	Sustainable Agriculture			Unit C	Soil and Water Conservation
ESSENTIAL STANDARD:		**3.00**	**10%**		**Examine Soil conservation.**
Objective:		*3.01*	*5%*	*C2*	Understand basic properties and functions of agricultural soils.

A. Introduction to soils
   a. The top layer of the earth's crust. Includes organic matter and mineral materials.
   b. According to the USDA, it takes nearly 500 years to create just an inch of soil naturally. Soil is created through the decomposition and weathering of rock.
   c. Soil's Importance
      i. Acts as a filter
      ii. Growing medium
      iii. Habitat
      iv. Contributes to biodiversity
      v. Provides most of the antibiotics that are used to fight disease
   d. Role of soil in agriculture
      i. Provides the nutrients and space to grow food, fiber, feed and fuel
      ii. Stores fresh water necessary for plant and animal growth (groundwater)
   e. Soil Profile
      i. Soil layers are called horizons. All soil profiles do not have the same number or level of horizons. For example, a sandy soil may not have an "O" horizon if it has been under cultivation. Other soils may have a horizon missing due to erosion.
      ii. Most typical soils in North Carolina will have a **minimum** of the A, B and C or R horizons.
         1. 0- Organic matter layer
         2. A- Topsoil layer (mixture of organic matter, minerals, root zone for most plants)
         3. B- Subsoil layer (somewhat leached layer with usually fewer nutrients)
         4. C- Substratum (weathered from bedrock and partially decomposed)
         5. R- Bedrock (inpenetrable with shovel, unweathered parent material)
   a. Soil Structure
      i. Soil structure is how the soil particles fit together
      ii. Sandy soils typically have a loose soil structure.
      iii. Silty soils have a granular soil structure.
      iv. Clayey soils have a blocky or platy structure.
      v. Granular soil structure is the best. Plants have good root development. Water movement is at an appropriate rate – doesn't stay to wet or too dry.
   b. Soil Classification
      i. Soil taxonomy is the principal reference to soil classification
      ii. Use taxonomic keys for soil classification
      iii. Soil Survey is an official overview by the USDA of the soil in an area
      iv. See your soil survey at: http://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/
   c. Texture
      i. Sand has the largest particles. Sandy soils have low moisture and nutrient holding capacity.
      ii. Silt has medium sized particles. Silt has a good moisture and nutrient holding capacity.
      iii. Clay has the smallest sized particles. Clayey soils have high water and nutrient holding capacity.
      iv. Loam has almost equal parts of sand, silt and clay. This is the ideal texture for most non container outside plants.
   d. Soil pH
      i. Soil pH is a measure of the acidity or alkalinity of soils.

ii. Soil pH ranges from 0-14. 0-6.9 (low pH) is considered an acid soil, 7 indicates a neutral soil and 8-14 (high pH) is considered an alkaline soil.
iii. Lime will raise the pH value in soils (make the soil less acidic).
iv. Calcium or sulfur will lower the pH value in soils (make the soil more acidic).
v. The ideal pH value for vegetable garden soils are 5.5 to 7.0.

e. Physical Properties of Soils
   i. Permeability is the rate at which water moves through the soil.
   ii. Water holding capacity is the ability of a soil to hold water for plant use.
   iii. Porosity is the amount of air space between soil particles.
   iv. 50% of soil should be pore space which includes 25% water space and 25% air space.
   v. 50% of soil should be soil particles which include 45% mineral matter and 5% organic matter.

f. Soil Sampling
   i. Soil sampling and testing is essential for an accurate fertilizer recommendation for growing plants.
   ii. Soil sampling procedures.
      1. Create a visual grid of the area to be planted. For gardens and landscapes, take 5-10 subsamples from the site to be evaluated. Sample before the growing season.
      2. Use a stainless steel soil-sampling probe.
      3. Take the surface sample to tillage depth or about 3-4 inches for lawns and 6-8 inches for crops.
      4. Mix the soil samples together.
      5. Remove any grass, rocks or other material besides soil.
      6. Avoid unusual spots in the lawn or field. Those areas need to be sent in a separate box.
      7. Place soil samples in a box, which you can obtain from the County Extension Office along with Soil Sample Information sheet, send the box and information to Agronomic Division Soil Test Lab in Raleigh for a free soil test.

B. Explain the basic principles of soil fertility.

a. Soil quality is a review of the soil's general health by a soil scientist or conservationist and includes a study of the soil's health, including:

   i. Physical properties:
      1. bulk density- indicator of soil compaction. It is the weight of the soil in a given volume. The greater the density (more than 1.6 g/cm3) the more soil compaction there is and therefore greater restriction of root growth.
      2. moisture
      3. aeration
      4. slaking- indicates the ability of stability or ability to resist erosion
      5. infiltration- how quickly water can move downward into the soil
   ii. Chemical properties:
      1. electrical conductivity- measure of salts in soil
      2. nitrate – form of inorganic nitrogen found naturally in the soil, plays a role in nutrition of plants
      3. pH- measure of acidity or alkalinity in a soil
   iii. Biological properties:
      1. Earthworms
      2. Microbes
      3. Enzymes- catalysts in decomposition, releasing nutrients from plants in the soil, play a role in nutrient cycling

        4. Soil respiration- carbon dioxide release from the soil from decomposition of soil organic matter by soil microbes and respiration from plant roots.
        5. total organic carbon- carbon stored in the organic matter of the soil, affects plant growth as a form of available nutrients
    b. Soil nutrients
        i. Nitrogen, Phosphorus, and Potassium are the three primary nutrients and are needed by plants in the greatest quantities. These are usually lacking first because plants use these in the largest quantities.
        ii. Calcium and Magnesium are of found in soil as the result of adding lime to adjust the pH of acidic soils.
        iii. Sulfur is usually found in soils as the result of slow decomposition of organic matter
    c. Micronutrients are essential elements but are needed in very small quantities.

C. Nutrient cycles
    a. Plants obtain nutrients from the soil solution and uptake those nutrients via their roots.
    b. Sources of these soluble nutrients are:
        i. Weathering of soil minerals, decomposition of organic matter, fertilizer applications, organic matter amendments, Nitrogen fixation by legumes, atmospheric addition (lightning discharges), industrial additions (wood ash), depositions from erosion and flooding
    c. Soils can lose nutrients.
        i. These nutrients can be lost or made unavailable.
        ii. Nutrient losses in soil are wasteful and can have a detrimental effect on the ecosystem.
        iii. Losses in nutrients from the soil can occur from runoff, erosion, leaching, gaseous losses, and crop removal.
    d. The basic plant nutrient cycle highlights the central role of soil organic matter.
        i. Cycling of many plant nutrients, especially N, P, S, and B, closely follows parts of the Carbon Cycle.
        ii. Plant residues and manure from animals fed forage, grain, and other plant-derived foods are returned to the soil.
        iii. This organic matter pool of carbon compounds becomes food for bacteria, fungi, and other decomposers.
        iv. As organic matter is broken down to simpler compounds, plant nutrients are released in available forms for root uptake and the cycle begins again.
        v. Plant-available K, Ca, Mg, P, S, and some micronutrients are also released when soil minerals and precipitates dissolve.

D. Soil contamination is either solid or liquid hazardous substances mixed with the naturally occurring soil. Usually, contaminants in the soil are physically or chemically attached to soil particles, or, if they are not attached, are trapped in the small spaces between soil particles.
    a. Soil contamination results when hazardous substances are either spilled or buried directly in the soil or migrate to the soil from a spill that has occurred elsewhere.
    b. Contaminants in the soil can hurt plants when they attempt to grow in contaminated soil and take up the contamination through their roots. Contaminants in the soil can adversely impact the health of animals and humans when they ingest, inhale, or touch contaminated soil, or when they eat plants or animals that have themselves been affected by soil contamination.
    c. There are three general approaches to cleaning up contaminated soil:
        i. Soil can be excavated from the ground and be either treated or disposed.
        ii. Soil can be left in the ground and treated in place.
        iii. Soil can be left in the ground and contained to prevent the contamination from becoming more widespread and reaching plants, animals, or humans. Containment of soil in place is usually done by placing a large plastic cover over the contaminated soil to prevent direct contact and keep rain water from seeping into the soil and spreading the contamination.
        iv. Treatment approaches can include:
            1. Flushing contaminants out of the soil using water
            2. Chemical solvents

        3. Destroying the contaminants by incineration
        4. Encouraging natural organisms in the soil to break them down
        5. Adding material to the soil to encapsulate the contaminants and prevent them from spreading

E. Soil microbiology
    a. Just a few grams of soil (less than a teaspoonful) is the home to hundreds of millions and sometimes billions of microorganism.
        i. Some are easily seen like insects and annelids (worms)
        ii. Microscopic (not seen with the naked eye) includes:
            1. Fungi
            2. Algae
            3. Cyanobacteria
            4. Nematodes- microscopic worms that can be detrimental to plants and vectors for disease (some are beneficial and parasitze other pests)
            5. Protozoa
            6. Bacteria (single celled organisms)
        iii. Soil microorganisms can have several hundred to thousands of pounds of biomass per acre.
    b. Rhizosphere is the soil zone immediately around the roots of a plant.
        i. Here is the highest microbial activity.
        ii. Exudates (material released from the root) create a food rich region for microorganism growth
        iii. Rhizosphere microorganisms fix nitrogen from the soil air and dissolve soil minerals and decomposing organic matter: gives the roots the nutrients it needs to promote plant growth
        iv. Rhizobia bacteria associate with the roots of legumes to form nodules.
            1. This symbiotic relationship provides the bacteria with a source of carbon in exchange for making nitrogen available to the plant.
            2. Farmers are familiar with this process, and often encourage it by inoculating legume seeds with a commercial preparation of the Rhizobium species that is suited to the crop species they are planting.
        v. Mycorrhizae also associates with plants.
            1. By colonizing large areas of roots and reaching out into the soil, mycorrhizae aid in transfer of soil nutrients and water into the plant.
            2. This is especially important in situations where nutrient availability or moisture is limited.
    c. Support microbial activity in the soil through microbial management.
        i. Create the right environment for both crops and microbes.
            1. Appropriate tilling to avoid compaction or no-till practices
            2. Irrigation and drainage practices that keep the soil moist but not saturate
            3. Maintain a neutral pH
            4. Incorporation of organic matter to provide energy for the microbes

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ESSENTIAL STANDARD:		**3.00**	**10%**		**Examine Soil Conservation.**
Objective:		*3.02*	*5%*	*C3*	Apply management techniques to improve soil health.

3.03 Apply management techniques to improve soil health.

A. Soil conservation
   a. Promises future production and use of the soil.
   b. Prevents erosion, protects the soil by keeping it in place, fosters soil health

B. Tillage
   a. Tilling is used to remove weeds.
      i. Leads to soil compaction, erosion, loss of organic matter, degradation of soil structure, and loss of soil microbes and biodiversity in the soil.
      ii. Plowed soil has been scientifically proven to be much less stable or healthy than no-till soils. However, there are crops where tillage practices are somewhat necessary (like tobacco production)
   b. To promote healthier soils, no-till (also called zero-till) farming is commonly employed
      i. The no-till practice consists of managing crop residues on the soil surface year round while limiting soil disturbing activities to only those needed for the placement of nutrients, residue conditioning, and/or planting crops.
      ii. Increases the amount of water the infiltrates the soil, organic matter retention, and nutrient cycling
      iii. No-till must be managed very differently than traditional tilling practices.
         1. Special attention to timing of crops and planting of seeds must be monitored.
         2. Weeds, crop rotations, water use, pests, fertilizer management, and residues must be monitored and managed.
      iv. Less tillage of the soil leads to reduction in labor, equipment, fuel, and irrigation costs leading to possibilities for an increase in profit for the farmer.
      v. Other conservation tillage practices can include:
         1. Strip tilling
         2. Minimum tilling

C. Cover cropping
   a. Cover crops are plants seeded into agricultural fields, either within or outside of the regular growing season, with the primary purpose of improving or maintaining ecosystem quality.
   b. Benefits of cover cropping includes
      i. Suppressing weeds
      ii. Improving soil health
      iii. Fixing nitrogen
      iv. Reducing diseases and pests in soil
      v. Adding organic matter to soil
      vi. Preventing erosion
   c. Common cover crops used in North Carolina:
      i. Red Clover
      ii. Alfalfa
      iii. Ryegrass
      iv. Barley
      v. Oats
      vi. Clover
      vii. Vetch
   d. Cover crop management

        i. Choose type needed and Seed
        ii. Cultivate (cover crops are low maintenance compared to other crops)
        iii. Kill them when they are flowering (usually mowed down)
        iv. Incorporate back into the soil by digging in or rototilling
        v. Wait 2-3 weeks before planting your crop of choice (allows for full decomposition of cover crop and makes nitrogen available to future crop)
        vi. Plant your crop of choice: can include legumes, radish, wheat, barley and many more

D. Nonconventional plantings
    a. Strip cropping- Growing crops in a systematic arrangement across a field. Strips alternate between dense foliage and less coverage of the soil. This method:
        i. Reduces soil erosion and sediment transport
        ii. Protects growing crops from wind damage
        iii. Improves water quality
    b. Contour Plowing- follows the natural shape of the slope without altering it.
    c. Terracing- used to grow crops along hill and mountainsides. The shape of the slope is altered to create flat steps against the grain of the terrain. Water does not flow down the steep grade because there are terraces or flat areas to catch the water. Soil is not eroded with these methods.

E. Crop rotation is a systematic approach of planting crops from season to season or year to year. The goal of crop rotation is to prevent soil erosion, disease and pest problems, increase soil fertility and crop yields.
    a. Alternating nitrogen fixing plants with those who deplete the soil of nitrogen (example is soybeans and then corn).
    b. Crops within the same family or genus should never be planted consecutively (example is tomato and then eggplant).

F. Mulches help to make gardens and planting sites more weed and pest free with increased fertility, and more drought resistance. Usually apply a 3-4" layer of mulch (depending on the type) around plantings.
    a. Organic mulches are made of once living plant or animal materials. These amend and improve the soil structure and fertility.
    b. When applying check the Carbon to Nitrogen ratio (C:N). Depending on what and where you are applying the material will determine what C:N ratio is acceptable. The higher the value of C and the lower the value of N (example 50:1) of a material, the more likely it should be placed in an area where plants are not grown and soil is just covered (walkways)
        i. Straw (not hay- more weed seeds)
        ii. Compost (mushroom, vermicompost, manures or garden compost)
        iii. Wood products (sawdust, barks)
        iv. Chopped and aged leaves
        v. Grass clippings
        vi. Pine needles
        vii. Paper
    c. Inorganic mulches never living matter. These do not break down in the soil.
        i. Gravel
        ii. Stone
        iii. Black plastic
        iv. Geotextiles (landscape fabric)
    d. Living Mulch
        i. A living mulch is used for weed suppression and interplanted with another crop.
        ii. Hairy vetch is often interplanted with corn to provide protection against weeds.
        iii. Ryegrass can be broadcast into vegetables to prevent weed invasion.

G. Compost and amendments
    a. Compost is the use of once living material to create a nutrient-rich material to add to soil.
        i. Vermicompost- made from worm castings (litter)
        ii. Mushroom compost
        iii. Livestock manure (should usually be pasteurized and smell like earth before adding to soil)
        iv. Garden and food waste

1. Commercial or homemade, aiming for 2 parts of green or Nitrogen based goods to 1 part of brown or carbon based goods
2. Should be pasteurized (5 days at or above 120F for a compost pile to control pathogens)
3. Compost piles- Add moisture to help break down organic matter
4. Compost bins- great for small production or backyard sustainability and urban dwellers

b. Organic soil amendments may enrich nutritional and microbial values of soil or adjust the pH of soil. Incorporated into the topsoil by hand or with equipment.
   i. Kelp Meal (nutrient)
   ii. Greensand rich in Glauconite (nutrient)
   iii. Rock phosphate (nutrient)
   iv. Bone meal (nutrient)
   v. Blood Meal (nutrient)
   vi. Soil acidifiers or lime (to change pH)