Soils for New Jersey Trees

SOILS FOR NEW JERSEY TREES

This publication is the result of the research, education, technical knowledge and creativity of some very dedicated individuals. I acknowledge with tremendous graititude the following individuals for dedicating their time and expertise in creating and gathering information to give us a basic knowledge about soils for New Jersey trees.

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Lastly, I would like to acknowledge the authors behind the links and adaptations that are referenced throughout this publication.

Donna Massa
Executive Director
New Jersey Shade Tree Federation

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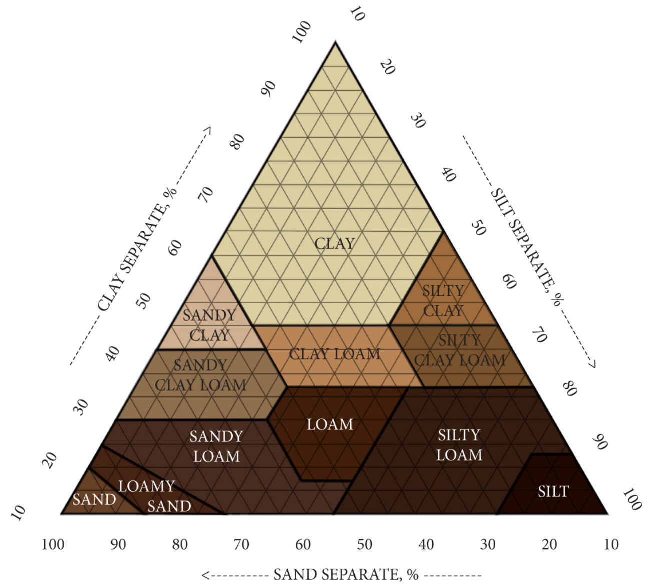
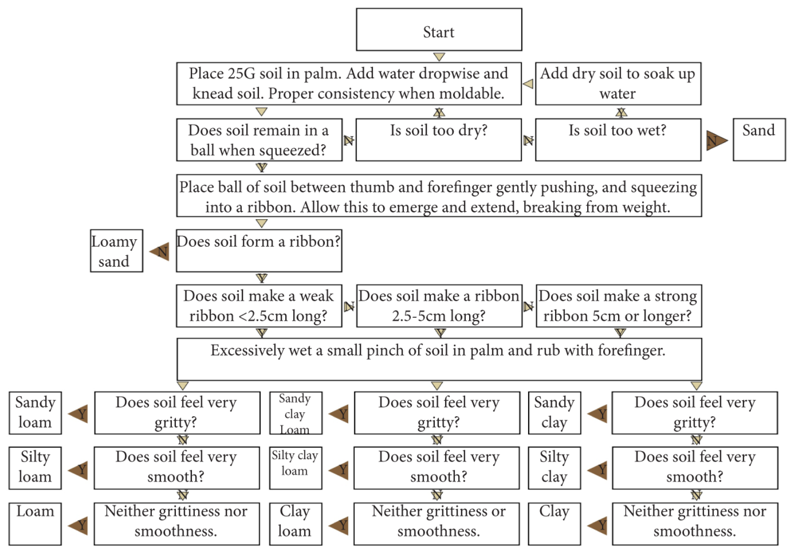
INTRODUCTION

New Jersey street trees are required to endure a unique set of factors that trees outside of urban areas do not encounter. Due to a number of issues found in urban soils such as compaction, nutrient differences, and much more, choosing the correct tree to plant in a given area is no easy task. Possessing an adequate background knowledge of New Jersey soil, its characteristics, and what tree species thrive in what conditions is vital to assuring a long and healthy life for an urban tree. New Jersey is home to different geological zones, soil structures, and tree species. With a proper knowledge of soil characteristics and tree viability, the proper species can be more reliably chosen.





Top Right: Soil Texture Triangle
Bottom Right: Flow Chart For Texture By Feel

BASIC DEFINITIONS

Soil Texture/Classification

Soil texture is a way to define and organizationally classify soils. It is used to communicate, understand, and manage landscape resources. Texture of a soil is a key determinant in defining an area's fitness and suitability to sustain the expected life of the tree. Classifying a particular texture depends on the amount of sand, silt, and clay in a given soil. These classifications refer to particle size with sand featuring the largest particles and clay being the smallest.

The terms sand, silt and clay are used when characterizing soil particles. Loam is a term used when there are enough of each particle size to influence behavior. Sandy soils will feel gritty to the touch compared to the softer and greasy feel of a clay. The overall texture classification of a soil is based on the percentage of each of these particles in a given soil volume. These percentages can be estimated using a touch test and flow chart or determined with more accuracy through a laboratory testing process including sieve analysis and hydrometer test. Your soil classification can be identified using the soil texture triangle.

Understanding or knowing the texture of a soil is crucial because it helps determine how much water can either flow through or be retained in the soil system. This permeability factor also comes into play when considering the ability of a tree's roots to make its way through the soil. Sandy soils have the highest infiltration rates of water and roots while soil with an abundance of fine clay particles will be more difficult to permeate. Sandy soil will also struggle to hold nutrients while clay-based soil will retain more nutrition. Sand particles are typically blocky compared to the thin and flat nature of most clay particles, creating an even larger difference when comparing permeability. In forestry, soil texture has influence on moisture, aeration, and nutrient availability, making it an important consideration in plant selection.

Different tree species have different requirements in these areas, so the rate of growth of a particular tree will often closely correlate with soil texture. Sandy soils typically support the growth of trees such as pines, aspens, and white birch while soils with more clay can support the growth of a maple, elm, or white ash. With the goal of planting a tree that will grow properly and thrive in a given condition, the texture of the soil ought to be considered to find the correct match.

Soil Structure

Soil texture indicates the type of particles that are present while soil structure describes how those particles are arranged and how that arrangement influences soil, air, and water behavior. Soil structure refers to the arrangement of soil particles with consideration to the amount of space or pores between them. The interactions of soil particles such as how they bind, aggregate, or clump together determine what type of soil structure is present. These factors determine how easily water, air, and nutrients can be accessed by a plant. For example, good soil structure can allow a loam soil to drain like a sandy soil, but it will also hold more nutrients and water for plants. Structure also contributes to the ability for a plant's roots to permeate the soil and properly gain nutrition. It will help determine the rate of erosion, root penetration, nutrient availability, water infiltration, and rate of seedling sprouting.

A soil aggregate occurs when particular soil particles bond with one another in a stronger manner than other nearby particles. The space between aggregates is the biggest factor in the retention and exchange of water and air. The formation of soil aggregates can occur through a variety of natural processes. Wetting and drying, freezing and thawing, decay through the activity of microbial activity, absorption of ions, and root activity all lead to creating aggregates.

These aggregates are how one determines the structure of a particular soil. On occasion, a soil can be "structureless" which means that it has no aggregation when dry. Working or compacting soil when wet can destroy soil structure in surface layers of the soil resulting in a structureless condition.

A granular aggregate will have a rounded surface. A crumb aggregate will also be rounded but is larger than a granular. Blocky aggregates are cubed with flattened sides and pointed edges while subgranular blocky aggregates are the same but with rounded edges. Prismatic aggregates are rectangular with a flattened top and long profiles. Columnar and platy aggregates are similar, both featuring a rectangular shape. As its name suggests, the columnar aggregate has a longer vertical profile while the platy aggregate has a longer horizontal profile.

In granular and crumb structures, the rounded particles allow water to circulate very easily. Blocky aggregates are more resistant to the penetration and circulation of water due to their high accumulation of clay particles. Prismatic and columnar soil will allow even less water circulation and drainage due to accumulation of clay and less space between aggregates. Platy aggregates impair water circulation the most because they tend to overlap one another and are separated pile on top of one another horizontally. The structure of soil can tell you a lot about the level of water and air that will be available to a tree on a planting site.

Soil layers or horizons are characterized as sections of soil that are parallel to the surface. There are five main categories of soil layers. They are separated based on factors such as texture, color, chemical properties, and biological presence. When a soil pit is dug, you can often see clear distinctions in color and particle size to help determine where each soil layer begins and ends.

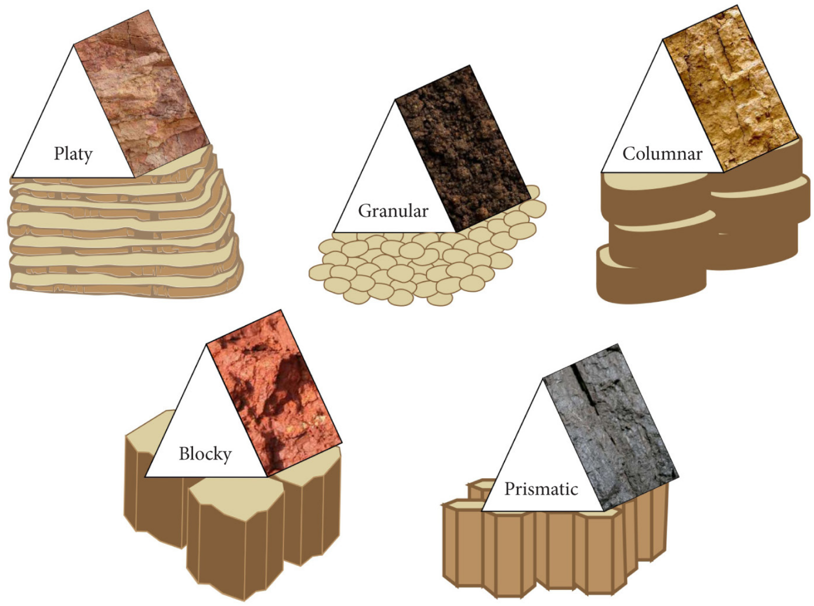
Layers

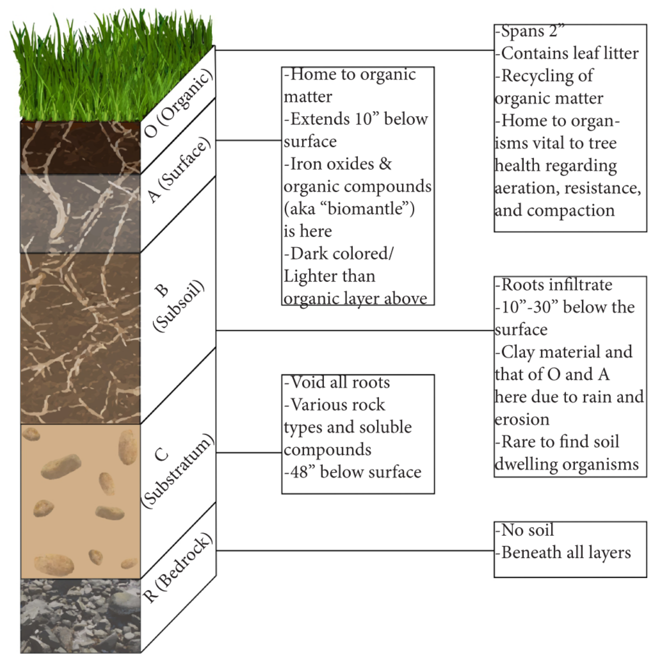
A soil layer, also known as a soil horizon is a layer that lies horizontally to the surface. The physical, chemical, and biological characteristics of each horizon will vary from one another. A cross-section of soil will reveal a difference in color and texture from top to bottom, providing distinct evidence in a change in horizon. A soil horizon is a result of a soil-forming process called pedogenesis. This process occurs under the influence of factors such as climate, organisms present in the soil, relief or soil location, parent material, and the passing of time.

Any soil that has not yet undergone pedogenesis is simply a soil layer and not a horizon. Horizons will be indicated with the use of the letters: O, A, B, C, and R.

The O horizon typically spans about two inches and is the “organic layer.” This layer contains leaf litter along with the highest concentration of biological content. This is where the recycling of organic matter and vital nutrients takes place. It is also the home to various soil-dwelling organisms which can be vital to the health of a tree, especially in terms of aeration and resistance to compaction.

The A horizon is considered surface soil and is home to a wide range of organic matter and supports the life of more biological organisms. It extends approximately 10 inches below the surface. Iron oxides and organic compounds are often found in this layer which is also referred to as the “biomantle” because of its rich nature and ability to support life. The A horizon is typically a dark color but lighter than the organic layer that sits above it.
The B horizon, also called subsoil, contains less organic and biological material than the





Top :Soil Aggregates
Bottom: Soil Layers Cross Section

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A horizon but roots will still often infiltrate this layer. This layer extends approximately 10 to 30 inches beneath the surface on average. More clay minerals will be found at this layer along with material displaced from the O and A layers due to rain and erosion. It is very rare to find soil-dwelling organisms in this layer compared to the O and A horizons.

The substratum layer which is also considered the C layer is typically void of all roots and lifeforms. Various types of rocks can be found at this layer as can soluble compounds. This layer typically extends at least 48 inches beneath the surface before reaching bedrock. Bedrock can also be called the R layer and is at the earth's surface beneath the other soil layers. The R horizon does not contain any soil.

A single soil horizon can only contain one soil structure. Still, different horizons within a particular soil can contain different structures. A horizons most commonly feature granular or crumb structures while subgranular blocky, columnar, and prismatic structure is typical of the B horizons. Platy soils can be found in surface or subsoil and structureless is typically found in the C horizon. Taking into account the structure of each soil horizon will help one determine the amount of water it can hold, how easily it can be eroded or compacted, and how much pressure will be put on the roots of a tree.

Note: There is no established definition for topsoil. Topsoil is simply whatever soil is on top, regardless of its original location within a soil profile. Because of this variable, hiring a specialist to specify soils on larger projects is warranted.

Soil pH

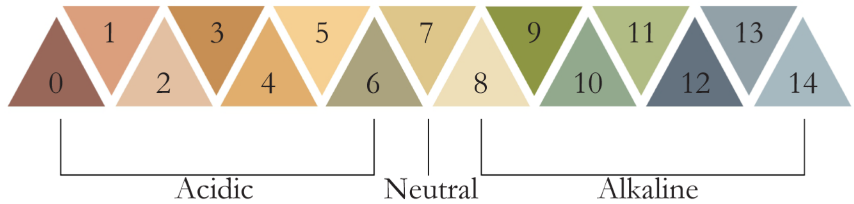
pH is an indication of how basic or acidic a particular area of soil is. The pH scale spans from zero to 14, with zero being the most acidic and 14 being the most basic while 7 is the neutral point. The pH scale is a logarithmic one. This means that with each integer change in pH, acidity or alkalinity is increased or decreased tenfold. For example, a pH of 6 is ten times more acidic than a pH of 7 and one hundred times higher than a pH of 8. Conversely, a pH of 10 is ten times more basic than a pH of 9 and one hundred times more basic than a pH of 8.

For a soil, it is unusual to find a pH level under 3 or over 10. Using a pH meter is obviously the simplest and most accurate way to measure the acidity of a soil but there are other ways including the use of dye and indicators which change colors upon a change in pH due to the soil. Because different species are more adept to dealing with higher or lower pH, so accurately measuring the pH of a soil is an important step when planning planting efforts and choosing tree species.

A soil's pH plays a huge role in many of its chemical processes. It affects the solubility of minerals and nutrients which can greatly influence the health of a tree. Most plant life thrives in a soil pH ranging from 5.5 and 7.5 but there are certainly outliers. Soils in areas with higher rainfall tend to be more acidic than soil in more arid regions. Areas with intensive farming will also typically have more acidic soil.

Conditional factors can alter the pH of soil. Rainwater can lead to the leaching of basic ions including calcium, magnesium, potassium, and sodium. A reduction in these ions causes the soil to become more acidic. The release of carbon dioxide due to decomposition of organic matter as well as root respiration create an organic acid that will lower the overall pH of the soil. Decaying material can create nitric or sulfuric acid. In less natural situations, oxidation of fertilizers can also create a more acidic environment. Conversely, closer proximity to concrete will raise the soil's pH.

Soil pH is not easy to alter, but sandy soils are the most susceptible to acidification due to their lower buffering capacity. Buffer capacity refers to a soil's ability to resist pH changes. When lime neutralizes hydrogen ions in the soil, ions from the soil surface are released to resist a change in pH and maintain equilibrium. Loams tend to require more effort to change pH, but that pH change will last longer due to clay and organic matter providing a strong buffer capacity and retention of nutrients.



pH Changes Depending on Material Added

Weathering of silicate and carbonate materials can release magnesium, potassium, sodium, and calcium ions to naturally make a soil more basic or alkaline. Adding liming materials to soil can also increase the pH by replacing hydrogen ions to bring it back to a more regulated and inhabitable number. It also gives important nutrients such as calcium, magnesium, and phosphorus to thrive while making nitrogen more readily available. Limestones that are high in calcium or magnesium are great ways to bring up a soil's pH as well as wood ash.

Site Carrying Capacity

Site carrying capacity is a concept that is important for gauging the expectations for both growth and success of any given planting system. You can think of the soil resource as a volume with finite resources to provide. If 10 units of water or any soil mineral can be provided, there will be 10 trees using one unit each or one tree using all ten units. If you plant 10 trees, in time you will be left with one or two trees of a likely diminished capacity. This is where the plant selection phrase "small spaces, small trees" comes from. Investing more in soil conservation or planting space and a bit less for fewer trees often enables better management in the long run.

Different types of soil vary greatly in their capacity to hold water. This determines the availability and continuity of water to a tree. Factors that can lead to maximum water capacity not being achieved include insufficient rainfall, weeds or other plants taking up water, rapid evaporation, or runoff. The maximum capacity often depends on the soil type. For example, high bulk density or compaction levels will inhibit infiltration and hold water for a longer period of time, not allowing water to drain as quickly as a sandy soil. Soils with more pores and space between the particles will have a lower maximum capacity due to more rapid runoff and faster drainage.

IMPORTANCE OF SOIL STRUCTURE

Water, Roots, and Minerals

Soil structure plays a role in determining water and mineral availability to a tree as well as growth of roots. Clay-heavy soils will retain water for longer since drainage occurs very slowly with little pore space. A healthy soil has enough pore space to allow for water infiltration and oxygen availability. Having biological life that provides aeration and increases pore space is vital in this process. In these ideal soil conditions, stable pores will span from shallow areas to deeper areas of the profile. Root penetration and air exchange can occur more easily in soil with pores from top to bottom.

If the soil is too dense and lacks porous characteristics, water will drain very slowly and it will be more difficult for roots to penetrate deeper into the soil and access the proper nutrients and oxygen. In some cases, if a soil is too dense and lacks any porosity, root penetration comes to a complete stop. If the pore size is too large, especially in sandy soils, water will drain too fast and nutrients will be difficult to obtain for the tree.

The structure of a particular soil can be altered through a variety of outside processes. Cations such as calcium, magnesium, and aluminum typically bind clay particles together which will create a more dense soil. Freezing and thawing as well as wetting and drying will also push particles closer together and make a more dense soil aggregate. Decomposing organic matter and excretions from roots can also cause soil particles to stick together.

Needs of Roots and Plants

Plants obviously need water, air, nutrients, and sunlight to thrive, but soil also plays an important role in plant health. Soil is responsible for the plant's ability to acquire most of these vital commodities. The texture and structure of a soil determines how much water it can hold and for how long. A tree takes water up through its roots to nourish its roots, leaves, and stems. It is important that a section of soil can retain an adequate amount of water to remain available to the roots of a tree. A soil that is too porous and features mostly sand will allow water to drain too quickly before it can be used by a tree. The addition of organic matter to the soil will help it hold more water and lead to a healthier plant.

Air is another factor in plant health that can be influenced by soil structure. A soil that has too high a percentage of clay will make it difficult for the roots to access proper oxygen levels to thrive. Good soil drainage is imperative for proper root function. Small pore sizes in soil will hold water more easily while large pores make air accessibility easier. Striking the perfect balance of both will create an ideal living space for a tree to reach its best health. Trees use carbon dioxide from the air to create sugars and starches to keep themselves healthy. Oxygen helps the tree's roots stay healthy and grow which allows them to successfully do their job of transporting water and other nutrients.

Even with perfect soil conditions for a particular tree, it is important to remember that sufficient access to sunlight is important in the health of any plant. Chlorophyll gives foliage its green color and is used to collect energy from the sun and create sugars and starches for it through photosynthesis. When leaves are exposed to sunlight, the solar energy is absorbed through chloroplasts and works together with adsorbed carbon dioxide to create healthy leaves and fruit. A lack of sunlight will be evident through small or wilting leaves and a spindly overall structure.

In addition to access to water, air, and light, soil needs to have the proper nutrient levels provided by soil to produce healthy growth. The three soil-derived nutrients needed at the highest levels for tree growth are nitrogen, potassium, and phosphorus. Calcium, magnesium, and sulfur are also extremely beneficial in plant growth. These can typically occur naturally, but if the soil is deficient in one area, fertilizers may be required to achieve the ideal conditions. Other important factors for ideal tree growth include adequate space, comfortable temperatures, and protection from disease, invasive species, and extreme weather.

Limiting Factors

There are a variety of limiting factors that can relate to soil structure. The most common of these limiting factors is compaction. Compaction is the input of energy resulting in the rearrangement of soil by packing particles closer. It can also refer to a loss in porosity. Larger air-filled pores are often lost first because of their fragility due to their size. A range of things can cause compaction including the wheels of machinery and the footsteps of people and animals. Over time, this reduction in pore space causes soil degradation. When a soil suffers too much compaction, root penetration slows significantly or completely stops. Extreme compaction can also lead to significantly slower or a complete halt in water permeability. The more silt and clay particles a soil has, the more susceptible it is to compaction.

Access to air is another factor that can limit plant growth and it is directly related to issues regarding compaction. If a soil that is rich in clay becomes too compact, it may be impossible for worms and other organisms that typically aerate an area to penetrate. This results in a loss of air which is essential to plant life. It shuts down the fabrication of any new pore spacing which will only lead to further soil compaction. If organisms that typically aerate the soil die off, compaction will continue, making the soil even more uninhabitable for other organisms as well as the plant itself.

Depending on the type of soil, a tree may have access to a limited number of nutrients. For ideal growth, a soil should have nitrogen, phosphorus, and potassium in the greatest quantities to promote healthy growth. Deficiencies in these areas or a lack of aeration will often lead to disease. An abundance of insects can occur from deficiencies in these nutrients as a result of stress compounds. Typically, soils that are too heavy in sand or clay tend to be the ones guilty of these vital deficiencies. Assuring a proper air to water balance through porosity will help avoid or resolve these issues.

In an ideal situation, half of the pores would be holding water for 24 hours after draining from a heavy watering, and about half of the total soil volume would be pores. For a very rough estimate of total porosity, divide the dry density measurement (in g/cm3) by 2.65.

A plant that is deficient in nitrogen will have difficulty making enough chlorophyll which will lead to a pale green or yellow leaf color, starting on older leaves then to younger leaves. Slow growth will also be a result of nitrogen deficiency. A phosphorus deficiency will often lead to slowed and stunted growth, especially early in the life of a plant. If a plant does not have adequate potassium can display chlorosis between leaf veins, purple spots on the bottom side of a leaf, a brown color on leaf tips, and slowed growth of fruit and roots. These issues are in addition to the increased likelihood of disease and insect invasion, so any deficiency of an important nutrient should be swiftly treated.

Soil in a Tree System

Soil and trees affect each other and rely on one another for various reasons. The soil is a storage area for water as well as nitrogen and nutrients a tree needs to live. The soil must be dense enough to hold water long enough for minerals to dissolve so they can be properly consumed. This density is also key to anchoring trees in place. Soils with a healthy organic or hummus layer are great for tree systems because they help slow the evaporation process, keeping water in the ground and available to a tree for a longer period.

In turn, the roots of a tree keep the soil porous and aerated. As the roots grow, they create space between soil particles which avoids over-compaction. As long as this process is not interrupted, the soil can be home to a range of organisms that will help in the aeration of the soil, resulting in a healthy cycle. The anchoring of the roots of a tree will also help slow the rate of erosion from wind and water on the soil.

TYPES OF SOIL THROUGHOUT NEW JERSEY (PHYSIOGRAPHIC PROVINCES)

As goes the underlying geology or bedrock, so goes the resulting soil systems developed by weathering. Movement and erosion from glaciers over the centuries has a mixing influence and drainage patterning effect that has resulted in a rich and diverse soil genesis in New Jersey, over a comparably small geographic area. We call systems derived from geologic soil patterns, with common environmental patterns in water and temperature as physiographic provinces.

Northern New Jersey

Northern New Jersey is incredibly diverse in terms of its geological makeup. The state has five physiographic provinces and three of them are in the northern section of the state. The Valley and Ridge province is the northernmost province. It is a part of the Appalachian Mountain region and is composed mostly of early Paleozoic sedimentary rocks. Limestone and shales which are susceptible to erosion can often be found in this region. A bit further south is the Highlands province which is composed of Precambrian igneous and metamorphic rock. These rocks are the remnants of a billion year old mountain range. Finally, North Jersey holds the Piedmont province which contains igneous rock such as basalt and diabase. It is part of a group of sedimentary rock known as the Newark Supergroup.

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Top Left: Physiographic Provinces

The Valley and Ridge province is dominated by the Rockaway soil series, as are small parts of the Highlands and Piedmont provinces. Established in 1939, this soil series mostly contains wooded soil along with some that has been cleared for farming purposes. It is typically coarse to loamy in texture. Rockaway Series soil features moderate to good drainage which is a great middle ground for different species of New Jersey trees. Thanks to this soil drainage, the area is not overly susceptible to flooding or water table issues. The bedrock is shallow to moderately deep which can be an issue for urban development. Because of the sloping and hilly nature of the area, precautions may need to be taken for erosion prevention.

The Boonton Series dominates Morris County and contains a wide range of soil types from coarse to loamy in texture. It also ranges from moderately deep to very deep in terms of the soil's profile from top to bedrock with the C horizon reaching down to about 125cm. The soil tends to drain very well but is not problematically permeable. Because of a typical gentle to very steep slope, erosion prevention is an issue on the Boonton Soil Series as well. The soil in this area was formed as a result of glacial till and is composed of basalt, gneis, sandstone, and shale.

Central Jersey

The Piedmont and the Inner Coastal Plain are the two dominant physiographic provinces in Central Jersey. The

Piedmont extends into the northern section of the state while the Coastal Plain is shared with the southern half. The Readington Series can be found in the Piedmont area in Central New Jersey. The texture of this soil is fine to loamy but still drains moderately well despite its fine particles. Because of a lack of porosity, saturated hydraulic conductivity, or ease with which pores transmit water, is fairly slow. The soil profile is deep to very deep and can be over 200cm to bedrock. Slopes in the area rarely surpass 15 inches, so runoff and erosion are not as problematic. Soil in this area is a result of sandstone, angular shale, siltstone, and quartz gravel. As the quartz weathers, it lowers the pH of the soil because of its acidic properties.

South Jersey

The vast majority of Southern New Jersey is home to the Outer Coastal Plain physiographic province. It is by far the largest province in the state. Unconsolidated sediments that have been deposited since the Cretaceous period make up the rock in this huge area that extends out into the Atlantic Ocean. This is the most erosion-resistant province in New Jersey and it is relatively flat in most areas. The coastal areas feature sand, iron-sedimented material, and gravel-heavy sediments while inland areas are suited for farming.

Unsurprisingly, the soil in such a large area is extremely diverse. Southern New Jersey is home to soils that are rich in sand, silt, and clay, depending on location and circumstances. An example of a South Jersey soil series is the Lakewood Series which is known for its incredibly fast drainage and high permeability. This rate of permeability can be problematic depending on the species tree present. Bedrock is not reached for over 150cm but the water table is still high due to the rate of infiltration. This region features some of the sandiest soil in the state and tree planting needs to be carefully considered. Sandy soil found in this region is more susceptible to erosion from wind and water.

To contrast the extremely sandy conditions, the Woodmansie series is composed of loamy to coarse soil. This soil series has good drainage but it is not problematically fast like it is in the Lakewood series. This South Jersey soil has a low rate of runoff but a high water table and a very deep distance to bedrock of about 150cm. Perhaps the biggest limiting factor in the Woodmansie Series is its extremely acidic pH. The breakdown of quartz lowers the pH of the soil making tree selection far more important when planting in the area.

Urban Soil Surveys

Web Soil Survey (WSS) is an online soil mapping tool that is often used in urban forestry. This tool provides official soil data throughout the United States. All of the data and maps are produced based on the National Cooperative Soil Survey, making it the best spot to find reliable and accurate resource information. Other online tools can be found on the USDA website, including the Geospatial Gateway, Block Diagram Locator, and soil property maps.

Urban soils are soils influenced by human activities. They are a class of Anthropic soils which are produced through long periods of cultivation and fertilization by humans. This dark-colored soil typically contains at least 1 percent organic carbon and is warmer than non-urban soils. Typical issues with urban soil include extreme compaction, aeration issues, nutrient imbalance, erosion, and contamination from outside sources. These issues can all have a negative impact on tree growth and viability.

It is still important to test specific urban soils that can be found on the Web Soil Survey. This will help you identify problems or changes in the soil compared to the initial survey. This will provide some insight into what can be expected and where soil remediation efforts may need to be focused in a particular area.

SOIL TESTING TECHNIQUES

Soils are a bit complicated in their definition which suggests that some basic tests are needed in order to understand your soils and in an area before you can effectively manage a site or make choices for preferred tree species with the goal of planting the right tree, right place."

Sample Collection

Soil samples often need to be collected for laboratory analysis. These tests help determine if a section of land can support plant life and growth with acceptable fertility and nutrient levels. Finding the constraints associated with a piece of land is important in deciding what species of tree, if any, to plant. To assure accurate information, one must provide a precise and properly cultivated soil sample. Taking and analyzing a soil sample is a great start to targeting a project's specific needs based on its results.

To achieve the most accurate results in a larger area, it is advisable to obtain many soil samples from all over the test field in equal sized cores. Sampling should also occur at a time when the ground is not too cold or wet. Soil sampled from these irregular conditions can result in inaccurate readings. Remember to clear any surface litter or plant growth before taking a sample. A full soil sample is made up of a combination of soil cores that are all the same volume and depth. Samples should be taken in two separate depth increments. The first from zero to six inches and the second from six to eighteen inches. This assures that each soil horizon is represented in the sample.

Collecting a soil sample begins with digging a small hole and removing an approximately six inch deep section. This section should be the same width on the top and bottom to limit variability of depths during testing. Using a penetrometer is the best way to instantly record the hardness of your samples at both depths before storing it for testing. Next, samples from all the different core sites should be mixed together to create an accurate representation of the entire space.

These samples can be stored in standard freezer bags and should be kept out of direct sunlight and lower temperatures. Store all samples in a refrigerator but do not freeze or dry them or inaccurate test results are inevitable.

The soil testing laboratory at Rutgers can be contacted at soiltest@njaes.rutgers.edu or (848) 932-9295. Their hours of operation are 7:30 a.m - 5:00 p.m Monday through Friday.

Percolation Testing

A percolation test determines the water absorption rate of a soil sample. Sandy soils have higher percolation rates as they are known to drain quicker. Soils with a lot of clay will retain more water and have very slow percolation. If a clay soil is oversaturated or too compact, it may not percolate at all. This test will help determine how readily available water and nutrients will be to a tree planted in the same soil. To conduct a simple percolation test at home, all you need is a shovel, a ruler, and a way to measure water volume.

To conduct a percolation test, start by digging a vertical hole that is approximately 12 inches deep and 12 inches in diameter. Place a measuring device, preferably a ruler vertically into the pit and make sure that it reaches the top of the hole. Place a stick or a similar item across the hole to keep the measuring device straight and stable. The hole must be filled with water and drained naturally several times to assure that it is properly saturated. If the soil is heavy in clay, do not be surprised if this takes hours or overnight to complete due to slow drainage.

To begin the test, fill the hole with water again and time how long it takes for all of the water to drain out. For the most accurate results, take note of how much water is lost each hour. Track your results in inches per hour and take the average of each hourly reading to determine your final result. These results can also be taken in milliliters per minute or minutes per inch depending on preference and goals. Ideally, your soil drainage rate should be around two inches per hour for vegetation to thrive. Rates between one and three inches per hour are acceptable in general. Percolation readings below one inch per hour indicate that your drainage is too slow and trees that are not extremely tolerant to wet soil could struggle. To combat this low drainage, compost or organic matter can be added. This process works two ways and will also help slow the drainage of sandy soils. A sandy soil can be identified by a percolation rate of over four inches per second. Such fast drainage does not leave adequate time for a tree to receive proper nourishment.

Bulk Density Measurements

The bulk density of a soil refers to the mass of dry soil in a particular volume of space. This includes air space between soil particles. Large levels of organic matter leads to a lower bulk density while soil compacting activity creates a higher bulk density. A bulk density test should be performed at the surface of the soil and preferably near the site of the previously performed percolation test. The average soil will typically have a bulk density that ranges from 1.0 to 1.8 grams per cubic centimeter.

The most common way to measure bulk density is with the core method. Collecting a core, requires a plastic ring that is roughly three inches in diameter. Use a hammer with a block of wood or similar buffer on top to drive the ring approximately three inches down into the soil. Find the exact depth of the ring in the soil by subtracting the total length from the height of the section of the ring that sticks out of the soil. An accurate height measurement is vital in determining an accurate volume.

To remove the ring, carefully dig around it and remove the ring with the soil intact. Remove any excess soil before transferring the sample from the ring to a plastic bag. Transfer the soil into a microwave-safe container when returning from the field and dry it in a microwave for at least two four minute intervals at full power. This process can also be done in an oven. The oven should be set to 105°C and the soil should be heated for two hours. Weigh the soil, remembering to note the weight of its container and record. Dividing the weight of the dried soil by the volume of your sample will give you your bulk density in grams per cubic centimeter.

In some cases, for larger projects in particular, it may be preferable to hire an engineering firm to create a nuclear density map of soil and moisture. This will be done in a grid across a large site and provide surface and 8-inch depth mapping. This process comes with a cost of course, but it can be worth the price in some situations to gain a better understanding of the site.

Occasionally, a soil will be too coarse or gravel-heavy to properly carry out the core method. In cases like these, the excavation method is used. For this method, choose a level sampling site where water can fill a hole evenly. First, dig a hole that is three inches deep and about five inches in diameter. Simply take all the soil from this excavation and place it in a plastic bag. Next, a sieve will be required to get rid of any material larger than 2mm.

After separating the gravel, keep the smaller particles in a plastic sample bag. Line the original hole with plastic wrap then take the original gravel and rocks and fill the hole above the plastic wrap without coming over the soil surface. Add water to the hole using a 140cc syringe until the water level is even with the surface. Keep track of how much water is being added. The volume of water it takes to fill the hole is equal to the volume of smaller soil particles removed.

Next, weigh the bag of smaller soil particles and dry it in the microwave. Repeating the same process used for the core method, dry the soil and weigh it. Dividing the weight of the sample by the volume of water needed to refill the hole results in the bulk density. With this information, you will have a better idea of how easy it is for root growth and penetration as well as seedling germination based on the compaction of the soil.

Penetrometer

A penetrometer is a device that is forced into soil to determine its resistance to vertical penetration. This tool is incredibly useful in determining soil compaction. Too much soil compaction can lead to poor root penetration and difficulty for seedling germination. Electronic cone penetrometers can be used by one person and penetrate up to 500mm into the soil with ease. The penetrometer is designed to simulate the root of a tree to see how it would fare in a particular soil.

Root penetration resistance is measured in PSI. A reading over approximately 300 PSI means that a root will not be able to properly grow and penetrate the soil. Natural functions like freezing and thawing, wetting and drying, and air pockets are not taken into account by a penetrometer. Still, when its data is combined with other tests such as soil structure, bulk density, and moisture levels, it can help provide a clearer picture of the viability of a particular tree in a particular soil.

When choosing to use a penetrometer, there are a few key issues to look out for. The penetrometer might encounter a different resistance based on the moisture status of the soil. You will need to create a protocol for testing the day after heavy rain or irrigation. Resistance measurements can also be influenced if you hit stones or roots, causing an artificially high resistance.

ALTERING THE SOIL/AMENDMENTS

The alteration of soil or addition of amendments should only be carried out if the soil is shown to need improvement. There are physical amendments, chemical amendments, and biological amendments. Identifying the need for an amendment is required before deciding on a specific amendment and choosing the best method to use. In urban trees, the most common issue that requires amendments is physical soil problems due to compaction. Treat this problem with a physical amendment and wait to see the results before resorting to a chemical amendment. Remember that amendments are costly and can often be avoided with proper tree selection.

Amendments

In addition to the scoop and dump process, there are many ways to amend a soil to more adequately support trees. Soil amendments can be either organic or inorganic depending on your goals. Organic amendments come from natural materials that were once alive. Four to five percent organic matter is ideal in soils because it allows for the mineralization of nitrogen which will eliminate the need for other fertilizers. Inorganic amendments are man-made products created to specifically target an issue. Different amendments can deal with nearly any problem including compaction, a lack of nutrients, water retention issues, and pH imbalances.

Before choosing an amendment, it is important to consider how long the benefit of the amendment will last and all of the ways, desired or undesired, it can alter a soil. One must know the pH and salt levels of an amendment to avoid any unwanted chemical changes that could negatively affect the health of a tree. When looking for a quick fix, be sure to choose an amendment that decomposes rapidly. For a more long-lasting option, look for a slowly decomposing amendment.

Garden soil can be added to an already existing soil to improve its organic properties and overall fertility. The benefits of the addition of garden soil include improved aeration and moisture retention. This option would be good for a soil that is too high in clay and has seen compaction issues in the past or for a sandy soil that has trouble holding water. Depending on the needs of a particular soil, the garden soil used may contain additional fertilizers to treat a nutrient deficiency.

Composted wood products such as mulch or sawdust can be used as an amendment for soil when implemented properly. Before using these wood products, add them to a compost pile that is high in nitrogen with items such as grass clippings and manure. This will start the decomposition process and will offset the tendency of the wood to tie up nitrogen that the tree would typically use as nourishment. When used properly, these products assist in maintaining moisture for the tree's roots, controlling temperature by blocking soil from direct sunlight.

Sphagnum peat moss is another amendment that assists in water retention and is great for sandy soils. This moss is also acidic and can be used to lower the pH of a soil that is too alkaline. Introducing sulfur is also a way to lower the pH of a soil with too much alkalinity. In the other direction, if a soil is too acidic, adding lime will increase its pH. Calcium and magnesium carbonate are commonly used liming materials. Liming is often used on farms to manage the pH of soil for crop growth.

Manure that is aged in compost can be used as an amendment but fresh manure should be avoided due to its excess ammonia levels. Preferably, manure is aged for six months so ammonia levels can drop while salt content remains high. Under these ideal circumstances, the aged manure can introduce new organic material to the environment and the salt included can help leach out excess water during times of extreme rainfall. This is especially effective in a soil with poor drainage.

Cost vs. Return

Amending soil will certainly improve its overall health, but it is vital to focus efforts that need alterations the most to achieve the best return for your investment. The cost of amendments becomes especially high in larger remediation areas. Still, amendments can be worth the cost in the long run. If the change in soil properties increases or reduces the volume of retained stormwater, as a management goal, a soil amendment might be the most economically reasonable option. The same can be said if the soil amendment helps trees achieve a longer life so removals and replacements become less frequent.

Scoop and Dump

Scoop and dump is a technique used during efforts for soil remediation. It is not uncommon for an area of soil in an urban area to be low on organic matter, especially in the deeper horizons. Compaction is also an issue in areas with a high level of human activity, especially during construction. Construction processes can often leave a soil so heavily compacted that tree health and growth rate will greatly decline due to a lack of air access and root permeability. The scoop and dump process assures that proper levels of organic material as well as adequate aeration are achieved, resulting in healthier urban trees.

This process can be carried out with shovels in smaller areas but is far easier with a backhoe or small excavator. The first step is to apply a layer of about six to eight inches of organic compost on top of the compacted soil. Next, use the chosen digging tool to dig approximately 18 inches deep. Simply lift this new mixture of compost and compacted topsoil and drop it back onto the ground. Repeat this method throughout the whole area of affected soil before smoothing it out. This will create a more inhabitable and stable soil for a tree to thrive in. Scoop and dump is a simple way to assure the presence of organic material while greatly increasing a tree's access to air and nutrients. As straightforward as the process is, the results of scoop and dump are impressive. Trees planted in soil amended by scoop and dump have seen nearly 40 percent more aggregate stability compared to unamended soils according to a study done by Cornell University. These amended soils will also have nearly triple the amount of organic material and active carbon present. Scoop and dump soil areas see huge improvements in water holding capacity and mineralizable nitrogen as well. Scoop and dump is a relatively new practice. More research can be done at the New York State Urban Forestry Council website (nysufc.org) on the process with the help of Dr. Susan Day and Dr. Nina Bassuk.

TREES FOR DIFFERENT TYPES OF SOIL

One of the keys to successful planting of new trees is matching tree species to soil types that they can thrive in. Some trees will do best in wet conditions and do not mind swampy areas that retain water due to clay-heavy soil. Others do not need a large amount of water to survive and should be chosen when planting in sandy soil. Having a full profile of soil texture, compaction levels, pH, and mineral content will make choosing what species of tree to plant a far easier task.

Trees for Wet/Poorly Drained Soil

Poor drainage in soil is hardly an ideal condition for most trees, but there are plenty of species that will thrive under these circumstances. Most of these trees can even survive when planted in standing water.

Atlantic white cedar (Chamaecyparis thyoides) is a great example of a tree that thrives in wet conditions in New Jersey. This tree is an evergreen with scaly leaves and small rounded cones. It does best in acidic soil with a pH around 5.5 and at elevations below 200 feet. They are typically resistant to diseases and insect issues but should be planted in an area that is protected from high-speed winds.

River birch (Betula nigra) is a deciduous option that can do well in wet and poorly drained soil. This species is known for its distinct tan colored peeling bark and multiple stems. It is also easy to transplant and can grow very fast in these soil conditions and many others. Like the Atlantic white cedar, it can also tolerate sandy and acidic soils. Because these trees have brittle branches, it is best to keep them protected from extreme wind conditions. Poorly drained but fertile wet soils are a great place to plant river birch. Red maple (Acer rubrum) is an extremely popular tree in New Jersey and can survive in wet and poorly drained soil, though the lack of drainage is not ideal for its growth. It is common in swampy areas and on the banks of streams so even in these areas with low drainage, there is plenty of evidence that a red maple can survive. An acidic clay or loamy soil with plenty of access to sunlight is ideal for the red maple. It is important to consider the provenance of the trees in this species (and many others) since some populations are adapted to wet soils while others are adapted to drier sites.

Other trees that are known to survive well in poor drainage and wet soils include Sycamore (Platanus) Hornbeam (Carpinus), Hackberry (Celtis occidentalis), and Sweetgum (Liquidambar styraciflua) Bald Cypress (Taxodium distichum), and the Dawn Redwood (Metasequoi glyptostroboides). Poor soil drainage is rarely an ideal situation for a tree to live in, but these species are your best bet to make it work. They all thrive in clay-rich soil and will not be deterred by the oversaturation of water.

Some trees do great in clay soil but still need adequate drainage to survive. Flowering trees like Cherries (Prunus), Pears (Pyrus), and Crabapples (Malus) are great examples of this case. These trees are known for their dense wood and ability to grow in a wide range of soil acidity. Other options for planting in clay-rich soil include Ginkgo (Ginkgo biloba), Maples (Acer), Hawthorn (Crataegus), and Willows (Salix). Most trees that thrive in clay include features like slender branches, tough wood, powerful roots, and often contain multiple stems.

Trees for Acidic Soil

Just because a soil has a lower pH than expected does not mean that it is uninhabitable for trees. Some tree species in New Jersey actually flourish in acidic soil. Soils with a pH of 4.5 to 5.5 are considered to be acidic but still inhabitable by these trees and most species do best closer to 5.5. These soils tend to have deficiencies in phosphorus and magnesium. Many conifers tend to do well in acidic soil and their needles can actually be used like mulch to lower the pH of a neutral soil. Still, there are options for deciduous trees to plant in an acidic soil as well.

	Physical	Chemical	Biological
Wood Mulch	Yes	Yes: (Over Time)	No: (except providing a food source for other organisms)
Moss Peat	Yes	Yes: (Over Time)	No: (except providing a food source for other organisms)
Garden Soil	Yes	Yes: (Limited)	Yes: (Transfer of micro flora/fauna)
Sulfur	No	Yes: (radical pH drop/soil texture dependant)	Could do damage with radical pH shift

Examples of Physical, Chemical, and Biological Effects of Amendments Table

Fir trees (Abies) are known for their ability to thrive in acidic soils as well as their tendency to make soil more acidic for plants below when they shed their needles. When planting a Fir tree, it is important to make sure that any other species within range can also handle lower than normal pH. Most Fir trees prefer a pH of around 5.5 but some can survive in soil as low as 3.5. This applies to many evergreens as well. Other coniferous trees that are native to New Jersey and prefer acidic soil include: Hemlocks (Tsuga), Cedars (Cedrus), White Cedar (Thuja occidentalis), Spruce (Picea), and Pines (Pinus). All of these trees produce cones and needles which are highly acidic, making their love for low pH soils no surprise.

It is far less common for a deciduous tree to make its home in an acidic soil but there are certainly enough exceptions to fulfill the needs of any project. Some Oak (Quercus) species do great in acidic soil including post, scrub, southern red, and willow oak. These Oak species are most commonly found in the southern half of New Jersey. Sweet Birch (Betula lenta) does well in acidic soil and is more common to Northern New Jersey. Other trees that can be considered when dealing with a low pH soil include Sorrel (Oxydendron arboreum), Dwarf Chestnuts (Castanea pumila) and American Mountain Ash (Sorbus americana). American Mountain Ash is not known to be a host of the Emerald Ash Borer so it is safe to plant in New Jersey.

Trees for Alkaline Soil

On the other end of the pH scale, some trees do their best in alkaline soils. This type of soil typically has a pH ranging from 7.5 to 8.5 when supporting plant life. These soils are usually deficient in minerals like iron and manganese. Trees growing in soil with high pH levels may experience low vigor, long-term health deterioration, stem dieback, and a very slow growth rate. Luckily, there are trees native to New Jersey that can be planted in alkaline soils without experiencing these fatal issues.

Elm (Ulmus) trees are known for their ability to survive in a wide range of soil pH. They do just fine in alkaline soil but do require good drainage. Elm trees have a very fast rate of growth and a very appealing structure. They are an outstanding choice for home-owners, landscapers, and urban forestry projects. With all of the devastation to Ash trees in New Jersey at the hands of the Emerald Ash Borer, Elms are a viable option for replacement. As long as the soil can drain freely, most species of Elm will thrive, even in a high pH soil level.

Linden (Tilia) is another good option for a tree to plant in alkaline soils. Like Elms, Linden trees can survive in a wide range of pH conditions, ranging all the way to the slightly acidic side of the scale. Still, they do their best growing in soil with a neutral to slightly basic pH. Their overall resistance to poor conditions, including high alkalinity, has made Lindens one of the most commonly used street trees around the world from Europe to New Jersey. They are also known for their soft wood which is easy to carve and craft. As an attraction to pollinators like bees and butterflies, Linden trees are very practical in any setting.

Salt Tolerant Trees

Salt is an important factor to consider when selecting a tree species. Salty air conditions are most common in areas near bodies of saltwater. Salt spray along the coastline and barrier islands can eject salt particles into the atmosphere or overwash directly into nearby soil. It can also occur in areas where rainfall does not exceed approximatel 20 inches per year. Salt can also become an issue for trees planted along the road during the winter months when rock salt is used for snow clearing. For many species of trees, high saline exposure will reduce the rate of growth or lead to death. For example, white pines and sugar maples have a very difficult time surviving when exposed to salty soil. Near areas with these variables, it is important to focus on trees that are resistant to these saline conditions.

American elm (Ulmus americana) is known for its high tolerance to saline soil and moderate resistance to aerosol salt. It is a very versatile tree that can thrive in nearly any soil structure including sand, silt, and loam. The American elm can also tolerate both alkaline and acidic soils as long as it is exposed to proper sunlight. Other trees with high salt tolerances include black gum (Nyssa sylvatica), hackberry (Celtis), and Ginkgo (Ginkgo biloba). All of these species can tolerate salty conditions and are good choices along coastal areas.

TREES AND SOIL EROSION

Protection from Natural Erosion

Trees are known to greatly reduce the rate of soil erosion. The simplest way they do this is by shielding the soil from rainwater with foliage. If an area with no trees suffers heavy rain, a large quantity of soil will be lost due to runoff. With the simple shade from a tree, the soil and its structural integrity will stay intact. The same can be said for wind which will quickly disrupt and move soil particles in a bare area of land. Soil becoming oversaturated with water is less of an issue with trees in the area because their roots will transpire a large amount of that moisture. Trees can be strategically planted to protect soil in important areas from both water and wind erosion.

The root systems of trees are another way that the rate of erosion in a forested area will be far slower than on bare land. Root systems begin with larger roots that are close to the tree and branch out into smaller roots that can extend far into the surrounding soil. Such an intricate and stable base to a tree is also useful in supporting and maintaining the structural integrity of its surrounding soil. This huge network of roots does everything from aerating the soil to compaction prevention and promotion of water infiltration into the ground. Tree roots are especially effective in maintaining the position and stability of soil on sloping land such as a hill or mountainside.

Prevention of Man-made Erosion

Farming is yet another cause of erosion but strategically planting trees can help mitigate the damage. Tilling of land can loosen the soil in a way that would typically make it easier for wind or water to carry it away, but the root network of trees helps greatly lower the amount of soil lost. The same holds true for disruption of soil due to grazing animals. These agricultural practices make the natural processes like wind and water erosion more of a danger so it is a great idea to use agroforestry as a combatant to those issues.

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