SMA ROUNDTABLE

Adventures with Slopes

In the summer of 2006 I was asked to help with the removal of junk vegetation, such as common hackberry (*Celtis occidentalis*), ailanthus (*Ailanthus altissima*), and shrub honeysuckle (*Lonicera* spp.), as a new high rise condominium complex was nearing completion. The building had been sited on the south bank of the Tennessee River in downtown Chattanooga overlooking the Tennessee Riverwalk and the new waterfront. Just downhill from the condominium, the 14,000-square-foot (1300-square m) patch of mostly invasive species had become an eyesore and I was just itching to clear this long-neglected area. Furthermore, the developer knew that the views of the river were a key selling point for prospective buyers.

After several meetings with stakeholders, an agreement was reached whereby the City's Urban Forestry Division would remove the existing vegetation and the condominium owner would contract with a locally owned company, Earthscapes, to design and install a system that would stabilize the steep bank and prevent soil erosion and at the same time would be aesthetically pleasing. Earthscapes chose to use the technology from Filtrexx called the "Living Wall." In this system, mesh tubes ("socks") filled with composted leaf material from the City's wood recycling center were placed on mostly bare soil. A nurse crop of grass seed was planted on top of the Filtrexx socks. As each sock was installed, a permanent crop of native red and yellow twig dogwood (*Cornus sericea* and *C. sericea* 'Flaviramea') and false indigo bush (*Amorpha fruticosa*) was planted between the socks.

The results were stunning! Within a few weeks, a beautiful carpet of green grass quickly germinated and the dogwoods and false indigo bushes soon followed. The nurse crop of grass lived long enough for the hardwood trees to become established and grow. The project exceeded all expectation and an added bonus was the claim of sustainability by using native species and re-purposed leaf compost. More information on the project can be seen *here*.

The slope in Chattanooga, Tennessee at the beginning of the clearing operation. Photo by Gene Hyde

The Chattanooga slope in mid-project. Photo by Gene Hyde

A portion of the completed Chattanooga slope project. Photo by Gene Hyde

—Gene Hyde, City Forester, Chattanooga, Tennessee

The City of Tacoma, Washington is exploring extensive steep slope tree management techniques on many of our open space properties throughout the City. We are just finalizing the report for the recent assessment and classification through the *Forest Landscape Assessment Tool (FLAT)* of our 496-acres (201 ha) of open space property that the City of Tacoma owns and is responsible for. This rapid ecological inventory and assessment tool provides essential information to help forest managers to be able to appropriately allocate resources. Out of those acres assessed, approximately 50% of the land area is on slopes greater than 40%, which requires specialized management strategies.

One of the defining characteristics of the Puget Sound region is the dynamic coastline, which includes over 1400 miles (2253 km) of beaches built out of sands and gravels from nearby bluffs. These actively eroding bluffs are an essential part of our coastal ecosystem. They provide a significant amount of coastal forest,

Tacoma's Schuster Slope as seen across the Foss Waterway in Commencement Bay. Photo Courtesy City of Tacoma

Washington Conservation Corp crews hard at work installing erosion control blankets on Schuster Slope. Photo Courtesy City of Tacoma

Erosion control and plantings along the Schuster hillside in between existing trees. Photo Courtesy City of Tacoma

support nesting birds and raptors, serve as refuge for native wildlife, and provide sediment and nourishment to our beaches as they erode along the shoreline.

Our first large scale restoration project to specifically address restoration to improve the stability of steep bluff slopes, the Schuster Slope (31 acres/12.6 ha), has just finished the first phase of restoration after a two-year public process to develop a landscape management plan for the property.

Schuster Slope is located along the west shore of Commencement Bay in Tacoma. The lack of healthy vegetation on the steep slope, along with frequent rainfall, causes Schuster Slope to experience skin slides, debris flows, and sloughing as it tries to revert to its pre-development, natural feeder bluff state. The entire Schuster Slope area is classified as a Critical Area under Tacoma Municipal Code (TMC) 13.11 due to the steep slopes, wetlands, streams, and priority habitat (as defined by the Washington Department of Fish and Wildlife). For long-term management activities to occur, a 20-year programmatic minor development permit was obtained, allowing the Environmental Services Department to efficiently move forward with restoration actions to address the slope stability.

The work that was just completed in March is on a 3-acre (1.2-ha) portion at the southernmost point of the slope, which has been designated as Management Unit 1. This site was deemed to be the highest priority for restoration, due to the complicated site conditions. Highlights of the work in this area include removal of 8-10 unsafe trees; removal of over an acre (.4 ha) of invasive weeds; installation of nearly 1.5 acres (.6 ha) of erosion control nets, blankets and straw wattles; posting of signs to educate the public and help deter vandalism, dumping, and encampments; and planting approximately 450 trees and 5,700 shrubs and groundcovers.

You can see the Schuster Slope Landscape Management Plan *here* and follow the project implementation *here.*

—Michael Carey, Urban Forest Program Manager, ISA Certified Arborist, City of Tacoma Environmental Services

Panoramic of hillside in Totalan, Spain that landscape architect Margarita Blanco is re-envisioning. Photo by Sven Roettger

Totalan is a small, 12th-century village perched above the city of Malaga, Spain, overlooking the Mediterranean Sea. The park of Totalan is located at the urban edge of the village, standing above the new Plaza Antonio Molina. The park is a fundamental part of the urban fabric which, over the centuries, has suffered profound transformations that have distorted its original layout. Its most recent transformation was the beautification project undertaken in 2009 by the villagers themselves to stop erosion of the park with a massive planting of native and exotic shrubs and trees on its steep slope. Due to its difficult access, lack of shade, steep topography, and the scarcity of resting places, the park has very little use.

The new design proposal aims to convert it into a meeting place were villagers can seek refuge from the heat of summer and warmth from the sun in the cold winter months. It will be a place where time stops, and from where you can appreciate the last rays of the sun that heat and illuminate the intense Mediterranean Sea.

Inspired by the Andalusian gardens of the Alhambra, the new linear park will be accessible and will be planted with aromatic plants impregnated with deep culinary and floral fragrances. Falling water is heard as background music to the wonderful views that extend over the sea as far as Africa.

The steep slopes will be regraded into accessible terraces, and in the Moorish tradition, the 10,000 linear meters (6.2 miles) of park will gradually ascend to the summit, offering places of rest during the climb up the hill. The park will be built in stages with recycled materials harvested locally, and existing native vegetation will be transplanted and re-used. The new Andalusian Park will be a place for everyone and serve as a model for the Pueblos Blancos or White Villages of Andalucía to follow.

—Margarita Blanco, ASLA, LEED AP, Director of Arquitectonica Geo, Miami, Florida

The existing slope condition in Totalan park in Malaga, Spain. Photo by Sven Roettger

When I began my PhD program in the summer of 2011, emerald ash borer (EAB) was well established in Pittsburgh, Pennsylvania (see Figure 1). Ash was a large and important canopy species within the city and EAB was spreading quickly. Pittsburgh is a city that is prone to landslides, and Pittsburgh's urban forest plays a significant role in stabilizing the city's hillslopes by reinforcing soil and removing excess water. There was some concern that the loss of ash from Pittsburgh's urban canopy could lead to increases in landslide susceptibility. With the help of two Pittsburgh urban forest NGOs, Tree Pittsburgh and TreeVitalize, I carried out a project to assess the impact of the loss of ash trees on Pittsburgh's slope stability.

To accomplish this task, I used geographic information systems (GIS) to model changes in the risk of slope failure following the loss of ash trees. Specifically, I modelled Pittsburgh slope stability with the SINMAP (Stability INdex MAPping) equation. This model is built on the key factors of slope stability including: soil density, soil water transmissivity, rainfall rate, and slope angle (see Figure 2 for all properties). The model uses these characteristics to classify forested pixels (segments) into 1) stable areas that would not fail, 2) moderately unstable areas that might fail, and 3) unstable areas that would fail as a result of a specified rainfall intensity (see Figure 3 for an example of the output).

Figure 1. Dead ash trees in Pittsburgh, PA. Aerial image from Google Earth; ash tree and EAB galleries photos by Erin Pfeil-McCullough

The soil property most affected by the loss of ash was cohesion, as the loss of root cohesion should be substantial. Cohesion is the tendency of a soil to stick together under stress. Tree roots further increase cohesion by anchoring soil in place and removing excess water.

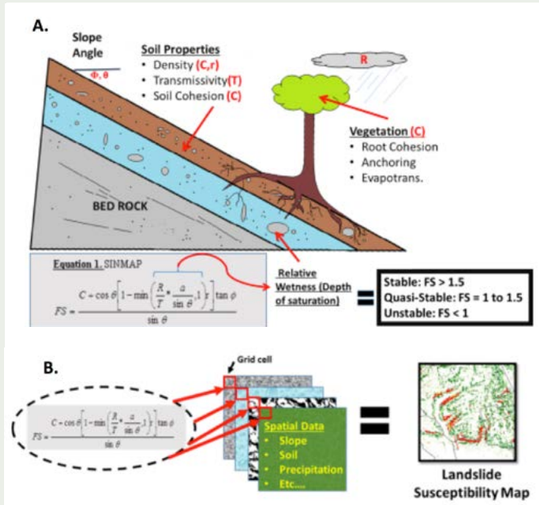


Figure 2.A) The SINMAP equation and the landscape characteristics that determine slope stability. B) The application of SINMAP in ArcGIS using gridded spatial data. In the equation, FS stands for "Factor of Safety," whic is a ratio indicating slope stability.

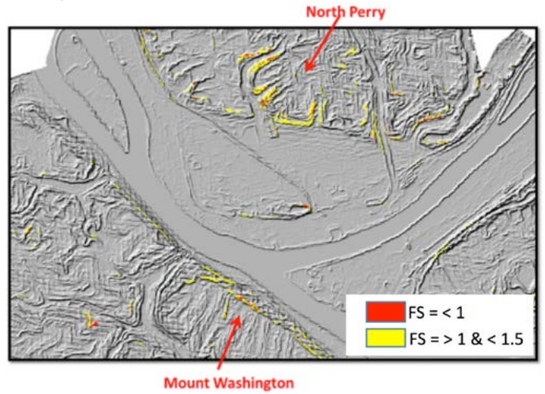


Figure 3. This is a hillshade (shaded relief) of a DEM (Digital Elevation Model), with a SINMAP landslide model output overlain on top. Mount Washington and North Perry are identified in the image. Yellow pixels are considered quasi-stable and the red pixels are considered unstable and likely to fail under the given rainfall conditions in the model.

To determine where ash was most likely to occur across Pittsburgh, local plot survey data was used. Using the plot data, ash tree distributions were estimated for Pittsburgh's forested areas, based on the steepness of the hillslope. Ash was most common on the city's steeper and most landslide prone slopes. The loss of ash was simulated by lowering the cohesion variable of the SINMAP equation. Four scenarios of ash tree death were the applied to the model to understand the implications of different loss severities (0%, 25%, 50%, and 75%). In these scenarios, we would rerun the model with the lowered cohesion values reflecting increasing tree loss and examine changes in landslide likelihood.

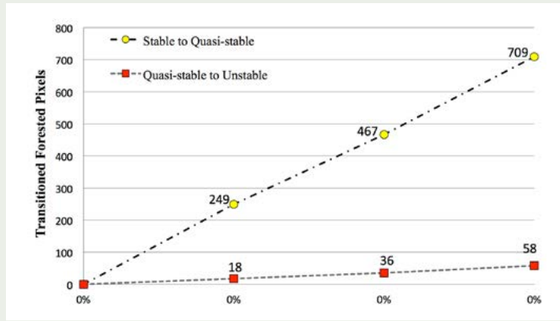


Figure 4. This plot shows increasing landslide susceptibility as ash is lost from the canopy. Transitioned forested pixels are pixels that went from containing an ash tree to not containing an ash tree to simulate mortality from EAB (Pfeil-McCullough et al. 2015).

There were several important lessons learned as a result of this study. Most importantly, the results revealed that ash tends to be located on the most landslide prone slopes of Pittsburgh (likely due to development patterns). When ash was lost from those landslide prone slopes, areas that had previously been classified by SINMAP as stable and not going to fail, transitioned to a moderately unstable classification with a possibility of failure during heavy rains. With the loss of 75% of the ash from Pittsburgh, 709 locations on slopes around the city that were once stable, transitioned to a less stable condition (Figure 4). Ultimately, these areas predicted to be unstable can be considered potential landslide initiation points following the loss of ash.

This GIS landslide model can be used as a tool to inform urban forest managers of areas that might be most destabilized from the loss of trees (ash or otherwise). With aggressive mitigation (e.g., planting, etc.) these increases in slope instability can be avoided. For more details, see the publication of this work (*doi:10.1016/j.scitotenv.2015.06.145*).

—Erin Pfeil-McCullough M.S., PhD Candidate at the University of Pittsburgh

Citation:
Pfeil-McCullough, Erin, Daniel J. Bain, Jeffery Bergman, and Danielle Crumrine. 2015. "Emerald Ash Borer and the Urban Forest: Changes in Landslide Potential due to Canopy Loss Scenarios in the City of Pittsburgh, PA." The Science of the Total Environment 536:538–45.

In South Florida where the grade is typically flat, slopes can still be an issue. When the construction of Parrot Jungle Island (an 18-acre/7.3 ha zoological park) began in 2000, a critical factor was that the site was an island, surrounded by water, that was affected twice daily by tide changes and by occasional storm surges. The exposed edge of the site needed to be protected from erosion. Typically, the entire edge (approximately 700 feet/213 m) would have been covered with large limestone rocks as shoreline protection (known as rip rap).

Initial slope grading at Parrot Jungle Island. Photo by Jeff Shimonski

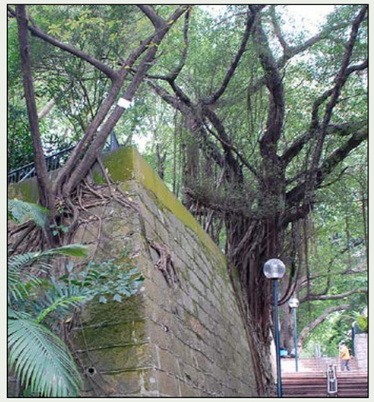
Five months after planting, carefully selected vegetation was doing its job nicely for the perimeter of Parrot Jungle Island. Heavy rainfall never washed out these planted slopes. Photo by Jeff Shimonski

Instead, to prevent erosion I was able to get approval for the installation of a layer of compost topped by another layer of mulch to secure the sides of the slope. After the layers of compost and mulch were installed, a vegetative cover consisting of salt-tolerant vines and groundcovers was planted on top of the other stabilizing materials. This method saved approximately $60,000 by not having to install ground cloth and rip rap.

A substantial amount of "shotcrete" has been laid to aid in slope stabilization in Hong Kong. Photo by Jeff Shimonski

Many engineered slopes in Hong Kong have trees planted on them inside small planters.

The rugged terrain of Hong Kong, where I've traveled extensively, is quite different from the relatively flat landscape of South Florida. There is very little flat land in Hong Kong's group of mostly mountainous islands. This has required substantial engineering on its steep slopes to enable this densely populated and heavily built country state to live right up to these mountains and steep grades. Slope stability is a constant issue and the different methods that have been developed over time are readily apparent as one travels through Hong Kong.



In Hong Kong, one sees the famous stone retaining walls with the ever-attendant Chinese banyan trees growing on top of them. Photo by Jeff Shimonski

Stone pitching (seen in the photo above) is common in some of the older areas where retaining walls were built well over 100 years ago. Atop many of these walls are the famous "Stonewall Trees." These highly protected volunteer Chinese banyan trees (*Ficus microcarpa*) give quite a few challenges to both the engineers charged with maintaining the walls and the municipal arborists charged with tree preservation at all costs. Most slopes in newer areas are now covered in "shotcrete" with weep holes—pipes that protrude from below the concrete designed to allow ground water from heavy rainfalls to escape. A substantial effort is made, with varying results, to plant trees and other vegetation on these concrete slopes to green up and cool off these engineered areas.

—Jeff Shimonski, President, Tropical Designs of Florida, Inc., *Jeff@TropicalArboriculture.com*

As anyone who has ever tried to garden on a slope knows, it can be an arduous challenge. Gravity and drought are almost always working against you, making erosion control and plant establishment difficult. Maintenance becomes more of a headache, as even keeping your balance while working can be tricky.

Based on several years of woody groundcover research I conducted at Cornell University with Nina Bassuk (see resulting bulletin *here*), as well as over 20 years of field experience in the nursery, landscaping, and arboricultural industries, I offer here some advice for successfully designing, planting, establishing, and maintaining interesting and functional slopes.

As is true for any type of landscaping project, site assessment is critical. Knowing sun/shade patterns, aspect (which direction the slope is facing), soil drainage, soil type, presence of underground infrastructure (especially in urban areas), presence of existing vegetation, and any microclimate effects will help determine any site modifications that may need to be performed and will help guide plant selection.

It is rarely recommended to till or amend a slope, as that can increase erosion potential. If soil organic matter is an issue, a simple top-dressing prior to planting of 1 to 2 inches (2.5 to 5 cm) of compost can help. It may also be necessary to divert the water coming from above the slope using swales or drains so that excessive erosion can be avoided after soil disturbance and planting. Jute blankets pinned down to the soil can also be helpful. At planting time, just cut appropriate holes in the jute to allow for planting. Over time, as plants establish, the jute will biodegrade.

It is imperative that you start weed-free, and depending on whether you have annual, biennial, and/or perennial weeds, getting the site completely weed-free prior to planting can often take more than one growing season, depending on the time of year you start the project. Both pre-emergent and post-emergent herbicides can be extremely helpful in this regard, but use them carefully and according to label recommendations.

Plant selection is the next important decision to be made. One important thing to know about any type of ground covering plant is the method by which it spreads. Is it rhizomatous or stoloniferous? Can it be overly aggressive or potentially invasive? Will it spread by self-seeding? Will it tip-layer itself as its arching stems come back in contact with the ground? If it is to be a mixed planting, do the plants behave in the same manner with a similar growth rate so that one will not outcompete the other?

Spacing and installation size is also a factor to consider. Research has shown that installing a smaller size plant from the nursery (i.e. a rooted cutting or a quart or 1-gallon container plant) at closer spacing can achieve cover and therefore weed suppression faster, as opposed to installing larger sizes (i.e. 3-gallon or balled-and-burlapped plants) at farther spacing. On purely utilitarian sites, hydroseeding can also be an option.

A list of recommended woody plants that I find work well for slopes in the Southeast US region is included in this article for reference; some of these plants may work for you if they have the appropriate cold or heat hardiness for your region. I also prepared a list of recommended herbaceous plants for slopes which you can request from CT Editor Michelle Sutton at *citytreeseditor@gmail.com*.

Once the site has been assessed and prepared and plants have been selected, planting can begin. It is recommended that all plants be placed out on the slope prior to digging so that spacing and placement can be adjusted as needed. Oftentimes, what made sense on paper in the design process does not make sense on the actual site, so stay flexible!

It is sometimes easier to spread a 2 to 4 inch (5 to 10 cm) layer of wood mulch prior to planting, place the plants, and then dig. If you do so, be careful to pull the mulch back from each plant as you dig so that the roots are in contact with the soil and the holes do not backfill with mulch, which will cause the plants to dry out too quickly. This is especially true if using rooted cuttings or small container plants. Try to smooth out the soil and mulch on the slope as you plant. After planting, make sure to carefully "fluff" the mulch around the crowns of the plants so that the stems are not buried under excessive mulch, which can cause the plants to rot before they become established.

As for any kind of new planting, careful watering is critical to establishment. If watering by hand, be sure to use a wand and breaker so that erosion can be avoided. If using a sprinkler or automatic irrigation, be sure that coverage is adequate without causing runoff and that the site is not over-watered. It is imperative to keep the newly planted slope well-weeded, likely by hand, during the first two growing seasons. This can be a huge factor in the success of the planting, so be sure to consider it when planning for labor and budgets and schedule. Herbicide use can be very risky after planting, if not impossible.

Once plants become established, annual pruning to remove dead, diseased, or broken branches is recommended. For herbaceous plants, cutting back the stems in fall can be beneficial and will give the slope a tidier look for winter and spring. Top-dress with a 1 inch (2.5 cm) layer of compost annually, and refresh mulch as needed, being careful to never let the compost and mulch depth together exceed 4 inches (10 cm), and from piling up against stems of woody plants. Over time, plants may need a hard rejuvenation pruning, especially larger shrubs.

—Jamie Blackburn, Vice President & Chief Operating Officer, Arborguard Tree Specialists, Avondale Estates, Georgia

Woody and Herbaceous Plants for Slopes in the Southeastern U.S.

This woody plant list was prepared by Arborguard Tree Specialists Vice President & Chief Operating Officer Jamie Blackburn; they are plants that work well for him on slopes in the southeastern United States. Check to make sure they are appropriately heat-tolerant or cold-hardy for your region before considering them. If you would like Blackburn's recommended *herbaceous* plants for slopes list, send a request to *citytreeseditor@gmail.com.*

Woody Plants for Slopes in the Southeastern US

* evergreen leaves

^ aggressive or potentially invasive

species or one of hybrid parents is native to southeastern US

Woody groundcovers and small spreading shrubs for shade

Ardisia japonica 'Chirimen' *^ (variegated marlberry)
Cephalotaxus harringtonia 'Prostrata' * (plumyew)
Clethra alnifolia 'Sixteen Candles' # (summersweet)
Leucothoe axillaris *# (doghobble)
Lonicera nitida * (evergreen honeysuckle)
Microbiota decussata * (Siberian cypress)
Sarcoccoca hookeriana var. *humilis* * (sweetbox)
Sasa veitchii *^ (kuma zasa bamboo)
Symphoricarpos x *chenaultii* 'Hancock' # (snowberry)
Xanthorhiza simplicissima # (yellowroot)

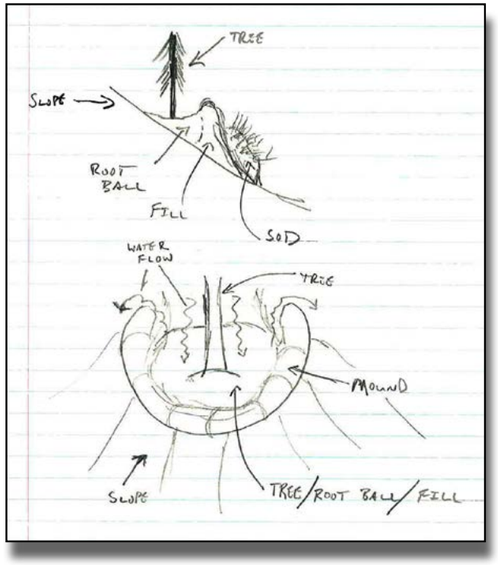
Woody groundcovers and small spreading shrubs for sun

Abelia x *grandiflora* 'Prostrata' * (glossy abelia)
Comptonia peregrina # (sweetfern)
Conradina verticillata *# (beach rosemary)
Deutzia gracilis 'Nikko' (creeping deutzia)
Ephedra americana ssp. *andina* *^ (ephedra)
Forsythia Gold Tide™ (dwarf forsythia)
Gardenia radicans * (dwarf gardenia)
Hypericum calycinum * (St. John's wort)
Ilex opaca 'Maryland Dwarf' *# (prostrate American holly)
Indigofera kirillowii 'Rose Carpet' ^ (false wild indigo)
Itea virginica 'Little Henry' # (Virginia sweetspire)
Jasminum nudiflorum ^ (winter jasmine)
Juniperus procumbens 'Nana' * (dwarf Chinese juniper)
Juniperus horizontalis 'Bar Harbor' * (spreading juniper)
Juniperus conferta 'Blue Pacific' * (shore juniper)
Lantana 'Miss Huff' ^ (lantana)
Rhus aromatica 'Gro-Low' (sumac)
Rosa rugosa Pavement Series™ (salt rose)
Rosa 'Snow Carpet' (carpet rose)
Spiraea decumbens 'White Lace'
Stephanandra incisa 'Crispa'
Trachelospermum asiaticum * (Asiatic jasmine)
Trachelospermum jasminoides * (star jasmine)
Vitex rotundifolia ^ (beach vitex)
-- do not use in coastal dune areavs, highly invasive

Large shrubs and trees

Aesculus parviflora # (bottlebrush buckeye)
Chaenomeles spp. (flowering quince)
Corylus americana # (filbert)
Foresteria acuminata # (native privet)
Hibiscus syriacus (rose of Sharon)
Hydrangea quercifolia # (oakleaf hydrangea)
Ilex verticillata # (winterberry)
Ilex vomitoria # (yaupon holly)
Myrica cerifera *# (bayberry)
Robinia pseudoacacia # (black locust)
Rhus copallina # (winged sumac)
Rhus glabra # (smooth sumac)
Rhus typhina # (staghorn sumac)
Sassafrass albidum # (sassafras)
Viburnum awabuki *
Viburnum rufidulum # (southern blackhaw)

Planting Trees on Slopes



When digging holes for trees on slopes, I've found that it's useful to put the soil on the downhill side of the hole that the tree will be planted in (why fight gravity?). When the tree has been placed in the hole, the fill on the lower side creates a berm; any sod that was removed goes on the berm that was created by the tree planting. I have attached a simple diagram to illustrate what it looks like.

—Paul Eriksson, Natural Resources Specialist, Engineering Division, City of Cumberland, MD