Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

The USDA-ARS Appalachian Farming Systems Research Center (AFSRC) has undertaken several research projects investigating soil properties, plant responses, and how to construct optimum soils for turfgrass. Part of that effort includes the development of rain gardens (shown above), or bio-retention filters--areas where run-off water accumulates, percolates through a soil zone, and then drains to streams after the turf and soil have trapped various contaminants (i.e. oil, salt, silt, nutrients, and other contaminants) usually found in run-off water.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 400 projects at a cost of $35 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
1032 Rogers Place
Lawrence, KS 66049
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

Engineering the Best Soils for Turfgrass Applications

Kevin Morris, Richard Zobel, and Amir Hass

SUMMARY

To perform at their maximum, turfgrass systems require optimum soils. However, there is little information available on the critical soil properties needed for turfgrass. In addition, how would these properties be combined to construct the best possible soils for different applications? The USDA-ARS Appalachian Farming Systems Research Center (AFSRC) has undertaken several research projects investigating soil properties, plant responses, and how to construct optimum soils for turfgrass.

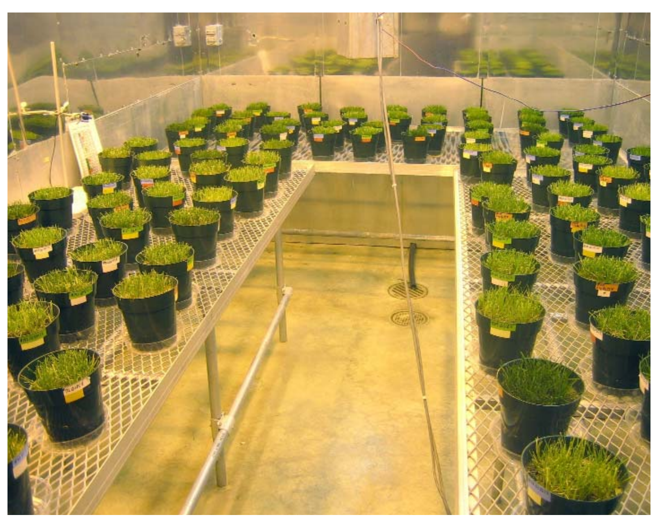
- An analysis was conducted of topsoil definitions and what constitutes a quality topsoil. This information is useful in attempting to build a good constructed soil.
- A growth chamber study was conducted to determine the chemical, physical, and biological soil characteristics of several agricultural and industrial by-products compared to a reference commercial topsoil mix. Plant responses were similar, but significant differences in microbial and soil enzyme activity were seen among products.
- A field experiment was established at a mine reclamation site to further test these products, as well as to evaluate vegetation performance.
- A soil mix was constructed for a rain garden, which is a biofilter for stormwater. The rain garden contained various plants, including turfgrass, which may be a significant use for turf in the future.

A majority of Americans come into contact with turfgrass every day. Considering parks, golf courses, athletic fields, home lawns, and roadsides, turfgrass maintenance is more visible to Americans than any other agricultural system. Thanks to the National Turfgrass Research Initiative (NTRI), funding for turfgrass research within the United States Department of Agriculture's Agricultural Research Service (USDA-ARS) has increased to about $1 million per year. In addition, NTRI is designated a high-priority research initiative in the 2007 Farm Bill, under the Specialty Crops label (7).

Homeowners are somewhat familiar with grass types, as well as the fertilizer, insecticide, herbicide needs for their lawns, but few are familiar with soil needs. Golf course superintendents, parks and grounds managers, sports turf managers, and landscape maintenance firms understand better that the soil resource is critical to the sustainability of their turf systems. However, there is not a great understanding of what makes a good turfgrass soil.

Often, when a lawn fails, or a golf course fairway needs increasing inputs, or an athletic field suffers from overuse, problems such disease, lack of proper maintenance, and overuse are often blamed. How often is the lack of a quality topsoil and/or subsoil frequently the ultimate cause of the turf demise?

Quality topsoils and subsoils provide for deeper, healthier root systems, greater water-holding capacity (i.e. greater drought tolerance or reduced watering frequency), and greater tolerance to mowing, and foot and vehicle traffic. But what are the characteristics of a quality soil in



A growth chamber study was conducted to determine the chemical, physical, and biological soil characteristics of several agricultural and industrial by-products compared to a reference commercial topsoil mix.

KEVIN MORRIS, President, National Turfgrass Federation, Beltsville, MD; RICHARD ZOBEL, PhD., Plant Physiologist, USDA-ARS Appalachian Farming Systems Research Center, Beaver, WV; and AMIR HASS, Ph.D., Post-doctoral Research Associate, West Virginia State University, Institute, WV.

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terms of turfgrass establishment and sustainability? In typical subsoils of many subdivisions or construction sites, there are pieces of wood, concrete, rock, pipe, nails, etc. found just under the surface. In addition, during construction, the soils of many athletic fields are compacted to 95 percent of maximum compression as they would prior to laying down asphalt for a parking lot.

Why Engineer Soils for Turfgrass?

Turfgrass areas are often specialized agricultural systems that are functional, as well as aesthetic. Turfgrass filters water, reduces soil erosion, provides air cooling, captures carbon, and provides a safe surface for recreation as well as athletic activity (2, 3, 9). Maximizing these benefits should be a goal of the turfgrass industry. This is where the Appalachian Farming Systems Research Center in Beaver, WV comes into the picture. Constructed soils research is one of the four project areas at the Center. This laboratory has a history of working with by-products from coal-burning facilities and with mine-land reclamation. The lab was selected by the USDA-ARS to carry out research into constructed soils for turfgrass applications and, where possible, to include industrial and commercial by-products into the mix.

So why should we conduct constructed soils research for turf? Previous research suggests that models can be developed to predict how two different soil components will interact when

Determining the suitability of locally available soil is an important part of developing sustainable turfgrass systems.

mixed, but there is no theoretical basis for predicting how mixtures of three or more components will interact. Soil mixing and construction is an inexact science. Beard (1) lists many of the difficulties in the soil modification process. Also, since funding available for constructing a soil for turf areas is often limited, the cost of materials and construction has to be kept to a minimum. This emphasizes the need to determine the suitability of locally available soil and other components to use in their construction.

Even though the United States Golf Association has spent much time and effort in developing specifications for putting green soil mixes (10), the same cannot be said for other high performance turf areas, or general turf areas for that matter. Even though there are guidelines for developing turfgrass constructed soils (5), currently, there are no protocols to measure soils for appropriate characteristics and to assess their suitability for a given project. Scientists at AFSRC have begun the process of developing protocols to determine the basic parameters that should help develop constructed-soil prediction models. These models will allow contractors and architects determine the correct soil components and the appropriate amounts to mix for constructing a soil with given characteristics. Developing models will require extensive basic research into the chemistry and physics of the soil components to build a suitable knowledge base.

Another important thrust of the Center's research is to determine the appropriate level of compaction of topsoils and subsoils for athletic fields, recreational areas (soccer, football, baseball, playgrounds), golf courses, and lawns. Excess compaction reduces the pore size of the soil, reducing water infiltration and inhibiting root growth, decreasing establishment and sustainability of sod plantings (12). On the other hand, insufficient compaction leads to large pore sizes, reduced water holding capacity, a need for more frequent watering, and increased drought sensitivity. Insufficient topsoil compaction over a highly compacted subsoil will create similar problems over a longer time frame. Appropriate sub-soil compaction and topsoil quality are critical to

Compacted sub-soil plots following a heavy rain event. Top soil is still to be added to the plots, at three thicknesess per compaction treatment.

reducing injuries and maintaining a healthy turf that can sustain the abuse that comes with use.

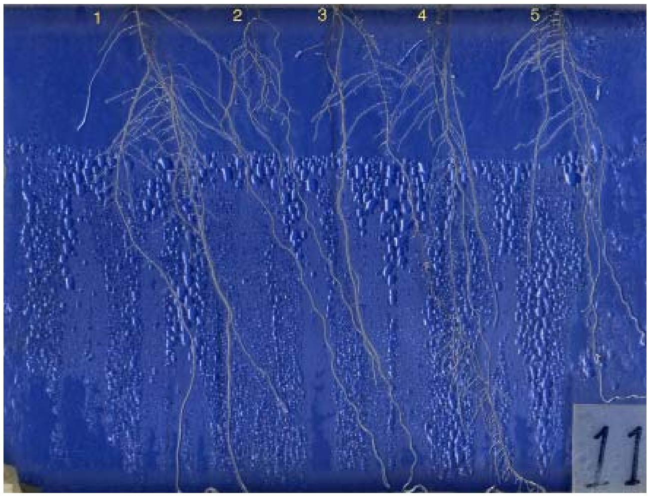
Understanding Topsoils

Before research in this area can be initiated, it is helpful to understand how topsoils are defined. It was discovered that topsoil definition itself varies among authoritative sources and include the A horizon surface layer, the A master horizon (A_m), or a mixture of A and E master horizons. A study was conducted to evaluate how different topsoil definitions affect these properties of the borrowed topsoil. The hypothesis was that a mixture of A and E horizons will result in larger salvaged soil volume while having minor, if any, adverse effects on the borrowed topsoil characteristics.

Of the over 100,000 entries of the USDA-NRCS National Soil Survey Center (NSSC) database (11), 59,300 entries of different soil orders (excluding histosols, oxisols, and andisols) from the 48 contiguous states were used. AE-mix topsoil resulted in an average reduction of 38% in organic carbon and negligible changes in average sand, silt, and clay content compared to its respective A_m topsoil (i.e. among A_m and AE-mix constructed from the same pedon). Yet, average thickness of AE-mix topsoil was over 2.5 times that of its respective A_m topsoil. The study provides average topsoil characteristics on a soil order basis that can serve as a reference in developing and/or refining guidelines for topsoil characteristics and specifications for constructed topsoil.

Evaluating By-products for Their Use in Constructed Soils

The approach of this research is to develop specifications for physical, chemical, and/or biological soil characteristics for specified turfgrass uses and to develop and test approaches for meeting these specifications using agricultural and/or industrial by-products as a soil amendment. Organic materials resulting from thermophilic (requiring high temperatures) anaerobic digestion of agricultural wastes are known to have biological value. As part of the multi-disciplinary



In preliminary research, AFSRC scientists find a wide variety of root development patterns and forms in tall fescue and perennial ryegrass roots.

Bioplex project, investigators at West Virginia State University have developed recommended practices for the use of digested, poultry-litter solids and liquids as replacements for commercial fertilizers in row and vegetable crops. This project builds upon these research efforts by testing the potential for improving the critical characteristics of turfgrass soils using combinations of digested agricultural and/or industrial by-products as amendments.

To start this research, a selected suite of municipal and agricultural organic by-products (anaerobically digested poultry litter, poultry litter compost, yard waste compost, and turkey litter compost), and quarry industry products (<1/4" particle size from sandstone, limestone, and greenstone rock formations) were evaluated as topsoil replacements in a growth chamber experiment. The objective was to determine which by-product mix(s) provided the most desirable soil properties for turfgrass growth compared to a reference commercial topsoil mix. Biological parameters commonly used as indicators of soil quality (microbial biomass and soil enzyme activities) were used to evaluate all the formulations.

Results indicated that plant biomass developed was similar in most mixtures, however it was consistently and statistically significantly lower in mixtures where yard waste compost was used. Soil pH was significantly different ($p<0.001$) in the commercial reference mix (pH=6.2) compared to the rest of the mixtures (average pH=7.4).

Microbial activity varied among treatments. Based on calculated fungal and bacterial quotients (C_{bac}/C_{org} and C_{fun}/C_{org}), it was found that the substrates present in the constructed soils promoted bacterial dominance compared to the fungal dominance in the reference commercial mix. It is also likely that the higher pH of the quarry mixes promoted the observed bacterial dominance in those treatments.

Similarly, soil enzyme activities also varied among treatments. B-glucosidase activity varied with the type of quarry material and organic amendment. Organic amendments increased soil B-glucosidase activity in all treatments over their non-organic amended controls. The data also showed that B-glucosidase activity was significantly higher using poultry litter compost compared to turkey litter compost or yard litter compost. Also, B-glucosidase activity was lower in the limestone mixes compared to the sandstone or greenstone ones. A strong correlation was found between B-glucosidase and available P. This correlation is attributed to a change in carbon (C): available phosphorus (P) balance.

Phosphatase activity was the highest in the reference commercial mix. Correlation analysis showed a positive and significant relationship between acid phosphatase activity and soil total nitrogen (N). Phosphatase activity was negatively correlated to available P.

Results of this study suggest that selected waste streams can be effectively used in constructing topsoils. However, careful attention must be paid to the source of organic matter and the nutrient balance ratios in order to provide sustainable and long-term benefits for the above ground components as well as for nutrient cycling.

A field experiment was established during 2007 (a complete randomized block design, with four replications) including different soil amendments (none, liquid, or solids of the digester), application rates, and vegetation cover treatments, on a mining reclamation site in south central West Virginia. Selected chemical (e.g., pH, CEC), biological (e.g., total bacteria, fungal, enzyme activity), and physical (e.g., aggregate stability, water holding capacity) soil properties, as well as vegetation performances, are being evaluated semi-annually and compared to a non-treated control. Preliminary results demonstrate differential species survival on the different treatments. Chemical analyses are in process.

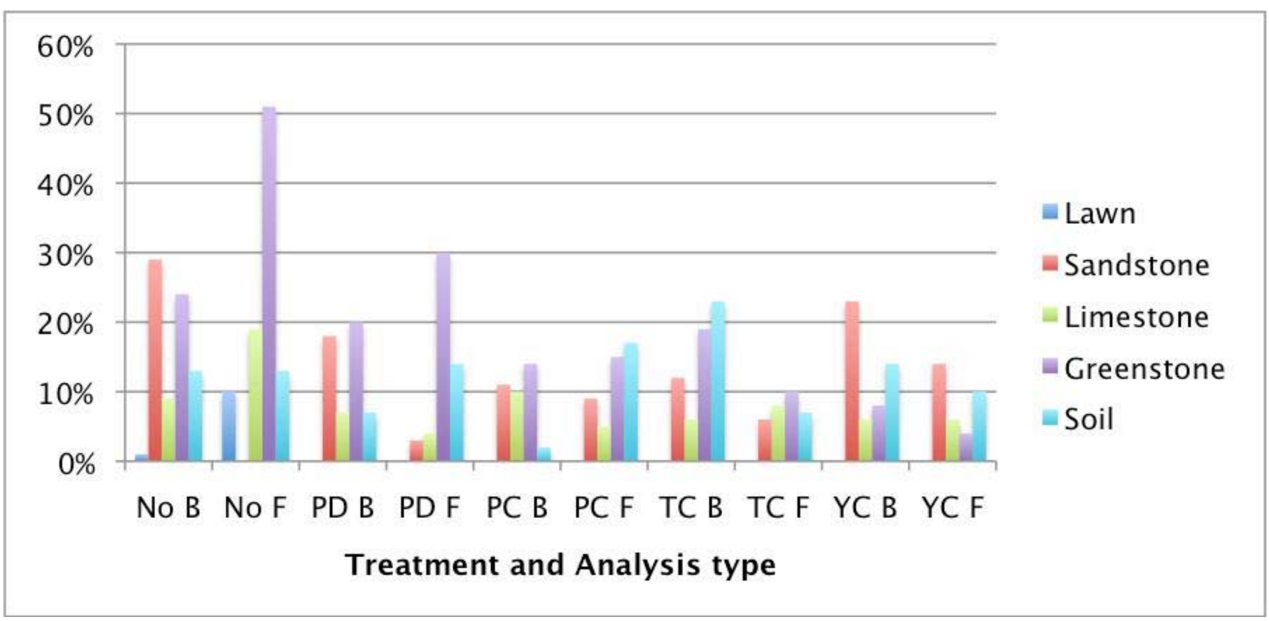
Evaluating Soil Compaction Tolerance

A partnership was formed with Virginia Tech soil scientists, civil engineers, and turfgrass scientists to determine the optimum compaction levels for the three predominant subsoils of the central Appalachian region. The assumed ultimate use is as athletic fields, so AFSRC scientists will design research approaches with athletic fields in mind. Some research plots for this research will be established at the Raleigh County Solid Waste Authority near Beckley, West Virginia. The plots will consist of the three soils at three compaction levels with three topsoil thicknesses. The plots will be seeded with a recommended mixture of bluegrasses normally used on athletic fields in the region. Once established, the plots will be monitored for changes in compaction, hydraulic conductivity, chemistry, plant and root growth, and eventually resistance to foot traffic and resilience to heavy foot traffic (mimicked soccer games, etc.).

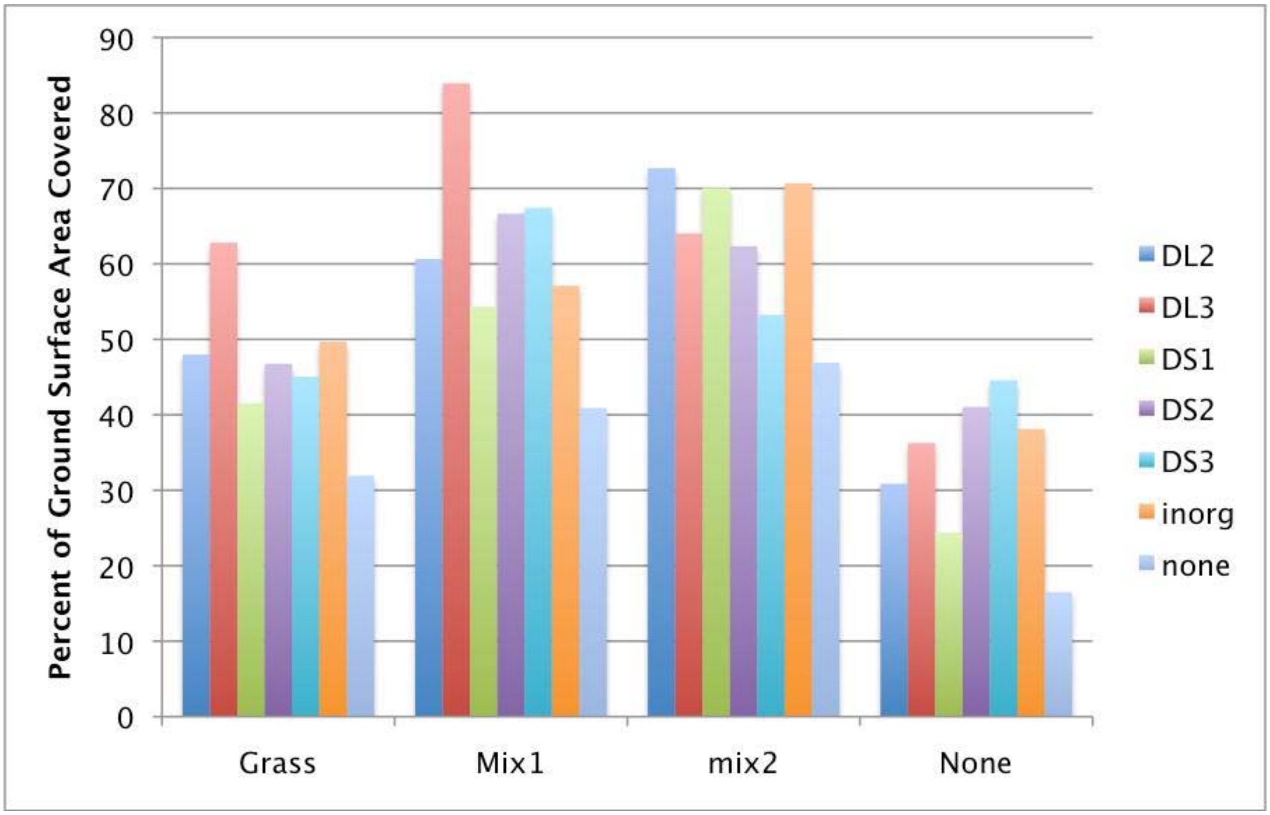
The Use of Rain Gardens

A relatively new use for turfgrass is in the development of rain gardens, or bio-retention filters--areas where run-off water accumulates, percolates through a soil zone, and then drains to streams after the turf and soil have trapped various contaminants (i.e. oil, salt, silt, nutrients, and other contaminants) usually found in run-off water. Typically, municipalities and corporations use rain gardens to filter stormwater that comes off of parking lots and industrial sites. These rain gardens frequently have an assortment of perennial plants, grasses, shrubs, flowers, and the occasional patch of grass in median strips and around the edges of the site.

Researchers with rain gardens (4) have suggested this technique for the edges of lawns to trap fertilizer and other household run-off from gutters and sidewalks. This use would typically have turfgrass as the primary plant component. Unfortunately, rain gardens require soils with carefully defined drainage qualities and water and



Impact of byproduct addition to soils on the percentage of soil organic carbon that comes from soil bacteria versus soil fungi. No = no additions; PD = digested poultry litter; PC = composted poultry litter; TC = composted turkey litter; YC = composted yard clippings; B = bacterial carbon; F = fungal carbon. The soils are those used in the sub-soil compaction study.



Percent of ground cover at the Six-mile mine reclamation site. DL = digested chicken litter (Liquid); DS = digested chicken litter (Solids); the numbers represent equivalent fertility levels with 3 matching the inorganic fertilizer amendment. Grass was tall fescue; Mix 1 was Annual-ryegrass (43), Birdsfoot trefoil (21), P-ryegrass (11), Foxtail millet (11), White Clover (6), Red top (4), Weeping lovegrass (4) ; Mix 2 was A-ryegrass (42), Tall fescue (31), Timothy (6), Red Clover (6), Alta Sweet clover (6), Yellow clover (ball) (6), White Clover (3).

chemical holding capacities. Several commercial firms produce these soils, but they are relatively expensive when transportation to the rain garden construction site is considered.

A year ago, the Beckley, WV Sanitary Board contacted the Center about the possibility of determining an appropriate soil mix for a demonstration rain garden. Commercial soils for that purpose were out of the question because of transportation costs and local contractors preferred to use local materials if possible. Amir Hass, a post doctoral research associate from West Virginia State University, who is working at the Center, took on the task of testing possible soil mixes and came up with a recommendation. The garden was built and is being monitored for storm water input and drain-water output volumes and quality. Dr. Hass is in the process of testing other potential soil mixes and plant species for filtering out specific chemicals such as nitrates, phosphorus, herbicides, and oils. AFSRC plans to establish a number of test bioretention plots on reclaimed land at the local landfill where the turf athletic field plots are located.

Understanding Turf Rooting Characteristics

An interesting aspect to this research is the study of plant roots, or "rhizobotany". Most grass cultivars used for turf or sod (perennial ryegrass, tall fescue, fineleaf fescue, etc.) are genetic mixes which have been selected for relative uniformity of leaf size, color, quality, tensile strength or knitting (8). Because they are genetic mixtures, there is little uniformity of root development within the cultivars. In preliminary research, AFSRC scientists find a wide variety of root development patterns and forms in tall fescue and perennial ryegrass roots. This variation is an important and beneficial feature of a plant community where conditions at a site can vary substantially within a relatively small area.

Variation in rooting characteristics enables plants to avoid or tolerate intermittent drought or grow more rapidly to form a strong and effective sod. Variation in the rate of root branching, fineness of branch roots, number of shoot-borne roots, and size and numbers of root hairs have been documented in many species (13). Specific selections of these characteristics are critical for improving turf growth on soils that have differing physical characteristics. For example, large roots improve the ability of the plant to root on dense and/or compacted soils and increase root cross-over from sod to topsoil (stronger knitting). Fine roots with extensive branching are useful in low-nutrient soils or systems where there is an excess of chemicals which the roots can extract from the soil (14).

Turf systems with trees can suffer from shade effects and the deleterious effects of chemicals like tannins and humic acids that come from leaf litter or are washed off the trees during rain events. These chemicals are natural products of the trees. AFSRC scientists have shown they can be stimulatory to root and plant growth under some soil conditions and inhibitory under others.

Scientists at the Appalachian Center are also studying the interaction of tannins with the soil and the resulting impact on nutrient availability and plant growth. In constructed soil systems like rain gardens, organic matter should be incorporated into the soils. Organic matter helps retain water for plant use and modifies the soil chemistry to potentially trap tree-produced compounds. Organic matter decomposes over time and can release humic and tannic acids as well as nitrogen and phosphorus compounds to the outflow water (6). ARS scientists are monitoring the impact of tannins on root growth and on the microbial community which is critical to fixing these compounds to soil particles.

Summary

Appalachian Center scientists understand soils and plant roots in detail, but insights and expertise in many other fields (economics, for instance) need to be taken into account. AFSRC scientists are working with Virginia Tech to establish cost/benefit studies on each of their projects so they can determine the cost to construct specific soil mixes. Their first attempt to conduct cost/benefit analysis addresses the length of time a rain garden can be effective before being renovated, the use of sod verus seed verus mixed plantings, the durability of a athletic field (resistance to wear), as well as the frequency of renovation, fertilization, watering, and other cost inputs to a given system.

AFSRC is also working with university landscape architects to obtain input in the planning and design of lawns, athletic fields and rain gardens. They are working with urban horticulturists on the integration of turf systems with tree plantings and entrapment of stormwater. Although AFSRC has been involved with turfgrass constructed soils for only three years, they are actively engaged in pulling together an integrated, multidisciplinary team to deal with urban issues like storm water, quality athletic fields, and sustainable lawns. This consortium will be able to combine basic and applied research and develop designs and best management practice (BPM) specifications for constructed soils in an urban context.

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