CHANGES IN MORPHOLOGICAL PROPERTIES OF A PRIME LAND SOIL RECLAIMED IN 1979

by

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Abstract: Shortly following the publication of the interim regulations of the Federal Surface Mining Control and Reclamation Act in 1978 (SMACRA), an experimental project was initiated to study how prime farmland may be restored and managed to meet the productivity goals of SMCRA. Two blocks, 125ft x 250 ft, containing prime land were laid out, the subsoil of one of these blocks was limed with an equivalent of 5 T/A, and the remaining block was a non-limed control. Four crop management systems were used, one with corn (*Zea mays* L), one with alfalfa (*Medicago sativa* L.), one tall fescue (*Festuca arundinacea* Schreb.), and the fourth in a corn/ wheat (*Triticum aestivum* L.) / soybean (*Glycine max* (L.) Merr.) rotation. After five years, corn was planted the following two years on the entire area, followed by soybeans, grain sorghum (*Sorghum bicolor* (L) Moench.), and grass/legume hay the subsequent three years. Pits were dug immediately after the soil was replaced, and again in five, ten, and twenty-one years. After five years, a few changes in soil morphological features were observed, primarily in the Ap horizon of the various treatments. However, little change was observed in any of the horizons below 10 in. By ten and twenty-one years, significant changes were observed in the upper 24 to 36 in., especially in the upper part of the subsoil (or Bw horizons) where there were pronounced changes in soil structure. The massive structure initially described in the subsoil was replaced with weak or moderate subangular blocky structure. The typical redoximorphic features (referred to as mottles when first described) originating from the somewhat poorly drained soil that was replaced in 1979 were no longer recognized within the upper part of this reclaimed soil. Classification of the soil is pending, but since it now has a cambic horizon, a change from Entisols or most commonly Typic Udorthents in the soil classification system is indicated. This study illustrated that the time needed for significant soil formation is much shorter than had been thought to be required.

Additional Key words: Prime Farmland, Soil Structure, Soil Classification.

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Introduction

In 1978, an experiment was initiated on the reclamation of prime farmland. This was conducted on the Alston Surface Mine, the first mine in Kentucky which had prime farmland to have a permit issued after Public Law 95-87 (SMACRA) was passed. This project lasted ten years and several objectives were accomplished, after which the area was essentially abandoned following seeding to a mixture of grasses and legumes in 1988. Soil pedons were described shortly following the construction of this experimental area in October 1978, and again in October 1983, August 1988, and finally in November 1999. Each time we attempted to dig pits in the same general area as those initially described, and this paper describes the changes in morphology which occurred over that 21-yr period. Pits were dug five years following construction of the area, but these descriptions will not be presented since few changes occurred during the initial 5-yr period. A paper was presented in 1988 (Barnhisel et al.) but was never submitted for publication.

There were three experimental conditions at this site with respect to soil depth: non-prime land, non-prime cropland, and prime farmland. The total thickness of replaced soil was 8, 24, and 40 in., respectively. The latter soil thickness is less than the 48 in. now required by SMCRA, however, this site was constructed in accordance with the interim requirements prior to any state including Kentucky receiving primacy. Only soil data collected from the prime farmland treatment will be presented here.

Methods

Experimental Treatments

In order to be complete, a brief description of the construction plan is given here even though more detail is found elsewhere (Barnhisel, et al., 1979; Powell et al., 1985). An area of replaced overburden was selected which had a slope of about 2%. Three benches were constructed with differing elevations so that each one would accommodate one of the three types of soils being constructed. Each bench was about 250 feet square, and allowances for transition between these benches were about 15 feet wide. The first bench on the west side of the area was 16 inches higher than the bench to its east, or the middle plot area, and was used to construct the non-prime cropland. The third bench, on the east side of the area, was about 16 inches lower than the middle plot and was used for the prime land, where subsoil from a mixture of Sadler (Fine-silty, mixed, semiactive, mesic Oxyaquic Fraglossudalfs) and Belknap (Coarse-silty, mixed, superactive, acid, mesic Aeric Fluvaquents) silt loam soils was placed with scraper pans to bring the surface to grade (2%). The ratio of Sadler to Belknap was about 4 to 1.

Each of the three 250-foot areas was then divided in half, with one half receiving 20 T/A of agriculture grade limestone. This lime was incorporated into the spoil or soil materials to a depth of about 4 inches, after which 8 inches of topsoil (Sadler-Belknap mixture) was placed over the entire area. In summary, the three soil treatments included: the non-prime treatment (upper or western bench) which was 8 inches of topsoil over both the limed and un-limed spoils overburden; the non-prime cropland area (center bench) which consisted of 8 inches of topsoil over 16 inches of both limed and un-limed subsoil; and the prime farmland plot (eastern bench) which was 8 inches of topsoil over 36 inches of both limed and un-limed subsoil.

Each of these areas was further divided into 24 x 36 foot plots with a 24-foot wide turn strip seeded to tall fescue, giving 12 areas to impose revegetation treatments of continuous corn, alfalfa, and wheat/corn/soybeans rotation. These treatments were continued for the first five years, then the entire area was planted to corn for two years, then soybeans, followed with two years of grain sorghum. After the tenth year, the area was seeded to tall fescue-alfalfa and hay cuttings were taken from this area a few years by a local farmer, but the area has now been abandoned or un-managed for perhaps the last six years.

Soil Pedon Data

Initially, soil pits were dug in six locations in the experimental area: two in each of the three soil depth treatments, one in which the subsoil had been limed, and one in the non-limed area. A portion of the soil morphological data is presented below. The first six pedons were described in the fall of 1978, while other groups of six pits were dug in 1983, 1988, and 1999. Data from the 1983 excavations will not be reported as changes in pedon characteristics occurred entirely in the Ap horizon, with the exception of a significant increase in the number of roots to a depth of at least 36 in. The soil structure improved in the Ap horizon between the two time periods. Essentially, the only difference that was observed between the pedon pairs of each soil depth treatment described for the various treatments in 1988 and 1999 was the strength of soil structure; therefore, only one description of each will be presented here. In all cases, these descriptions came from the limed subsoil pair.

Pedon 5, initial description, prior to establishing revegetation treatments. Alston Surface Mine, Ohio Co. Kentucky

Ap 0-11 inches, brown (10YR 4/4) silt loam; common fine distinct gray (10YR 6/1) and yellowish-brown (10YR 5/8) mottles; weak fine granular and weak fine subangular blocky structure; firm to friable; clear smooth boundary.

C1 11-17 inches, yellowish-brown (10YR 5/6) silty-clay loam; common medium distinct light-brownish gray (10YR 6/2) mottles; weak fine subangular blocky structure; firm; abrupt smooth boundary; lime particles in upper 4 inches of horizon.

C2 17-21 inches, yellowish-brown (10YR 5/6) silt loam; common medium distinct light gray (10YR 7/1) and yellowish brown (10YR 5/4) mottles; weak medium subangular blocky structure; firm; abrupt smooth boundary.

C3 21-30 inches, yellowish brown (10YR 5/4) silty-clay loam; many medium distinct strong brown (7.5YR 5/6) and common medium distinct light gray (10YR 7/1) mottles; massive; firm; clear smooth boundary.

C4 30-40 inches, brown (10YR 4/4) silty-clay loam; common medium faint yellowish brown (10YR 5/6) and few fine distinct light gray (10YR 7/1) mottles; massive structure; firm; clear smooth boundary.

2C 40-51+ inches, dark gray (10YR 4/1) silty-clay loam; massive; very firm; 40% siltstone and black shale channery fragments.

<u>Pedon description 17 -- ten years following reclamation.</u>

Ap 0-6 inches, brown (10YR 4/4) silt loam; medium fine granular; very friable; many fine roots; fresh organic matter at the abrupt smooth boundary.

AB 6-8 inches, yellowish brown (10YR 5/4) silt loam; few fine distinct light-brownish gray (10YR 6/2) mottles; weak fine platy and weak fine subangular blocky structure; very friable; many fine roots; clear smooth boundary.

Bw1 8-18 inches, yellowish brown (10YR 5/4) silt loam; many fine distinct light-brownish gray (10YR 6/2) mottles; moderate fine and medium subangular blocky; common fine roots in vertical cracks; gradual smooth boundary; lime particles in upper 2 inches of horizon.

Bw2 18-31 inches, yellowish brown (10YR 5/4) silt loam; few faint light-brownish gray (10YR 6/2) mottles; moderate fine and medium subangular blocky; firm; few fine roots in vertical cracks, gradual smooth boundary.

Bw3 31-40 inches, yellowish brown (10YR 5/4) silt loam; few faint light-brownish gray (10YR 6/2) and strong brown (7.5YR 5/6) mottles; massive; firm; few fine roots in vertical cracks, abrupt smooth boundary.

2C 40-50+ inches; dark grayish brown (10YR 4/2, 4/3) silty-clay loam; firm; 50% channery gray and black shale fragments.

<u>Pedon description 23 -- 21 years following reclamation.</u>

Ap 0-8 inches, brown (10YR 4/3) silt loam; moderate medium granular; very friable; many fine roots, clear smooth boundary.

Bw1 8-15 inches, brown (10YR 4/3) silt loam; common fine faint brown (10YR 5/3) redoximorphic features (mottles); weak medium platy and moderate medium subangular blocky; friable; common fine roots; clear smooth boundary.

Bw2 15-30 inches, brown (10YR 4/4) silt loam; many medium distinct brown (10YR 5/3) relict redoximorphic features or mottles; common prominent Fe-Mn oxide stains (relict) and faint fine zones (7.5YR 5/8) occur around roots (around oxidized rhizosphere) weak medium platy and moderate medium subangular blocky; friable; common fine roots; 5% sandstone fragments; clear smooth boundary.

C 30-40 inches, brown (10YR 4/4) silty-clay loam; many medium distinct yellowish brown (10YR 5/6) and many medium prominent (7.5YR 5/8) redoximorphic features or mottles; 10% (10YR 6/1 and 6/2) silt coatings (i.e., skeletans from Sadler); massive with some relict brittleness; very firm; very few fine roots; abrupt smooth boundary.

2C 40-64+ dark grayish brown (10YR 4/2) loam; massive; firm; 85% gray and black shale channery fragments.

Discussion

Comparison of Pedon Descriptions

Contrasting the pedon descriptions, between three pedons taken initially and at 10 and 21 years following soil replacement, revealed some significant changes in soil morphology. These will be presented according to the changes for the various horizons. This process is not always a clear comparison, as both the number of horizons and their thickness changed between the three sampling dates. The senior author was the only person present when all three pedon descriptions were made. For the first pedon descriptions, Mr. Frank Cox, a retired NRCS soil classifier, Gary Wilmhoff, and myself made the determinations; for the second Mr. Frank Cox and James E. Haagen presided; whereas, Mr. James E. Haagen, Jerry McIntosh, and Bill Craddock were responsible for the third pedon descriptions.

The Ap horizon in 1978 was described as being 11 inches thick, whereas in 1988 and 1999 this zone was broken into two separate horizons. The color did not change over the first ten years, but was darker the following ten years, especially for the second horizon (AB and Bw1) described in 1988 and 1999, respectively. In 1978, mottles or redoximorphic features were described in the Ap horizon, whereas in the subsequent descriptions mottles or redoximorphic were not present in the Ap. The structure improved during each ten-year period going from weak fine granular and subangular blocky to moderate fine granular in 1988 and 1999. The consistence also improved during the first ten years. Roots were described in the replaced soil horizons in 1988 and 1999, whereas in 1978 they were either not present, as this soil material had been stockpiled for over 6 months, or were ignored since plants were not growing on the soil when it was described initially.

By 1988 and 1999, as indicated above, the Ap horizon described in 1978 was divided into two separate horizons. As mentioned above, not only did the color of this horizon become darker, but the mottles were less pronounced and had lower hues and higher chromas, especially between 1988 and 1999.

The greatest change occurring in the AB or Bw1 horizon from the Ap of 1978 was the change in soil structure. Platy structure was described in these horizons both in 1988 and 1999. In 1988 it was described as weak fine platy and in 1999 as being weak medium platy. A component of subangular blocky was described all three sampling periods, but between 1988 and 1999 this had a stronger development, going from weak to moderate and the size increasing from fine to medium. Consistence was also improved between 1978 and the later samplings.

Based on several literature citations, Sencindiver and Ammons (2000) suggested that often these platy structures develop from machinery compaction during minesoil construction. However, this is not likely the case here, since the platy structure was not observed in the initial pedon sampled in 1978. It seems more likely that the platy structure developed as a result of tillage with a heavy-duty disk harrow used to incorporate the lime or prepare the seedbed for planting. A heavy-duty disk likely caused the weak medium platy structure that occurred with the moderate medium subangular blocky structure in the Bw2 described in 1999, as it was only described in the lime-treated pedon (non-mimed data is not shown). This platy structure in the AB horizon as well as that in the Bw1 pedon described in 1999 is more likely caused by disking during seedbed preparation.

In 1978, a C1 horizon was described between 11 and 17 inches, however in 1988 this was described as the Bw1, but a horizon in this region was not delineated as a horizon in 1999. The presence of lime particles was noted in 1978 as being in the upper 4 inches, and subsequently as being in the upper 2 inches of the Bw1 in 1988. This serves as a marker and indicates that this region is the upper portion of replaced subsoil material, since 20 T/A of lime had been incorporated into this soil material prior to replacement of the topsoil materials. This is evidence that the Bw1 horizon described in 1988 was derived from the C1 of 1978; however, this zone was incorporated into the Bw2 of 1999. The Bw2 or third horizon described in 1999 is much thicker than comparable horizons described in 1978 and 1988, and therefore will be used two times for comparisons of soil morphological development over the 21- year period.

The soil color of the third horizon (C2 and Bw1) became darker between 1978 and 1988, going from 10YR 5/6 to 10YR 5/4. This region or horizon (Bw2) was darker still in 1999, as it was described as being 10YR 4/4. The hue and chroma of the mottles or redoximorphic features also changed going to lower hues and higher chroma, as observed in the horizon discussed above. This trend indicates that the soil was, and perhaps is continuing to become better drained than the Sadler soil possessed in its original setting prior to surface mining. Soil structure in this horizon also improved. In 1978, this zone (C 2) was described as being weak medium subangular blocky, whereas in 1988 this region (Bw1) was described as being moderate fine and medium subangular blocky. This same region (Bw2 horizon) in 1999 was also moderate medium subangular blocky. The presence of roots was also described in 1988 and 1999, whereas, in 1978, if present, they were not mentioned.

The next zone to be discussed is the layer from 17 to 30 inches. In 1978, this portion was broken into two horizons, the C2 and C3. It is speculated that the two horizons described in 1978 were a function of the method of soil replacement. This abrupt boundary could have resulted from the scraper pan depositing the soil material as separate lifts. However, one major difference existed between the C2 and C3 horizons of 1978; the C3 horizon was described as being massive. In 1988, this region (the Bw2 horizon) was described as being moderate fine and medium subangular blocky. In 1999, a platy and subangular blocky structure was described for this region (Bw2). Therefore, at least the lower part of this zone (C3 in 1978) and the comparable depth in 1988 and 1999 had significantly improved in soil structure in only ten or twenty-one years. Significant changes in hue and chroma also occurred similar to that described for the two horizons lying above this zone. Again, roots were described in 1988 and 1999. In 1988, the few fine roots were confined to vertical cracks, but in 1999 they were described as being common fine roots and not limited to vertical cracks. It is important to note that staining of the soil adjacent to roots was described in 1999. This was either overlooked in 1988 or a new feature had formed between 1988 and 1999.

The lowest of the replaced soil horizons occurred at 30 to 40 inches. The color essentially did not change over the observed time period. Massive structures were described at all sampling intervals, although in 1999 the presence of a relict brittleness was described. This morphologic characteristic originated from the Sadler soil prior to its being disturbed. This feature was not seen earlier, but this could be a function of the soil moisture, as in 1999 the pedons were described in the late fall, whereas in 1988 the pedons were described in mid summer. In 1999, soil moisture was low due to drought, whereas in 1988 normal precipitation was received.

The lowest horizon described, or the 2C layer, was derived from overburden materials generated from the mining activity. This material had a gray to dark gray matrix color with other colors attributed to the type of rock fragments. These colors were not described. The spoil was primarily neutral gray shale or siltstone with black channery fragments of shale. Occasional sandstone fragments could be found which were gray in color, in contrast to oxidized sandstone, which had a redder hue.

Conditions Described in Published Soil Survey

The Ohio County Soil Survey was published in 1987. The reclaimed soil in this area was mapped as a Fairpoint, Bethesda, and Morristown complex. None of the official descriptions for these three soils have listed the presence of replaced soil materials. These soils are not designated for soils mined under SMCRA regulations associated with most coal mines in western Kentucky. In other words, these three soils do not have the replacement of the original Ap soil horizon. Therefore, this portion of the Alston Surface Mine was not correctly mapped. Approximately 1000 acres existed on this mine when this portion of the county was mapped, based on the aerial photograph in the published soil survey. All of this acreage was mined after passage of Public Law 95-78 in 1977, but little if any of the surface mined areas in other parts of Ohio county would have had the A or Ap horizon replaced. In fact, this mine had the first surface mine permit issued in Kentucky, which was not "grandfathered" during the first few years following enactment of the regulations associated with SMCRA. Grandfathering was only allowed for those mines, which were not in existence when this law was adopted. Because at the time this area was mapped the acreage of this type of mine soils was small in comparison to the size of the county, these mine soils may have been included in the Fairpoint, Bethesda, and Morristown complex. This type of reclaimed mined area would represent only 0.2% of the county. Since the time mapping was completed, several more thousands of acres of similar soils could have been generated in western Kentucky. The proposed series name for the replaced prime farmland is Alston silt loam. This name does not exist in the National Cooperative Soil Survey (NRCS) database (www.statlab.iastate.edu/soils/osd), but the process of naming this soil has not begun, since data from this and other pedons collected at different locations in 1999 have not been completed.

The soil described here does not have the same characteristics as the 72 pedons described by Bell et al., (1994) in Pennsylvania. The pedons they described were from relatively recent construction of 1 to 2 years. Dunker and Barnhisel (2000) has a brief discussion of soil classification in their chapter, but do not give detailed morphological descriptions.

Summary and Conclusions

Significant improvements in soil morphological properties were observed in a relatively short time period of ten to twenty-one years. This pedogenic process is continuing and the soil is returning to more nearly resemble its pre-mining morphology. Due to the change in internal drainage, soil colors are changing with the subsoil horizons becoming darker. Many of the redoximorphic features are becoming less pronounced. Perhaps placement of this soil in a better drained landscape position will not allow this soil material to return to the characteristics it had prior to mining. The potential for not returning to the original morphologic conditions is further complicated by the mixing of the two soils, Sadler and Belknap. A new soil series Alston (proposed) is needed to describe this reclaimed soil.

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Literature Cited

Barnhisel, R.I., Gary Wilmhoff, and J.L. Powell. 1979. Characterization of soil properties of reconstructed prime and non-prime land in western Kentucky. *in* S.B. Carpenter (ed) Proceedings – 1979 Symposium on Surface Mining, Hydrology, Sedimentology and Reclamation. University of Kentucky, Lexington, KY pp. 119-122.

Barnhisel, R.I., J.L. Powell, and D.H. Hines. 1987. Changes in chemical and physical properties of two soils in the process of surface mining. Am. Soc. Surf. Mining and Reclamation 4:87-97.
https://doi.org/10.21000/jasmr87010313

Barnhisel, R.I., J.L. Powell, and F.R. Cox, Jr. 1988. Restoration of prime farmland following surface mining. Agronomy Abstracts. P36.

Bell, J.C., R.L. Cunningham and C.T. Anthony. 1994. Morphological characteristics of reconstructed prime farmland soils in western Pennsylvania. J. Environ. Qual. 23:515-520.
https://doi.org/10.2134/jeq1994.00472425002300030016x

Dunker, R.E., and R.I. Barnhisel. 2000. Cropland reclamation. p. 000-000. *In* R.I. Barnhisel (ed.) Reclamation of drastically Disturbed Lands. Agron. Monograph 00. ASA, CSSA, and SSSA. (in press).

Powell, J.L., R.I. Barnhisel, W.O. Thom, M.L. Ellis, J.R. Armstrong, and F.A. Craig. 1985. Reclamation of Prime Farmland in Kentucky. Am. Soc. for Surface Mining and Reclamation 2:1-13.
https://doi.org/10.21000/JASMR8501

Sencindiver, J.C., and J.T. Ammons. 2000. Minesoil genesis and classification. p. 000-000. *In* R.I. Barnhisel (ed.) Reclamation of drastically Disturbed Lands. Agron. Monograph 00. ASA, CSSA, and SSSA. (in press).

Soil Survey of Ohio County, Kentucky. 1987 Frank R. Cox, Jr. Editor. Published by USDA-SCS in cooperation with the Kentucky Natural Resources and Environmental Protection Cabinet and the University of Kentucky Agricultural Experiment Station.