Chapter

Integrating Ecological Site Descriptions with Soil Morphology to Optimize Forest Management: Three Missouri Case Studies

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Abstract

Academics and University Extension personnel have experience with soil mapping and providing soil suitability interpretations; however, a more efficient information conveyance to land custodians is desired to support informative land management applications. In the USA each state, in concert with the United States Department of Agriculture, has embarked on developing an online format linking soil survey with ecological site descriptions to provide information for forest and rangeland management to encourage soil protection - health and optimizing ecological services on individual land parcels. In this Missouri-based manuscript, we discuss three cases where soils and their associated ecological site descriptions provide land custodians information concerning their logical reference state vegetation community and detail land management decisions that transform the reference vegetation community to a different vegetation community. With each case, landscapes and their associated vegetations communities are potentially partitioned by soil, physiography, hydrology, and other attributes.

Keywords: ecological sites, forest management, Alfisols, Ultisols, soil mapping

1. Introduction

Alfisols are a soil order in USA "Keys of Soil Taxonomy" [1]. Alfisols are typically developed under mixed forests in temperate climates that maintain a low to moderate level of soil organic matter, a neutral to acidic pH and have a moderate degree of base saturation. One requirement of Alfisols is the presence of an argillic horizon, coupled with the requirement of having a base saturation greater than 35% in the argillic horizon control section [1]. In Missouri, Alfisols typically have aquic and udic moisture regimes and support deciduous forest vegetation [2]. Ultisols are a soil order in USA "Keys of Soil Taxonomy" that are similar to Alfisols with the exception that Ultisols have less than 35% base saturation in the control section [1].

The USDA-NRCS has developed the National Soils Information System based on a national soil survey composed of establishing soil characteristics using observations along soil delineation boundaries and determining map unit compositions by field transects [3]. Three different geographic databases have been established having different mapping intensities: (i) State Soil Geographic database (STATSGO at a scale of 1:250,000, (ii) Soil Survey Geographic (SSURGO) at a scale ranging from 1:12,000 to 1:63,360, and (iii) National Soil Geographic (NATSGO) at a scale of 1:7,500,000. The STATSGO database is well-suited to represent soil data relative to specified soil associations (a soil association represents two or more different soils that appear in a regularly repeating landscape pattern) and are well-suited for regional, multi-state, river basin and multi-county resource planning, management, and monitoring. The SSURGO database provides detailed information about individual soils and is well-suited for landowners, municipal, and county planners for more local and site-specific resource planning, management, and monitoring. The NATSGO database establishes information and the identification of the Major Land Resource Area (MLRA) map and associated attribute data. The MLRA is a land area having a clearly defined composition of geography, geology, soils, climate, physiographic features, potential natural vegetation, water resources and land practices.

Ecological classification is predicated on the separation of a landscape into discrete and repeatable land parcels, wherein the individual land parcels provide information to guide land management. An ecological site is defined as "a distinctive type of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances" [4]. As such, ecological sites provide a framework for connecting soils and landscapes to vegetational communities; after which, thoughtful and knowledgeable natural resource management may proceed with a full understanding of potential beneficial and negative consequences [5]. Once established, ecosystem site descriptions may be assembled to provide land management ranging from a woodlot to a landscape to an ecosystem.

In Missouri, ecosystem site identification/isolation and subsequent descriptions are prepared by a multiagency cooperation involving diverse disciplines within the Missouri Department of Conservation and the United States Department Agriculture-Natural Resource and Conservation Service (USDA-NRCS). Literature utilized by this multiagency cooperative project includes materials produced by the Missouri Department of Conservation, USDA-NRCS and other entities [6–12]. Eight soil and ecological factors are identified that significantly influence vegetation and site productivity: (i) landform, (ii) parent material, (iii) root restrictions, (iv) base saturation, (v) soil drainage, (vi) soil texture, (vii) flooding, and (viii) ponding.

These soil and ecological factors have been previously characterized by a 50+ year county-based soil survey program, resulting in a national database. Subsequently, land parcels having a commonality of these soil factors were correlated with historical and potential vegetation communities. Ecological site names are based on soil/substrate, landform and the historic plant community, with one example being "Loess Fragipan Upland Flatwoods". Based on a verification process, ecological sites are initially termed "provisional ecological sites", then with further review and data acquisition, the ecological sites are eventually termed "correlated ecological sites". In addition to soil, climate, local hydrology, and physiographic information, the final product contains additional information on species composition, canopy cover, biomass estimates, and ground cover information.

Products available to the public are termed "ecological site descriptions (ESD's) and provide additional information: (i) ecological site extent maps, (ii) physiologic features, (iii) landscape block diagrams, (iv) soil descriptions and interpretations, (v) ecological dynamics with state and transition models, (vi) plant lists, and (vii) site interpretations for forestry and wildlife management.

Ecological site descriptions are not mapping units, rather they are taxonomic units. However, ecological site descriptions of an appropriate areal extent may be used as mapping units when the sites are highly patterned because of site topography, soil distribution, geology, and other attributes. The repeatable distribution of ecological sites provides for their useful application to manage land under the influence of livestock grazing, wildlife habitat, recreation, rural or urban development, forestry, and a multitude of other land uses. In general, we accept the definition proposed by Bestelmeyer et al. [13] and Briske et al. [14] to define an ecological site as landscape units that have similar characteristics of soil, topography, geological formations, and climate regimes that differ because of (i) the production and plant species composition under the disturbance of reference conditions associated with soil properties, the natural dynamics of vegetation and the ecosystem services provided, and (ii) the responses to management, processes of degradation, and restoration.

State and Transition Models attempt to explain how ecosystems transition from one state to another state. A state is a series of plant communities associated with specific soil properties that produce persistent attributes over time with structural and functional ecosystem characteristics [15]. The reference state is a state that provides the largest range of potential environmental services and typically is the "ideal" state. At its essence, researchers aim to understand how ecosystems function and respond to management or natural influences. Ecological resilience is the capacity to absorb and/or reorganize after a disturbance yet maintaining the site's structural integrity [15]. Thresholds are key biotic and abiotic factors and modified ecosystem functions that alter the ecosystem structure beyond the limits of ecological resilience resulting in a transition to a different state or limits recovery. Triggers are events, factors, processes and/or drivers that initiate a transition from one state to another.

The objectives of this project are to document the importance of combining soil survey information with ecological site descriptions to show relationships (i) between soil genesis-soil morphology with their resident plant communities, and (ii) and the actions of land management to alter the resident plant communities to a different plant community.

2. Materials and methods

2.1 Study areas

The study areas are all located in southeastern Missouri, USA. The study area containing the Knobtop, Taumsauk and Irondale Ultisol pedons is located at Taumsauk State Park and was selected because of its variable pedon depths and the presence of loess over igneous residuum/colluvium. The Knobtop (Fine-silty, mixed, active, mesic Aquic Hapludults) pedon is a moderately deep, moderately well-drained soil formed in loess overlying Precambrian rhyolite residuum. The pedon is located on a summit position having a 1 to 2 percent slope. The Irondale (Loamy-skeletal, mixed, active, mesic Typic Hapludults) pedon is moderately deep, well-drained, and moderately permeable soil formed in rhyolite residuum on a steep 35% slope supporting an oak forest. The Taumsauk (Loamy-skeletal, mixed, active, mesic Lithic Hapludults) pedon is a shallow, somewhat excessively-drained, moderately permeable soil formed in rhyolite colluvium. The Taumsauk pedon is located on a 10% convex slope and exhibits a mountain glade area.

The Caneyville and Hildebrecht pedons are in Sam A Baker State Park and were selected because the pedons were formed in loess over limestone residuum, which is a very common occurrence across east-central Missouri. The Caneyville (Fine, mixed, active, mesic Typic Hapludalfs) Alfisol pedon is a moderately deep, well-drained soil formed in a thin silty mantle overlying fine-textured limestone residuum. The Hildebrecht (Fine-silty, mixed, active, mesic Oxyaquic Fragiudalfs) Alfisol pedon is a very deep, moderately well-drained soil on a side slope. The pedon is formed in loess over weathered dolomitic residuum. Permeability is moderate above the fragipan and slow or very slow in the fragipan.

The study area containing the Amagon (Fine-silty, mixed, active, thermic Typic Endoaqualfs) and Calhoun (Fine-silty, mixed, active, thermic Typic Glossaqualfs) pedons are located in the Mingo National Wildlife Refuge. This study area was selected because these poorly-drained pedons were formed in alluvium, which is representative of the Mississippi River Embayment. The Amagon pedon is a very deep, poorly-drained, slowly permeable Alfisol that formed in loamy alluvium. The Calhoun pedon is a poorly-drained, slowly permeable Alfisol formed from loess-like material on a Pleistocene-age terrace.

The Knobtop, Taumsauk and Irondale study area and the Caneyville and Hildebrecht study area have a continental humid climate with winter having dry and cold air masses and summer having moist, warm air masses producing abundant rainfall events. The average annual precipitation 112 cm, whereas the average annual temperature is about 13°C [16]. The Amagon and Calhoun study area has a continental humid climate with an average rainfall of 126 cm. Mean winter temperatures are 4°C and mean summer temperature of 26°C, whereas the mean annual temperature is 13°C [17]. The The Knobtop, Taumsauk and Irondale study area and the Caneyville and Hildebrecht study area does not experience flooding, whereas the Amagon and Calhoun study area annually experiences either flooding or seasonal water saturation.

2.2 Methodology

Pedons were located, described, and sampled according to Soil Survey Division Staff [18] in undisturbed forest settings using excavated pits. Samples were oven-dried, lightly crushed, and sieved to remove materials larger than two mm. Soil pH using equal volumes of soil and water, the NH_4-acetate (pH 7.0) extraction of exchangeable bases, the total acidity by slow titration to pH 8.2, and the soil organic matter content (SOM) by loss on ignition were performed using standard methods [19]. The particle size distribution (mechanical analysis) was determined by Na-saturation of the exchange complex, dispersion in Na_2CO_3 (pH 9.0) and centrifuge fractionation to remove clay and wet sieving of the silt and sand separates [19].

The ecological site descriptions were obtained using the Ecosystem Dynamics Interpretive Tool (EDIT), which is an online information system for the sharing of ecological site descriptions [20] or ([https://edit.jornada.nmsu.edu/], verified February 2021).

3. Results and discussion

3.1 Knobtop Irondale Taumsauk Ultisol Assemblage

The Knobtop, Irondale and Taumsauk soils are Ultisols having fine silty or loamy-skeletal textures and exhibiting A-E-Bt-rhyolite rock horizon sequences. The Knobtop pedon resides on a summit position developed in a moderately thick loess mantle overlying rhyolitic residuum, whereas the Irondale and Taumsauk pedons occupy side and convex (shoulder) slope positions, respectively. The Irondale and Taumsauk pedons exhibit thin and very thin loess mantles overlying rhyolite colluvium, features attributed to erosion and mass-wasting during and subsequent to loess deposition.

The Knobtop (Aquic Hapludult), Taumsauk (Lithic Hapludult) and Irondale (Typic Hapludult) pedons reside in MLRA 116 in the St. Francois Knobs and Basins region. The Knobtop pedon exhibited a silt loam texture in the ochric epipedon and silty clay loam texture in the majority of the argillic horizon (**Table 1**). The Taumsauk pedon exhibited a very cobbly silt loam ochric epipedon (A horizon) and very cobbly silt loam (E horizon) transitioning to a very cobbly silty clay loam within the comparatively shallow-to-bedrock argillic horizon. Soil pH in the Knobtop and Taumsauk pedons are extremely acid, with a corresponding base saturation much less than 35% (**Table 2**). The exchangeable calcium concentration is very low, which is reflective of the very small Ca concentration of the analyzed rhyolite samples (rhyolite composition not shown). The Irondale pedon exhibits

Knobtop Horizon	Depth cm	Texture	Structure	Boundary	Color Matrix
A	3	Silt loam	1f&m gr	a,s	10YR5/2 grayish brown
E	13	Silt loam	1f sbk	a,s	10YR5/3 brown
Bt1	32	Silt loam	2 f&m sbk	c,s	10YR5/4 yellowish brown
Bt2	55	Silty clay loam	2 f&m sbk	c,s	10YR4/6 dark yellowish brown
Bt3	76	Silty clay loam	2 f&m sbk	c,s	10YR4/6 dark yellowish brown
2 BC	83	Silt loam	1 thick platy	a,s	10YR4/6 dark yellowish brown
R-rhyolite					
Taumsauk					
Horizon					
A	3	Silt loam	1f gr	a,s	10YR3/1 very dark gray
E	8	Silt loam	1f sbk	a,s	10YR4/3 brown
Bt1	25	Silt loam	2f&m sbk	c,s	10YR5/4 yellowish brown
Bt2	33	Silty clay loam	2f&m sbk	a,s	10YR5/6 yellowish brown
R-rhyolite					
Irondale					
Horizon					
A	8	Loam	1f&vf gr	a,s	10YR4/2 dark grayish brown
E	25	Silt loam	1f&vf gr	a,s	10YR 5/3 brown
Bt1	46	Silt loam	1f&vf sbk	c,s	5YR5/6 yellowish red
Bt2	56	Silt loam	1f sbk	c,s	7.5YR5/6 strong brown
R-Rhyolite					

Structure: 1 = weak, 2 = moderate, f = fine, m = medium, gr = spherical, sbk = subangular blocky.
Boundary: a = abrupt,, c = clear, s = smooth.

Table 1.
Morphological and physical properties of the Knobtop, Taumsauk, and Irondale pedons.

Horizon	pH	Total Acidity	SOM	Calcium	Magnesium	Potassium	Sodium	CEC	Base Saturation
Knobtop	**water**	**cmol/kg**	**%**	**cmol/kg**	**cmol/kg**	**cmol/kg**	**cmol/kg**	**cmol/kg**	**%**
A	4.1	19	12	0.83	0.67	0.35	0.15	20.8	9.6
E	4.1	12	1.6	0.25	0.2	0.15	0.11	12.6	5.6
Bt1	3.9	15.5	1.4	0.25	0.31	0.21	0.17	16.3	5.8
Bt2	3.9	19	1.7	0.25	0.66	0.32	0.15	20.2	6.8
Bt3	3.9	17	1.1	0.25	0.7	0.22	0.22	18.2	7.6
2 BC	3.9	15.5	0.7	0.25	1.03	0.16	0.22	16.9	9.8
Taumsauk									
A	4.7	17	16.5	2.85	1.98	0.52	0.15	22.4	24.6
E	4.2	16	3.4	0.25	0.56	0.21	0.14	17	6.8
Bt1	3.8	19.5	2.6	0.25	0.71	0.29	0.15	20.8	6.7
Bt2	3.8	19.5	2.5	0.25	0.63	0.27	0.16	20.6	6.4
Irondale									
Horizon									
A	4.4	5.8	6.1	1.5	0.13	0.24	0.26	7.9	27
E	4.4	5.5	2.9	1	0.08	0.28	0.25	7	22.2
Bt1	4.3	10.9	3.1	1.5	0.28	0.35	0.26	13.2	18.1
Bt2	4.3	6.3	3.3	1.3	0.34	0.28	0.39	8.6	26.8

SOM is soil organic matter, CEC is cation exchange capacity.

Table 2.
Chemical properties of the Knobtop, Taumsauk, and Irondale pedons.

a very acidic reaction, with a relatively greater base saturation; however, the base saturation remains less than 35% as required for the Ultisol order. The soil organic matter content is greatest in the A horizons and declines with increasing soil depth. Given the shallowness of these pedons, especially for the Taumsauk pedon, seasonal dryness during the summer and fall months is presumed to be a limiting factor for tree growth. The extreme soil acidity contributes to the reduced tree growth and limits the vegetational diversity.

For the Knobtop-Irondale-Taumsauk Ultisol assemblage, the corresponding provisional ecological site descriptions are (i) Dry Igneous Upland Woodland (F116CY003MO) having the Knobtop and Irondale soil series, (ii) the Dry Igneous Exposed Backslope Woodland (F116CY011MO) having the Irondale soil series, and (iii) the Shallow Igneous Knob Glade (R116CY006MO) having the Taumsauk soil series. For the Dry Igneous Exposed Backslope Woodland the dominant vegetation is post oak (*Quercus stellate*), black oak (*Quercus velutina*) with scattered blackjack oak (*Quercus marilandica*), northern red oak (*Quercus rubra*) and a ground flora of native grasses and shrubs (fragrant sumac (*Rhus aromatica*) and little bluestem (*Schizachyrium scorparium*)). For the Dry Igneous Upland Woodland, the vegetational community is similar, with exceptions including a slightly greater abundance of northern red oak (*Quercus rubra*) and a greater abundance of the herbaceous species *Danthonia spicata*. The Shallow Igneous Knob Glade has a few species of blackjack oak (*Quercus marilandica*) and the herbaceous species *Schizachyrium scorparium* and *Croton michauxil* var. ellipticus. Canopy closure varies with aspect and soil depth, ranging from 30 to 50% on exposed positions and shallower soil depths to 50–80% on protected positions and deeper soil depths. Fire, including controlled burning, has been present in these vegetational communities, reducing litter accumulation, stimulating grasses and forbs, and reducing the encroachment of woody species.

The Dry Igneous Upland Woodland has post oak (*Quercus stellate*) and northern red oak (*Quercus rubra*) as the dominant tree species in the reference state, with a fire-free interval of 10–15 years witnessing the encroachment of eastern red cedar (*Juniperus virginiana*). The reference state is in quasi-equilibrium with (i) the fire excluded mixed oak woodland state and the (ii) fire excluded and logged mixed oak woodland state based on the contrasting practices of long-term fire suppression and the opposing practice of forest stand improvement using prescribed burning with and without tree species removal. The Dry Igneous Exposed Backslope Woodland reference site and transition sites are similar to that of the Dry Igneous Upland Woodland, with differences attributed to subtle species compositions. The Shallow Igneous Knob Glade has a blackjack oak (*Quercus marilandica*) tree composition with little bluestem (*Schizachyrium scoparium*) and lichens with and associated reference state having eastern redcedar. Fire suppression transitions to a state with the addition of winged elm (*Ulmus alata*). The soil surface cover is variable, but typical estimates are tree basal cover (1%), shrub/vine/liana basal cover (1%), grass and grasslike basal cover (1%), forb basal cover (1%), non-vascular cover (5%), litter (30–50%) and surface fragments (10%).

3.2 Caneyville and Hildebrecht Alfisol Assemblage

The Caneyville and Hildebrecht soils are Alfisols having fine and fine-silty textures and exhibiting A-E-Bt and A-E-Bt-2Btx-3Bt horizon sequences, respectively (**Table 3**). The consensus of soil scientists who mapped these soils is that the Caneyville series developed in loess, whereas the Hildebrecht series developed in Peoria loess overlying a previous bisequal soil derived from older loess developed on limestone residuum.

Horizon	Depth	Texture	Structure	Clay	Sand	Color
	cm			%	%	
Caneyville						
A1	10	sandy loam	2f&mgr	3	60	10YR4/2
A2	18	silt loam	2f&mgr	7	36	10YR4/2
E	33	silt loam	1msbk	10	24	10YR5/4
Bt1	46	silt loam	2msbk	24	14	5YR4/6
Bt2	69	silty clay	2msbk	42	13	7.5YR5/6
Bt3	71	silty clay	2msbk	48	10	7.5YR5/6
Hildebrecht						
A	1	silt loam	2fgr	4	36	10YR3/2
E	3	silt loam	lmpl	9	23	10YR5/4
BE	6	silt loam	lfsbk	13	12	7.5YR5/4
Bt1	13	silty clay loam	2msbk	28	8	7.5YR4/4
Bt2	19	silty clay loam	2msbk	32	11	7.5YR4/4
2Ex	21	loam	l c prism	26	25	10YR5/4
2Btx1	30	loam	l c prism	16	45	10YR5/4
2Btx2	38	loam	l c prism	17	44	5YR5/4
3Bt3	60	clay	3msbk	56	29	2.5YR3/6

For the Hildebrecht pedon, the 2 Btxl to 3Bt3 horizons are very gravelly to extremely gravelly.
Structure; 1 is weak, 2 is moderate, f is fine, m is medium, gr is granular, sbk is subangular blocky.

Table 3.
Morphological and physical properties of the Caneyville and Hildebrecht pedons.

The Caneyville (Typic Hapludalf) pedon has sandy loam and silt loam textures in the ochric epipedon and silty clay loam in most of the argillic horizon. The pH is neutral to slightly acidic in the near surface horizons and strongly acid in the lower argillic horizons, with exchangeable Ca showing a gradual concentration reduction on transition to the deeper horizons (**Table 4**). The Hildebrecht (Oxyaquic Fragiudalf) pedon shows a silt loam texture in the eluvial horizons and a silty clay loam texture in the illuvial horizons. The fragipan has a loam texture which abruptly transitions to clay in the 3Bt3 horizon. The eluvial and argillic horizons appear to be developed in Peoria Loess, whereas the fragipan and 3Bt3 horizons are apparently developed in older Roxana Loess overlying limestone residuum, thus the Hildebrecht pedon appears to be a bisequal soil. The soil organic matter concentrations are greatest in the A horizons and decline upon soil profile transition.

For the Caneyville-Hildebrecht Alfisol assemblage the corresponding provisional ecological site descriptions are (i) the Fragipan Upland Woodland (F116AY004MO) containing the Hildebrecht soil series, and (ii) the Loamy Limestone/Dolomite Upland Woodlands (F115BY007MO) containing the Caneyville soil series. The dominant vegetation of the reference state of the Fragipan Upland Woodland is post oak (*Quercus stellata*) and black oak (*Quercus velutina*) with native grasses and legumes and other forbs in open canopy areas. Land management practices are related to (i) silvopasture to create a post oak (*Quercus stellata*) -shortleaf pine (*Pinus echinate*) state, (ii) clearcutting to create a

				Exchangeable Cations				
Horizon	**pH**	**Acidity**	**SOM**	**Ca**	**Mg**	**K**	**Na**	**CEC**
		cmol/kg	**%**			**cmol/kg**		
Caneyville								
A1	7.3	0	6.1	11.7	3.9	0.12	0.08	15.7
A2	7.4	0	2.9	6.7	2.7	0.08	0.08	9.6
E	6.9	0.5	1.1	4.3	2.0	0.11	0.04	6.9
Bt1	6.6	2.0	1.0	5.0	4.1	0.28	0.09	11.5
Bt2	6.4	3.0	1.4	5.7	9.1	0.50	0.11	18.4
Bt3	5.1	8.5	1.7	3.8	9.9	0.53	0.08	22.7
Hildebrecht								
A	4.8	1.6	8.4	5.2	2.2	0.21	0.41	9.6
E	4.7	2.0	2.9	1.3	0.6	0.19	0.55	4.6
BE	4.6	1.8	1.3	0.4	0.8	0.15	0.28	3.4
Bt1	4.5	2.7	1.7	1.9	2.0	0.20	0.22	7.0
Bt2	4.8	4.7	1.8	2.3	2.3	0.24	0.17	9.6
2Ex	4.0	3.1	1.4	1.0	2.0	0.17	0.27	6.5
2Btx1	4.0	2.2	0.9	0.5	2.0	0.14	0.34	5.2
2Btx2	4.1	2.0	0.9	0.6	2.0	0.12	0.29	5.0
3Bt3	4.5	1.2	1.2	9.6	2.6	0.10	0.38	13.9

CEC is the cation exchange capactiy, an estimate of the soil organic matter content.
Acidity is total acidity.

Table 4.
Chemical properties of the Caneyville and Hildebrecht pedons.

tall fescue (*Festuca arundinacea*) mixed pasture, and (iii) fire exclusion and logging to create a post oak (*Quercus stellata*), black oak (*Quercus velutina*), and black hickory (*Carya texana*) woodland. The dominant vegetation of the reference state of the Loamy Limestone/Dolomite Upland Woodlands is White Oak (*Quercus alba*), Chinkapin Oak (*Quercus muehlenbergii*) with Red Bud (*Cercis canadensis*), Aromatic Sumac (*Rhus aromatica*), Virginia Wildrye (*Elymus virginicus*) and Little Bluestem (*Schizachyrium scoparium*). Land management practices related to (i) a high graded and grazed woodland to establish a black oak (*Quercus velutina*), post oak (*Quercus stellata*), black hickory (*Carya texana*), (ii) logging creating a tall fescue (*Festuca arundinacea*) pasture, (iii) an even-aged managed woodland establishes a white oak (*Quercus alba*), chinkapin oak (*Quercus muehlenbergii*), and post oak *(Quercus stellata)* community and (iv) an uneven-aged managed woodland establishes a white oak (*Quercus alba*), black hickory (*Carya texana*), and northern red oak (*Quercus rubra*) community.

3.3 Amagon and Calhoun Alfisol Assemblage

The Amagon (Typic Endoaqualf) pedon and the Calhoun (Typic Glossaqualf) pedon possess A-E-Btg horizon sequences showing extensive redoximorphic features supportive of their poor-drained status (**Table 5**). These pedons have a relatively high cation exchange capacity, reflecting the abundance of smectite in the clay separate (X-ray diffraction data not presented). The near surface horizons have a very strongly acid or strongly acid reaction, transitioning to a slightly alkaline to neutral reactions in the argillic horizons (**Table 6**). The Amagon pedon also exhibits an elevated exchangeable sodium percentage in the argillic horizon.

Horizon Amagon	Depth cm	Texture	Structure	Matrix color
A	13	sandy loam	2f&vfsbk	10YR3/2
E	33	loam	2vfsbk and 1fgr	10YR5/3
Btg1	53	loam	2&3f&msbk	10YR5/1
Btg2	81	loam	2fsbk	10YR5/3
Btg3	107	loam	2f&msbk	10YR6/1
Btg4	137	sandy loam	2vf&fsbk	10YR3/4
BCg	193	loam	1 m&csbk	10YR6/2
Calhoun				
A	13	silt loam	2fsbk	10YR2/2
E	38	silt loam	3f&msbk	10YR4/2
Btg1	69	silty clay loam	2msbk	10YR4/1
Btg2	97	silty clay loam	2msbk	10YR5/1
Btg3	114	silt loam	2fsbk	10YR5/1
Cg	152	silt loam	2csbk	10YR5/1

Structure: 2 = common, 3 = many, f = fine, vf-very fine, m = medium, sbk = subangular blocky, gr = spherical.

Table 5.
Morphological and physical properties of the Amagon and Calhoun pedons.

Horizon	pH	Total Acidity	Ca	Mg	K	Na	CEC	ESP
Amagon		cmol/kg	cmol/kg	cmol/kg	cmol/kg	cmol/kg	cmol/kg	%
A	4.3	2	2.4	0.9	0.15	0.32	5.8	5.5
E	4.8	1.7	5.7	1.5	0.05	0.57	9.5	6
Btg1	7	0.1	10.7	5	0.1	2.22	18.1	12.3
Btg2	8.1	0	15.5	5.3	0.18	1.94	22.9	8.5
Btg3	8.1	0	14.8	5.9	0.14	1.01	21.8	4.6
Btg4	7.1	0.1	13	4.3	0.14	0.37	18	2.1
BCg	7	0.2	15.4	4.2	0.13	0.28	20.3	1.4
Calhoun								
A	4.9	1.4	13.9	4.8	0.14	0.27	20.5	1.3
E	4.6	1.6	14.6	4.7	0.11	0.37	21.4	1.8
Btg1	5.7	0.6	25.9	9.8	0.19	0.56	37	1.5
Btg2	6.8	0.5	22	8.4	0.22	0.61	31.7	1.9
Btg3	6.5	0.4	23.6	8.9	0.22	0.49	33.7	1.5
Cg	7.3	0.4	19.8	6.3	0.21	0.43	27.1	1.6

Ca, Mg, K, Na are exchangeable cations.

Table 6.
Chemical properties of the Amagon and Calhoun pedons.

For the Amagon-Calhoun assemblage the corresponding provisional ecological site descriptions are (i) the Wet Footslope Forest (F134XY014MO) for the Calhoun soil series and (ii) the Northern Wet Alluvial Flat (F134XY020AL) for the Amagon soil series. The reference state for the Wet Footslope Forest is a wet-Mesic Bottomland forest with an overstory dominated by bur oak (*Quercus macrocarpa*), cherrybark oak (*Quercus pagoda*), willow oak (*Quercus phellos*), sweetgum (*Liquidambar*), pin oak (*Quercus palustris*), nuttall oak (*Quercus texana*), water oak (*Quercus nigra*), American elm (*Ulmus americana*), sugarberry (*Celtis laevigata*), and green ash (*Fraxinus pennsylvanica*), an understory dominated by blue beech (*Carpinus caroliniana*), spicebush (*Lindera benzoin*), and Ohio buckeye (*Aesculus glabra*), and a rich herbaceous ground flora.

The Northern Wet Alluvial Flat ecological site description has mature tree stands consisting of overcup oak (*Quercus lyrate*), willow oak (*Quercus phellos*), water hickory (*Carya aquatica*), and occasional bald cypress (*Taxodium distichum*), and water tupelo (*Nyssa aquatica*) on the lowest and wettest land positions. The reference state is the wet bottom land forest dominated by overcup oak (*Quercus lyrate*) and water hickory (*Carya aquatica*). The altered or managed states include (i) post large scale disturbance with mixed species regrowth forest, (ii) timber management, usually involving overcup oak (*Quercus lyrate*) and water hickory (*Carya aquatica*), (iii) pastureland, and (iv) row-crop agriculture.

4. Value-adding to soil survey by employing ecological site descriptions

The intent of soil survey was to map soils based on observable diagnostic soil horizons and to provide soil interpretations. The linkage of soil spatial distributions with the spatial distribution of ecological sites as a digital product provides opportunities to (i) assist land owner decision making to improve ecosystem services and protect soil as a natural resource, (ii) empower land custodians to understand the ecosystem response and vegetational outcomes from land management applications, and (iii) understand behavior and changes to the soil resource because of land management applications. Each outcome of the soil survey linkage with ecological site descriptions is critical and each has a unique benefit to society.

The ability to assist land owner decision making to improve ecosystem services and protect soil as a natural resource has always been the central theme of the United States Department of Agriculture-Natural Resources and Conservation Service and the Missouri Department of Conservation. With the advent of online digital technologies, the likelihood that land custodians will seek these resources to guide land management is substantial, provided these digital online resources are comparative easy to navigate and conceptualize. The role of the soil scientist to understand behavior and changes to the soil resource because of land management applications was founded in the infancy of soil science when soil genesis was postulated to result from the five soil forming factors: (i) parent material, (ii) climate, (iii) organisms, (iv) topography (relief), and (v) time.

Essentially all five of the soil forming factors are evident and treated in the ecological site description. What is also intriguing are some of the potential benefits that may be realized in the near-term: (i) manage forests to sequester carbon, (ii) support selected sites for maintaining soil and vegetation to assist the recovery of endangered species, (iii) supporting land management application to protect highly erodible soils, and (iv) reducing fire threats to small rural communities.

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