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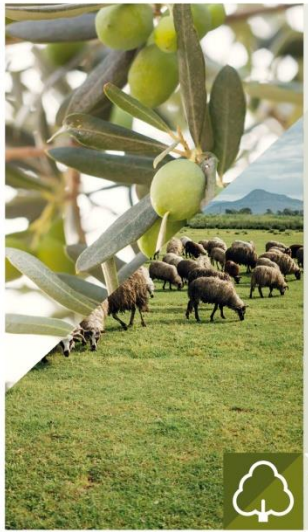

Module 2 for LL2, Agroforestry for Grazed Woodlands

Course 2 – Plant species for grazed woodlands

Chapter 1 - Tree Species for Grazed Woodlands: Species Selection Criteria

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Practicing agroforestry on a woodland area requires a detailed *plant inventory* as a first step

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Major factors influencing tree growth potential

- **Climate**
- **Site**
- **Soil**

To select suitable tree species for a site, it is necessary to have a good understanding of the major factors influencing growth potential, since these should influence species selection.

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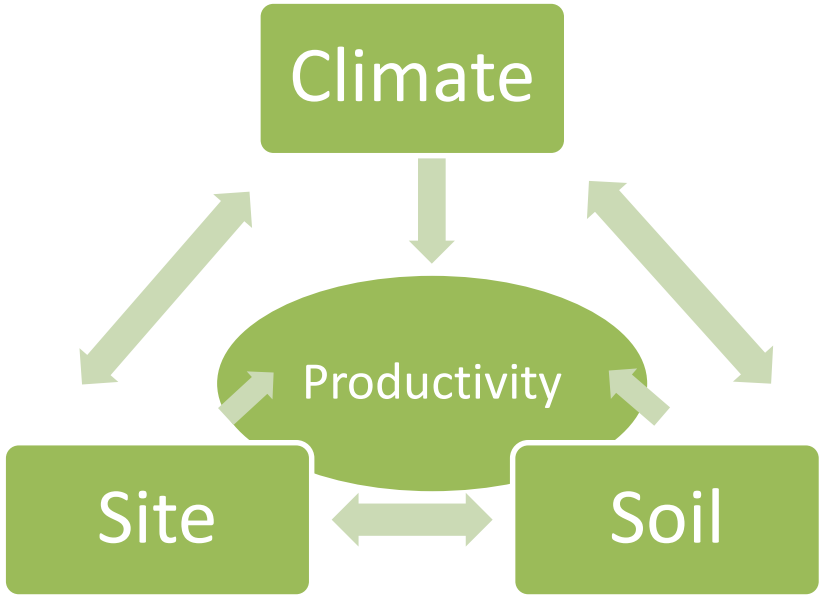
Interaction: Climate – Soil – Site and Productivity



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Tree Species for Grazed Woodlands: Species Selection Criteria

Course Outline

Climate, Site, Soil, and Their Effect on Productivity

1. Climate
   - 1.1. Temperature
   - 1.2. Frost
   - 1.3. Precipitation
   - 1.4. Wind
2. Site
   - 2.1. Topography
     - 2.1.1. Exposure
     - 2.1.2. Aspect
     - 2.1.3. Elevation
3. Soil
   - 3.1. Classification
   - 3.2. Groups

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Tree Species for Grazed Woodlands: Species Selection Criteria

1. Climate

1.1. Temperature

1.2. Frost

1.3. Precipitation

1.4. Wind

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Levels of Climate

Three levels of climate determine the environment in which trees grow:

- **Regional**: This level refers to large areas (greater than 10 Km2) and is not affected by topography or local vegetation.
- **Local**: This level (1-10 Km2 in extent) is affected by local topography, which can modify the local climate.
- **Microclimate**: Soil, vegetation and topography can also modify the climate in the vicinity of a planting location.

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Species Selection Criterion # 1, Climate

1.1. Temperature

Generally, increased temperature increases tree growth, except for tropical trees.

This probably occurs because temperate and boreal trees currently operate below their optimum temperature, while tropical trees are at theirs.

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Temperature effects: General case study

Species from colder environments would generally show a positive growth response to warming but could show reduced growth if water or nutrients were limited.

Species from warmer environments would always experience decreased growth with warmer temperatures, with less variation between individuals or species.

- Using both temperature change response and warming response: elevated temperatures enhance growth in deciduous species more than in evergreen trees.
- Tropical species are more susceptible to warming induced growth declines than temperate or boreal trees.
- More carbon may be available to allocate to growth at high temperatures because respiration acclimates more strongly than photosynthesis, increasing carbon assimilation but moderating carbon losses.

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Species Selection Criterion # 1, Climate

1.2 Frost

- Frost damages plants as water inside the plant cells expands when it freezes, breaking cell walls.
- Direct frost damage occurs when ice crystals form inside the protoplasm of cells (intracellular freezing).
- Indirect damage can occur when ice forms inside the plants but outside the cells (extracellular freezing).
- It is believed that intracellular ice formation causes a mechanical disruption of the protoplasmic structure. The extent of damage due to intracellular freezing depends mainly on how fast the temperature drops and to what level it cools before freezing.

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Frost: Considerations

In addition to minimum temperatures, the duration of a frost event and the rate of temperature change that can occur at specific times of year play an essential role in determining the potential risk of frost injury to plants and the actual killing temperature of any specific plant species.

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Species Selection Criterion # 1, Climate

1.3 Precipitation

- ✓ Many changes in physiological and morphological traits in response to changes in precipitation are observed in trees.
- ✓ Precipitation reduction delay needle emergence, decrease photosynthesis and stomatal conductance, increase water use efficiencies, decrease shoot elongation and induce shorter needles with a higher leaf mass area.
- ✓ Trees subjected to simultaneous reductions in precipitation and warming demonstrate a similar response.

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Differences in temperature or precipitation determine the types of plants that grow in a given area. Generally speaking, height, density, and species diversity decreases from warm, wet climates to cool, dry climates.

Photo credit: Dr. Peter Moubarak

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Species Selection Criterion # 1, Climate

1.4 Wind

- ✓ Wind is one of the most important climatic factors affecting agroforestry, because it transports water vapor, heat energy, pollen, spores, and seeds, as well as affecting evaporation and transpiration.
- ✓ From an ecological perspective, wind is an important agent for creating environments for natural regeneration, and for increasing diversity in forest stands.
- ✓ Moving in both horizontal and vertical directions, surface wind extends 50 to 100 meters above the earth.

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Wind Speed, Photosynthesis and Transpiration

Wind speed is an environmental factor that affects **air exchange**, **temperature** and **vapor of leaves**.

Low Wind Speed

- Reduces the boundary layer of humid air around the leaf
- Accelerates gas exchange through the leaf (CO2, H2O)

Strong Wind Speed

- Causes cooling and curving up of leaves
- Reduces the effective area of leaves
- Leads to a closure of stomata to reduce water loss and limit carbon dioxide entry

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Wind Damage: Leaf/Needle Damage

Wind can damage trees and environments at various levels. Statistical analysis has demonstrated that increasing tree height and local wind speed during a storm are the main factors associated with increased damage levels.

Photo credit: Dr. Peter Moubarak

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The Effect of Wind

Wind can have subtle effects on forest growth and development. Certain species (such as ash, European beech, western hemlock and Norway spruce) will not establish or grow well when planted in large blocks on very open ground. All of these results of wind damage will decrease the economic value of the crop:

- When trees are exposed to strong winds over their lifetime, they react by changing their form.
- Trees on the edges of plantations have greater taper and larger root systems than those in the center of the plantation.
- In extreme cases, individual trees can take on a form where the branches are swept to the leeward, resulting from the death of buds on the windward side.

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Establishing Windbreaks

Windbreaks help accumulate heat units, which is especially useful in cold places (Brandle *et al.* 2004).

The reduced turbulence in windbreak-sheltered areas may also increase the risk of frost damage (Cleugh 1998), so sites where frost is a limiting factor might need more judicious planning (sloping topography with no trees, for instance).

Selecting sites that are somewhat elevated relative to the surrounding terrain can reduce the risk of frost damage and contribute to optimal growth performance.

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Selecting Trees and Shrubs for Windbreaks

1. A mix of deciduous and coniferous plants is best.
2. Trees should be selected based on the purpose of the planting.
3. Use native plants whenever possible.

Photo credit: Dr. Peter Moubarak

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Climatic and topographic factors are related when it comes to vegetation distribution, composition, density, and the outward appearance of the area.

Photo credit: Dr. Peter Moubarak

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Species Selection Criterion # 2, Site

2.1 Topography

The topography of a location (the surface features of the land, including elevated or sloping ground) must be considered so a suitable planting density can be planned to ensure a healthy growing environment for trees, with adequate sunlight and humidity. Climatic factors directly impact plant growth, soil moisture and nutrient availability for plants. The combination of topography and climatic variables helps predict the success of tree growth in forest modeling.

In mountains, vegetation arrangement is controlled by three main topographic factors: elevation, aspect and slope.

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• Climatic factors are influenced by elevation which, in turn, controls vegetation spread at larger spatial scales.

• The topographic factors define the microclimate of an area.

• This affects ruggedness of terrain, curvature of surface, topographic position and flow of water.

• Aspect and slope angle greatly influence evapotranspiration (soil-water balance), air temperature and associated flora.

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Species Selection Criterion # 2, Site

2.1.1 Exposure

The term **exposure** combines many components, such as elevation, windiness and aspect. It refers to the positioning of a location in relation to climatic variables.

"Topex" or topographic exposure is a variable that represents the degree of shelter in a location. It is useful for a variety of applications, from the dynamics of drifting snow to the optimal location of wind farms passing by frost prediction.

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Species Selection Criterion # 2, Site

2.1.2 Aspect

Aspect is defined by Young (1989) as the direction of slope orientation (meaning the direction a slope is facing).

Aspect affects environmental variables that directly influence forest characteristics and, thus, control the occurrence of particular species.

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What does aspect do?

Aspect helps determine **which types of trees** will occupy a site.

Aspect affects

- **the microclimate** (wind, evapotranspiration, air and soil temperature)
- **soil properties** (chemical and physical properties, texture and organic matter content, plus the associated flora)
- **hydrological processes** (runoff dynamics, hydraulic conductivity, soil water retention)

In addition, aspect **controls the influence of insolation** (exposure to the sun) on moisture retention (primarily in the soil).

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Species Selection Criterion # 2, Site

2.1.3 Elevation

- Several studies have shown that elevation is the most important environmental factor determining tree communities' distribution.
- Nutrient levels and soil fertility are not as much of a limiting factor for tree species survival and distribution as elevation is.
- Elevation is known to decrease soil acidity and increase organic matter and total nitrogen in soil.
- With increasing elevation, climatic variables change rapidly. Thus, tree cover absence at high elevations is related to exposure levels and temperature, so that tree growth generally becomes scrubby at elevations.

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Healthy soil supports a landscape that is more resilient to the impacts of drought, flood, or fire.

Photo credit: Dr. Peter Moubarak

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Species Selection Criterion # 3, Soil

3.1 Classification

- ✓ **Soil Classification** concerns the grouping of soils with a similar range of properties (chemical, physical and biological) into units that can be geo-referenced and mapped.
- ✓ **Modern soil classification** started with the publication of the 7th Approximation of the USDA Soil Taxonomy.
- ✓ **Many countries** have developed their own classification systems, depending on the soils and needs of the country.

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Species Selection Criterion # 3, Soil

3.1 Classification

Although all countries do not use the same soil classification system, most pedologists (soil scientists) refer to an international means of communication: The World Reference Base (WRB).

The World Reference Base is the international standard for soil classification systems. It is endorsed by the International Union of Soil Sciences (the global union of soil scientists).

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The revised FAO World Classes of soils (Great Soil Groups) and their equivalents in the USDA Soil Classification System

FAO	USDA
Acrisols	Ultisols (all suborders)
Andosols	Andepts
Arenosols	Psamments
Cambisols	Ochrepts, tropepts, umbrepts
Chernozems	Borolls
Ferralsols	Oxisols (all suborders)
Fluvisols	Fluvents
Gleysols	Aquents, aquepts, aquolls
Lixisols	Oxic Alfisols
Alisols	Vertisols with high activity clays
Greyzems	Borolls, aquolls
Histosols	Histosols (all suborders)
Kastanozems	Ustolls, borolls
Luvisols	Udalfs, xeralfs, ustalfs, aqualfs, boralfs

FAO	USDA
Nitosols	Udalfs, ustalfs, udults, ustults, xerults, humults
Phaeozems	Udolls, aquolls
Planosols	Aqualfs, xeralfs, argids, ustalfs, aquults, albolls, borolls
Solonchaks	Orthids, ustolls
Solonetz	Ustalfs, xeralfs, argids
Podzols	Orthods, ferrods, humods, aquods
Podzoluvisols	Udalfs, boralfs, aqualfs
Leptosols	Lithosols, lithic subgroups
Regosols	Orthents, psamments
Vertisols	Uderts, usterts, xererts, torrerts
Calcisols	Calcic Aridisols
Gypsisols	Aridisols
Lithosols	
Anthrosols	Various orders

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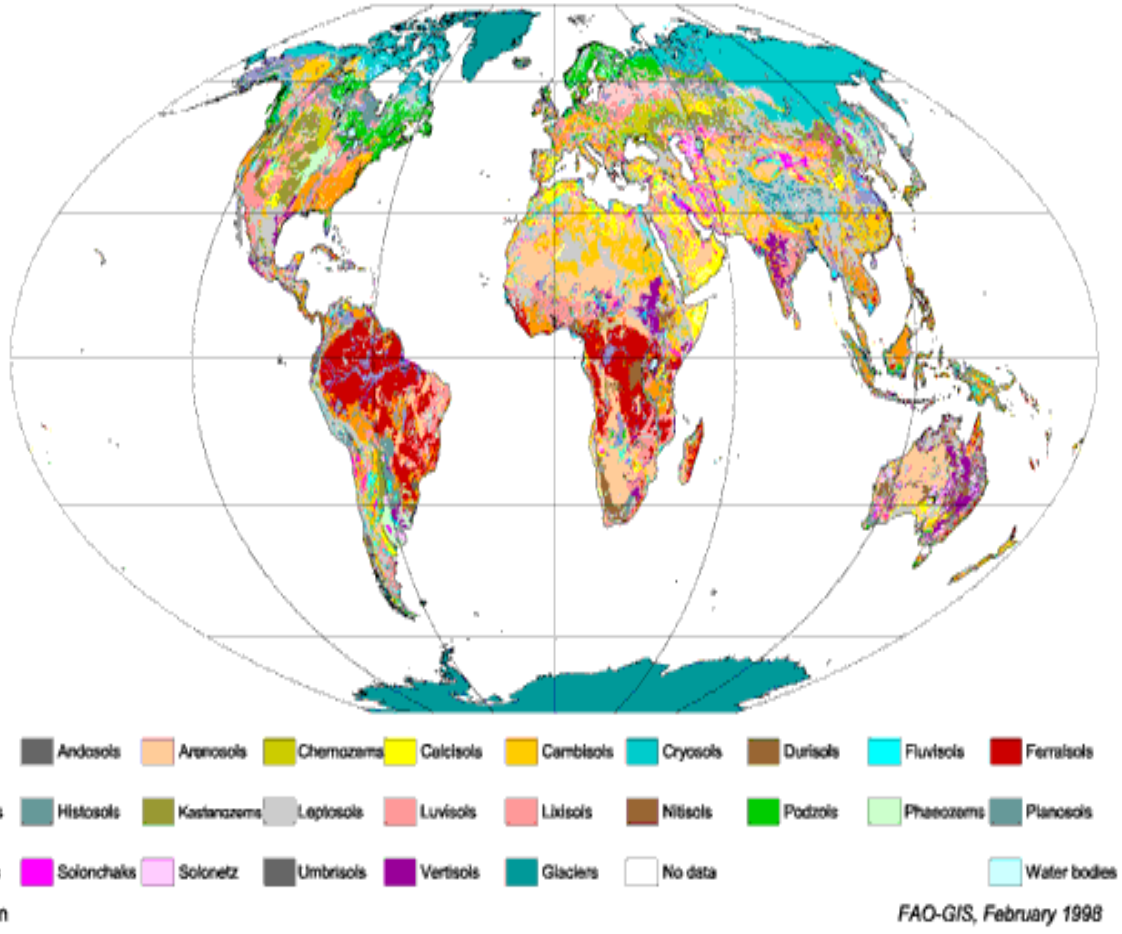
Dominant soils of the world



Soil Assessment Land Capability Classification

- ✓ In addition to the soil classification, a Soil Assessment Land Capability Classification is crucial for determining the most suitable soil for each desired species.
- ✓ The Land Capability Classification shows the suitability of soils for most kinds of agricultural land use or field crops. It identifies the potential of local areas for agricultural production.
- ✓ The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management.
- ✓ There are two primary categories in this classification system, the Capability Class and Capability Subclass.

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Soil Assessment Land Capability Classification System
Main Categories

Land Capability Class

The classes indicate the degree of limitation imposed by the soil if used for mechanized agriculture.

Land Capability Subclass

The subclasses indicate the kinds of limitations that affect agricultural land use, either individually or in combination with others.

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The USDA classification system

The USDA classification system uses numbers for classes and letters for subclasses.

Class codes 1, 2, 3, 4, 5, 6, 7, and 8 are used to represent both irrigated and non-irrigated land capability classes.

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The USDA classification system

Class	Description
Class 1	soils have slight limitations that restrict their use.
Class 2	soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
Class 3	soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
Class 4	soils have very severe limitations that restrict the choice of plants or require very careful management, or both.

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The USDA classification system

Class	Description
Class 5	soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
Class 6	soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
Class 7	soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.
Class 8	soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for esthetic purposes.

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The USDA classification system

SubClass	Description
Subclass e	is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their use. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.
Subclass w	is made up of soils for which excess water is the dominant hazard or limitation affecting their use. Poor soil drainage, wetness, a high water table, and overflow are the factors that affect soils in this subclass.
Subclass s	is made up of soils that have soil limitations within the rooting zone, such as shallowness of the rooting zone, stones, low moisture-holding capacity, low fertility that is difficult to correct, and salinity or sodium content.
Subclass c	is made up of soils for which the climate (the temperature or lack of moisture) is the major hazard or limitation affecting their use.

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The Canadian Classification Methodology

The Canadian classification methodology, the Canada Land Inventory (CLI), shows the varying potential of a specific area for agricultural production.

It indicates the classes and subclasses according to the Soil Capability Classification of Agriculture, which is based on characteristics of the soil as determined by soil surveys.

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The Canadian Classification Methodology

Class	Description
Class 1	Soils in this class have no significant limitations in use for crops.
Class 2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.
Class 3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.
Class 4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices.

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The Canadian Classification Methodology

Class	Description
Class 5	Soils in this class have very severe limitations that restrict their capability in producing perennial forage crops, and improvement practices are feasible.
Class 6	Soils in this class are capable only of producing perennial forage crops, and improvement practices are not feasible.
Class 7	Soils in this class have no capacity for arable culture or permanent pasture.
Class 0	Organic Soils (not placed in capability classes).

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The Canadian Classification Methodology

SubClass	Description
Subclass C	Adverse climate
Subclass D	Undesirable soil structure and/or low permeability
Subclass E	Erosion
Subclass F	Low fertility
Subclass I	Inundation by streams or lakes
Subclass M	Moisture limitations

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The Canadian Classification Methodology

SubClass	Description
Subclass N	Salinity
Subclass P	Stoniness
Subclass R	Consolidated bedrock
Subclass S	Combination of subclasses
Subclass T	Topography
Subclass W	Excess water
Subclass X	This Subclass is comprised of soils having a limitation resulting from the cumulative effect of two or more adverse characteristics

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The soil is in constant evolution. Thus studying its physical, chemical and biological properties permits us to understand the past and present of the soil, and to predict its future.

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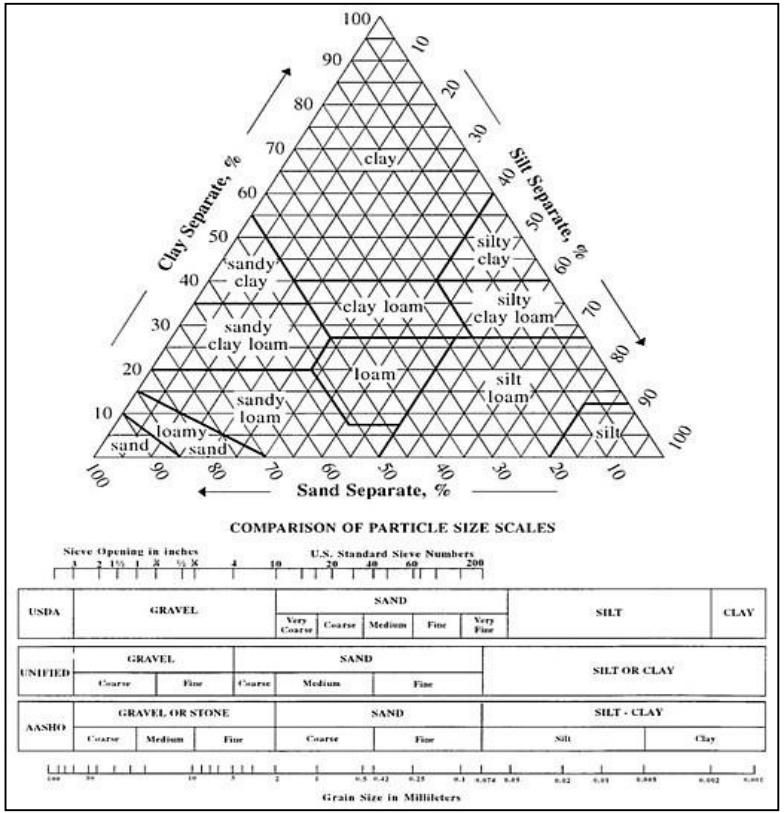
Soil Texture and Mineral Composition of Soils

In the soil, we find particles of rock or minerals produced from rock by weathering and other geological processes.



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Soil moisture

- ✓ Soil moisture, which is key to the establishment and growth of plants, is closely linked to soil texture.
- ✓ The pores between soil particles hold the water and air needed by plants for good growth.
- ✓ Generally, coarser soils are well-drained and are often dry for longer periods, while soils with finer textures hold more water and are likely to remain moist longer.
- ✓ Other factors, such as the ground water level and the presence of an impermeable layer that restricts drainage, also determine soil moisture.

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Soil depth:

determines the rooting ability of plants, influencing how they can grow. Forest soils can be quite shallow, requiring extra care in management.

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Nutrient Availability

- The availability of nutrients in the soil also affects trees' health. Soil can be tested to determine its pH (acid/alkaline balance) and specific nutrient levels; the results can influence recommendations for the most appropriate crops to grow in a particular location.
- Soil pH governs the availability of nutrients to plants and also affects the activity of soil microorganisms.
- Most trees can grow in soils with a pH between 4.8 and 7.2. If the soil pH is less than 4.8, acid tolerant trees must be selected. If the soil is greater than 7.2, alkaline tolerant trees must be chosen. Few trees grow well in soils with a pH above 9.0.
- Plant tissue can be analyzed to determine the nutritional status of existing trees and plants, in order to see if the soil is giving them what they need.

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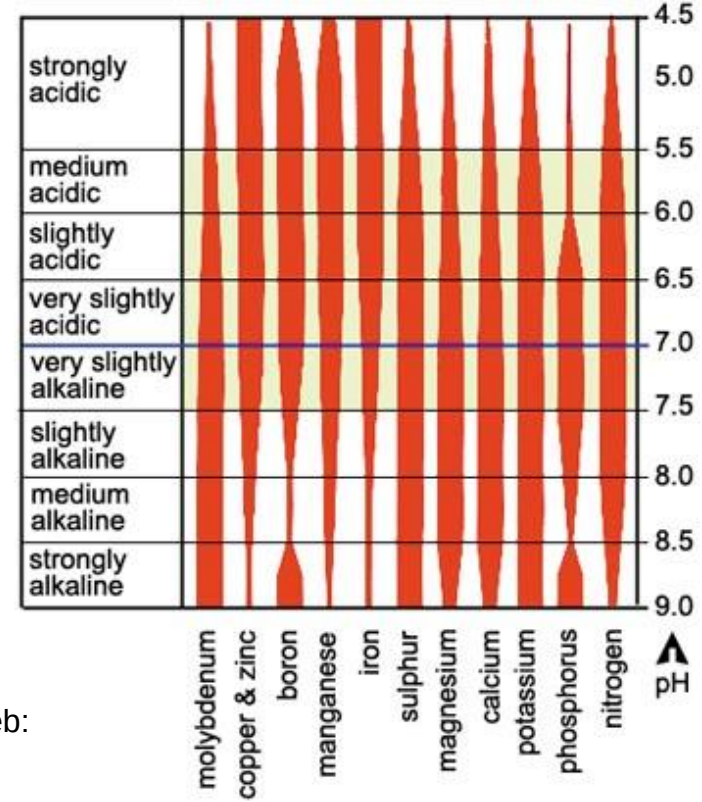
How soil pH affects nutrient availability?



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Species Selection Criterion # 3, Soil

3.2 Groups

- ✓ Soils are assigned to one of four **hydrologic soil groups** based on measured rainfall, runoff, and infiltrometer data about the rate at which a soil can absorb water.
- ✓ Hydrologic soil groups play an important role in the determination of surface runoff, which is crucial for **soil and water conservation** efforts.
- ✓ Soils are classified based on the minimum **rate of infiltration** obtained for bare soil after prolonged wetting.

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Soil Groups

Group A

- low runoff potential and high infiltration rates when thoroughly wet: water is transmitted freely through the soil
- usually less than 10% clay and more than 90% sand or gravel
- saturated hydraulic conductivity (soil's ability to absorb water) of all soil layers exceeds 40.0 micrometers per second
- some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35% rock fragments

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Soil Groups

Group B

- moderately low runoff potential and moderate infiltration rates when thoroughly wet: water transmission through the soil is unimpeded
- typically between 10% and 20% clay and 50% to 90% sand
- saturated hydraulic conductivity ranges from 10.0 to 40.0 micrometers per second
- usually loamy sand or sandy loam textures
- some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35% rock fragments

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Soil Groups

Group C

- moderately high runoff potential and low infiltration rates when thoroughly wet: water transmission through the soil is somewhat restricted
- typically between 20% and 40% clay and less than 50% sand
- saturated hydraulic conductivity ranges from 1.0 to 10.0 micrometers per second
- usually loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures
- some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35% rock fragments

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Soil Groups

Group D

- high runoff potential and very low infiltration rates when thoroughly wet: water movement through the soil is restricted or very restricted
- typically greater than 40% clay, less than 50% sand
- saturated hydraulic conductivity is less than or equal to 1.0 micrometers per second
- usually clayey textures
- in some areas, high shrink-swell potential

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Soil Groups

Group D and Dual Hydrologic Soil Groups

- Certain wet soils are placed in group D based solely on the presence of a high water table.
- Once adequately drained, these soils are assigned to dual hydrologic soil groups (A/D, B/D and C/D) based on their saturated hydraulic conductivity.
- The first letter applies to the drained condition, and the second to the undrained condition.

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Soil Groups

LIVINGAGRO Soil texture calculations and mapping to hydrologic soil groups

Relationship between Sand, Silt and Clay Percentages	Textural Class	Hydrologic Soil Group
((silt + 1.5 * clay) < 15)	SAND	A
((silt + 1.5 * clay ≥ 15) AND (silt + 2 * clay < 30))	LOAMY SAND	A
((clay ≥ 7 && clay < 20) AND (sand > 52) AND ((silt + 2 * clay) ≥ 30) OR (clay < 7 && silt < 50 AND (silt + 2 * clay) ≥ 30))	SANDY LOAM	A
((clay ≥ 7 AND clay < 27) AND (silt ≥ 28 AND silt < 50) AND (sand ≤ 52))	LOAM	B
((silt ≥ 50 AND (clay ≥ 12 AND clay < 27)) OR ((silt ≥ 50 AND silt < 80) AND clay < 12))	SILT LOAM	B
(silt ≥ 80 AND clay < 12)	SILT	B
((clay ≥ 20 AND clay < 35) AND (silt < 28) AND (sand > 45))	SANDY CLAY LOAM	C
((clay ≥ 27 AND clay < 40) AND (sand > 20 AND sand ≤ 45))	CLAY LOAM	D
((clay ≥ 27 AND clay < 40) AND (sand ≤ 20))	SILTY CLAY LOAM	D
(clay ≥ 35 AND sand > 45)	SANDY CLAY	D
(clay ≥ 40 AND silt ≥ 40)	SILTY CLAY	D
clay ≥40 AND sand ≤ 45 AND silt < 40	CLAY	D

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Conclusion:
Summary of Key Points about
Species Selection Criteria

1. Sort species according to their suitability for **climate conditions.**
2. Sustainable tree growth is most easily achieved when the tree species is well adapted to the **inherent conditions of a site**.
3. Choose from pre-selected species according to their suitability for **soil conditions.**

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Tree Species for Grazed Woodlands: Species Selection Criteria

Thank you

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Agenzia forestale regionale per lo sviluppo del territorio e dell'ambiente della Sardegna
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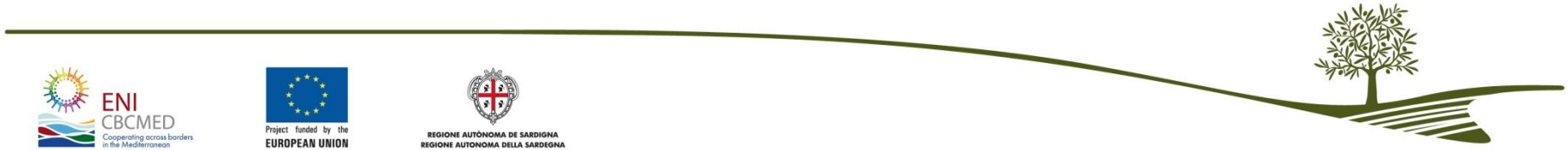

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