

TOPSOIL: WHAT IS IT AND WHO CARES?¹

R.G. Darmody², W.L. Daniels, J.C. Marlin, and D.L. Cremeens

Abstract. Topsoil means many things to many people, but to everyone it represents the best part of the soil from a plant-growth perspective. Many activities alter the soil profile including surface mining, agriculture, and urban development. Of these, mining is subject to state and national regulations for protection of soil and the USDA has a series of programs to protect topsoil from erosion. The extensive use of mass grading to remove topsoil from entire subdivisions during construction will likely create pressure for additional standards and regulations governing topsoil protection and replacement, as will national efforts to restore brownfields. Topsoil is the subject of mine reclamation regulations and is viewed as something to be protected and preserved, but also something that regulators will allow, in certain situations, to be removed or buried and replaced by a topsoil substitute. When there is a need for a suitable growth medium to support vegetation at a site that has lost its native topsoil due to mining or other earth moving activities, a wide range of materials can be used as topsoil, including subsoil or selected overburden materials. The Surface Mining Control and Reclamation Act (SMCRA) was the first federal statute to specifically define operations involving the handling, storage, and substitution of topsoil. Within SMCRA, “*topsoil*” is not specifically defined, but the A horizon is identified in the prime farmland subsection, and by implication it is topsoil. SMCRA also specifically allows for the use of topsoil substitutes when the pre-mining A⁺ E horizons are less than 15 cm thick. Blasted sedimentary overburden materials are routinely converted into successful topsoil substitutes in the Appalachian coal mining region, but compaction commonly limits their productivity, and post-mining pH must be carefully matched to intended post-mining vegetation. A wide range of organic and mineral wastes and residual products can be beneficially used for either *in-situ* soil reconstruction or on-site remediation. Similarly, many run-of-mine mineral wastes can be successfully combined with organic composts to produce commercially viable manufactured topsoils. This paper will review the authors’ experience with “*topsoil*”, both in a scientific and practical, applied sense. Of necessity, it will focus on surface mine issues, while raising other issues and discussing some case studies.

Additional Key Words: Cover Soil, A Horizon, SMCRA, Landfill Covers, Surface Soils, Restoration, Reclamation, Manufactured Topsoil, Brownfields.

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Introduction

Topsoil means many things to many people, but to everyone it represents the best part of the soil from a plant-growth perspective. It is the subject of federal and state mine reclamation regulations and something to be protected and preserved. Topsoil is also something that regulators will allow, in certain situations, to be removed or buried and replaced by a topsoil substitute. When there is a need for a suitable growth medium to support vegetation at a site that has lost its native topsoil due to mining or other earth moving activities, a wide range of materials can be used as topsoil, including subsoil or selected overburden materials. The Surface Mining Control and Reclamation Act (SMCRA) was the first federal statute to specifically define operations involving the handling, storage, and substitution of topsoil. Within SMCRA, “*topsoil*” is not specifically defined, but the A horizon is identified in the prime farmland subsection, and by implication it is topsoil. SMCRA also specifically allows for the use of topsoil substitutes when the pre-mining A + E horizons are less than 15 cm thick and pre-mining physical and chemical analyses of a designated overburden strata indicate that it can be utilized to create equal or better topsoil conditions when compared to on-site native soils. It is usually assumed that the soils being reclaimed had been cleared of trees prior to being disturbed. If this is not the case, it may be impossible or impractical to remove enough of the “true” A horizon(s) during salvage operations, and a topsoil substitute will be needed to provide a suitable amount of topsoil for subsequent revegetation.

For purposes of enforcing SMCRA in Illinois, the Illinois Department of Natural Resources defines topsoil in IL Admin Code 62-1701 as “*the A and E soil horizon layers of the four master soil horizons.*” Illinois landfill regulations specify that daily and final cover should be “*soil material*”, which is not defined. While regulators recognize that “Mother Nature knows best” when it comes to topsoil, the regulations allow other materials as substitution for topsoil in certain circumstances. Examples include: B or C or even R horizons if soft materials like shales or saprolite meet the chemical and physical requirements. For example, Texas soils are often better after mine reclamation when deeper C horizon materials are used instead of local sodic topsoils (Askenasy et al., 1997). Likewise, in mountainous regions, where the native topsoil may be thin and difficult to recover, the material placed on the top of a reclaimed area may be more appropriately referred to as “cover soil” and may include blasted hard rock spoils, saprolite, decomposed shale, fly ash, or many other fine grained materials (e.g. water treatment plant

sludge, biosolids, river sediment dredgings, etc.) that are available and do not pose a soil or water quality threat. In general, topsoil substitutes must first be carefully selected to avoid acid-forming or other deleterious materials and to provide sufficient rooting depth and associated water holding capacity. Ideally these materials will break down mechanically during the replacement activities to a loam or silt loam texture to maximize water holding capacity. Nutrient deficiencies are usually readily met via routine fertilization.

Topsoil substitutes made primarily from materials on-site minimize the costs associated with transport of large volumes of imported materials, and in addition, the off-site damage associated with “borrowing” natural topsoil is eliminated. Furthermore, manufacturing “topsoil,” rather than removing it from a borrow area, may offer the advantage of a beneficial use of material that would otherwise need disposal, such as biosolids, fly ash, dredged sediment, etc. Furthermore, many of these residuals may be highly effective at mitigating or minimizing soil phytotoxicity or water quality threats on highly contaminated sites (EPA, 2007).

Generally, the biggest obstacle in revegetating a disturbed site utilizing a topsoil substitute or replaced topsoil is retaining enough plant available water (PAW) in the seedbed to insure survival of the seedlings, assuming acid formation is not the primary concern. Maximizing PAW requires both a favorable medium-textured material and a non-root restricting density of a topsoil of sufficient thickness to provide moisture for plant growth. Concerning soils manufactured from some waste materials, dealing with excesses of soluble salts or other potentially plant growth limiting constituents is more difficult, and many industrial byproducts must be diluted with relatively inert material. Contract specifications in these cases generally include requirements related to the ability of the cover soil to support plant growth, including ranges of essential soil properties such as texture and available nutrients, but not about the materials used *per se* in the cover soil. One potential complication with mixing materials to manufacture “topsoil” may be a patent infringement. A patent was awarded in 1998 for manufactured “topsoil” that is composed of clay, organic compost, and sand. However, this has not proven to be a problem in practice. The narrow legal view is that the patent only protects someone making a nearly identical product from exactly the same kind of material, and any deviation from this in materials or mix eliminates that concern.

Topsoil in a retail sense is anything bought by the truckload or in a bag labeled “*Topsoil*”. To our knowledge, there are no regulations controlling what is sold as topsoil. Commercial

topsoil is available from a wide variety of sources, and ranges from native materials removed and trucked from construction sites, to industrial waste products, and to carefully controlled manufactured topsoils. States and localities vary widely in how these materials are regulated. For example, in Virginia, topsoil *per se* is not regulated and labeled, but any product that is offered as a horticultural growing medium, soil conditioner, or soil amendment must be tested, labeled, and periodically inspected. One very successful manufactured topsoil product from Virginia is described in detail in a later section. We have also analyzed a few randomly selected bags of topsoil offered for sale in Illinois and found that overall the fertility and texture were favorable and compared well against high quality Illinois natural topsoil. However, the bags did not identify what the source material was and there was some foreign matter, such as small pieces of plastic and glass, included in the mix.

This paper reviews the authors' experience with "topsoil" both in a scientific and practical, applied sense. Of necessity, it will focus on surface mine issues while raising other issues and discussing some case studies.

Definitions of "Topsoil"

Topsoil is one of those things that are hard to define, but you know it when you see it. Generally, it is recognized as the surface few cm or more of soil darkened with organic matter, often mechanically and chemically manipulated by farmers to control weeds or enhance desirable plant growth. Oftentimes, its importance is recognized in regards to its superior ability to support plants, thus warranting protection from erosion or other degradation. Various definitions are offered for topsoil. The first Google hit on the word "topsoil" is found in Wikipedia (<http://en.wikipedia.org/wiki/Topsoil>):

"Topsoil is the upper, outermost layer of soil, usually the top 2 to 8 inches. It has the highest concentration of organic matter and microorganisms and is where most of the Earth's biological soil activity occurs. Plants generally concentrate their roots in and obtain most of their nutrients from this layer. The actual depth of the topsoil layer can be measured as the depth from the surface to the first densely packed soil layer known as subsoil. As one of the layers of soil on the Earth's surface, topsoil is sometimes referred to as the A horizon. This layer is formed from the deposition of eroded material as well as decaying organic matter. A variety of soil mixtures are sold commercially as topsoil, usually for use in improving gardens and lawns, or for ideal growing conditions in container gardens, by using potting soil, for example."

The second “topsoil” hit on Google is from a site called The Wise Geek (<http://www.wisegeek.com/what-is-topsoil.htm>). Topsoil there is:

“The upper surface of the Earth's crust, and usually is no deeper than approximately eight in. (20 cm). The Earth's topsoil mixes rich humus with minerals and composted material, resulting in a nutritious substrate for plants and trees. It may one of the Earth's most vital resources, because it represents a delicate nutritional balance that provides food for many of the animals on Earth, either directly in the form of plant material or indirectly in the form of products from animals that eat plants.”

A little more formal web site, the Merriam-Webster on-line dictionary (<http://www.merriam-webster.com/dictionary/topsoil>) defines “topsoil” as *“surface soil usually including the organic layer in which plants have most of their roots and which the farmer turns over in plowing”*. Another web dictionary (Dictionary.com Unabridged (v 1.1) Random House, Inc. (<http://dictionary.reference.com/browse/topsoil>) (accessed: October 28, 2008) defines “topsoil” as *“The fertile, upper part of the soil”*. The standard text used in many university introductory soil classes is The Nature and Properties of Soils (Brady and Weil, 2004). In it, “topsoil” is defined as *“The organically enriched A horizon at the soil surface”*. The Soil Science Society of America, in their Glossary of Soil Science Terms (<https://www.soils.org/ssagloss/index.php>) defines “topsoil” as: *“(i) The layer of soil moved in cultivation. Frequently designated as the Ap layer or Ap horizon. (ii) Presumably fertile soil material used to topdress roadbanks, gardens, and lawns.”* In addition, they define “surface soil” as: *“The uppermost part of the soil, ordinarily moved in tillage, or its equivalent in uncultivated soils and ranging in depth from 7 to 25 cm. Frequently designated as the plow layer, the surface layer, the Ap layer, or the Ap horizon”*. In the Encyclopedia of Earth Sciences Series, Encyclopedia of Soil Science (Chesworth, 2008) “topsoil” is defined as: *“The upper part of the solum, essentially the part affected directly by plowing (the plow-layer). More or less synonymous with the A horizon.”*

None of these definitions are particularly technical, a deficiency not mitigated in the more technical literature. For example, the field soil scientist bible, Soil Taxonomy (ftp://ftp-nc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/tax.pdf), does not include the term “topsoil” nor is “A horizon” defined. However, it does define the Epipedon, a Diagnostic Surface Horizon:

“The epipedon (Gr. epi, over, upon, and pedon, soil) is a horizon that forms at or near the surface and in which most of the rock structure has been destroyed. It is darkened by organic matter or shows evidence of eluviation, or both. Rock structure as used here and in other places

in this taxonomy includes fine stratification (less than 5 mm) in unconsolidated sediments (eolian, alluvial, lacustrine, or marine) and saprolite derived from consolidated rocks in which the unweathered minerals and pseudomorphs of weathered minerals retain their relative positions to each other. An epipedon is not the same as an A horizon. It may include part or all of an illuvial B horizon if the darkening by organic matter extends from the soil surface into or through the B horizon.”

In addition, the other important book used by the field soil scientist is the Soil Survey Manual (<http://soils.usda.gov/technical/manual/>). It also does not define “topsoil”, but it does define surface soil horizons:

***A horizons:** Mineral horizons that formed at the surface or below an O horizon, that exhibit obliteration of all or much of the original rock structure, and that show one or more of the following: (1) an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons (defined below) or (2) properties resulting from cultivation, pasturing, or similar kinds of disturbance.*

***E horizons:** Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles. These horizons exhibit obliteration of all or much of the original rock structure.*

The take home message is that topsoil is a common sense, lay term that is not well defined anywhere, and is roughly synonymous with epipedon, or A or Ap horizon. It forms in place via pedogenesis over the course of several scores to several thousands of years and supports most of the biological activity in the soil ecosystem and provides mechanical support and nutrients plants. Removing it and placing it in another location may alter some of its desirable characteristics such as its generally favorable granular structure. Any other “soil material” intentionally placed at the surface might better be termed “cover soil” or “surface soil”, or manufactured topsoil, and not “topsoil” in the natural sense, but even that material may or may not be the subject of reclamation or other regulations. What is in the 40 lb (18 kg) bags labeled “topsoil” at Walmart or other retailers is anybody’s guess.

Evaluation of natural, in place materials as topsoil

If a project requires topsoil, one option is to “borrow” it from another location. The NRCS provides guidelines for the evaluation of soil units as source areas for “topsoil” in their Soil Interpretations Rating Guides (ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Survey_Handbook):

(e) Topsoil.

- (1) The term "topsoil" as used here, describes soil material used to cover an area so as to improve soil conditions for the establishment and maintenance of adapted vegetation.
- (2) Generally, the upper part of the soil, richest in organic matter, is most desirable for use as topsoil; however, material excavated from deeper layers is also used. In this rating, the upper 40 inches of soil material is evaluated for use as topsoil. In the borrow area, the material below 40 inches is evaluated for its suitability for plant growth after the upper 40 inches is removed.
- (3) As shown in Table 1, the soil properties used to rate the soil as topsoil affect plant growth; the ease of excavation, loading, and spreading; and the reclamation of the borrow area.
- (4) The physical and chemical soil properties and qualities that influence plant growth are the presence of toxic substances, soil reaction, and those properties that are inferred from the soil texture, such as the available water capacity and fertility. The properties that influence the ease of excavation, loading, and spreading are the amount of rock fragments, slope, depth to the water table, soil texture, and thickness of suitable material. The properties that influence the reclamation of the borrow area are the slope, depth to the water table, amount of rock fragments, depth to rock, and the presence of toxic material.

Table 1. Suitability of a soil mapping unit as a source for topsoil.

Property	Limits			Restrictive Feature
	Good	Fair	Poor	
1. USDA Texture	---	---	Ice	Permafrost
1a. Texture (thickest layer 10-40")	---	LCoS, LS LFS, LVFS	CoS, S, FS, VFS	Too sandy
1b. Texture (thickest layer 0-40"), >3% Organic Matter, and <35% Clay	SCL, CL, SiCL	---	---	Too clayey
1c. Texture (thickest layer 0-40")	---	SCL, CL, SiCL	SiC, C, SC	Too clayey
1d. Texture (thickest layer 0-40")	---	---	FB, HM, SP MPT, Muck Peat, CE	Excess humus
2. Depth to bedrock (in.)	>40	20-40	<20	Depth to rock
3. Depth to cemented pan (in.)	>40	20-40	<20	Cemented pan
4. Depth to bulk density >1.8 g/cc (in.)	>40	20-40	<20	Area reclaim
5. Stoniness class	1	2	3, 4, 5	Too stony
6. Weight % 2mm-3" (0-40")	<5	5-25	>25	Small stones
6a. Weight % >3" (0-40")	<5	5-25	>25	Large stones
6b. Weight % 2mm-3" (40-72")	<25	25-50	>50	Area reclaim
6c. Weight % >3" (40-72")	<15	15-30	>30	Area reclaim
7. Salinity (thickest layer 0-40") mmhos/cm	<4	4-8	>8	Excess salt
8. Layer thickness (in.)	>40	20-40	<20	Thin layer
9. Depth to high water table	---	---	<1	Wetness
10. Sodium adsorption ratio (0-40")	---	---	>13	Excess sodium
11. Soil reaction (pH, thickest layer 0-40")	---	---	<3.5	Too acid
12. Slope (%)	<8	8-15	>15	Slope
13. Calcium carbonate (% , 0-40")	---	---	>40	Excess lime

Source: <http://www.itc.nl/~rossiter/Docs/NRCS/620nsh.pdf>.

Evaluation of soil reconstruction material for drastically disturbed areas

Evaluation of soil material for use as soil in reclamation of disturbed areas is included in the NRCS Soil Interpretation Guide (<http://www.itsc.nl/~rossiter/Docs/NRCS/620nsh.pdf>):

(1) Soil reconstruction of areas drastically disturbed, as in surface mining, is the process of replacing layers of soil material or unconsolidated geologic material, or both, in a vertical sequence of such quality and thickness that a favorable medium for plant growth is provided.

(2) Most new state strip [*sic*] mine programs emphasize that the land surface be restored to about its natural configuration or better and that the soil be reconstructed to maintain or improve its suitability for the intended use. Thus, knowledge of the soil and underlying material is needed to plan proper reconstruction operations of mined land. This guide for soil reconstruction material evaluates the material as a medium for plant growth. It can be used to rate any segment of the soil profile or unconsolidated geologic material that is thick enough to warrant consideration in planned soil reconstruction. For example, for named kinds of soil, it will be necessary for most purposes to rate the A horizon, the B horizon, and the C horizon separately. If they all rate good, there may be little justification for keeping them separate for soil reconstruction. If the A horizon is rated better than the B or C, then it generally should be kept separate, depending upon its thickness and the anticipated use of the land.

(3) When the soil materials are properly used in reconstruction, a rating of good means that vegetation is relatively easy to establish and maintain, that the surface is stable and resists erosion, and that the reconstructed soil has good potential productivity. Material rated fair can be vegetated and stabilized by modifying one or more properties. Topdressing with better material or applications of soil amendments may be necessary for satisfactory performance. Material rated poor has such severe problems that revegetation is very difficult and costly.

(4) The major properties that influence erosion and stability of the surface and the productive potential of the reconstructed soil are listed in the guide Table 2.

(5) Excessive amounts of substances that restrict plant growth, such as salt, Na, S, Cu, and Ni, create problems and also influence erosion and the stability of the surface. Other substances, such as Se, B, and As, are toxic.

(6) Materials that are extremely acid or have the potential upon oxidation of becoming extremely acid are difficult and expensive to vegetate. They also contribute to poor water quality, in runoff or in ground water. Materials high in pyrite and marcasite without offsetting bases have high potential acidity.

- (7) Vegetation is difficult to establish on soils that have high pH. Many of these soils also have a high sodium adsorption ratio, which indicates potential instability and water transmission problems.
- (8) The available water capacity also is important in establishing vegetation.
- (9) The stability of the soil depends upon its erodibility by water and wind and its strength.
- (10) Soil texture also influences available water capacity and erodibility by wind or water, soil structure and consistence, water intake rate, runoff, fertility, workability, and trafficability.
- (11) The fraction 3-10 inches is a weight percentage of rock fragments. The amount and size of rocks influence the ease of excavation, stockpiling, and respreading and the suitability for the final use of the land. A certain amount of rock fragments can be tolerated.
- (12) This rating guide does not cover all the soil features considered in planning soil reconstruction, such as slope, thickness of material, ease of excavation, potential slippage hazard, and soil moisture regime.
- (13) Thickness of material suitable for reconstruction and the ease of excavation are important in planning soil reconstruction operations, but they are not in this guide.
- (14) Soil moisture regime, climate, and weather influence the kind of vegetation to plant and the rate of revegetative growth, but the best soil in a moist environment is also the best soil in a dry environment.

Table 2. Soil reconstruction material for drastically disturbed areas.

Property	Limits			Restrictive Feature
	Good	Fair	Poor	
1. Sodium adsorption ratio	<4	4-13	>13	Excess sodium
2. Salinity (mmhos/cm)	<8	8-16	>16	Excess salt
3. Soil reaction (pH, 0-40")	5.0-8.5	4.0-5.0	<4.0	Too acid
3a. Soil reaction (pH, >40")	---	<4.0	---	Too acid
3b. Soil reaction	---	---	>8.5	Too alkaline
4. Available water capacity (in./in.)	>0.10	0.05-0.10	<0.05	Droughty
5. Erosion factor (k)	<0.35	>0.35	---	Erodes easily
6. Wind erodibility group	---	---	1, 2	Soil blowing
7. Texture	---	SCL, CL, SiCL	C, SiC, SC	Too clayey
7a. Texture	---	LCoS, LS, LFS, LVFS	CoS, S, FS, VFS	Too sandy
8. Weight % 3-10"	<25	25-50	>50%	Too cobbly
8a. Weight % >10"	<5	5-15	>15	Too stony
9. Layer thickness (in.)	>40	20-40	<20	Thin layer
10. Organic matter (%)	>1	0.5-1.0	<0.5	Low fertility
11. Clay activity (CEC/clay)	>0.24	0.16-0.24	<0.16	Low fertility
12. Calcium carbonate eq. (%)	<15	15-40	>40	Excess lime

Source: <http://www.itc.nl/~rossiter/Docs/NRCS/620nsh.pdf>

What is topsoil worth?

Soil erosion is a big concern all over the world because loss of topsoil changes the capacity of the soil to function and restricts its ability to sustain future uses. Erosion, like surface mining or urban development, or other anthropogenic disturbance, removes or redistributes topsoil, the layer of soil with the greatest amount of organic matter, biological activity, and nutrients. The ability of a plant community to recover after topsoil is lost is restricted. The NRCS estimated the value of in place topsoil in terms of 1997 dollars (Table 3). This is a crude evaluation and does not include the full cost of sedimentation or full cost of reclamation of an area that has lost its topsoil (Fig. 1).

Table 3. Estimated value (1997 dollars) of topsoil in place.

Item	Cost/ton
Cost by the bag	\$40 - \$80
Cost by the truckload	\$15
Cost to replace soil functions and remedy off-site damage	\$19*
Cost of erosion to downstream navigation	\$0 - \$5
Cost to human health	\$3
Cost to return soil to its original, non-eroded condition	Priceless

Source: http://soils.usda.gov/sqi/concepts/soil_organic_matter/som_value.html

Components of the value of a ton of topsoil worth \$19

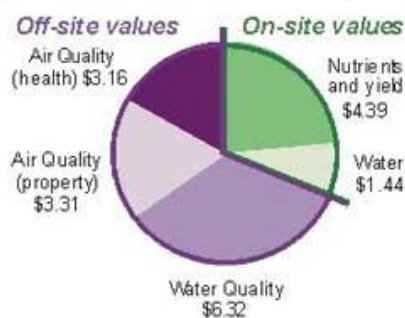


Figure 1. Components of the value of a ton of topsoil worth \$19, adjusted to 1997 dollars.

Source: http://soils.usda.gov/SQI/concepts/soil_organic_matter/som_value.html

Bagged Retail Topsoils

Bagged topsoil is available seasonally in many locations in 40 lb (18 kg) bags. To the best of our knowledge, there are no legal definitions of topsoil, or regulations about what is sold in bulk as topsoil off of trucks, or in bags labeled “*Topsoil*”. We analyzed material in triplicate from bags of three brands of “topsoil” purchased at various locations in central Illinois. The bags did not list their ingredients, but they appeared to be made up of a mixture of actual soil material plus some organic compost-like material. There are no regulations in Illinois concerning bagged topsoils, and as far as we know, this situation is typical. The physical analyses of the topsoils indicated that the texture varied within the brands of topsoil. The overall texture class from all samples was a desirable loam (Table 4). Sand contents ranged from 16-67%, silt from 17-55%, and clay from 16-29%, all within a reasonably good range.

Table 4. Texture of bagged topsoil.

Topsoil Bag	Class ¹	Sand	Silt	Clay	VCoS	CoS	MS	FS	VFS	CoSi	FSi
BRN A	CL	26	46	28	2	4	6	9	5	24	22
BRN B	SiCL	16	55	29	1	3	4	4	3	28	27
BRN C	CL	22	50	28	2	4	6	6	4	26	24
Mean	CL	21	50	28	2	4	6	7	4	26	24
GRN A	L	42	41	17	0	1	3	20	18	28	13
GRN B	L	38	42	20	0	1	3	15	19	27	15
GRN C	L	33	48	19	0	0	1	9	23	32	16
Mean	L	38	44	19	0	0	2	14	20	29	15
RED A	FSL	67	17	16	1	2	15	36	12	8	9
RED B	L	29	45	26	2	7	14	5	2	20	25
RED C	SL	65	17	18	1	2	36	25	2	6	11
Mean	SL	54	26	20	2	3	22	22	5	11	15
Overall Mean	L	38	40	22	1	3	10	14	10	22	18

1. Analyses by the hydrometer method (Gee and Bauder, 1986)

Soil fertility of the bagged topsoils was generally comparable to a grab sample of a typical east central Illinois natural topsoil (Table 5). The cation exchange capacity (CEC), pH, soil organic matter (SOM), and extractable S, P, Ca, Mg, K, Fe, were all higher than the reference natural soil. The extractable Na is higher in the bagged topsoil, but probably not enough to be a concern.

Table 5. Soil fertility¹ of bagged topsoil; means of four samples per bag.

Sample	CEC	pH	SOM %	Extractable (mg kg ⁻¹)											
				S	P	Ca	Mg	K	Na	B	Fe	Mn	Cu	Zn	Al
GRN	19	7.8	5.8	44	127	2,583	470	807	84	1.2	333	67	3	9	48
BRN	36	6.7	9.2	840	698	5,729	721	388	144	4.9	265	53	5	48	178
RED	23	7.8	10.0	107	238	2,571	706	1,354	112	1.8	298	31	2	10	63
Overall Mean	26	7.4	8.3	330	354	3,627	632	850	113	2.7	299	50	3	22	96
Typical Illinois Mollic Epipedon	18	5.9	4.0	25	26	2,380	341	178	12	0.5	130	64	2	3	441

1. Analyses done by Brookside Labs, Inc. Mehlich III weak acid extractions, water pH, CEC by summation.

Federal and State Topsoil Regulations in Mine Reclamation

Federal Regulations Involving Topsoil in Mine Reclamation, SMCRA

In SMCRA SEC. 515, relevant topsoil regulations start with paragraph 5:

(5) remove the topsoil from the land in a separate layer, replace it on the backfill area, or if not utilized immediately, segregate it in a separate pile from other spoil and when the topsoil is not replaced on a backfill area within a time short enough to avoid deterioration of the topsoil, maintain a successful cover by quick growing plant or other means thereafter so that the topsoil is preserved from wind and water erosion, remains free of any contamination by other acid or toxic material, and is in a usable condition for sustaining vegetation when restored during reclamation, except if topsoil is of insufficient quantity or of poor quality for sustaining vegetation, or if other strata can be shown to be more suitable for vegetation requirements, then the operator shall remove, segregate, and preserve in a like manner such other strata which is best able to support vegetation;

(6) restore the topsoil or the best available subsoil which is best able to support vegetation;

(7) for all prime farm lands as identified in section 507(b) to be mined and reclaimed, specifications for soil removal, storage, replacement, and reconstruction shall be established by the Secretary of Agriculture, and the operator shall, as a minimum, be required to:

(A) segregate the A horizon of the natural soil, except where it can be shown that other available soil materials will create a final soil having a greater productive capacity; and if not utilized immediately, stockpile this material separately from other spoil, and provide needed protection from wind and water erosion or contamination by other acid or toxic material;

(B) segregate the B horizon of the natural soil, or underlying C horizons or other strata, or a combination of such horizons or other strata that are shown to be both texturally and chemically suitable for plant growth and that can be shown to be equally or more favorable for plant growth than the B horizon, in sufficient quantities to create in the regraded final soil a root zone of

comparable depth and quality to that which existed in the natural soil; and if not utilized immediately, stockpile this material separately from other spoil, and provide needed protection from wind and water erosion or contamination by other acid or toxic material;

(C) replace and regrade the root zone material described in (B) above with proper compaction and uniform depth over the regarded spoil material; and

(D) redistribute and grade in a uniform manner the surface soil horizon described in subparagraph (A).

Note that nowhere in SMCRA is the term “topsoil” defined, but the A horizon is identified in the prime farmland subsection. The need to replace the original thickness and quality, from a plant growth perspective, of the native topsoil, or something better, was clearly the objective of this section of SMCRA.

Illinois Mine Reclamation

The Illinois Surface Mine Reclamation Act [(225 ILCS 720/3.06) (from Ch. 96 1/2, par. 7903.06) Sec. 3.06] is similar to SMCRA but it contains a definition of topsoil and it is as follows:

(a) The topsoil shall be removed from the land in a separate layer, replaced on the backfill area, or if not used immediately, segregated in a separate pile from other spoil. When the topsoil is not replaced on a backfill area within a time short enough to avoid deterioration of the topsoil, a successful cover shall be maintained by quick-growing plant or other means thereafter so that the topsoil is preserved from wind and water erosion, remains free of any contamination by other acid or toxic material, and is in usable condition for sustaining vegetation when restored during reclamation.

(b) If topsoil is of insufficient quantity or of poor quality for sustaining vegetation, or if other strata or combinations of strata can be shown to be more suitable for vegetation requirements, then the operator shall remove, segregate, and preserve in a like manner such other strata which are best able to support vegetation.

(c) The topsoil, or the best available subsoil or combination of soil which is best able to support vegetation, shall be restored.

(d) The term "topsoil" shall be defined by the Department by rule. Such definition shall consider regional differences in conditions in this State. In this case, the "Department" is the Illinois Department of Natural Resources, which defines topsoil in IL Admin Code 62-1701 as "the A and E soil horizon layers of the four master soil horizons."

Use of Topsoil Case Studies

A Revegetation Work Plan- Design of Cover Soil in Pennsylvania

The following is an example of specifications for “topsoil” or “cover soil” use for revegetating a disturbed non-SMCRA site for a large field project in Pennsylvania:

In designing the revegetation of final graded slopes the overall objective is to optimize the plant growth environment with regards to composition and construction of a cover soil, while at the same time providing material suitable for an engineered stable slope configuration. These two goals are not necessarily compatible, and a compromise often needs to be reached that favors slope stability. The final graded slopes will then be seeded and planted with plants chosen for their ability to thrive in that environment. As opposed to the land application (single or repeated disposal) of various agricultural, industrial, or municipal by-products on existing soil, the design and construction of a cover soil is a one-time event involving procurement of materials and placement of the materials on a finished grade typically using heavy earth-moving equipment. Cover soil construction may occur over an extended period of time, either continuously, or in segments. However, construction of the cover soil is usually the final construction episode, particularly on large, complex engineering projects. There may be maintenance and evaluation procedures during and following construction of the cover soil. Designing and constructing a cover soil can be presented in four sections: 1) establishment of parameters for soils that will be acceptable for use; 2) detail of sampling and analyses that will be required of soils and alternative materials obtained from on and off-site sources; 3) discussion of amendments that may be required, 4) a plan for producing the cover soil on the finished slopes, and 5) follow appropriate regulations.

1. Parameters for Acceptable Soil. The finished cover soil should provide an optimal growing environment for the chosen plants. The key properties of soil as a growing media can be roughly divided into physical and chemical attributes. Performance parameters of the finished cover soil, which vary from state to state, are often confused with material properties based on initial laboratory analysis. The material properties may change upon handling and placement of the materials during construction, and many performance parameters are for the constructed final cover soil. Performance parameters based on physical properties include: a) being able to store enough plant-available water (PAW) to sustain plant growth; b) being amenable to root growth; and c) being able to support above-ground and below-ground plant parts. These parameters are

largely influenced by the physical properties of the soil material and its placement with heavy equipment during construction.

Storing PAW is the main physical parameter that can be determined by the choice of soil materials. PAW is a partial function of soil texture (the relative proportions of sand, silt, clay, and rock fragments), and the organic matter content. Materials with extremes of soil texture are not suitable for use because they do not have a great enough PAW and can be unstable on steep slopes. Sand and loamy sand do not hold enough water to get plants through dry periods. Textures with clay contents greater than 35%, clay, silty clay, and sandy clay hold the water too tightly for plants to utilize. Textures with less than 10% clay and greater than 50% silt will not be stable on finished slopes. Acceptable soil textures are shown on the USDA textural triangle (Fig. 2). Being amenable to root growth and supporting above and below-ground plant parts is more of a function of how the material is placed. The finished cover soil will be compacted via heavy equipment handling and as a means of constructing stable slopes, which is good for stability, but not for plants.

The more compact the final cover soil, the less favorable an environment it is for root growth. This can be critical for the seedling phase. In addition to allowing for the proliferation of roots, the cover soil must provide for root anchorage where large shrubs and trees are to be grown. Where an infiltration limiting cap or liner underlies the cover soil, the cover soil must be thick enough to provide space for the roots and still provide protection for the cap.

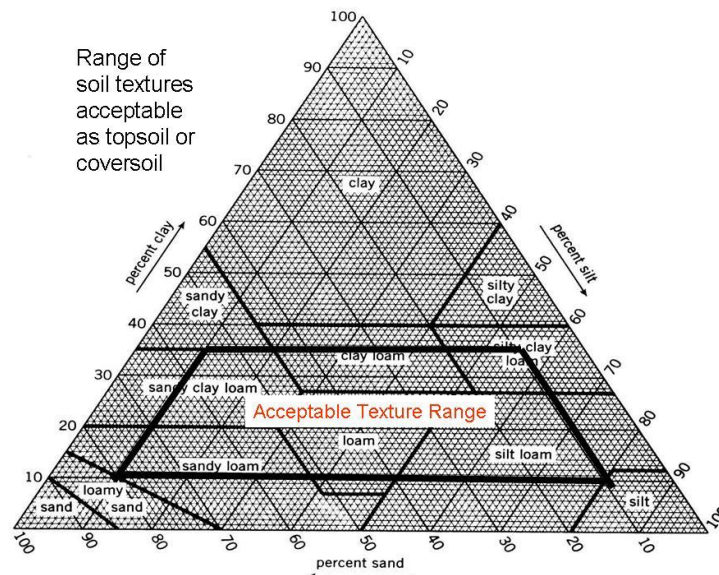


Figure 2. Acceptable texture ranges for material used as topsoil or cover soil.

Performance parameters of a suitable growing media based on chemical properties include: a) meeting plant nutrient requirements over the course of a growing season and in successive years; b) having no extremes of nutrient content or pH that are either phytotoxic (excessive) or at deficient levels; and c) do not produce plants that contain potentially excessive levels of elements toxic to the food web. The choice of soil materials can eliminate any with excessive or phytotoxic levels of chemical properties. Low pH levels are easily corrected with lime. Unusually high pH is more difficult to deal with, but can be corrected with sulfur and other amendments. Deficiencies in nutrients can be eliminated with amendments (bulk fertilizers).

2. Sampling and Analyses Required for Soil Materials. The construction of a final cover soil will often require tens to hundreds of thousands of cubic yards of soil and/or alternative materials. Soil materials existing on site are the most logical choice due to minimal transportation costs, and the environmental costs of developing a borrow site (essentially a shallow strip mine). Off-site soil materials have to be used when there is a lack of significant quantities of soil materials remaining on the property. Soil materials can include topsoil, subsoil, colluvium, and alluvium. Alternative materials include fine granular materials such as coal combustion by products (e.g. fly ash), dredged fine-grain sediments from water bodies, and weathered broken-down shale materials; provided the materials are desirable chemically and physically.

3. Soil Amendments. A cover soil will be produced from some combination of acceptable soils materials found on site, acceptable soil materials brought onto the site, possible alternative materials, compost materials either generated on site through clearing activities or imported onto site, and bulk fertilizers. The blended cover soil will be placed on the slopes prior to final slope shaping and seeding.

Compost material consists of on-site or imported, properly composted plant materials (bark, sawdust, shredded leaves, municipal chipped plant debris) and/or composted biosolids that meet EPA Part 503 Grade A “exceptional quality” requirements (free of pathogens and odors). Sawdust may not be used alone, and when used with other organic materials will be free of arsenic and chromium often used in pressure-treated lumber. All organic materials must be properly composted and screened to less than 1 inch, and free of any foreign materials such as plastics, metal fragments, and concrete fragments.

Bulk fertilizers shall consist of commercially purchased fertilizers applied at appropriate application rates. Bulk fertilizer will be blended with cover soil in stockpile or during construction. The N portion will consist of slow release N fertilizer such as sulfur-coated urea, methylene urea, organic nitrogen fertilizers, or other forms.

In order to break the erosive and washing action of surface flow on the long slopes, coir wattles, straw wattles, coir logs, or similar products will be installed perpendicular to water flow and parallel to slope contour at 15-foot intervals across the entire slope as the slope is being constructed. These slope break devices will be installed during the construction phase. Such devices temporarily stabilize slopes by reducing sheet and rill erosion, capturing sediment, and capturing seeds. The devices will breakdown after one to three years and add organic matter to the surrounding soil.

4. Production of Cover Soil. Production of the cover soil should be done as soon as possible after soil materials and amendments are brought to the site and/or processed. Amendments, mainly fertilizers and compost, should not sit in exposed stockpiles on the site. If not used right away, these materials should be covered with waterproof tarps. Soil materials and blended cover soil should be utilized on a continuous basis. If they are to remain in stockpiles for longer than one month, then they shall be temporarily seeded according to the attached specifications. Production of the blended cover soil will take place at designated locations on site. The soil materials will contain no foreign debris such as metal fragments or concrete fragments.

Blending will be conducted by mixing with a backhoe or small bulldozer in the stockpile or staging area. The backhoe will use its bucket as a volumetric measure, while the bulldozer will use the windrow method of blending. Dust control measures will be used to control fugitive dusts. Mixing shall continue until the materials are thoroughly blended. Mulching and tacking will occur following seeding. Mulch and tack will be used to provide protection for germinating seedlings, and to minimize surface erosion during the germination period.

5. Relevant State Regulations: (PA Landfill Cover Soil Regs 288.234):

- (a) The operator shall provide final cover in the following manner:
 - (1) A cap shall be placed and graded over the entire surface of each final lift. The cap may be no more permeable than 1.0×10^{-7} cm/sec. The following performance standards for the cap shall be met:
 - (i) The cap shall minimize the migration of precipitation into the landfill.
 - (ii) The cap shall be resistant to physical and chemical failure.
 - (2) A drainage layer capable of transmitting flow and preventing erosion of the soil layer shall be placed over the cap.
 - (3) A uniform layer of material shall be placed over the drainage layer. The layer of material shall support vegetation and protect the cap.
- (e) The layer of material described in subsection (a) (3) shall meet the following performance standards. The layer shall:

- (1) Prevent vectors, odors, blowing litter and other nuisances.
- (3) Be capable of allowing loaded vehicles to successfully maneuver over it after placement.
- (6) Be capable of supporting the germination and propagation of vegetative cover as required by 288.236 and 288.237 (relating to revegetation; and standards for successful revegetation).
- (7) Not crack excessively when dry.
- (f) Unless alternative design requirements to meet the performance standards in subsection (e) are approved as part of the permit under 287.231 (relating to equivalency review procedure) the layer of material described in subsection (a) (3) shall meet the following design requirements:
 - (1) The cover soil shall fall within the USDA textural classes of sandy loam, loam, sandy clay loam, silty clay loam, loamy sand, and silt loam as defined in the *Soil Survey Manual*.
 - (2) At least 40% by weight of the cover soil shall pass a 2 mm, No. 10 mesh sieve.
 - (3) The cover may not include rocks that are greater than 6 inches in diameter.
 - (4) The layer of cover soil shall be at least 2 feet in thickness.
 - (g) The grade of final slopes shall be designed, installed, and maintained to accomplish the following:
 - (1) Ensure permanent stability.
 - (2) Control erosion due to rapid water velocity and other factors.
 - (3) Allow compaction, seeding, and revegetation of cover material placed on the slopes.
 - (4) Ensure minimal infiltration and percolation of precipitation, surface water run-on and runoff into the disposal area.

In general, the topsoil on a landfill cover must meet contradictory requirements, it must meet surface and slope stability requirements while minimizing erosion and water infiltration, and at the same time support healthy vegetation. This is a tall order for any soil.

Case Studies

Use of Shales as CCB Disposal Landfill Cover Soils in Pennsylvania

In certain circumstances, weathered shale can be an alternate cover soil material for landfills where natural soils are in short supply. In western Pennsylvania excavated (ripped) silty shales, when fresh, are not suitable for cover soil according to Pennsylvania regulations, but when excavated and allowed to “weather” for a year or more, the same material may break down

enough to be suitable. In addition, some fresh shales can be crushed in a rock crusher to pass cover soil requirements. Suitability in this case is based strictly on grain-size distribution, specifically in that the fresh shales are too coarse and do not contain enough of the fine-earth fraction (< 2 mm particles) to function as cover soil. This has nothing to do with the chemical nature of the shales. After a year of exposure and handling (stockpiling), shales can weather and mechanically break down such that the material contains sufficient amounts of the fine-earth fraction to meet the regulatory requirements for cover soil.

In one test case using ripped shales in western PA (GAI, Inc.) the freshly ripped shale had a grain-size distribution of 16% <2 mm (the fine-earth fraction, #10 sieve) and 84% rock fragments. As such, this material is unsuitable for use as a cover soil on a landfill in Pennsylvania, where regulations require at least 40% <2mm. After one year, however, the sample showed an increase in the fine-earth fraction to 30%. This is still not suitable for cover soil in Pennsylvania, but additional weathering or mechanical crushing would further decrease the particle size. This has implications for increasing the water holding capacity of the material, a critical property when establishing permanent vegetation on a landfill cover.

The conclusion of the test case was that ripped silty shales, when handled and stockpiled (weathered) for a year or more, have the potential to provide a significant source of cover soil material for residual waste landfills where natural soils are in short supply. The handled/weathered (processed) shales may be used by themselves, or used to dilute limited supplies of existing soils. In addition, blending acidic processed shales with calcareous fly ash or other coal combustion by-products could mitigate potential acidic problems while providing a use for the ash. Any of these scenarios may provide an economic alternative to importing off-site soils for constructing the final cover of a landfill. The process of weathering excavated shales to make cover soil material is feasible in western Pennsylvania where the silt and clay-rich Permian to Pennsylvanian aged shales are soft enough to weather over a short time period. Hard shales and slate type rocks would not break down in a short enough time to be feasible. Typically, manufactured topsoils can be made from low cost, readily available materials including native soil with added materials such as slag, ash, and organic materials with added lime or fertilizer if necessary. The organic materials may include chipped trees and brush from land clearing operations, biosolids, straw, sawdust, etc. to add organic matter.

Use of Mining Residuals for Manufactured Topsoil Production in Virginia

As discussed in detail above, the upper darkened layer of natural soil that is enriched in organic matter and plant available nutrients is referred to as “topsoil” and is typically a superior plant growth medium to deeper subsoil layers. In contrast, subsoil Bt horizons or “clay pans” in Virginia are usually yellow to red, much higher in clay content and associated stickiness, lower in pH (acidity), and virtually devoid of beneficial organic matter. Natural topsoil materials in Virginia, on the other hand, are typically loamy in texture, but do vary quite a bit in pH, available plant nutrients, and organic matter content (Table 6). Native Virginia soils have been weathered and extensively leached for thousands of years, and for that reason they are generally quite low in the primary minerals that provide plant-available Ca, Mg, K, and P. In fact, virtually all native topsoils in Virginia are strongly acidic and relatively infertile without the addition of substantial amounts of lime and fertilizers over time.

The majority of materials that are marketed and sold in Virginia as “topsoil” are generated by the land development and construction process and may or may not be true “topsoil” as defined above. Additionally, these topsoils are highly variable over time as they are hauled from differing sites with different soil properties, soil removal depths, and handling/storage procedures. Very few of these materials are offered with any guarantee of pH, texture, or nutrient supplying ability relative to established soil testing standards.

The “ideal soil” for most turf establishment and landscaping applications is loamy in texture to ensure adequate water holding and aeration without being sticky and plastic when handled and graded. Beyond that, the soil should be moderate in pH (between 6.5 and 7.5) to ensure maximum beneficial biological activity, and moderate to high in plant available nutrients such as calcium (Ca), magnesium (Mg), potassium (K) and phosphorus (P). Good topsoils contain small but adequate amounts of plant essential micro-nutrients like iron (Fe) and copper (Cu), but should also be low in soluble salts and sodium (Na) which can damage soil structure and harm plants. Finally, the ideal soil will contain approximately 3 to 6% organic matter that serves as a long term source of plant nutrients (especially nitrogen-N), maintains biological activity, and greatly enhances physical properties such as water holding. Perhaps most importantly, the ideal soil for turf and landscaping applications will be consistent over time in all of the above properties that so that the user will not have “fine tune” establishment and management protocols for each batch of soil received.

Table 6. Important soil properties for topsoil made from papermill sludge and hardrock mining residuals (Greene Manufactured Topsoil) compared to highly productive prime farmland topsoil (Orangeburg series) from Dinwiddie County, Virginia and the range of typical topsoil properties found in Virginia (<http://www.cses.vt.edu/revegetation/>).

Soil Property	Greene Man. Topsoil	Prime Farmland	Avg. Va. Topsoil
Texture	Sandy loam	Sandy loam	Sand to Clay Loam
pH (acidity)	6.6 to 7.2	6.0 to 6.5	4.5 to 7.5
Organic Matter	5 to 7 %	1 to 2%	0.5 to 5%
Available* Ca	>1200 ppm	200 to 300 ppm	< 50 to 600 ppm
Available K	>250 ppm	30 to 60 ppm	< 20 to 80 ppm
Available P	75 to 150 ppm	20 to 30 ppm	< 5 to 30 ppm
Available Cu	1.5 ppm	0.6 ppm	0.2 to 0.7 ppm

*Available soil nutrients are those contained in an acid-extractable form that would be expected to contribute to plant uptake needs over the growing season, and are typically expressed in parts per million of total soil weight. For a common sense conversion, 100 ppm of available Ca in a soil would equate to approximately 200 lbs of calcium in the upper six inches of topsoil over one acre.

Virginia Tech has cooperated with a regional mining company (Luck Stone Corporation) since the early 1990's in the development of manufactured topsoil products for commercial markets and occasional on-site mining use for revegetation. Luck operates a wide range of hard rock and sand & gravel mines in Virginia. The hard rock mines in particular generate a wide array of potentially useful soil building components including pond fines, air classifier fines, crusher screenings, overburden, and saprolites. These materials will obviously vary widely based upon the rock type mined, crushing and screening operations, overburden + saprolite thicknesses, etc. However, we have performed detailed physical and chemical analyses from the suite of residuals produced at over 20 mines in Virginia and found that in most instances, a viable manufactured topsoil could be produced. A typical data set for one mine's materials is presented in Table 7. Review of these data indicated that all materials would be suited for use in manufactured soil blends. Due to their abraded surfaces, the pond fines and #10's exhibited very high pH and extractable nutrient values. However, these pH levels are "artificial" with respect to long-term soil reaction and are weakly buffered. Similarly, the extractable nutrient levels are much higher than would be expected from natural soil materials. This is due largely to their enhanced extractability in the strong acids used and to the presence of readily soluble primary mineral forms. The physical properties of the materials were also quite favorable, particularly the overburden.

Table 7. Basic chemical and physical properties of mineral soil components from a diabase mining operation in northern Virginia.

Material	pH	acid extractable mg /kg (Mehlich I)				% of < 2mm		
		P	K	Ca	Mg	Sand*	Silt	Clay
Pond Fines	8.7	116	93	2546	221	64	30	6
#10 Sands	9.3	176	77	1543	180	82	15	3
Overburden	7.4	52	19	1221	373	82	10	8
Saprolite	7.0	46	24	1526	457	77	13	10

* Sand is 2 to 0.05 mm, silt 0.05 to 0.002 mm and clay < 0.002 mm. Pond fines are fine sands, #10's are coarse sands, and the overburden is well-graded in the sand fraction.

Thus, in our experience, most hard rock mines in Virginia have sufficient quantity and quality of mining residual products to generate a suitable mineral framework for a good manufactured topsoil product, but a suitable source of organic matter must be located and acquired. In general, the organic matter must be stable and relatively low in salts. For a variety of practical and regulatory reasons, stable composted products are the clear choice for this use. We have utilized a wide range of composted yard waste, biosolids, and papermill sludge products in our manufactured soil research programs. Currently, the most widespread product in use for this purpose in Virginia is a composted papermill sludge product generated by Greif Brothers in Amhest Virginia (Evanylo and Daniels, 1999). In the late 1990s, we added the compost at varying rates to a mix of mineral products similar to those described in Table 7 to determine the optimal volumetric addition rate to generate a high quality manufactured topsoil. Plant growth response is shown in Fig. 3. In general, results from this trial and others have led to a base recommendation of 15 to 20% compost by volume in manufactured soil mixes such as these.

The most successful manufactured topsoil product to date in Virginia and the mid-Atlantic region is the Greene topsoil product manufactured by Luck Stone from granitic saprolites, papermill compost, and mineralized igneous rock dust at their Greene mine just north of Charlottesville. This topsoil provides balanced levels of plant available micro-nutrients (e.g. B, Cu, Fe, Mn, and Zn) (Table 7).



Figure 3. Tall fescue response to additions of papermill sludge compost to hard rock mine residuals. Treatments from left to right are prime farmland control topsoil (Orangeburg series) and 0, 15, 30, and 45% compost by volume added to mixture of mineral fines and crushed overburden. In general, results from this trial and others have led to a base recommendation of 15 to 20% compost by volume in manufactured soil mixes such as these.

Currently, Luck Stone produces over 50,000 cubic meters of this product per year and sells it for > \$10 per yard, FOB. Due to the inherent fertility of this topsoil, use of initial or starter fertilizers (especially P and K) may not be necessary. This label guarantee applies to fresh topsoil only because available nutrients will be depleted over time by plant uptake. This topsoil product is not recommended for root zone use with acid loving plants such as blueberries, azaleas, and native pines unless it is blended with naturally acidic (pH < 6.0) soil materials.

Use of Topsoil Substitution in Appalachian Coal Mining

In the Appalachians, native A + E horizons are frequently less than 15 cm in combined thickness, and topsoil salvage and storage from steep native pre-mining slopes poses significant logistical and operator safety challenges. Therefore, blasted rock overburden has been commonly employed as a topsoil substitute since the early 1980's (Daniels & Amos, 1985; Roberts et al., 1988). In general, as long as net acid-forming materials can be excluded, sufficient thickness of sedimentary rock strata can generally be located to produce viable topsoil substitutes of sufficient thickness to support most post-mining land use revegetation needs. The topsoil substitution allowance is generally based upon conventional soil chemical tests and an

estimation of the post-blasting texture and rock content of the resultant spoils (Daniels & Zipper, 1997). Since the native forest soils are typically acidic, infertile, and high in coarse fragment content, historically it has been rather simple to demonstrate superior soil chemical properties such as higher pH and extractable Ca and P from the relatively unweathered rock spoils (Daniels & Amos, 1982). However, post-placement mine soil compaction is a significant limiting property over time (Haering et al., 2004). Therefore, it is critical to ensure that topsoil substitutes are placed with sufficient uncompacted thickness (at least 50 cm) to support long-term plant growth. Most of the spoils employed are also quite rocky (> 40% rock fragments > 2 mm), so sufficient thickness is also required to provide adequate plant available water and associated rooting volume.

These topsoil substitutes are usually devoid of natural soil organic matter, but do accumulate it via natural processes quite quickly, consequently, organic matter additions are not a standard practice in the region. Simple addition of lime and appropriate amounts of N-P-K fertilizers, along with rapid establishment of N-fixing legumes, are generally sufficient to provide for effective herbaceous revegetation in this environment. However, many of the topsoil substitute strata employed in the central Appalachian region (S. WV/SW VA/E. KY) are often quite high in pH (> 7.0) and are often quite unsuitable for establishment of native forest species (Torbert et al., 1986). This high pH coupled with use of highly competitive grass and legume species has been identified as a major hindrance to effective reforestation of coal mined lands. In this instance, the use of more highly weathered and lower pH strata that occur in the upper portions of the mining sequence is superior to the use of deeper less weathered strata. When this appropriate overburden selection is combined with the use of lower N-fertilizer rates and non-competitive vegetation, superior reforestation results are more probable (Burger and Zipper, 2002).

Organic Amendments and Other Residuals for In-Situ Soil Reconstruction and Remediation

A wide array of organic waste/residual products including biosolids, papermill sludges, fly ash, kiln dust, dredge materials, and alum sludges are widely available for soil reconstruction on mining sites and for rehabilitation of contaminated sites (USEPA, 2007). In many instances, these materials are available at very low cost and may quite useful in suppressing phytotoxicities (e.g. Fe-rich biosolids can bind As and Pb). However, their use must be carefully matched against site/spoil properties, climate, future land use demands etc. (USEPA, 2007), and proximity to high quality surface waters.

Organic amendments, particularly biosolids, have a long history of use in coal mine soil reconstruction (Haering et al, 2000) and other applications. The initial work in this area was conducted in western Pennsylvania (Sopper et al., 1993). Biosolids have since been widely used in most regions of the USA as a mine soil organic matter amendment. Routine one-time application rates range between 75 and 150 Mg/ha with the presumption that the one time benefits of organic matter and nutrient additions counterbalance short-term concerns of N leaching and P runoff. These one-time loading rates are considerably higher than agronomic rates used for one-season crop production permit scenarios. While nitrate-N leaching has been a concern of many, detailed studies at a number of sites (e.g. Daniels et al, 1999; Haering et al., 2000) have indicated very limited effects that are most observable the first winter following application. The profound short and long-term beneficial effects of appropriate biosolids amendment to mine soils have been demonstrated in a number of studies across the USA (Haering et al., 2000), particularly for establishment and maintenance of herbaceous vegetative covers. Use of these higher than agronomic loading rates has been shown to be detrimental to pine seedlings, however (Moss et al., 1989), presumably due to excess salt and nutrient loadings.

We have also used higher than agronomic rates of biosolids and waste lime to stabilize highly toxic Pb and Zn smelter wastes and tailings in Poland (Stuczynski et al., 2007) and very acidic (pH < 3.2) and metalliferous Coastal Plain sediments (Orndorff et al., 2008) in Virginia. In both instances, heavy biosolids loading rates (75 to > 250 Mg/ha) were coupled with lime additions that matched acid-forming potentials to stabilize soil chemistry and construct a suitable plant growth medium that supported viable plant growth for over 10 years in Poland and 5 years in Virginia.

Dredged River Sediment as Topsoil Substitute

Pekin Landfill, Tazewell Co., Illinois. Sediment removed from Lower Peoria Lake on the Illinois River provided topsoil for final vegetative cover on the clay cap of the Pekin Landfill in Central Illinois. The project also benefited two nearby marinas by removing sediment from their access channels. The sediment deposits in the lake are over ten feet deep near the commercial navigation channel, making it possible to load barges directly with a barge mounted crane (Fig. 4A). The sediment was the consistency of toothpaste and was placed on deck barges for a six mile (9.6 km) trip to a downstream dock. From there it was loaded into semi-trucks with a hydraulic clamshell excavator. The trucks traveled 17 miles (27 km) to the landfill. Normal

trailers with tight sealing gates were used and spillage and leaking from the trailers was not a problem. Once there, it was end-dumped onto the cap (Fig. 4B), and if necessary, pushed into place with a bulldozer. The material stayed in place without containment and was left in a stockpile for later distribution over the cap. The sediment was placed in September of 2007, too late for grass seed to become well established. It dried and cracked over the next few months (Fig. 4C) and freezing and thawing cycles hastened the development of soil structure. By spring the upper layer was granular to a depth of three to six inches (7.5 to 15 cm) and had not experienced excessive erosion. Planted annual rye and volunteer weeds germinated and the sediment stockpile was quickly vegetated. Soil formation continued through the summer with granular material filling desiccation cracks around massive polygons. Fig. 4D shows the contrast between the sediment pile and an adjacent landfill cap in August of 2008.

Banner Marsh State Fish and Wildlife Area. The Banner Marsh State Fish and Wildlife Area largely consists of pre-law strip mined land adjacent to the Illinois River. In July of 2004 two barge loads of sediment removed from Lower Peoria Lake were placed on a field with very poor soil planted in alfalfa. The material was shipped about 20 miles (32 km) by barge and then loaded on semi trucks for the remaining five miles (8 km). Figure 5A shows the consistency of the material as it was loaded into the trailers. There were no issues with spillage on roads. At the site, the sediment was dumped in adjacent rows on a field with the crown of the row 12 to 18 in. (30 to 45 cm) deep. Within a month the sediment had largely desiccated and formed polygons (Fig. 5B). The material was not planted. By fall, soil formation was progressing as polygons cracked due to wetting and drying. By spring, freezing and thawing had largely reduced the polygons to granular material (Fig. 5C). The field was left unplanted again in 2006 and it supported volunteer plants. In the spring of 2006, it was disked and planted in sunflowers to provide a food plot for doves and other wildlife. Figure 5D shows the immature sunflowers adjacent to the alfalfa on the untreated portion of the field. The sediment developed good soil structure and performing as an excellent topsoil.



Figure 4. Sediment application as a topsoil substitute at Pekin IL Landfill: A, clam shell bucket loading Peoria Lake sediment onto a deck barge; B, stockpiling sediment on top of Pekin Landfill clay cap; C, drying sediment one month after placement; D, volunteer vegetation thriving on sediment, unvegetated foreground is landfill clay cap, one year later.



Figure 5. A, Truck receiving sediment from barge for transport to Banner Marsh pre-law strip mine area; B, Sediment drying one month after placement; C, frost shattered sediment polygons the following spring; D, Planting of sunflowers thriving on sediments after tillage, foreground is untreated.

Topsoil and Urban Development

Soil management and restoration in urban areas is likely to become increasingly important as suburbs expand and cities attempt to restore or redevelop brownfields and other old urban sites. The use of various mixtures of materials to develop soil material for use as topsoil will continue to grow. This topic is tied to water supply, storm water management, species diversity, and general quality of life.

Urban redevelopment sites frequently have highly disturbed soil, including a history of cut and fill and a variety of economic or residential activities. Planned future uses may range from ecological areas and parks to residential or industrial applications. The use will determine the soil requirements, but most options will require at least some topsoil or “topsoil material” to

support envisioned vegetation. Soil for these projects can be topsoil excavated from new developments or farmland, soil material from other locations, or soil mixed with a variety of materials such as compost or biosolids. The quality and quantity of soil placed on the site, as well as factors like compaction during placement and subsequent landscaping activities, will determine how well it performs.

The advent of mass grading for new residential and other developments presents a number of issues. In Illinois, typically all topsoil is removed during construction and temporarily stockpiled on site (Fig 6A). Some is returned to the residential lots and the rest is sold or used for other off site purposes. The amount replaced on the lots varies depending upon the developer and any local regulations. In Illinois, prospective residents are often given the opportunity to buy back the soil that once covered their lot. Many owners of new homes on former prairie farms find that the topsoil depth is not sufficient to support a garden or tree. The lack of topsoil likely requires that residents use extra water to maintain grass. Fig. 6B shows the “lawn” of a home in a subdivision in central Illinois. Another concern is the loss of local plants and soil fauna caused by mass grading, which leaves no refuges for potential recolonizers.

Conclusions

Topsoil is universally recognized as vital in ecosystem health, landscape hydrology, and revegetating disturbed lands including brownfields, landfills, mined lands and lawns in urban areas. However, topsoil presents conflicting requirements and goals. The common practice of borrowing it from one place to restore another creates a topsoil deficit in the borrow area, while requiring expensive transport of large amounts of the dense material. Placement of topsoil often involves heavy machinery that compacts it to the detriment of plant growth. Compacted soils have been identified as the limiting factor in reclaiming prime farmland minesoils in Illinois (Dunker et al. 1995). Ironically, trees growing on mine soils often do better where soils have not been replaced, again due to compaction (Gorman et al., 2002). A related problem often associated with topsoil application is the lack of appreciation of the subsoil’s importance on water supply to plants. Because of the expense, topsoil is often applied in a thin layer over compacted or scalped surfaces. This is especially true in urban and suburban developments (Craul, 1999).



Figure 6. A, Site stripped of topsoil, stockpile visible in distance, as part of suburban development in Northern Illinois; B, sod laid directly on graded subsoil in new Central Illinois suburban development.

Sediment will likely become an increasingly important source of soil material and as a topsoil substitute for landscaping, restoration, and redevelopment as dredging and handling options become more efficient. The nation's reservoirs and waterways hold vast quantities of sediment, much of it fine grained and relatively uncontaminated. Removing the sediment realizes recreational and ecological benefits, restores water storage capacity, and can provide soil material that is currently a resource out of place. When a planned dredging project can be matched with a soil placement project, both projects may benefit economically. In locations where it can be delivered by barge, it also keeps thousands of trucks from moving soil over urban highways and through neighborhoods. The technology exists to ship wet or dry sediment to areas needing fine-grained material by rail or by slurry pipelines. In Illinois the authors have used sediment as topsoil material in several studies and demonstration projects including moving sediment 165 miles (270 km) for a lakefront park in Chicago (Marlin, 2004, Marlin and Darmody, 2005). The sediment is from the Illinois River, and for the most part eroded from farmland and stream banks. The sediment was quite similar to native Drummer-Flanagan topsoil and performed well in greenhouse and field studies. It has also been mixed with biosolids and compost (Darmody, et al, 2004; Kelly et al, 2007) and used as an amendment on sandy soil. The Great Lakes Commission maintains an extensive bibliography on the beneficial use of sediment (Great Lakes Commission, 2004).

When it comes to revegetating a disturbed site, topsoil, or a high quality topsoil substitute, in sufficient thickness and appropriate density is paramount in achieving success. No matter where it comes from, or what you call it, the upper skin of the earth is vitally important in maintaining a healthy, functioning ecosystem that we both love to look at and depend on for water, fiber, and food.

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