ATTRIBUTES OF RECONSTRUCTED PRIME FARMLAND AFTER SURFACE COAL MINING COMPARED TO PRE-MINED CONDITIONS[1]

H. Raymond Sinclair, Jr.,[2] Robert R. Dobos, and Karl W. Hipple

Abstract: Important farmland consists of prime farmland, farmland of statewide importance and local importance, and unique farmland. Prime farmland has the best combination of soil chemical and physical characteristics and suitable climate for producing food, seed, fiber, forage, and oilseed with minimum inputs of fuel and plant nutrients. Further characteristics are none to very slight hazard for wind and water erosion, none to small limitation to maintain soil quality, and sustainable. Reconstruction of Prime farmland soils after surface mining for coal are set forth in federal rules and regulations. Illinois has soil reconstruction criteria for non prime farmland soils (high capability land) that are very similar to soil reconstruction for prime farmland soils. Most of the high capability land also qualifies as farmland of statewide importance. Prime farmland soils, before the current federal law, were not reconstructed as cropland. The present federal law requires that prime farmland be reconstructed to cropland with yields equal to or more than the premined soil. Reconstructed prime farmland after surface mining for coal is dominantly massive (no soil structure) whereas typically a premined soil has structure. It has higher soil bulk density that is critical or limiting for crop root growth, lower soil root zone available water capacity, slower hydraulic conductivity, and lower corn yield than the pre-mined silty loess or lacustrine soils, loamy lacustirne soils, and some loamy glacial till soils. A possible explanation of yield differences for reconstructed mined soil and premined soil is the methods and procedures used to determine their yields. The present and future soil reconstruction of prime farmland soils will need to address saturated hydraulic conductivity (Ksat), develop technology to enhance infiltration of precipitation, and movement of water within the soil profile to result in a field capacity water content of 8 to more than 12 inches. All future soil reconstruction needs to use appropriate conservation practices and shape the landscape to increase infiltration of water into the soil.

Additional Key Words: 62 ILL. ADM. CODE.1825, permeability, soil climate, root zone available water capacity, 62 ILL. ADM. CODE.1816, 30 CFR 823

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Introduction

The information in this paper is intended for anyone involved in reconstructed prime farmland soils after surface mining for coal. It uses data from Illinois, but similar technical situations exist in other states, such as Indiana (Sinclair et al., 2004 and 2005). The State Regulatory Authority working in conjunction with USDA Natural Resources Conservation (NRCS) developed rules and regulations for reconstruction of prime farmland soils after surface mining for coal (30CFR, 2002 and Sinclair, 2004). For example, Illinois also recognizes other soils ("High Capability Land."). Selected soil properties for reconstructed and unmined soils such as soil depth, landscape position, saturated hydraulic conductivity (Ksat), and root zone available water capacity could also explain the differences in crop yield (Schroeder and Doll, 1984). The use of conservation practices could reduce this difference in crop yield under some situations.

Important Farmland

According to the Natural Resources Conservation Service (NRCS)[1], important farmland consists of prime farmland, unique farmland, farmland of statewide importance, and farmland of local importance. Determining important farmland based on soil properties and other soil features, along with locally selected factors, allows for a quantifiable, scientific, and defensible system of farmland classification. The presence of important farmland is used by federal and state agencies when land use decisions may affect soil use and/or productivity. It provides decision-makers with basic building blocks for an evaluation system that systematically ranks different soils based on selected soil properties and/or other soil information.

"*NRCS is concerned about any action that tends to impair the productive capacity of American agriculture*" (7CFR657.1). The Nation needs to know the extent and location of the best land for producing food, feed, fiber, forage, and oilseed crops. National criteria (7CFR657.5) are available that defines prime farmland. Prime farmland designations of soil map units are determined using the computerized criteria (Prime Farmland Criteria Checklist). Soil properties considered in determining prime farmland are: 1) available soil water capacity, 2) suitable soil temperature for crops commonly grown in an area, 3) suitable soil pH for crops commonly grown in an area, 4) water table depth, 5) electrical conductivity, 6) exchangeable

[1] Prior to 1992, NRCS was known as the Soil Conservation Service (SCS).

sodium, 7) flooding frequency, 8) water and wind erosion, 9) saturated hydraulic conductivity, and 10) rock fragments in the soil surface layer. Farmland of statewide importance and farmland of local importance are, in addition to prime and unique farmlands, important for the production of food, feed, fiber, forage, and oilseed crops. Unique farmland is farmland that is used for the production of specific high value food and fiber crops (7CFR657.5(b)). It has special combination of soil quality, location, growing season, and moisture supply needed to economically produce sustained high quality and/or high yields. Appropriate State and Local agencies are responsible for identifying and developing the criteria, in conjunction with NRCS, used for defining and delineating state and local lands.

Surface Mining for Coal on Farmland used Historically as Cropland

It is important to understand the definition of the term "historically" because by definition it allows some prime farmland to be reclaimed differently than other prime farmland.

"*Historically used for cropland are those lands that have been used for cropland for any 5 years or more out of the 10 years immediately proceeding the acquisition, including purchase, lease, or option of the land for the purpose of conducting or allowing through resale, lease, or option the conduct of surface coal mining and reclamation operations … productivity of the land" (30 CFR, 2002).”*

Thirty Code of Federal Regulations (30CFR, 2005) explains USDA-Natural Resources Conservation Service (NRCS) activities with prime farmland historically used as cropland. After surface mining, P.L. 95-87 (Surface Mining Control and Reclamation Act of 1977 - SMCRA law) specifies that prime farmland will be reclaimed to its original productivity (30CFR823, 2005).

As a result of P.L. 95-87, productivity of land reclaimed after surface mining for coal improved in most states. Illinois rules and regulations for soil reclamation were more strict after P.L. 95-87 was signed into law. It is the only state, to our knowledge, that recognized that prime farmland soils are the very best prime farmland soils in the world for producing crops commonly grown in that area. Illinois recognized other soils ("High Capability Land.") that are as productive as some prime farmland soils, but High Capability Lands (HCL) require conservation practices not needed on prime farmland soils. A brief explanation of HCL is land not meeting the definition of prime farmland and land designated Classes I, II, III and capability Class IV with slopes of five percent or less (62ilac, Chapter I, Sec. 18252, 2002).

The University of Illinois is doing soil reclamation research. It had been doing research on surface-mined soils since 1945 and in 1977, U of Illinois initiated studies to improve reclamation procedures (Fehrenbacher et al., 1977). These studies target: 1) changes in amount and condition of cropland, 2) factors that affect crop rooting and stands, 3) segregation and replacement of darkened surface soil and root medium, 4) how moisture content at various stages of handling spoils affects moisture regime in reclaimed soils, and 5) use of runoff for irrigation.

Research Findings

Dunker et al. (1991), Schroeder (1992), and Olson and Lang (2000) investigated and correlated reclaimed soil properties and crop yields after surface mining. Dunker et al. (1991) noted that the soil physical condition is the most limiting factor in the reclamation of prime farmland soils. Excessive soil strength or increased bulk density (reduced pore space) limits rooting depth and during dry years the reduced soil available water storage is insufficient to achieve maximum yields. Figures 1, 2, 3, 4, 5, and 6 are reclaimed soils after surface mining for coal. Figures 5 and 6 show some of the variability of rooting media in the trench (Fig. 4). Schroeder (1992) reported that small grain yields on down slope (examples - foot and toe) positions of the landscape produced 30 to 80 percent higher yields than upslope positions when averaged over several years. This demonstrates that landscape position plays an important role in small grain yields. Olson and Lang (2004) assert that crop yields are the result of environmental factors such as soil, climate, and management inputs. The effect of technology and management on crop yield is determined, in part, by the characteristics of the soil. Many soil properties considered important for explaining crop yields have been related to moisture-holding capacity. Soil parent material was recognized by Olson and Lang in 2004 as an important property in their regression models. Since pre-mining properties of prime farmland soils are typically nearly optimal for crop growth, any negative change to the properties of highly productive soils is generally damaging. Olson (1992) worked on assessment of reclaimed farmland disturbed by surface mining in Illinois. Olson (1992) stated that it is very possible that the productivity index (PI) of a parcel of land reclaimed under provisions of the 1977 SMCRA law could be lower than 100 percent of the PI of the original soil on a tract for prime farmland. Possible reasons for the difference are the methods and procedures used to determine long term yields. The 1997 SMCRA law only requires 3 years of crop yields (within a 10-year period) to meet target yield which is adjusted for yearly weather differences.

Figure 1 is a soil reclaimed prior to the 1977 SMCRA law in southwestern Indiana. Its tentative soil classification is loamy-skeletal, mixed, active, nonacid, mesic Typic Udorthents. Figures 2 and 3 are soils reclaimed to 1977 SMCRA law in southwestern Illinois. Their tentative soil classification is fine-silty, mixed, active, nonacid, mesic Alfic Udarents. The soil profile in figure 2 was reclaimed using scrapers. The soil profile in figure 3 was reclaimed using trucks. Figure 4 is a trench showing the variability in reclaimed soil after surface mining for coal in west central North Dakota. The trench is dominantly reconstituted fine loamy glacial till and shale from surface mine operation. Figures 5 and 6 are soils reclaimed to 1977 SMCRA law in west central North Dakota. Their tentative soil classification is fine-loamy, mixed, superactive, frigid Haplic Ustarents. The soil profiles in Figs. 5 and 6 were reclaimed using scrapers.

Figure 1. Soils reclaimed before the 1977 SMCRA law (scale in cm).

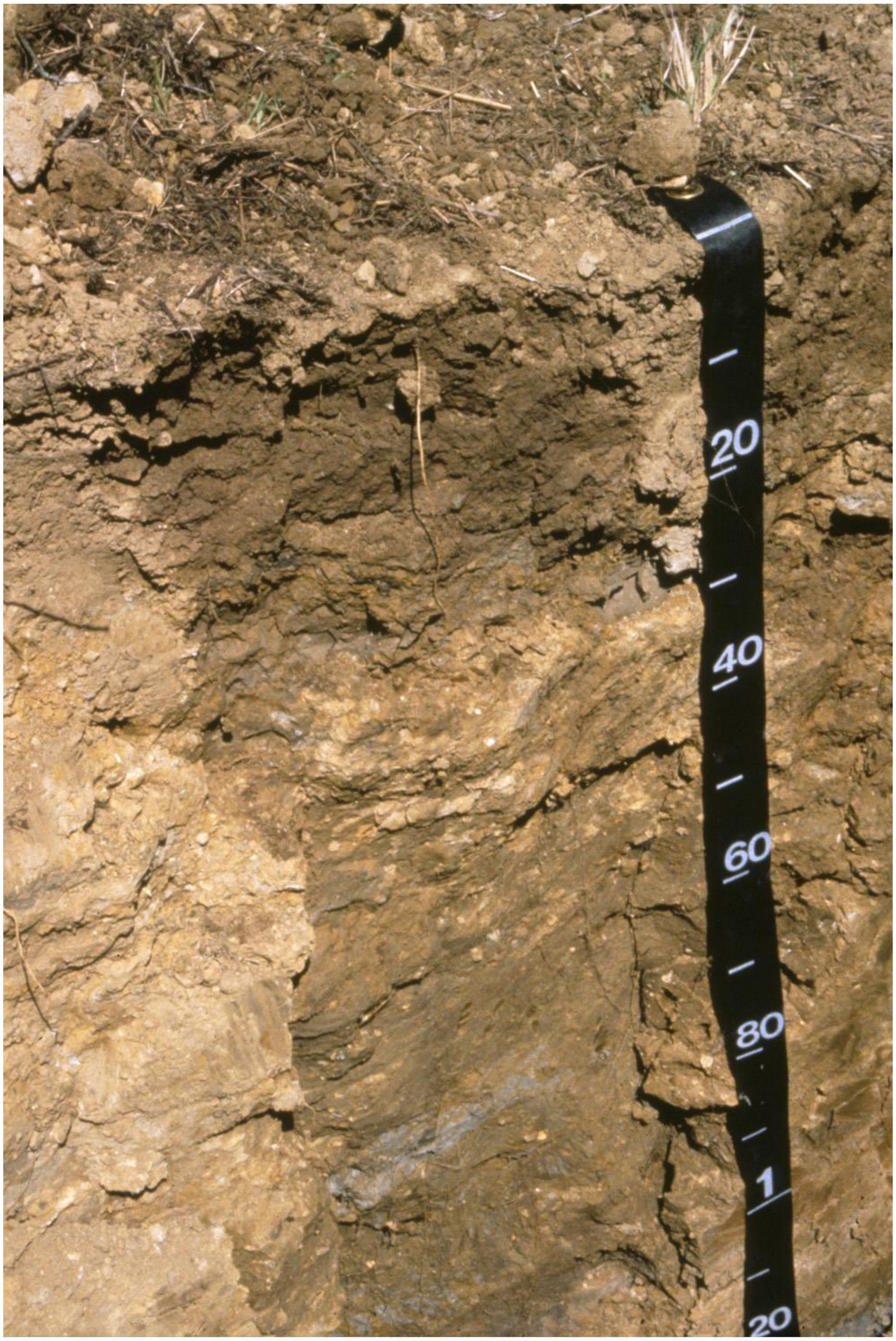

Figure 2. Reclaimed soil using scraper (scale in cm).

Figure 3. Reclaimed soil using truck (scale in cm).

Figure 4. Trench showing variability in reclaimed soils after surface mining for coal.

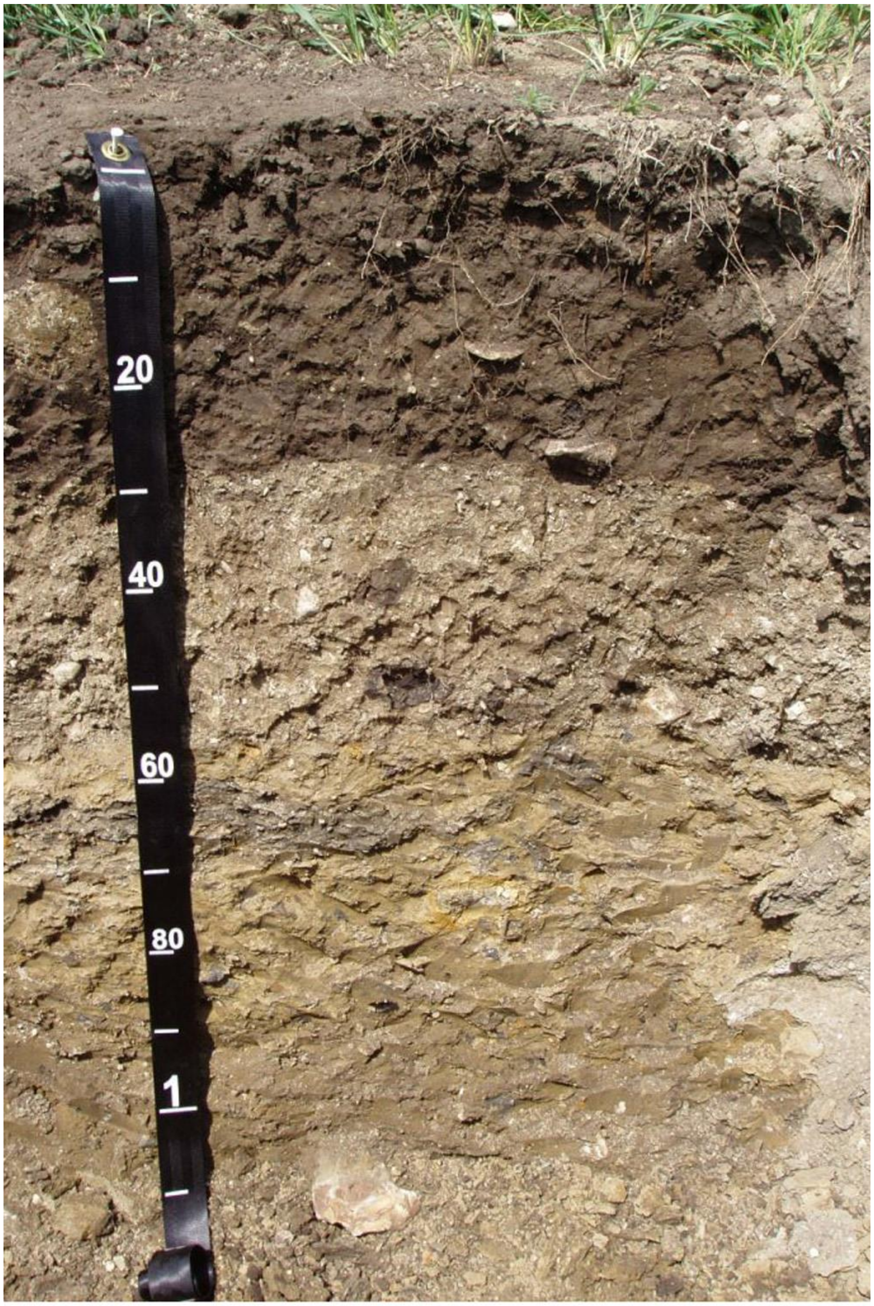

Figure 5. Profile of a reclaimed soil after surface mining for coal (note reduced porosity below 30 cm).

Figure 6. Profile of a reclaimed soil after surface mining for coal (note reduced porosity below 70 cm).

Discussion

Tables 1 through 3 contain selected information for soils in the northern half of Illinois. The soils information is from the USDA,NRCS Soil Data Mart and publications by Wascher et al. (1960), Drablos and Moe (1984), Olson and Lang. (2000), and Fehrenbacher et al. (1986). The presence of a favorable subsoil rooting media means the difference between successful crop production and crop failure (Fehrenbacher et al., 1982). Table 4 (Pierce et al., 1983) compares the nonlimiting, critical, and root limiting bulk densities for each family texture to the moist bulk density values in Table 3.

Tables 1 through 3 provides relationships among soil structure, saturated hydraulic conductivity (Ksat), and root zone available water capacity (RZAWC), corn yields (non-irrigated) and tile drainage. These data support the conclusions in earlier papers by Sinclair et al. (2004 and 2005) and Sinclair and Dobos (2007). These data substantiate that some laboratory soil properties, soil taxonomic classifications, and selected soil morphological characteristics of the premined soils were more favorable for plant growth than those of the reclaimed soils. The earlier paper explained how differences in soil classifications (unlimited compared to shallow soil depth classes), soil properties (available water capacity and bulk density), and selected soil morphological characteristics (strong to moderate blocky structure compared to weak structure or no soil structure) of soils before mining and after mining affected soil productivity.

Soil structure and saturated hydraulic conductivity (Ksat) are soil properties used for determining drainage tile spacing and depth. Soil structure, saturated hydraulic conductivity (Ksat), and root zone available water capacity (RZAWC) are strongly related to corn yields (non-irrigated). Moist bulk density determines the desirability of rooting media for plant growth. It is also a surrogate for soil structure, saturated hydraulic conductivity (Ksat), and RZAWC (Table 4).

Rapatee soils are created during the reconstruction after surface mining for coal in areas where originally Ipava, Muscatune, Osco and other similar deep loess soils occurred in the northern half of Illinois. Rapatee soils do not have the favorable soil structure, saturated hydraulic conductivity (Ksat), RZAWC, and bulk density that naturally occur in the original soils. Thus, the corn yields (non-irrigated) are lower and tile spacing must be closer to drain the Rapatee soil when wetness is a concern.

Swanwick soils (fine-silty, mixed, active, nonacid, mesic Alfic Udarents) are similar to Rapatee soils, but have a lighter colored surface layer. Swanwick soils are reconstructed after surface mining for coal and are in west-central and southwestern Illinois. Rapatee soils are reconstructed after surface mining for coal and are in west-central and south part of northwestern Illinois. Some fine-silty unmined soils in southwestern Illinois are Ava, Hosmer, Stoy, and other silty soils. Swanwick soils (111 bushels per acre of corn, bu/ac) have slightly lower corn yields than Rapatee (132 bu/ac), Ava (121 bu/ac), Hosmer (126 bu/ac), and Stoy (131 bu/ac) soils

(Olson and Lang, 2000). Ava and Hosmer soils are Oxyaquic Fragiudalfs. Stoy soils are Fragiaquic Hapludalfs

Table 1. Classification and Structure of the Soil

soil map unit symbol	name of soil	classification of soils	soil structure (a)	subsoil rooting (b)
147	Clarence	fine, illitic, mesic Aquic Argiudolls	2-m-abk	unfavorable
146	Elliott	fine, illitic, mesic Aquic Argiudolls	2-f-abk	favorable
154	Flanagan	fine, smectitic, mesic Aquic Argiudolls	2-m-sbk	favorable
43	Ipava	fine, smectitic, mesic Aquic Argiudolls	2-m-abk	favorable
189	Martinton	fine, illitic, mesic Aquic Argiudolls	2-m-abk	favorable
442	Mundelein	fine-silty, mixed, superactive, mesic Aquic Argiudolls	1/2-m-sbk	favorable
51	Muscatune	fine-silty, mixed, superactive, mesic Aquic Argiudolls	2-m-sbk	favorable
490	Odell	fine-loamy, mixed, superactive, mesic Aquic Argiudolls	2-m-sbk	favorable
86	Osco	fine-silty, mixed, superactive, mesic Typic Argiudolls	2-m-sbk	favorable
872	Rapatee	fine-silty, mixed, superactive, nonacid, mesic Mollic Udarents	m	favorable
91	Swygert	fine, mixed, active, mesic Aquic Argiudolls	1-f/m-abk	unfavorable

(a) Dominant subsoil structure to 40 inches. First desigation: 1-weak, 2-moderate. Second
designation: f-fine, m-medium. Third desgination: akb-angular block, sbk-subangular blocky, M-massive
(b) Olson and Lang, 2000

Table 2. Soil Morphology, Properties, and Drainage Information

soil map unit symbol	name of soil	surface texture	percent slope	subsoil parent material	soil structure (a)	drainage tile spacing (feet) (b)	drainage tile depth (inches) (b)
147	Clarence	silty clay loam	0-2	clayey glacial till	2-m-abk	less than 70	18-30
146	Elliott	silt loam	0-2	loamy glacial till	2-f-abk	70-90	36-42
154	Flanagan	silt loam	0-2	loess/loamy glacial till	2-m-sbk	80-120	36-48
43	Ipava	silt loam	0-2	loess	2-m-abk	80-120	36-48
189	Martinton	silt loam	0-2	loamy lacustrine	2-m-abk	70-90	36-42
442	Mundelein	silt loam	0-2	loamy lacustrine	1/2-m-sbk	80-120	36-48
51	Muscatune	silt loam	0-2	loess	2-m-sbk	80-120	36-48
490	Odell	silt loam	0-2	loamy glacial till	2-m-sbk	80-120	36-48
86	Osco	silt loam	0-2	loess	2-m-sbk	80-120	36-48
872	Rapatee	silty clay loam	0-2	Reconstructed loess soil	m	70-90	18-30
91	Swygert	silty clay loam	0-2	clayey glacial till	1-f/m-abk	less than 70	18-30

(a) Dominant subsoil structure to 40 inches. First designation: 1-weak, 2-moderate. Second designation: f-fine, m-medium. Third designation: akb-angular blocky, sbk- subangular blocky, M-massive.

((b) Drablos and Moe. 1984. Illinois Drainage Guide. Circular 1226. U. of Il.
Rapatee and
Osco numbers assigned based on morphology and physical soil properties

Table 3. Soil Interpretations

soil map unit symbol	name of soil	land capability subclass	maximum % clay in B horizon	saturated hydraulic conductivity (a) micro m/sec	moist bulk density (b) g/cc	root zone available water capacity inches	corn yield (bushels/acre) (c)
147	Clarence	3w	50-60	0.00-0.42	1.65-1.75	3.6	126
146	Elliott	2w	35-50	1.41-4.23	1.60-1.75	6.3	151
154	Flanagan	1	35-42	1.41-4.23	1.30-1.50	11.4	175
43	Ipava	1	35-43	1.41-4.23	1.30-1.50	11.8	172
189	Martinton	2w	35-45	1.41-4.23	1.25-1.45	10.5	156
442	Mundelein	1	25-35	4.23-14.11	1.40-1.55	9.9	169
51	Muscatune	1	30-35	4.23-14.11	1.35-1.55	12.3	180
490	Odell	2w	25-35	4.23-14.11	1.70-1.90	8.6	158
86	Osco	1	24-35	4.23-14.11	1.35-1.40	11.8	172
872	Rapatee	2s	22-35	0.42-4.23	1.50-1.90	7.3	132
91	Swygert	2w	45-50	0.42-1.41	1.40-1.70	5.4	143

(a) Slowest with 20 inches

(b) highest with 40 inches

(c) Olson and Lang, 2000

Table 4. Nonlimiting, critical, and root limiting bulk densities for each family texture class (Pierce et al., 1983).

Family Texture Class	Nonlimiting Bulk Density $g\ cm^{-3}$	Critical Bulk Density $g\ cm^{-3}$	Root-Limiting Bulk Density $g\ cm^{-3}$
Sandy	1.60	1.69	1.85
Coarse loamy	1.50	1.63	1.80
Fine loamy	1.46	1.67	1.78
Coarse silty	1.43	1.67	1.79
Fine silty	1.34	1.54	1.65
Clayey: 35-45%	1.40	1.49	1.58
Clayey: 45-100%	1.30	1.39	1.47

The type of soil reclamation used in Fulton County, Illinois, as well as other Illinois counties, depends on the time period. The time periods are grouped: prior to 1971, 1971 to 1977, and 1977 to present. The 62ilac (62 Illinois Administrative Code), Chapter I, Sec. 1825 (2002) entitled "High Capability Land" was passed in 1971 and amended in 1976 by the Illinois legislature to reclaim certain mined land to arable soils. Currently the State of Illinois uses both the federal reclamation law (P.L. 95-87) to require the reclamation of soils that are prime farmland and also the "High Capability Land" law to reclaim many prime and non-prime farmland soils to cropland status.

Upland soils in Fulton County, Illinois, disturbed by mining, are dominantly fine-silty (soil particle-size class) – 95.8 square kilometers (37 square miles) (Sinclair, 2007 and Suhl, 2003). If all the Ipava, Osco, and other similar deep loess soils in Fulton County, Illinois were reconstructed to Rapatee soils, estimated corn yields would be lower by at least 40 bushels per acre. Thirty-seven square miles is slightly more than the size of a legal township. The difference in assessment between Rapatee soils and Ipava/Osco soils would generate a lower assessed valuation to operate the taxing unit.

More attention is needed during removal and replacement of soil material to enhance vertical and horizontal water movement during reconstruction of prime farmland soils and High Capability Lands (HCL) after surface mining for coal. These concerns were addressed in the Northern Great Plains (Schroeder, S.A. 1992). It now needs more attention given to states in the eastern corn belt (Stuff and Dale, 1973).

Summary

Reducing compaction to acceptable levels in the upper two meters of reclaimed soils will alleviate most productivity problems in reconstructed soils. Precipitation needs to be given more time to infiltrate and move vertically and horizontally through reclaimed soils. A hydropedologist should assist in the development of mineland reclamation plans on how mined soils will be reconstructed after mining to accomplish these objectives. Ipava and similar soils are highly productive because of its hydraulic characteristics and landscape position. When disturbed, its soil water-landscape relationship and other soil properties are dramatically and negatively changed. Terraces, conservation tillage, configuration of soil landscape to enhance infiltration, and installation of tile are possible practices that could utilize precipitation to increase crop yield for reclaimed soils (USDA-NRCS, 2007). Terraces have been used for years in the western corn belt to reduce soil erosion, but most importantly, terraces also to increase the amount of precipitation entering the soil.

The reclamation process used to reconstruct soils after surface mining for coal is continuingly changing. Reclamation using scraper placement after surface mining for coal is becoming a thing of the past as the more progressive mining companies are using shovel-truck replacement of soil. The partnership among the coal companies, USDI's Office of Surface Mining, State Regulatory Authority, researchers, and NRCS is improving reclamation technology.

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