SOIL RESOURCES

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Introduction

The Soil Ecosystem

Forest soils are composed of an assortment of materials and organisms that when viewed in whole function as a living ecosystem. This "soil ecosystem" performs several key functions essential to healthy forest ecosystems. The soil ecosystem helps to:

- Sustain biological activity, diversity, and productivity by providing habitat for plants, animals, and other organisms;
- Regulate water flow;
- Filter, buffer, immobilize, and detoxify potential pollutants;
- Store and cycle nutrients;
- And provide structural support for plants.

The maintenance of these soil functions requires careful consideration of the entire soil ecosystem, including soil floral and faunal communities, which are composed of bacteria, algae, fungi, protozoa, nematodes, arthropods, earthworms, insects, small vertebrates, and plants, as well as the physical and chemical properties of the soil. Providing and protecting the necessary habitat components and physical conditions for soil organisms is critical for managing soil resources.

Physical, chemical, and biological properties of Pennsylvania's forest soils have changed over time as a result of long-term climate change, glaciation, acid precipitation, and erosion that occurred during the period of heavy harvesting from the late 1800s to the early 1900s. Because of these changes, establishing a historical baseline for evaluating soil ecosystem health and productivity in a conventional sense may not be possible for the forest soils of Pennsylvania. Instead, the Bureau of Forestry will use a relative measure, such as current conditions, for establishing baseline soil conditions, while still recognizing that soil productivity should be increased or maintained at current levels, but not be allowed to decrease.

As we increase our knowledge of soil ecosystems, the Bureau of Forestry will adopt new management strategies aimed to further protect and enhance soil resources. Techniques such as rotating forest types (similar to agricultural practices) or inoculating soils with microorganisms such as mycorrhizae may help to protect, maintain, and enhance soil productivity.

Soils and Acid Precipitation

Acid precipitation is a long-term and complex concern that has potential negative impacts on Pennsylvania's water and forest ecosystems. While the extent and significance of its effects are not yet fully defined, Pennsylvania receives some of the most acidic precipitation in the country originating from industrial centers in Chicago and the Ohio Valley regions. Although many forest soils in Pennsylvania are naturally acidic, the added effects of acid precipitation are changing soil chemical properties and affecting the health of some tree species. As soils become more acidic, calcium and magnesium (important for tree nutrition) become less available to trees, and aluminum, which is toxic to trees, becomes more available. Research conducted by the U.S. Forest Service and the Bureau of Forestry on the Susquehannock State Forest indicates that sugar maple, white ash, and basswood are most sensitive to soil acidification; while species such as black cherry, American beech, and birch are mostly insensitive and not affected. Research results are not conclusive on the effects of acid precipitation on oak species. Additionally, the buffering capacity of soils is highly variable, thus complicating efforts to understand the impacts of acid deposition on forest ecosystems.

Scientists and natural resource professionals are currently debating the effects of acid deposition on forest regeneration. Some believe that acid precipitation is the most significant factor affecting forest
regeneration, while others attribute it to a combination of factors, including white-tailed deer browsing. The Bureau of Forestry recognizes that while acid precipitation is changing soil chemistry and could be affecting tree growth, the impact of the overpopulated white-tailed deer herd complicates the issue even further. The Bureau of Forestry supports research attempts to determine the effects of acid precipitation and deer overabundance on forest ecosystems. Additionally, the Bureau of Forestry recognizes that silvicultural treatments could be modified in certain situations to minimize adverse changes to soil chemistry, such as:

- Leaving non-commercial wood and tops of trees on site by restricting whole-tree harvesting to allow for nutrient cycling. Note: Only about 20% of the nutrients in a tree occur in the merchantable stem.
- Managing for longer rotations and partial removals on nutrient-poor sites.
- Limiting nitrogen fertilization on low base cation sites and during stand establishment, which could accelerate calcium and magnesium leaching, thus causing soil acidification.

The following is a list of references on acid precipitation and Pennsylvania soils and forests:


Soils GIS Data
In addition to considering soils at the site- and stand-level, the Bureau of Forestry will begin to incorporate soils GIS information into its landscape-level planning. The United States Department of Agriculture, Natural Resources Conservation Service (NRCS) is currently in the process of digitizing county soil surveys in Pennsylvania. The Bureau of Forestry is incorporating this information into its GIS library. While traditional concerns, such as compaction and erosion, will continue to be addressed, future management objectives will strive to develop a holistic approach to managing soil resources.

**History**

In 1897 the legislature passed an act authorizing the purchase of unseated lands for forest reservations in the headwaters of each of the main rivers of the Commonwealth-the Delaware, Susquehanna, and Ohio rivers. This legislation marked the beginning of the present state forest system. Although management plans were not initially developed for state forest acquisitions, the act of purchasing the cutover lands itself was the first step toward managing and protecting soil resources on state forest land.

From 1898, when the first tract was purchased, until 1955, when the first written management plan was developed, management efforts were focused primarily on administration and operations activities such as forest fire protection, tree planting, road construction, and establishing boundary lines. Indirectly, however, soil resources were being protected as these management activities were implemented.

The management objectives of the first official management plan, the *Forest Resource Plan of 1955-1970*, were:

1. Produce the greatest possible sustained supply of timber products.
2. Improve species composition and quality of existing stands and provide for adequate residual growing stock as well as to reduce the damage caused by insects and diseases.
3. Regulate the cutting of timber so that the supply and flow of products from the forest will be constant and adequate. This will tend to stabilize wood-using industries and the employees and communities dependent upon them.
4. Develop and preserve the recreational values of the forests.
5. Protect the watersheds from erosion and obtain from them the maximum yields of useable water.
6. Harvest timber in such a way that an adequate, uniform supply of food and cover for wildlife is produced.

The management objectives for subsequent resource plans (1970-1985 and 1985-1999) were expanded to include specific objectives for watershed management, mineral development, recreation, and flora and fauna. Although it was not stated explicitly as an objective, the Bureau of Forestry managed soil resources throughout these previous management periods. Efforts focused on protecting soils from erosion and compaction during management practices, with the basic goal of protecting watersheds. Additionally, The Bureau of Forestry actively managed soil resources at the various tree nurseries throughout the state.

The Bureau of Forestry has been active in developing and implementing best management practices for forestry operations, which in large part focus on preventing soil loss (erosion and sedimentation), minimizing soil compaction, and to a lesser degree, maintaining or enhancing soil fertility. As the Bureau of Forestry develops and implements the 2000-2005 State Forest Resource Management Plan, it will begin to develop partnerships with other organizations and agencies to begin to consider and manage soil as an ecosystem, consisting of floral, faunal, and microbiological communities, where soil productivity is viewed as an integral part of forest ecosystem health.

**Inventory**

**Soil Sources of Information**

2. The Bureau of Forestry currently uses the county soil surveys published by the NRCS for soil series information when planning management activities. District personnel consult soil survey maps when planning management activities having the potential to affect soil resources. The Map Compilation and Digitizing Center at Penn State University is working to digitally capture soil survey data for Pennsylvania counties. The Bureau of Forestry is in the process of incorporating this data into its GIS library. The following website is maintained by the Map Compilation and Digitizing Center. It provides links to soils information, updates on county soil surveys, updates on the soil survey digitizing project, and other information. http://mcdc.cas.psu.edu/

3. The Pennsylvania Association of Conservation Districts, Inc. (PACD) was organized in 1950 to serve as a collective voice of Pennsylvania’s conservation districts, which are grass-roots organizations focusing on land and water conservation issues at the county level. The following website contains general information on the PACD as well as links to all 67 county conservation districts. http://www.pacd.org/

4. The US Department of Agriculture, NRCS maintains an Internet site designed to help people understand soils. The site provides information on soil surveys, soil uses, classification, education, research, and more. http://soils.usda.gov/

5. The PA DCNR, Bureau of Topographic and Geologic Survey provides background information on the geology of Pennsylvania, including groundwater, lithology, minerals, and geologic hazards, all of which relate to soil resources. http://www.dcnr.state.pa.us/topogeo/index.htm

6. The US Geologic Survey (USGS) provides general geologic and water resources information, as well as the State Soil Geographic (STATSGO) Soil Characteristics and STATSGO Data Base for the Conterminous United States, which “...were derived for use in regional (multi-state) and national studies requiring estimates of soil characteristics. The georeferenced soil characteristics were intended to be averaged over large areas, such as over a river basin, and used (1) for watershed simulation models that require spatially lumped estimates of soil hydraulic parameters and (2) as explanatory variables in regional and national water-quality assessment studies” (USGS). http://www.usgs.gov/

7. The Pennsylvania Biological Society (PABS) is a nonprofit organization whose purpose is to increase the knowledge of and foster the perpetuation of the natural biological diversity of the Commonwealth of Pennsylvania. Their website provides information on soil organisms such as protists and fungi, bryophytes and lichens, vascular plants, invertebrates, amphibians and reptiles, and birds and mammals. http://www.dickinson.edu/prorg/pabs/pabs_main.htm

8. The Saskatchewan Centre for Soils Research at the College of Agriculture, University of Saskatchewan maintains a website with a wealth of information on soil ecosystems and soil biology. http://interactive.usask.ca/ski/agriculture/soils/soilliv/index.html

9. The Bureau

Plan management activities to protect and maintain soil productivity and attempt to restore and enhance soil productivity whenever possible.

Support and engage in soil ecosystem research and efforts focused on developing applications for:

- Identifying and inventorying areas of diminished soil productivity.
- Identifying and eliminating ongoing causes of loss of productivity.
- Identifying and implementing cultural practices to increase soil productivity.

10. The Bureau of Forestry maintains copies of soil survey maps and soils information in the compartment files in the district offices and in a central library in the bureau's central office.

**Policy Statement**
An integral part of the larger forest ecosystem, soil ecosystems are critical to sustaining healthy forests. The Bureau of Forestry will continue to follow BMPs to protect soil resources and investigate new strategies for actively managing soil resources in order to protect, enhance, and restore soil ecosystem health and productivity.

**Goals and Objectives**

**Goal 1:** Protect, maintain, restore, and enhance soil ecosystem health and productivity.

**Objective 1:** Provide habitat for soil organisms by considering forest floor litter composition when planning management activities.

**Objective 2:** Prevent accelerated soil erosion and mitigate ongoing soil erosion on problem sites.

**Objective 3:**

**Objective 4:**

**Objective 5:** Increase Bureau of Forestry staff knowledge and understanding of the relationships between soil ecosystems, forest ecosystems, and forest management activities.

**Objective 6:** Develop partnerships with other agencies and organizations to investigate the feasibility of implementing a program to monitor soil health and productivity.

**Goal 2:** Incorporate soils GIS information into resource management planning efforts.

**Objective 1:** Develop a soil resources GIS database.

**Objective 2:** Develop applications for using soils GIS data to assist with planning and management decisions.

**Guidelines and Actions**

A. Refer to the [Water Resources Guidelines](#), which in many cases also relate to protecting soil resources.

B. Consult county soil surveys when planning management activities.

C. Consult compartment soil maps, or GIS when available, for the presence of highly erodible soils or soils with stability characteristics that would severely limit the use of heavy equipment. Special precautions apply for such areas.

D. Consult the publication, *Prescribing Silvicultural Treatments in Hardwood Stands of the Alleghenies (Revised)*, for specific recommendations for conducting silvicultural treatments on soils located on the Allegheny Plateau.

E. All soil disturbing management activities, such as skidding and trail and road construction, will be implemented according to procedures outlined in the Silviculture Manual and Oil and Gas Guidelines. Soil Erosion and Sedimentation Control Plans will be developed and implemented for all applicable activities. All management activities will meet or exceed the recommendations for best management practices outlined in the following three documents, which provide guidelines for implementing BMPs:


### Silvicultural Guidelines for Protecting Soil Resources

While the following guidelines were adopted from the Silviculture Manual for silvicultural activities, they apply to all management activities having the potential to affect soil resources.

1. Consider timing (season of year and weather patterns), skid trail design, and layout to minimize compaction during harvest operations. If necessary, stipulate seasonal restrictions on skidding and limit skidder travel to permanently designated skid trails.
2. If applicable, consider the use of reduced-impact timber harvesting technology.
3. Greater care should be taken on sites with higher quality soils exhibiting thicker upper soil horizons, finer textures, or greater water-holding capacity, all of which tend to make them more vulnerable to compaction.
4. Promote regeneration (natural or planted) appropriate to the site and soil characteristics.
5. Facilitate nutrient cycling by leaving downed woody debris (non-commercial wood and tree tops) by limiting the use of whole-tree harvesting (refer to the Silviculture Manual).
6. Manage for longer rotations and partial removals on nutrient-poor sites.
7. To avoid accelerated calcium and magnesium leaching, and resulting soil acidification, nitrogen fertilizers should be used cautiously on low base cation sites and during stand establishment.
8. Consider site limitations such as wet areas, poorly drained soils, stoniness, and surface rocks:
   - a. Wet Areas and Poorly Drained Soils
      1. Wet, saturated soils may contribute to the failure of a site to regenerate. The excess moisture, lack of aeration, tendency toward frost pockets, tendency for lush growth of some types of interfering herbaceous vegetation, and release and possible buildup in the soil of allelochemicals all adversely affect seedling establishment and early growth. In areas of high deer population, slow seedling growth subjects regeneration to deer browsing for an extended period and further reduces the chance of success. Although regeneration is not impossible on such sites, the risk of failure is greater than on better-drained soils, and it is prudent to ensure that advance regeneration is well established, free of interfering plants, and large enough to survive well before the final overstory removal is made. Loss of advance seedlings due to logging damage also can be severe on wet soils.
      2. If poor soil drainage or rocky soils are present on the area to be regenerated, a three-cut shelterwood sequence is recommended. The seed cut is made as above, but the removal is spread over two cuts to allow the advance seedlings to reach large size, and ensure that they are well enough established to survive under the difficult environmental conditions that follow complete overstory removal. This three-cut sequence also can be used in areas where management goals make it desirable to have the new stand tall enough to avoid the appearance of a fresh clearcut when the final overstory removal is completed. However, if deer browsing is severe, the three-cut procedure, which requires the seedlings to grow under partial shade for an extended period, often will not work.
      3. The following information is useful in determining whether the soil in a particular stand is poorly drained and might pose a management problem.
         i. Poorly drained soils are those where a water table persists very close to the soil surface during all or most of the dormant season. Such soils usually have prominent mottling at depths ranging from 1 to 8 inches beneath the surface. Since soil examination is usually not feasible during the stand inventory, drainage must be estimated from landscape position, relief, and indicator plants.
         ii. Landscape position and relief have a strong influence on soil drainage. Look for poor soil drainage in concave positions of broad plateau tops, in upland bottoms, and at the base of
slopes. Low topography is more likely to be poorly drained than high topography. A convex topographic configuration generally indicates well- or moderately well-drained soils. In valley bottoms, soil drainage becomes poorer from the stream channel towards the base of the slopes. Concave and low-lying areas in bottoms, as well as toe slopes with many seeps, are especially likely to be poorly drained.

iii. Standing water in depressions and wet surface soils during the dormant season and during periods of normal rainfall in the summer and fall are indicative of poorly-drained soils.

iv. Depressions with leaves having a black or other dark color that is significantly different from leaves nearby on the forest floor are indicative of poorly-drained soils.

v. The presence of wet site plants, like sedges, rushes, sphagnum moss, sensitive fern, interrupted fern, cinnamon fern, skunk cabbage, false hellebore and marsh marigold on a site is indicative poorly-drained soils.

vi. The presence of a very deep spongy humus layer at the soil surface is indicative of poorly-drained soils.

b. Stoniness and Surface Rocks

1. Those areas that are almost completely covered with a surface layer of stones and rocks also present difficulties for regeneration. Advance seedlings are often rooted only in the forest floor material that covers the stony layer, and not in the deeper underlying mineral soil. When the overstory is removed, the forest floor dries quickly, and small advance seedlings die from desiccation. The presence of surface stones becomes increasingly important on well-drained soils located on southern and southwestern exposures where slope steepness is 15 to 20 percent or more. As with wet soils, it is imperative that advance seedlings be well established and large enough to be rooted in mineral soil before a final overstory removal harvest.

Zoning Guidelines to Protect Soil Resources

Natural and Wild Area Management Zones

Natural Areas have been designated to protect specific unique scenic, historic, geologic, and ecological values. Wild Areas cover extensive areas designed to provide forest users the opportunity to pursue recreation activities in remote and relatively undisturbed settings. By excluding most management activities, Natural and Wild Areas afford the greatest protection of soil resources.

Aesthetic/Buffer Management Zone

Connectivity, aesthetics, and water quality conservation are the primary values associated with the Aesthetic/Buffer Management Zone. Buffer zones applied to various stream designations help to protect soils in riparian ecosystems.

Limited Resource Management Zone

The Limited Resource Management Zone restricts management activities, such as timber harvesting and recreation development, on sites with steep slopes, surface rocks or other features affecting operability.

Multiple Resource Management Zone

The Multiple Resource Management Zone is applied to areas where timber, water, recreation, fauna, flora and minerals are the major values. This zone constitutes the majority of lands within the State Forest system and is the least restrictive, most encompassing management zone. BMPs will be followed during all management activities.

During the harvest allocation planning process for the Multiple Resource and Commercial land base, an area reduction factor of 10% was applied to reduce the available area for harvest to account for areas that are too rocky, too wet, too steep, or too small to small have been classified as a separate stand.
Special Resource Management Zone
The Special Resource Management Zone is applied to areas managed for specific values such as public plant sanctuaries, special wildlife management areas, certain recreation sites, vistas, and reservoirs. BMPs will be followed in these zones, which will have specific management recommendations or plans, depending on the values that are being recognized.

Anthropogenic Site Management Zone
Anthropogenic sites apply to structures or facilities such as roads, rights-of-ways, mineral sites, tower sites, leased campsites, and forest district buildings. BMPs will be followed in these zones.

Actions for Goals and Objectives

Goal: Protect, maintain, restore, and enhance soil ecosystem health and productivity.

Objective 1: Provide habitat for soil organisms by considering forest floor litter composition when planning management activities.

Actions:
1. Diversify forest floor litter composition by encouraging forest diversity.
2. Maintain sufficient woody debris and forest floor litter.
3. Follow Silvicultural Guidelines for protecting soil resources.

Objective 2: Prevent accelerated soil erosion and mitigate ongoing soil erosion on problem sites.

Actions:
1. Follow Silvicultural Guidelines for protecting soil resources.
2. Implement Best Management Practices on all Bureau of Forestry operations.
3. Develop and implement project-specific erosion and sedimentation control plans.
4. Identify and prioritize areas that have accelerated soil erosion.
5. Remediate conditions that cause accelerated soil erosion.

Objective 3: Plan management activities to protect and maintain soil productivity and attempt to restore and enhance soil productivity whenever possible.

Actions:
1. Consider soil productivity when planning management activities, such as silvicultural treatments by:
   - Considering timing and skid trail design and layout to minimize soil compaction;
   - Prohibiting whole-tree harvesting on nutrient-poor sites;
   - And, when prescribing regeneration treatments, match tree species (natural or planted) to site and soil characteristics.

Objective 4: Support and engage in soil ecosystem research and efforts focused on developing applications for:
- Identifying and inventorying areas of diminished soil productivity;
- Identifying and eliminating ongoing causes of loss of productivity;
- And identifying and implementing cultural practices to increase soil productivity.

Objective 5: Increase Bureau of Forestry staff knowledge and understanding of the relationships between soil ecosystems, forest ecosystems, and forest management activities.

Objective 6: Develop partnerships with other agencies and organizations to investigate the feasibility of
implementing a program to monitor soil health and productivity.

Action:

1. Develop partnerships with agencies and organizations with expertise on soil resources.

Goal Incorporate soils GIS information into resource management planning efforts.

2: Objective Develop a soil resources GIS database.

1: Action:

1. Acquire county soil survey GIS data for all counties containing state forest land.

Objective Develop applications for using soils GIS data to assist with planning and management decisions.

Monitoring

Indicators:

- Area and percent of forest land with significant soil erosion.
- Area and percent of forestland with significantly diminished soil productivity, organic matter, or changes in soil chemistry.
- Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities.

Critical Research Needs

- Soil quality indicators.
- Methodologies for measuring soil quality.
- Methodologies for restoring soil quality.
- Long-term impacts of silvicultural activities such as timber harvesting, herbicides, fertilizing, and liming.
- Extent and effects of acid precipitation on soil chemistry and tree growth.