MANAGING RESTORED PRIME FARMLAND FOR CORN PRODUCTION[1]

by

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Abstract. In Kentucky, as well as many other states, coal companies must demonstrate the return of productivity of prime farmland by growing corn at least one of the three required years to obtain Phase III Bond Release. Achieving sufficiently high corn yields is likely the most difficult task in meeting the productivity standards. In this paper, we have presented data from large corn fields where Peabody Coal Co. has applied knowledge gained from several research projects. Key factors will be presented in association with growing corn on prime farmland as a part of the final bond release process. We have tried to use the best facets of many basic research projects in this effort, and some aspects have not previously been tested side by side under "research" conditions. The result of this endeavor was successful by meeting the corn yield levels for Phase III Bond Release on approximately 80 hectares (200 acres) of prime land in 1989.

Additional Key Words: Phase III Bond release, applied research.

Introduction

Numerous research projects have been conducted on prime farmland, with the bulk being done in Illinois and Kentucky. In Kentucky, several research projects have been initiated with the central focus of compaction removal (Barnhisel et al., 1979; Barnhisel, 1983; Barnhisel and Powell, 1985; Barnhisel et al., 1987; Barnhisel et al., 1988; Huntington et al., 1980; Powell, et al., 1985; and Powell, et al., 1987). In one project, mining methods have been studied in which end-dump trucks versus scraper pans were used during soil replacement (Barnhisel et al., 1987). In this same study, the effect of stockpiling or double handling soil was also investigated. The effect to soil horizon replacement on row crop yields has been reported by Jansen et al. (1984).

Ripping and/or subsoiling has also been used in order to reduce the effects of compaction from heavy equipment used in soil transport (Barnhisel and Powell, 1985; Barnhisel et al., 1988; Huntington et al., 1980; Powell, et al., 1985; and Powell, et al., 1987). Comparisons are not easily made, since the operating depth and/or design of such subsoiling devices varied from experiment to experiment. We also investigated the effect of the soil moisture content on the ripping action of such equipment (Powell, et al., 1985). This latter experiment was conducted in an attempt to answer why ripping helped to increase yield in one field or set of circumstances, whereas in other cases, yields were not improved and/or even lowered.

Barnhisel et al. (1989) observed from a crop management experiment that crop

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1 Paper presented at the 1990 Mining and Reclamation Conference and Exhibition, Charleston, WV, April 23-26, 1990.

Published with the approval of the Director of Ky. Agr. Exp. Stn., as Journal Article No. (90-4-16).

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Proceedings America Society of Mining and Reclamation, 1990 pp 143-152

DOI: 10.21000/JASMR90010143

https://doi.org/10.21000/JASMR90010143

yields may be affected one or more years following a practice such as growing a deep-rooted crop. Combinations of deep-rooted crops and ripping were also investigated in this experiment and affect yields for at least five years after employed. Corn root development has been studied in constructed surfaced-mined land in Illinois by Fehernbacher et al. (1982).

Corn varieties were also evaluated on restored prime farmland in order to determine if a yield advantage could be achieved by simply making the correct choice of corn hybrid (Powell et al., 1988).

Although some of the above research projects are ongoing, many have been completed. In 1989, the utilization of ideas gained over the past 10 years was applied by Peabody Coal Co. to approximately 200 acres of prime farmland in an attempt to meet corn yields needed for Phase III bond release. The objective of this paper is to illustrate that productivity of disturbed prime farmland can be restored on a large scale.

Methods and Materials

In general, soil was replaced on each of the three mines being studied by scraper pans or end-dump trucks to the depth specified in the permit. This restored depth varied somewhat on each reclamation project due to differences in thickness of the original prime land soil. In one case on the River Queen mine, the data reported was from the second attempt to meet the corn production standards, as in 1988 the corn yield was too low. The sequence of the restoration process used on the Alston mine will be described in detail, and major differences from this procedure will be pointed out for the other two mines. The starting point for corn production following soil replacement varied no more than two years.

Alston Surface Mine.

This permit consisted of about 200 hectares (490 acres) with 30 percent being prime farmland. Prior to soil replacement, the spoil was graded to the topographic configuration approximating the original contour. In early summer of 1986, 75 cm (30 in.) of subsoil was replaced with end-dump trucks on all of the areas designated to be returned to prime farmland. After leveling the subsoil, 15-30 Mg/ha (7-14 T/Ac) of agricultural limestone was applied. The lime rate was adjusted to reflect differences in lime requirement for the different soils being replaced and was based on soil test results. The subsoil was then ripped with a Rome® "4T" ripper operated at an average depth of 75 cm. The next step was to prepare a seedbed with a heavy disk harrow and plant a grass/legume cover crop in the subsoil. The purpose of the cover crop was to increase the organic matter of the subsoil and to biologically help break up any compaction from the dozers and graders used in subsoil leveling.

The seed mixture consisted of: 45 kg sudangrass (_Sorghum bicolor_ L. Moench.); 34 kg tall fescue (_Festuca arundinacea_ Schrad.); 11 kg each of annual ryegrass (_Lolium multiflorum_ Lam); alfalfa (_Medicago sativa_ L.); and yellow blossom sweetclover (_Melilotus officinalis_ L. Lam). These rates were applied on a hectare basis. Fertilizer was applied using 112 kg/ha of 18-46-0 and 336 kg/ha of 0-0-60.

This cover crop was disked into the subsoil surface in late May 1987, and later that summer 12 cm of topsoil was replaced with end-dump trucks. The soil was ripped with the Rome® ripper and limed at 15 Mg/ha of agricultural limestone according to soil tests. In the fall of 1987, a grass/legume (annual ryegrass/hairy vetch, _Vicia villosa_ Roth) cover crop was seeded along with a companion crop of wheat (_Triticum aestivum_ L.) using the variety, Pioneer® 2551.

The original plan was to plant corn (_Zea mays_ L.) into this grass/legume/wheat cover crop in May 1988. However, due to the unusually dry fall of 1987, very little grass or legume was established, but an excellent stand of wheat was obtained. The revised plan was to attempt to meet the target yield goal for wheat, hence the wheat was topdressed with 225 kg/ha of urea (46-0-0) and harvested in June of 1988. The yield obtained for wheat was 3.4 Mg/ha (57 bu/a) which was large enough to exceed the target yield value for the soils being restored.

It was observed that several small depressions occurred in two tracts of the replaced prime land. Two treatments were used in an attempt to reduce, if not remove, the effects that these low spots might have on succeeding corn crops. In the summer of 1988 after wheat harvesting, these areas were first disked and then "land leveled" with a bucket type land leveler which is commonly used on river bottom soils in western Kentucky. This technique appeared to remove most of the small depressions, but still remaining were some larger low spots. It is presumed that the large depressions were caused by differential settling of the spoils occurring under the replaced top- and subsoil. These areas were "ditched" with sub-surface field drain (perforated plastic) pipe. This drain pipe was installed at a depth ranging from 45-60 cm.

A cover crop of ryegrass and hairy vetch, both seeded at 28 kg/ha, was established in the fall of 1988. Fertilizers used in the fall were 112 kg/ha of 18-46-0 and 56 kg/ha of 0-0-60.

In the spring of 1989, corn was planted at 54,600 kernels per hectare using a no-til corn drill into the cover crop "killed" with herbicide. Since not all of the area treated with herbicide resulted in a killed sod, part of the area (6 hectares occurring in two fields) had to be replanted to corn using the conventional approach, including plowing and seedbed preparation. The corn hybrid used on most of the area was McCurdy® 7676, which had been the top producer in the 1987 variety test conducted by Powell et al., 1988, and very near the top in the 1988. The two areas that were replanted were seeded to Pioneer® 3165, the top yielding corn variety in 1988.

Fertilizer used for the corn in 1989 was as follows: 450 kg/ha of urea (46-0-0); 112 kg/ha of 18-46-0; and 170 kg/ha of 0-0-60. The urea and potash were broadcast just prior to planting, and the 18-46-0 was applied in the row with the corn drill. In addition, 112 kg/ha of 34-0-0 was side-dressed on the corn when it had reached approximately 30 cm in height. However, anhydrous ammonia side-dressing was used for the replanted areas.

The herbicides and application sequences used to kill the cover crop as well as to control weeds were as follows. About two weeks prior to planting corn, glyphosate [N(phosphonomethyl) glycine] was sprayed at a rate of 4.6 l/ha (2qt./acre) in 325 l (35 gal.) of water with a tractor-mounted boom sprayer. The corn drill was also equipped with a sprayer and the following herbicides were used at planting: alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl) acetamide], 5.8 l/ha; triazine [6-chloro-N-ethyl-N'-(1-methyethyl)-1,3,5-triazine-2,4-diamine] at 4.7 l/ha. In addition, an insecticide [o,o-diethyl o-(3,5,6-trichloro-2-pyridinyl)-phosphorothioate] was also used at recommended rates. One field was resprayed with triazine following corn emergence to control the perennial ryegrass not killed initially.

Corn harvest began September 19 using two combines, and was completed October 10. One combine was a two-row "plot" combine which was used to measure yields on every 19th and 20th row (i.e., 10% of total acreage). This combine was driven at a constant speed across these reclaimed areas, and yields were determined about every 20 meters. Data (weight and % moisture) were recorded on paper (strip-charts). All grain harvested by both the plot combine and the conventional combine was placed in trucks and sold at a local grain elevator in order to obtain total yield from each field. At Alston, the permit was divided into 12 fields and corn yield from each was kept separate. This was useful for other reasons, as some of these fields were treated differently with respect to herbicide, corn hybrid, and planting technique used. At the other mines, only one yield was determined for each property.

<u>River Queen Mine</u>.

Two areas existed on this mine and both were treated in the same way. The two sites are referred to as "Cherry Hill" and "Cedar Grove," respectively. The soil at both sites had been replaced with scraper pans and not end-dump trucks as was used at Alston. In general, all of the other reclamation techniques, herbicide rates, and harvesting methods were the same as described for the Alston Mine with one exception. These areas had been in a sod cover crop for two years before they were planted to corn in 1988. In the fall of 1987, both areas were bush hogged as low as possible and 112 kg/ha of 34-0-0 was applied.

At one location, Cherry Hill, the target yield level for corn was obtained in 1988. Except for small experimental plots, this was the first time yield goals were met by Peabody Coal Co. in Kentucky on a field scale. Target yields were not obtained at the Cedar Grove site. Hence in the fall, this site was seeded to a grass/legume cover crop as described for the Alston Mine site, but this cover crop was largely grass.

<u>Moorman Mine</u>.

The soil for this area had been replaced using scraper pans, and was treated in a similar manner as described for the Alston Mine. Corn was first planted on this reclaimed soil in 1989.

<u>Results and Discussion</u>

Many soil and crop management factors can affect corn yield of restored prime farmland soils. Using the right combination (or combinations) should produce yields sufficiently high to meet the target yield for Phase III bond release. Minimizing the effect of excessive soil compaction is often the key factor in achieving a high corn yield on mined lands. Other factors such as providing adequate plant nutrients, selecting the best crop and crop varieties, proper land shaping, and the correct soil depth are also likely to limit corn yield when incorrect choices are made. It is as important to prepare a good mining and reclamation plan as it is to properly carry out these plans in the field. This includes everything from the initial soil removal phase to the harvesting of the crops.

The corn yield data are summarized in Table 1. All values were collected in 1989 except for the Cherry Hill site, for which the data was obtained in 1988. Field average yields ranged from 6620 kg/ha (100.8 bu/acre) to 8480 kg/ha (135.2 bu/acre). The weighted average for all sites was 7390 kg/ha (117.9 bu/acre). Differences between sites and/or fields are attributed to soil management practices, i.e., conventional versus no-til; sloping versus flat fields; and differences in weed control or efficiency of herbicides in controlling the cover crop.

Table 1. Corn yields from restored prime farmland.

Site	Field Name	Size		Yield
		hectares		kg/ha
Alston	Bell	18.9		7310
Alston	Tichner	32.6		7680
Alston	Tichner (plowed)	2.0		6480
Alston	Hoover (plowed)	4.3		8480
River Queen	Cedar Grove	3.7		7340
River Queen	Cherry Hill (1988)	8.1		6620
Moorman		3.8		6320
Summary	Total	73.4	Average*	7390

* Weighted Average -- All yields listed for individual fields are based on the elevator weigh tickets and area for the whole field.

Cover Crop and Soil Management

In Kentucky, the use of no-til corn planting equipment will more likely be the best approach to achieve maximum corn yield on restored mine soils. This allows a mulch to remain on the surface in the early stages of corn growth. Such a mulch reduces erosion and water evaporation losses, and since replaced soils are usually droughty, the reduced water loss should help achieve target yield level. However, problems may occur that could jeopardize yields. An example of this occurred for three fields at the Alston site. The herbicides used to control the cover crop did not work properly. A decision had to be made to answer the following question. Will the remaining grasses use water that the corn will need for maximum production? Two approaches were tried. One area was resprayed (Tichner) following corn emergance, and two fields were plowed and replanted using conventional methods. The reason for the poor kill was attributed to cold rainy weather and which rendered the contact glyphosate herbicide ineffective. Improper application or collection or the incorrect herbicide could have also resulted in a similar problem.

When the cover crop is not killed early enough prior to planting, corn yields may actually be reduced as a result of lower available soil moisture. Although it is not believed that reduced available soil moisture had occurred this early in the growing season, another problem was associated with the poor killing of the cover crop, this being the grasses and legumes caused the ground to become dry and hard at the surface, thus preventing the planter from running at the proper planting depth. A second factor could also be involved, the vigorous cover crop was so thick that it may have caused the depth gauges of the planter to hold the disk blades out of the ground. However, it is believed the problem was largely the result of the soil being dry and hard because in an adjacent preplanting data research plot, similar conditions existed for the first planting but, following a 0.5-inch rain the corn stand was excellent and apparently the vigorous stand did not prevent the no-til planter from penetrating the soil.

The corn yields from the two fields at Alston in which conventional tillage was used were different from the no-til area. In one case, the Tichner-plowed field had a lower yield than either the Tichner or Bell no-til fields, i.e., 6480 versus 7680 or 7310 kg/ha. However, for the other plowed field (Hoover), the yield was higher (8480 kg/ha) than for the two no-til sites. We did not have a true test as to what the effect of leaving the growing cover crop would have had on yield had we not plowed or resprayed the three fields. It should be pointed out that the yield from the Hoover field was the highest average yield reported in Table 1.

The grain from the small field that was resprayed was not weighed separately from the larger Tichner field in which a good herbicide kill of the cover crop occurred, hence direct conclusions cannot be drawn. Unfortunately, data for the individual strip harvests made by the combine have not been completely analyzed to statistically compare the yields from the strip harvests and the whole field data[3]. Variations in yield occurred within all fields including the two plowed fields, the resprayed field, and the field where a good kill of the cover crop was achieved. However, the means from the strip harvests were similar to the totals calculated from the whole field approach.

Although some problems were experienced in 1989 with the no-til method of planting corn, as stated earlier, we still believe this method to be generally superior to the conventional method. One additional problem that has been observed on mon-mined land is associated with the cover crop serving as a habitat for small animals, such as mice, that feed on corn seed prior to germination.

An adequate corn plant population is essential for maximizing corn yield. The number of kernels many farmers plant in western Kentucky near our study sites is 64,000 per hectare. However, it has been found that a population 22 to 28 percent lower (i.e., 46,000 to 50,000) gave better yields for restored prime farmland (Powell et al., 1988). This reduced population is especially desirable during years of moisture stress.

Soil Handling and Land Shaping.

Handling of soils in a way to minimize compaction and loss of natural soil structure is not an easy task. It has been found by Barnhisel et al. (1987) and Powell et al. (1985) that end-dump trucks which are not driven on the replaced soil is the most effective way of soil replacement. Even soil moved by trucks can be compacted during the leveling phase. The soil structure of wet soil tends to be damaged more by improper handling and leveling than dry soil.

Since scraper pans are often used in soil relocation, the increased compaction needs to be removed by some method. Biological loosening by growing deep-rooted crops such as alfalfa, has been shown by Powell et al. (1985) to be one method of reducing excessive compaction . The more common practice to reduce the adverse effects of excessive bulk density is with deep tillage. The Rome® ripper was used on all sites discussed in this paper, therefore an effect of ripping is not shown in Table 1. A yield response as much as 1250 kg/ha (20 bu/acre) has been observed in research plots[4]. Other methods of soil handling (e.g., bucket wheel excavator), ripping, or subsoiling may also achieve good conditions for rooting, as demonstrated[5] in Illinois by Jansen and associates (Jansen, 1981; Jansen and Dunker, 1987; and McSweeny et al., 1987).

It is highly desirable that the final graded surface have a slope and not be graded flat. The adverse effects caused by a nearly level field may be demonstrated by inspection of data in Table 1. The plowed Tichner field was essentially level. Differential settling of the spoils occurred during the winter of 1988-1989. Small depressions, 10-15 cm deep appeared similar to a micro Karst topography. Even though these low areas were relatively small, they retained water long enough to reduce corn stands and the final yield. It is likely that the effect of micro relief reduced yield as much as 2000 kg/ha (32 bu/acre), the differences between the Tichner- and Hoover-plowed fields. Furthermore, as noted in the methods section, a land leveler was used at this site in an attempt to remove these depressions. However, the spoils continued to settle and this was another reason why we plowed this field in a second try to remove the effects of differential spoil subscidence.

Spoils should be graded to the same proposed final grade of the prime farmland areas. This is necessary to insure sufficient soil depth is achieved on the entire area. If the topography prior to mining had very little relief, the coal operator should provide in his/or her mining plan, some way to provide surface drainage.

Increased bulk density or soil compaction causes restored prime farmland soils to be droughty and thus affects corn growth. This is largely due to the reduced water storage. Increased density has the potential of altering many soil properties, most of which will reduce the yield potential of the soil. Root growth is reduced due to a smaller number and size of soil pores in which to grow and expand. The roots that do exist tend to be more concentrated in the surface where tillage has loosened the soil. If the rainfall distribution is uniform or sufficient, yields may not be affected by excessive compaction except that there is a greater tendency for lodging upon maturity.

In summary, any soil property that affects water infiltration, movement, and storage could adversely affect corn yield. Any management practice that can minimize the effect of reduced root growth, or conversely stimulate root growth, will likely cause an increased probability of meeting target corn yield levels.

Conclusions

1. The use of end-dump trucks versus scrapper pans may result in less compaction, but in any case, if excessive bulk density were to occur, its removal or reduction is likely to be needed in order to achieve high

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3 These data will be available when the paper is presented orally or may be obtained by writing the Senior author.
4 Unpublished data of senior author
5 Also includes unpublished data presented at Field Days, 1988 and 1989.

enough corn yields to meet the target yield level for Phase III bond release.

2. Follow the best available agronomic soil and crop management practices available. For example, the no-til corn planting method appears to be superior than the convential plow-seedbed method. However, the advantages of the no-til system may be negated if problems were to occur as were experienced at one site, i.e., failure to kill the cover crop.

3. Selection of proper corn hybrids, seeding rate, and planting date may significantly affect the final yield. Plant one of the top yielding hybrids recommended for the area, preferrably one tested on restored mine land in the area.

4. Utilize soil test data to establish lime and fertilizer application rates and follow proven agronomic practices in applying and incorporating these materials.

5. There is an advantage to reducing the effect of differential spoil settling by preparing the final grade at a slope of 1 to 2 percent. Avoid large areas with final grades less than 1 percent and greater than 4 to 5. percent.

Acknowledgment

Many of the ideas incorporated into the reclamation concepts presented in this paper were generated from several persons, especially Mr. James L. Powell . Many of these ideas were contained in the vari[ous] permits prepared by Jim when he was an employee of Peabody Coal Co. Valuable ideas have been suggested by employees of Kentucky Reclamation Association (KRA) who have been contracted to do much of the revegetation, fertilization, etc. associated with these reclamation activities. We wish to acknowledge Mr. Harold Coleman and Mr. Ronnie Newton of KRA.

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