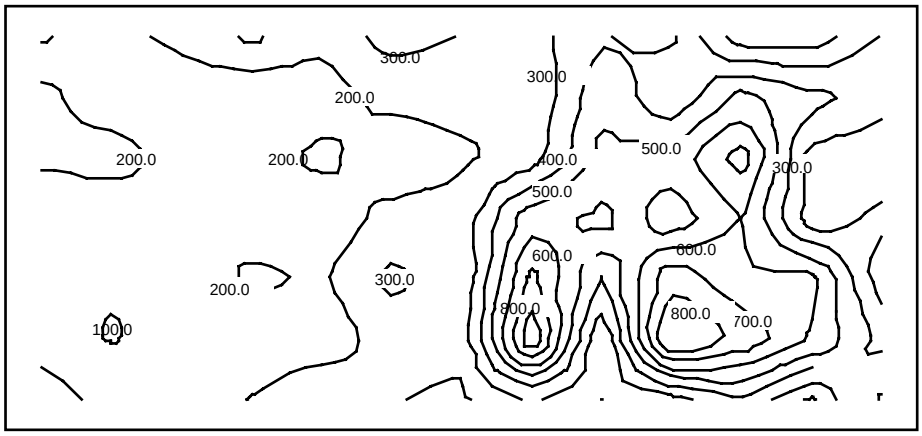
12 - 18 Inch Depth



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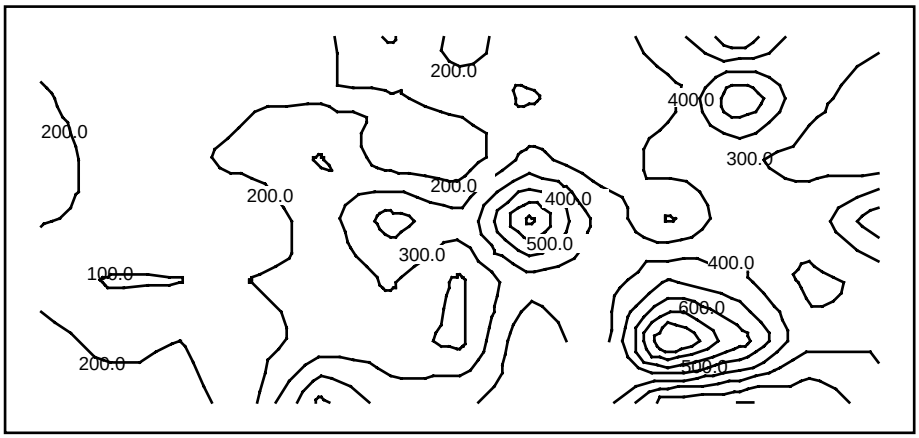

36 - 42 Inch Depth

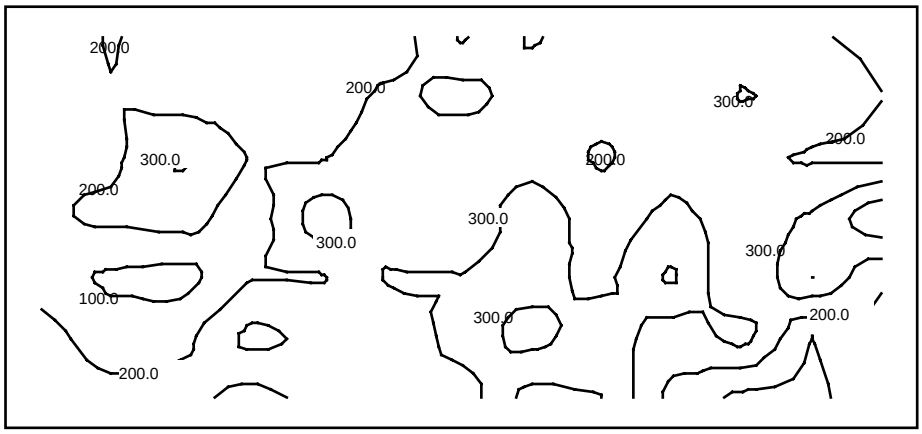

Figure 4. Soil Strength Depth Segment Contour Maps

EFFECT OF RECLAMATION METHOD ON MINESOIL PRODUCTIVITY IN ILLINOIS

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Abstract

Reclamation studies have shown that poor soil physical condition is the most limiting factor to successful row crop production on mined land. Critical to success are selection of the best available soil materials used in soil construction and a material handling method that will minimize compaction. Excellent corn and soybean yields have been achieved on low soil strength soils in high stress as well as low stress years. Total crop failures have occurred on high strength soils in years of weather stress. Deep tillage practices have been successful in improving compacted soils, but it is preferable to avoid compaction when the soil materials are handled. Soil strength measurements with a cone penetrometer have proven to be useful tools in evaluating rooting media and reclamation practices.

Introduction

This paper will report and summarize to date research work done by the University of Illinois concerning rowcrop response to various reclamation practices. Discussion of results will focus on reporting yield responses, observations, and summary to date from the Illinois work. There will be little attempt to distinguish between prime and non-prime farmland, even though prime farmland is addressed separately in federal legislation. The principles of reclamation for rowcrops and, to a large degree, the potential for success are quite similar for prime and non-prime farmland. Most prime farmland must by law be reclaimed to row crop capability, but not all row crop reclamation is on prime farmland.

Selection of Soil Materials

Segregation and replacement of horizons from the premine soils is a practice that is required by law under many conditions. Early reclamation research was focused on the evaluation and characterization of selected soil materials to be used for soil horizon replacement or substitution, if the substituted soil material could be shown to be as productive as the natural soil horizon it replaced. Construction of minesoils with good quality soil materials and desirable physical properties is essential to attaining productivity levels necessary for bond release.

Greenhouse evaluation revealed that replacement or alteration of the claypan subsoils of southern Illinois would increase crop growth by enhancing the chemical and physical properties of mined land (Dancer and Jansen, 1981; McSweeney et. al., 1981). Topsoil materials generally produced somewhat greater plant growth than did mixtures of B and C horizons, but the B and C horizon mixtures were commonly equal to or better than the B horizon materials alone. The natural subsoils of this region are quite strongly weathered and acid, or are natric and alkaline (Snarski et. al., 1981). The alternative material mixed in or substituted was generally much higher in bases than the acid soils and lower in sodium than the natric soils. Liming and fertilizing of the soil horizon material produced a good yield response and reduced the need for material substitution. McSweeney et al. (198 1) also got a favorable greenhouse response to blending of substratum materials with B horizon materials from the high quality Sable soils (Typic Haplaquolls) in western Illinois, This response to blending was less pronounced than that observed with materials from the Alfisols in southern Illinois.

Most of the Illinois research has centered around field experiments to evaluate row crop response to soil replacement and various reclamation practices. Premine soils ranged from the highly productive deep loess soils developed under prairie vegetation (Mollisols) at the western Illinois sites to the lighter colored, more strongly developed Alfisols at the southern Illinois sites. Corn (*Zea mays* L.) and soybeans *(Glycine max* (L.) Merr) were grown on these newly constructed soils to evaluate productivity. Following up on the greenhouse studies, most of the early field studies addressed the issue of topsoil and subsoil horizon replacement.

Topsoil replacement has generally been beneficial for seedbed preparation, stand establishment, and early season growth when compared to graded spoil materials (Jansen and Dancer, 198 1). Yield response to topsoil replacement has ranged from strongly positive to strongly negative. At the Norris Mine in western Illinois, scraper placement of 18 in, of dark prairie topsoil over graded wheel spoil resulted in a significant positive corn yield response in three of four years with irrigation and two of four when not irrigated (Table 1). Soybeans responded favorably to topsoil in one of the two years studied (Dunker and Jansen, 1987a). Significant negative yield responses to topsoil occurred in years of weather stress. Year to year variation in corn yield was considerably greater on the tmirrigated topsoil than the umrrigated wheel spoil. Compaction caused by the use of scrapers to replace topsoil is assumed to be the reason for low topsoil yields in years of weather stress. The zone directly below the topsoil has a bulk density of 1.7 to 1.9 Mg m3 and very low hydraulic conductivity.

Table 1. Corn yields in response to irrigation and topsoiling at Norris Mine in western Illinois.

Treatment	1979 bu/ac	1980 bu/ac	1981 bu/ac	1983 bu/ac	Mean bu/ac
Irrigated Topsoil/Wheel Spoil	191 a	166 a	175 a	193 a	181 a
Unirrigated Topsoil/Wheel Spoil	155 b	70 d	165 a	20 c	102 c
Irrigated Wheel Spoil	142 b	144 b	105 b	169 a	140 b
Unirrigated Wheel Spoil	100 c	89 c	109 b	70 b	92 d
Undisturbed Sable soil	156 b	124 b	173 a	70 b	131 b

Values followed by the same letter within a column are not significantly different at the 0.05 level.

At the Norris topsoil wedge experiment, A horizon material was replaced over wheel spoil by scrapers in thickness ranging from 0 to 24 in. There was a significant positive yield response to increasing topsoil thickness for corn, but not for soybeans. Year by year results showed positive relationships to topsoil thickness in years of favorable weather, but negative responses in years of moisture and temperature stress (Jansen et al., 1985).

At Sunspot Mine, in western Illinois, topsoil and B horizon replaced over dragline spoil was evaluated over an eight year period. Soil treatments consisted of 15 in. of topsoil replaced over replaced B horizon; 15 in. of topsoil replaced directly over dragline spoil; 36 in. of B horizon replaced directly over dragline spoil; and dragline spoil only. Bulldozers pushed the soil materials onto the plot areas; it is important to note that scrapers were never allowed directly on the plots at any time during construction. An undisturbed tract of Clarksdale soil (Udollic Ochraqualf) was used as an unmined comparison. Topsoil replacement resulted in significantly higher corn yields in four out of eight years when replaced over B horizon materials and six of eight years when topsoil was replaced directly over dragline spoil (Dunker and Jansen, 1987b). Corn grown on the topsoil replaced treatments had a higher percent stand at harvest, fewer barren stalks, and a higher shelling percentage than corn on the non-topsoil treatments. Soybean yields on the topsoil replaced treatments were significantly higher than yields from both non-topsoil treatments in six of seven years, The topsoil/B horizon treatment produced corn yields comparable to the undisturbed Clarksdale in five of seven years while the B horizon treatment without topsoil produced corn yields comparable to the undisturbed in only one year, The dragline spoil was unable to equal corn tmdisturbed Clarksdale yields in any of the years studied, regardless of topsoil placement (Table 2). Fehrenbacher et al., (1982)

Table 2. 198 l-86 average corn and soybean yields in response to topsoil and subsoil replacement at Sunspot Mine in western Illinois.

Treatment	Soybeans bu/ac	Corn bu/ac
Topsoil/B Horizon	36 b	130 a
Topsoil/Dragline Spoil	31 c	110 b
B Horizon only	27 d	86 c
Dragline Spoil only	17 e	65 d
Undisturbed Clarksdale soil	40 a	135 a

Values followed by the same letter within a column are not significantly different at the 0.05 level.

found that corn roots penetrated significantly deeper in the B horizon materials than the dragline spoil and that bulk densities were significantly higher in the graded dragline spoil than the replaced B horizon at depths of 22 in. and deeper. Bulk densities between the B horizon material and the undisturbed Clarksdale were similar. It is not possible to determine whether the favorable response to the B horizon treatment was due to the B horizon material or to the lower soil strength that resulted from the careful handling.

Response to soil horizon replacement in southern Illinois has been less dramatic than has been observed at the western Illinois sites (Table 3). This is understandable considering that A horizons are more highly weathered and average 8 to 9 inches in depth compared to 15 to 18 inches in the highly productive western Illinois soils. At River King in southern Illinois, topsoil replaced by scrapers over wheel spoil significantly increased corn yields in only one of eight years and soybeans in three of six. Row crop yields were lower than productivity goals and soil physical problems became suspect.

Table 3. 1978-85 average corn and soybean yields in response to topsoil and subsoil replacement at River King Mine in southern Illinois.

Treatment	Soybeans bu/ac	corn bu/ac
Scraper Placed Topsoil/Wheel Spoil	18 a	54 a
Wheel Spoil only	13 b	52 a
Scraper Placed Topsoil & Root Media	13 b	33 b

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Soil horizon replacement and thickness of soil materials from southern Illinois has been studied at the Captain Mine where the natural soils have chemical and physical problems that limit productivity. The Captain wedge experiment was used to evaluate corn and soybean yield response to thickness of scraper placed rooting medium (0 to 48 in. thick) over graded cast overburden, with and without topsoil replaced. Yields of both corn and soybeans increased with increasing thickness of hauled material to about the 24 to 30 in. depth. Meyer (1983) found very few roots below the 24 in. depth and found that roots in the subsoil were largely confined to desiccation cracks. The subsoil physical condition can best be described as compact and massive with very high bulk density levels and poor water infiltration. Soybean yields on the scraper placed root medium with and without topsoil were significantly lower than a nearby undisturbed tract in all seven years of the study. Corn yields were comparable to the undisturbed site in three of the years that can be characterized as low stress years (Table 4).

Table 4. 1979-86 average corn and soybean yields in response to scraper placed topsoil and root media replacement at Captain Mine in southern Illinois.

Treatment	Soybeans bu/ac	Corn bu/ac
Scraper Topsoil/Scraper Placed Root Media	13 b	33 b
Scraper Placed Root Media only	12 b	38 b
Undisturbed Cisne/Stoy soil	27 a	70 a

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Soil Physical Properties

Poor soil physical condition has proven to be the most severe and difficult limiting factor in the reclamation of many prime farmland soils. Indorante et al. (1981) in a comparison of mined and unmined land in southern Illinois, reported that reconstructed mine soils studied had higher bulk densities and they lacked any notable soil structure. Natural improvement in compacted mine soils is a slow process, Thomas and Jansen (1985) studied soil development in eight mine spoils ranging in age from 5 to 64 years looking at physical, chemical, and

micromorphological properties. All eight minesoils showed some evidence of soil development, but depth of structure development ranged from only 1.5 in. at the 5 year old site to 14 in. at a 55 year old site. No evidence of clay translocation attributable to soil development was found. Color and texture pattern changes were determined to be a result of the mixing of materials rather than developmental processes.

Illinois has an abundance of high quality soil materials to use for soil construction, and row crop success on mine land has been as dependent upon the method by which soil horizons have been excavated and replaced as the quality of soil materials selected. Excellent corn and soybean yields have been achieved on low soil strength soils in high stress as well as low stress years, Soil horizon segregation and replacement in Illinois has generally shown a moderate positive yield response in most cases; however, the soil physical condition that is established during soil construction is clearly a more significant concern (Jansen and Dancer, 1981).

McSweeney and Jansen (1984) studied the soil structure patterns and rooting behavior of corn in constructed soils. On a site that received extensive grading of the subsoil, the subsoil was severely compacted and massive. Root penetration into these subsoils was extensively horizontal instead of the normal vertical direction. Cross sections of the roots were noticeably flattened and compressed. McSweeney described a "fritted" soil structure in areas where soil materials were handled by a mining wheel-conveyor-spreader system where only minimal grading is necessary. Fritted structure was defined as an artificial soil structure consisting of rounded loose aggregates formed by the action of the wheel excavator and the subsequent tumbling at each drop point on the conveyor system. The soil conveyor system resulted in a low strength soil high in macropores. Although subject to compaction at the upper surface, the extensive void spaces between aggregates allow for excellent root penetration. Four year average corn and soybean yields on these plots with well developed fritted structure were equal to or better than yields obtained on nearby natural soils (McSweeney et al., 1987). By contrast, corn and soybean yields from a nearby set of plots with root media replaced entirely by scrapers were unable to produce comparable yields to the undisturbed soil in any of these four years. The rooting materials for both experiments were similar with the major difference being in the way the soil materials were replaced.

The Captain Mix Plots, constructed using the wheel-conveyor-spreader, were designed to follow up a series of greenhouse experiments which began in 1977. Greenhouse evaluation revealed that alteration of the claypan soils in southern Illinois would increase crop growth by enhancing the chemical and physical properties of the reclaimed land. The Captain Mix Plots consist of several treatments that are composed of differents depth mixes of the original soil profile replaced by the conveyor-spreader. Excellent corn and soybean yields have resulted on these low strength soils in high stress as well as low stress years. Penetrometer data from the Mix Plots reflect the excellent physical condition resulting from placing rooting materials with the wheel-conveyor system (Table 5). Rowcrop yields comparable to those obtained on nearby undisturbed soils were achieved in all eleven years of this study (Dunker et al., 1992). Topsoil replaced with the soil spreader on these plots only infrequently produced any significant yield response (Table 6).

Table 5. Mean penetrometer resistance values for soil treatments constructed with wheel-conveyor-spreader on the Captain Mix Plots.

Treatment	**9-18" Depth**	**18-27" Depth**	**27-36" Depth**	**36-44" Depth**
	PSI	**PSI**	**PSI**	**PSI**
Topsoil/3 'Mix	179 abc	97 d	77b	98 b
Topsoil/10' Mix	183 ab	136 bc	91 b	96b
Topsoil/15' Mix	210 a	161 ab	125 a	111 ab
Topsoil/20' Mix	219 a	176 a	117a	108 ab
10' Mix	135 c	103 b	100 ab	170 a
20' Mix	121 c	110 cd	101 ab	112 ab

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Table 6. 198 l-9 1 average corn and soybean yields in response to soil treatments constructed with wheel-conveyor-spreader at Captain Mine in southern Illinois.

Treatment	Soybeans bu/ac	corn bu/ac
Topsoil/3' Mix	29 a	113 a
Topsoil/10' Mix	27 ab	109 a
Topsoil/15 Mix	27 ab	111 a
Topsoil/20' Mix	27 ab	98 b
10' Mix	24 b	100 b
20' Mix	25 ab	102 b
Undisturbed Cisne/Stoy soil	27 ab	112a

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Although the mining wheel-conveyor-spreader system proved successful in constructing productive soils after surface mining, it does not offer a generally applicable solution to the problem of restoring land to agricultural productivity after mining. It is a very inflexible system which can not be used at most mine sites. Evident options are to either develop a method by which excessively compacted soils can be ameliorated to a significant depth or to develop other material handling options which will produce soils with good physical characteristics and will be more cost competitive and applicable than the conveyor system.

As an alternative to the wheel-conveyor system, corn and soybean response to mine soil construction with rear-dump trucks and scraper pans was studied from 1985-91 at the Denmark Mine in southern Illinois (Hooks et al., 1992). Two truck-hauled treatments, one which limited truck traffic to the spoil base only, and one which allowed truck traffic on the rooting media as it was placed were evaluated. A third treatment consisting of entirely scraper hauled rooting media was included. The rooting media was comprised primarily of the B horizon of the natural unmined soil and all treatments had 8 inches of topsoil replaced on the rooting media using dozers to prevent wheel traffic compaction. Significant differences in soil strength, a measure of soil compaction, and rowcrop yields were observed among treatments over the five year period. The lowest soil strength and highest rowcrop yields occurred on the truck without traffic treatment. Soil strength and yield response were similar for both the truck with surface traffic and the scraper treatments (Table 7 and Table 8).

Table 7. Mean penetrometer resistance values for soil treatments on the Denmark Plots.

Treatment	9-18" Depth PSI	18-27" Depth PSI	27-36" Depth PSI	36-44" Depth PSI
Truck Placed Root Media w/o Traffic	182 b	189 b	161 b	172 b
Truck Placed Root Media with Traffic	223 ab	227 ab	213 ab	217 ab
Scraper Placed Root Media	272 a	275 a	258 a	258 a

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Table 8. 1985-91 average corn and soybean yields in response to rear-dump truck placed and scraper placed root media at Denmark Mine in southern Illinois.

Treatment	Soybeans bu/ac	Corn bu/ac
Truck Placed Root Media w/o Traffic	20 b	99 a
Truck Placed Root Media with Traffic	16 c	71 b
Scraper Placed Root Media	16 c	63 b
Undisturbed Cisne/Stoy soil	26 a	103 a

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Severe compaction and compacted interfaces between soil layers have proven to be major problems which can limit the productivity of reclaimed soils. A truck handling system, which handles both topsoil and subsoil in one operation, was evaluated at Cedar Creek Mine in western Illinois from 1992-94. During plot construction, each rear-dump truck was loaded with the equivalent of 36 in. of subsoil and 12 in. of topsoil on top of the load. Subsoil and topsoil dumped in one operation eliminated the need for topsoil replacement by scapers. Some mixing of the topsoil and subsoil occurred but the majority of topsoil remained at the soil surface. Thin lenses of topsoil extended into the subsoil material. These lenses could actually encourage root exploration into the subsoil below. Two other treatments, one being rear-dump truck placed subsoil with scraper placed topsoil and the other rear-dump truck placed subsoil without topsoil, were included in the evaluation. Penetometer resistance data collected in 1994 indicated that wheel traffic from the use of scrapers to replace topsoil had a negative impact on the underlying placed subsoil. Soil strength values increased due to scraper traffic by 82% over that of the one operation rear-dump system. The 1992-94 mean yields indicate the system using rear-dump trucks to simultaneously replace both rooting media and topsoil is superior to using scrapers to replace topsoil over hauled rooting media. Results also show a significant response to topsoil replacement using this system (Table 9).

Table 9. 1992-94 average corn yields in response to rear-dump truck placed root media and topsoil and scraper placed topsoil at Cedar Creek Mine in western Illinois.

Treatment	**Corn bu/ac**
Truck Placed Root Media with Topsoil	159 a
Scraper Placed Topsoil over Truck Placed Root Media	131 b
Truck Placed Root Media w/o Topsoil	**130 b**

Values followed by the same letter within a column are not significantly different at the 0.05 level.

Thompson et al. (1987) used root length and root length densities to evaluate how bulk densities and soil strength values are predictors of root system performance. Because root restriction is generally the factor most important in limiting crop performance in mine soils, determining the suitability of soils for root system development could be a useful method of evaluating reclaimed soils. Soil strength was evaluated with the use of a constant rate recording cone penetrometer developed by Hooks and Jansen (1986). Results indicate that both penetrometer resistance and bulk density are useful predictors of root system performance in soils. They are especially useful in predicting root extension into deeper regions of the root zone. Penetrometer resistance and bulk density were highly correlated in the lower root zone, but poorly correlated nearer the soil surface.

Penetrometer data has proven useful for evaluating the soil strength effects of several reconstruction methods, of high traffic lanes on reclaimed areas, and of tillage methods for alleviating compaction (Vance et al., 1987). Soil strength values decreased with decreasing traffic. Scraper soil material handling systems produced the highest soil strengths; soils from truck-haul systems were intermediate; and soils built by a wheel-conveyor-spreader system had the lowest soil strength.

The relationship between soil strength levels measured with a recording cone penetrometer and five-year corn and soybean yields of four reclamation methods was studied at two mine sites in southern Illinois (Vance et al., 1992). Reclamation treatments included the wheel-conveyor system, truck-hauled root media with and without surface traffic, and a scraper-hauled rooting media system. Penetrometer measurements have resulted in wide ranging values between reclamation treatments and corresponding wide ranging values in crop yield. Correlation of penetrometer resistance with crop yield has been significant within most years for both corn and soybeans. Reclamation treatments with the highest soil strength had the lowest yields; those with the lowest soil strength had the highest yields. Average soil strength over the 9 to 44 in. profile depth was highly correlated with five-year mean yields across reclamation treatments.

Summary

In summary, results from the Illinois work shows that achieving mine land productivity is possible if reclamation plans are designed to minimize compaction, use good quality soil materials, and use high management levels (herbicides, fertility, adapted crop varieties) in rowcrop production. Illinois has an abundance of high quality materials to use for soil construction and row crop success on mined land has been dependent upon the method by which soil horizons have been replaced and the quality of the materials selected. Excellent corn and soybean yields have been achieved on low strength soils in high stress as well as low stress years. However crop failures have occurred when reclamation methods result in mine soils with high soil strength. Truck handling of rooting media with limited surface traffic has resulted in a more productive and less compacted soil compared to a high traffic scraper haul system for replacing root media. Compaction may be unavoidable in some reclamation systems. Illinois has continued deep tillage studies since 1984 to address this issue.

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SMALL MINES AND FUTURE TECHNIQUES

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Abstract

Many of the remaining surface mineable coal reserves of the Midwest are located in small non-continuous arms (“pods"). In order to economically recover these resources while providing for proper reclamation, it will take innovative approaches that incorporate many factors. Some of these include planning in the property control; forethought in the permitting process with regards to soil handling land uses, drainage control, blending to unaffected areas, etc.; engineered mine plans that incorporate the overall reclamation requirements; and flexibility/understanding by the regulatory agencies.

Introduction

Black Beauty Coal Company started mining in the late seventies on both small and mid-sized reserve blocks consisting mostly ofleased property on prime farmland. Over the yeas, activities have taken place at more than 40 locations using both Company mining and Contract mining. Many of these mines have been made up of small noncontinuous mining areas (pods). In most cases these pods are defined by topographic ridges with multiple landowners where the coal subcrops on three or four sides. Each area is divided into various land units (landowner/soil capability/land use). Prime farmland/cropland at 0% - 5% slopes will lie along the top and sides of the ridge. This then transitions to less capable soils (cropland, pasture, or forest/wildlife) at the edges (6% - 15%), then on into the subcrop that includes highly eroded upland drainage ways (noncropland capable/pasture, forest, or wildlife) where the soil depths are shallow and slopes are steep (15% - 30%).

Pod mining is particulary challenging in that it involves all of the details of area mining then adds the intricacies of multiple land units (landowner/land capability/land use) all within a much smaller reserve base. Given the small reserve base, cost control measures are extremely important. This not only affects the mining method but also involves all other aspects of the mining process, i.e., land leasing, permitting, mine operations, reclamation, and bond release.

Property Control

In pod mine situations, property is usually not owned since the mining is relatively short-lived and the landowner usually wishes to retain ownership. Land is normally controlled under some lease agreement where the landowner is compensated for coal mined and temporary loss of the use of land. In evaluating this cost, companies must keep in mind not only the area to be mined but also the support area required (basins, diversions, stockpiles, roads, etc.) since support and mined land is treated (regulatorily) the same. Regarding reclamation and prime farmland, the lease needs to specifically address post-mine land use comments (changes that the landowner may want to see in the permit) and farming arrangements. Once all the property is controlled to support the mining of the pod, considerable planning must go into how the different properties interact. This will include pre-mine vs. post-mine considerations for drainage, erosion control, field layouts, and property access.

Engineering/Permitting

From a reclamation standpoint, the areas of engineering/permitting for which pod mines are especially sensitive include soils, contours and land units (landowner, land capability, and land use).

Soils

Pod mines will usually run along ridges where soil types will start with prime farmland (0%-5 %) at the top and sides, then go to less capable soils (6% - 15%) at the edges, and end up at the sub-crop with highly eroded steep slopes (15% - 30%). Once the various soil capabilities are mapped (SCS soils map), existing soil quantifies and qualifies must be evaluated for the areas to be mined. At this point it must be fully understood that the area will not be mined or reclaimed according to the Soils map but that with planning, the overall capability of the affected land will be improved. Given this understanding a plan must be prepared that permits mixing of various soils, provides flexibility in soil handling and allows for the use of soil substitutes.

Soil mixes/substitutes and rooting media may include the original B horizon, a prime, B/C horizon mix, or a non-prime A/B horizon mix. The goal is to use the best rooting media available (within reasonable time and distance constraints) for all the areas to be reclaimed. In most cases there will be a sufficient amount of prime B/C horizon mix to provide all the rooting media for prime and non-prime areas. If a limited amount of higher quality roofing media exists, the better material should concentrated in areas to be reclaimed as prime; areas to be reclaimed to a lesser capability should receive lesser qualifies/quantities. As to soil replacement, as much area as possible should be replacedto prime standards. This will allow for much more flexibility in the post mine land unit placement. This also holds tree for post mine contours.

As to soil handling the permit must allow for removaland placement of soils in a very flexible manner. The plan should allow for disposal of poorer quality rooting media to allow for the use of better. It should also provide for a timing variance when better materials lie ahead of the current mining strips. (This may take added bond to satisfy the regulatory authorities.) The permit needs to allow for loading of upper soil horizons from within the pit and should also allow for removal of B and C horizon benches where a rooting media mix has been approved. The permit should address minimal stockpiling of rooting media in lieu of direct resoiling.

Contours

The permit needs to include planning for swell of mined areas, filling of highly eroded drainage ways, and blending to surrounding unaffected property. A balance must be kept for the various post-mine capabilities. In most cases, post-mine contours can be constructed that allow for maximizing prime farmland slopes while still maintaining pre-mine drainage patterns. These contours can also be planned to provide flexibility in the placement of post-mine land units.

Land Units

As noted earlier, land units are made up of three categories: landowner, land capability, and land use. These three categories thoroughly describe a piece of property. For each landowner there will be various land capabilities (prime, high capacity-Illinois, non-cropland/alt. topsoil) and various land uses (cropland, pasture, wildlife, forest, water, residential, roads and industrial). This gives up to 24 possibilities per landowner and with multiple landowners leadsto a very complicated set of data. These pre-mine land units are not geometrically uniform. Instead, they look like a jigsaw puzzle (the Soils map). In the pre-mine situation, landowners do not manage these land units as such - they square the field and take the average. In the post-mine state, the regulations require a separation of these land units by landowner and separate management as to revegetation and bond release requirements. As such, in the permitting process the land units must be precisely quantified.

Operations

Leasing and engineering/permitting provide much of the directions. Operations is where the product is made. One cannot function without the other.

Spoil Placement

The pre-mining condition of many pod areas includes highly eroded drainage ways along the edges. As mining starts at the box-cut then progresses along the ridge, it will begin at, then pass through, many of these draws. During mining and reclamation, these highlyeroded areas can be filled, flattened, and blended, then prepared for use in the post mine planned erosion control. These filled areas can also provide flexibility in the post-mine land unit locations. As with soil depths, post-mine contours should be planned to provide as much prime farmland as possible. Thiswill provide for both increased land unit flexibility and reduced erosion control problems/costs. One drawback with increased amounts of prime farmland slope is that the overall slope-length may increase. Regarding prime slopes, these need to be in the 2% - 3% range if at all possible. This will provide for both drainage and moisture retention and allow for settlement without having excessive wet areas. Final grades should always be established in the spoil material to minimize traffic and grading in the rooting media. This will also give a better overall grade and smoother transitions.

Soils Handling

Handlingshould occur such that the best soils are used for the entire mined areal. This may cause periods of increased graded spoil area but will be balanced by a better final product. Soils should be removed and placed such that compaction is minimized regardless of the post mine capability. Compaction reduction is accomplished by reducing traffic over the rooting media and grading the

materials during more favorable conditions. Traffic and grading on the rooting media is reduced by starting with the proper spoil grade.

Reclamation

Reclamation begins during operations. The final grade, soil handling, soil quantities, and soil quality will dictate the efforts required during reclamation.

Planned Erosion Control

Final grade should be planned to accommodate erosion control that compliments the field layouts. Erosion control begins where water initially meets the soil. Erosion is most easily controlled here. Once water is concentrated it becomes harder and more costly to control its affects. In nearly all cases it is best to intercept the flow in holding areas then convey it in a nonerodable material to its outfall point. The use of parallel tile outlet terraces and dry dams is highly recommended. One drawback to these is that under some state regulations terraces must be directed to sediment basins (increased amount of pipe). This seems odd since properly designed terraces have a greater standard retention time and a larger sediment holding capacity than sediment basins.

Revegetation

This is a process that starts with initial reseeding for erosion control, moves through the productivity stage, and ends in final bond release. Given the number and variety of land units and different requirements for each, considerable detailed management must be undertaken. Again, this is a process where the soil fertility and structure is developed, vegetative cover is established, and crop productivity is proven.

Field Layout

Post-mine field layout is based on pre-mine land units. In the pre-mine state these are irregular shaped areas based on soil capability lines, land use boundaries, and property lines. This is exaggerated in pod mines with multiple landowners, especially if each landowner is farming his own property. What is particularly difficult is that the regulations require a miner to reclaim to approximate original contour but also requires the miner to manage these land units separately even though no farmer has ever done this historically. OSM and most states have remedied this situation by allowing certified test plots to represent larger areas. This facilitates proper field layout, better erosion control, and more manageable crop productivity logistics. In addition, in most cases the land that is not being used as a test plot is returned to the landowner to manage under the miner's direction.

Crop Productivity and Bond Release

In the case of prime farmland, bond release is based on minimal grading and soil depth requirements and crop productivity. Crop productivity includes a target yield verses actual productivity. As to the target yield, OSM and most states use a weighted SCS yield by soil type based on the entire permitted area or allow for the use of an adjacent reference area. Illinois, on the other hand, uses a complicated and subjective formula that takes months to calculate and is based on some assumed variables and other uncorroborated information. As to actual crop productivity, as stated previously, OSM and most states allow the use of certified test plots to represent larger land units. This makes multiple landowner pod mining more workable. Illinois does not allow test plots but instead requires whole field harvest and state sponsored crop sampling. This makes multiple landowner crop management extremely complicated and a severe logistical problem.

Opportunities and Challenges

Pod mining can be a legitimate method of mining. Landowners can receive me income for a temporary use of the land that far surpasses normal farming. The property is then returned to its former use or an alternative as agreed upon by the landowner. Given some latitude and regulatory understanding, overall capability of affected areas can also be improved. Several areas that could improve the ability to further develop this type of mining include:

- Less complicated landowner differentiation and more control of the final product by landowner consent.

- More emphasis on overall soil quality, replaced soft depth, and soil handling. This should replace the costly, long and burdensome crop productivity process. Fifteen to 20 years of data has shown that properly handling the right type and amount of soil will lead to a product equal to or better than the pre-mine.
- An averaging of prime, high capability, and lesser capabilities for reclamation and bond release purposes.
- Actual reclamation and bond release credits/incentives for increasing overall capability of affected areas.

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SURFACE MINING - PRIME FARMLAND SOILS USING MIXED OVERBURDEN

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Abstract

Mining companies are required by regulation to replace prime farmland by, sequential soil horizon during the reclamation phase of mining. However, by the use of selective handling techniques, prime farmland soils can be produced using mixed overburden. Overburden characterization is performed using gridded geophysical logs and cores to determine the best material available to use during reclamation, A postmine soil mapping project indicated the Grayrock, Grayvar, and Bigbrown soil series at two mine sites in Texas could meet the criteria for prime farmland soils. At the Monticello Winfield Mine, the Grayrock and Grayvar soils on 1 to 5% slopes were declared as prime farmland by the U. S. Soil Conservation Service (SCS) in 1991. The Bigbrown soil series on 1 to 5% slopes was declared a prime farmland soil by the SCS in 1993 at the Big Brown Mine. Postmine prime farmland soils at Monticello Winfield Mine compose 65.9% of the mined area, compared to 38.8% prime farmland soils within the permit area prior to mining. Prime farmland soils at the Big Brown Mine made up 4.7% of the area before mining but 58.6% of the postmine soils. Use of selected overburden material, especially in areas where native soils have low to moderate productivity, is considered a viable alternative based on this and other studies.

Additional Key Words: stratigraphic units, postmine soil mapping, overburden evaluation.

Introduction

Mining companies are required by regulation to replace prime farmland soils by sequential horizons (A and B or C horizons) if the soils have historic cropland use. Regulatory authorities in most states may approve substitute materials in the top four feet of reclaimed soil if this material will produce a soil having as good, or greater, productive capacity as the native prime farmland soils. Productivity of the replaced prime farmland soil must also be proven.

The development of the prime farmland soils concept occurred in the 1970s because of the covering of the nation's best farmlands by concrete as urban areas spread across former cropland. A brief discussion of the criteria for prime farmland soils follows.

Criteria for Prime Farmland Classification

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses (the land could be used as cropland, pastureland, rangeland forest land, or other land, but not urban built-upland or water). It occurs in an area which has an adequate growing season and has the soil quality and available water capacity needed to economically produce sustained high yields of crops when treated and managed, including water management, according to acceptable fanning methods. The best farmlands typically are those derived from loessial materials or the grasslands of the Great Plains.

The Natural Resources Conservation Service's State Conservationist in each state has developed criteria for prime farmland soils specific to that state's climate and soils. There are requirements for soil moisture, temperature, pH, drainage and water table, salinity, flooding, slope and erosion, permeability, rock fragments, and calcium carbonate equivalent. This paper will deal with the criteria associated with Texas soils.

Soil Moisture

Texas is divided into moisture zones but, basically, either available water capacity must be equal to or greater than 4 inches in the top 40 inches of soil, or the land must have a developed irrigation water supply that is dependable and meets minimum water quality standards for irrigation water.

Temperature

The soil temperature at a depth of 20 inches is greater than 32' F. All soils in Texas meet this criterion.

Hydrogen Ion Concentration (pH)

The soil has a pH between 4.5 and 8.4 in all horizons within a depth of 40 inches or in the root zone if the root zone is less than 40 inches deep.

Drainage and Water Table

The soil drainage class is either somewhat poorly drained, moderately well drained, or well drained, or the soils lack a high water table that adversely affects production of crops commonly grown in the area or has an installed drainage system that prevents a high water table or poor drainage from adversely affecting the production of crops commonly grown in the area.

Salinity

The soil can be managed so that electric conductivity is less than 4 mmhos/cm in all horizons, and the soil lacks a natric horizon.

Flooding

The soil surface is flooded less than once in two years or for less than two days during the growing season of crops commonly gown in the area.

Slope and Erosion

The soil is not presently gullied, eroded, or severely eroded. The soil has a slope of less than or equal to 5%.

Permeability

The soil has a permeability rate of at least 0.06 inches per hour in the most restrictive horizon in the upper 20 inches.

Rock Fragments

Less than 35% by volume of gravel; less than 10% by volume of cobbles; no stones greater than 10 inches in diameter; or too few stones to interfere with tillage.

Calcium Carbonate Equivalent

The soil has a weighted average calcium carbonate equivalent. in the fraction less than 2 cm in diameter, of less than 40% in the root zone.

Problems with Existing Regulations

As stated earlier, regulations require the sequential removal and replacement of soil horizons, and soil productivity shall be returned to equivalent levels of yield as nonmined land of the same soil type in the surrounding area under equivalent management.

This sounds very good in theory; however, it is considerably more difficult to accomplish in the field. The method frequently used to replace native soil horizons sequentially is by, the use of scrapers or end dumps. Either method may result in soil compaction. Soils replaced using scrapers would often make better streets or parking lots than cropland due to the amount of compaction that was induced during the placement phase by loaded scrapers going over them.

Methods

The method which Texas Utilities Mining Company (TUMCO) employs for reclamation is the use of selected mixed overburden materials in mining. This approach was based at least in part, on a study (Angel, 1973) which found that east Texas overburden materials are favorable for vegetation. Selection of overburden for placement in the top four feet of reclamation is guided by the geologic studies required to obtain the permit for mining. Stratigraphic units are mapped and correlated throughout the mine area by use of gridded geophysical core data and electrical logs. Stratigraphic units are defined as strata within the overburden which exhibit distinctive textural composition., a reasonably consistent and predictable stratigraphic relationship with mineable lignite seams in the permit area, a recognizable geophysical log signature, and a mappable thickness and geographic extent (DeMent, et. al., 1992). Weighted averages of the major parameters (pH, ABA, texture, and trace elements) are obtained for each stratigraphic unit. These averages are then compared to the values in the native soils and the criteria set out by the state's regulatory agency to determine the best material for use in reclamation. The overburden is selectively handled by draglines or cross-pit spreaders during the mining, with unsuitable materials placed low in the spoil. The suitable strata are placed so that they are the only materials occurring in the leveled postmine topography from which minesoils could develop.

Texas Utilities, in cooperation with the Natural Resources Conservation Service (formerly Soil Conservation Service), developed a postmine soil mapping and classification program. Postmine soil mapping provides a valid procedure for comparing premine and postmine soil quality. The results of this program suggested that minesoils developed from mixed overburden could potentially meet all the criteria for prime farmland soils. Several years of field trials and data collection went into the effort. The NRCS, in 1991, declared the firstmixed overburden prime farmland minesoil at the Monticello Winfield Mine in northeast Texas.

Results

Postmine Soils

The native soils of east Texas are mostly either deep sands (>40 inches of sand or very fine sand) or have a claypan at shallow depths (<20 inches). Both tend to be very droughty soils, either because of the high sand content throughout or because of the abrupt textural break at shallow depths causing a boundary across which water, air, and roots have difficulty passing. Most native soils in Texas have low pH and low acid-base account (ABA) values (Smith and Sobek, 1978). Postmine soils where selective overburden handling is practiced tend to have higher mean values for these parameters and more consistent textures throughout the minesoil profile (Table 1).

The mining operation, in which selected geologic materials are used in the top four feet of reclaimed soil, breaks up the claypan where it exists and removes the deep sand layer where it occurs. The minesoils produced exhibit a much more uniform texture throughout than most of the native soils in east Texas. The surface of most of the reclaimed soils is more clayey, which allows for higher water-holding capacity and higher cation exchange capacity. The lower layers of these reclaimed soils are usually less clayey than the native soils, allowing freer movement of roots, water, and air.

At the Monticello Winfield Mine, the Grayrock soil series (fine-silty, mixed, nonacid, Typic Udorthents) on I to 5% slopes and the Grayvar soil series (fine-loamy, mixed, nonacid, thermic, Typic Udorthents) on I to 5% slopes were declared as prime farmland soils by the Natural Resources Conservation Service in 1991. The Grayvar series is a proposed series but meets the prime farmland criteria. The Bigbrown soil series (fine-silty, mixed, nonacid, Typic Ustorthents) on I to 5% slopes was declared a prime farmland soil by the NRCS in 1993. Table 2 presents a comparison of areal extent of prime farmland soils between premine and postmine areas.

Table 1. Mean values of premine and postmine soils

	Native Soils	Postmine Soils	Native Soils	Postmine Soils
	0-12"		12-48'	
Big Brown				
pH	5.6	6.5	5.4	6.4
ABA	0.5	3.2	-0.3	2.7
Sand	69	35	44	34
Clay	17	27	41	28
Monticello Winfield				
pH	4.9	6.9	4.9	7.0
ABA	-0.5	5.9	-2.7	5.3
Sand	72	31	54	30
Clay	12	28	30	28

Table 2. Percentage of prime farmland soils.

	% of premine area	% of postmine area
Big Brown	4.7	58.6
Monticello Winfield	38.8	65.9

Productivity

Estimated yield comparison for major forage crops such as coastal bermuda grass (Cynodon dactylon (L.) Pers.) and winterwheat (*Triticum aestivum* L.) are provided in Table 3 for the Grayrock soil series. Native soil yield estimates were made by the Natural Resources Conservation Service (USDA-SCS, 1989) for a low level of management and are based mainly on the experience and records of farmers, conservationists and extension agents from the area. These can vary in any given year depending on weather, management practices, and the presence or absence of disease and insects. Yields for costal bermuda grass for Grayrock series come from production averages over a number of years in compliance with regulatory requirements (TUMCO, 1996).

Estimated wheat yield were summarized in 1989 following three years of study on a 10-acre plot of Grayrock silty clay loam, 1 to 5% slopes. Management on the study area conformed to normal farming practices within the area. Due to variances in weather and damage from migratory geese, annual yields ranged from 29 to 59 bushels per acre. The estimated wheat yield shown in Table 3 is an average of the three-year study.

In addition to the above information, a 5-acre plot of alfalfa (*Medicago sativa L.*) planted in 1989 continued to produce a healthy crop through the 1996 growing season, producing four hay cuttings. This is in an area of the state where native soils are not adapted to alfalfa production.

Table 4 provides the estimated yield information for the Bigbrown soil series for coastal bermuda grass (TUMCO, 1997) and wheat. The wheat yield is based on one year' s data on Bigbrown.

Table 3. Premine/postmine yield comparisons - Monticello Winfield Mine.*

	Yields	
Soil	Coastal Bermuda	Wheat
	(tons/ac)	(bu/ac)
Bernaldo	3.1	-
Freestone	3.1	35
Nahatche	2.9	-
Wolfpen	2.6	-
Woodtell	2.8	35
Grayrock**	3.4	39

*A dash means not commonly grown. See text for source of estimates.
**Minesoil; remainder are native soils.

Table 4. Premine/postmine yield comparisons - Big Brown Mine.*

Soil	Costal Bermuda	Wheat
	(ton/ac)	(bu/ac)
Crockett	2.0	35
Edge	1.9	28
Gasil	2.2	28
Gredge	2.0	-
Nahatche-Hatliff	2.1	-
Padina	1.8	-
Silawa	1.9	-
Silstid	1.9	-
Bigbrown**	3.0	52

* A dash means not commonly grown. See text for source of estimates.
** Minesoil; remainder are native soils.

These studies have not received statistically valid testing but support the conclusions of the NRCS that the yield potential is equal to or greater than that of native soils of the area.

Conclusions

The general consensus among many people in the general public today, as in the past, is that surface mining is an

aberration and should be brought to an abrupt halt. Although it is true that mining may have caused environmental damage before mining regulations were promulgated in the mid-1970s, the reclamation work done by current mining techniques is proving beneficial to wildlife and soils in many instances. It is also furnishing a valuable soil resource for current and future users of the land. Many people in east Texas have sought for years a method to break up the claypans so prevalent in that part of the state. Surface mining has provided that method, and has even given an increase in the percentage of the landscape occupied by soils meeting the criteria for prime farmland soils. Flexibility to use techniques such as this should be encouraged as much as possible in applicable situations. Where overburden materials are as consistent and desirable as those in this study, the results can be very beneficial.

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RECLAMATION OF ANCILLARY SURFACE AFFECTED SOILS

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Abstract

The Surface Mining Control and Reclamation Act (SMCRA) requires the restoration of productivity for cropland affected by mining activities. Current Illinois reclamation directives require the planting and testing of the entire cropland areas that have been effected. Both surface and underground mines commonly affect small areas of cropland along the fringes of the mine. These areas are used for substations, stockpiles, minor roads, etc. These areas typically have only the topsoil removed and subsequently replacedduring reclamation. The subsoil remains intact. Because of their small size and irregular shape, the cropping and testing of these parcels is proving to be an administrative burden. Regulations and procedures are being evaluated to address this problem.

Introduction

In 1986 the division adopted the Agricultural Land Productivity Formula (ALPF) as its method for establishing productivity yield targets, sampling procedures, and yearly adjustments to reflect local weather conditions. These regulations were a cooperative effort between the Illinois Department of Agriculture, USDA Crop Reporting Service, Natural Resources Conservation Service, citizen and agricultural groups, University of Illinois, and the Land Reclamation Division. In its simplest terms, it establishes a mathematical relationship between the actual productivity of the cropland in the county and the baseline productivity of the prime or high capability soils each year. A baseline productivity is also calculated for the permit area. If weather is very favorable and county yields are better than the baseline, then the permit targets are increased by the same percentage. Likewise, if the county yields are depressed then permit targets are decreased by the percentage. The end result of ALPF is the following formula.

$$\textbf{Annual Adjusted Target Yield} = \textbf{Potential Yield for Soils in the Permit} \times \frac{\textbf{County Actual Yield}}{\textbf{Potential Yield for Soil in the County}}$$

ALPF also established a random sampling procedure based on whole field planting. Sampling is contracted to the crop enumerators in the employ of the Illinois Agricultural Statistic Service and the Illinois Department of Agriculture. This system has worked on mined land since its adoption. The number of fields tested varies from year to year but typically involves several thousand acres. To date, approximately 2,000 field test-years have been in the system. Annual costs to run the testing program are approximately $40,000 and involve numerous man-hours digitizing maps, determining random sample points, taking the samples, weighing the samples, and gathering county statistics.

The system works fine for fields greater than four acres in mined areas. Sampling can be done throughout the mining areas during the time span of crop maturity until harvest. Smaller fields currently require a whole field harvest sample that must be times to coincide with the harvesting of the remainder of the adjoining fields. Care must be taken to ensure the combine only harvests from the small field. It is very common that small, irregularly shaped pieces of surface-affected land occurs on the fringes of surface mines and underground mines. Examples of this include areas used for electrical substations, minor roads, soil stockpiles,or boreholes to underground works. By surface affected, I mean areas where the topsoil was removed and replaced and the original subsoil largely remains in place. As these areas may have a post mining land use of cropland, they are subject to productivity requirements. From an administrative point of view,the hardest case to deal with is a quarter acre piece of affected land that was used as a bore hold to deliver power or rock dust to an underground mine. This site may sit in the middle of a cornfield and represent the entire area affected for a mile. As the site is too small to use a combine, hand harvesting of the entire site is the only current option.

New Initiatives

The Department has been exploring a number of alternatives to deal with these small isolated areas, while at the same time to ensure the areas are returned to their premining capability. The current draft is:

1. limit the sites to those less than four acres,
2. limit the sites where the majority of the subsoil was left in place,
3. limit the sites where no toxic materials were present onsite,
4. require other contaminants (rocks) must be removed,
5. require compaction alleviation where appropriate, and
6. visually compare these areas with adjacent cropland using persons experienced in agricultural practices for the required number of years.

Once approved and implemented, the division will have a mechanism to document the reestablishment of productivity on small ancillary areas.

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