CHAPTER 10 FARMING: CONVENTIONAL AND SUSTAINABLE PRACTICES

Chapter Overview

This chapter provides the fundamental knowledge on agricultural practices. The importance of soil characteristics is also discussed. Soil type along with soil horizons are two important concepts for AP students. Soil conservation practices, water usage and irrigation, pesticide usage and integrated pest management, organic farming and sustainable agriculture are topics to be stressed to the AP student.

Topics and Key Concepts

Earth Systems and Resources

- Describe biotic components of soil, and evaluate the physical and chemical properties of soil and their implications for agriculture.
- Illustrate soil profiles to show the varied types of horizons present throughout the world.
- Use a soil triangle to determine the type of soil based upon its textural components.

Land and Water Use

- Explain the various types of soil erosion and predict which agricultural method would reduce the likelihood of each type of soil erosion.
- Describe the various cultivation methods used for soil conservation.
- Differentiate between desertification, waterlogging, and salinization.
- Explain the purpose and specific methods of integrated pest management.

Pollution

- Summarize the benefits of pesticides in eliminating human health vectors and crop-damaging organisms and the negative effects of pesticides on the environment.
- Discuss the term ‘organic’ as it applies to food production and agriculture.

Key Terms

Define the following vocabulary terms covered in this chapter:

biocides
biological controls
chlorinated hydrocarbons
contour plowing
cover crops
desertification
fumigants
fungicides
*grasshopper effect
*global distillation
gully erosion
herbicides
inorganic pesticides
insecticides
integrated pest management (IPM)
microbial agents
mycorrhizal symbiosis
natural organic pesticides
neonicotinoid
organophosphates
persistent organic pollutants (POPs)
pest resurgence
pesticide
pesticide treadmill
rill erosion
salinization
sheet erosion
*soil horizon
subsoil
terracing
topsoil
waterlogging

** These key terms are not boldfaced in the chapter text, but are still important for the AP Exam.*

Pacing Guide

7 to 10 days should be spent on this chapter. Soils, with respect to agriculture, are very important. Students need to be well versed in all aspects of agriculture, which can be challenging for AP Environmental Science students who are living in urban areas, with little exposure to agricultural practices.

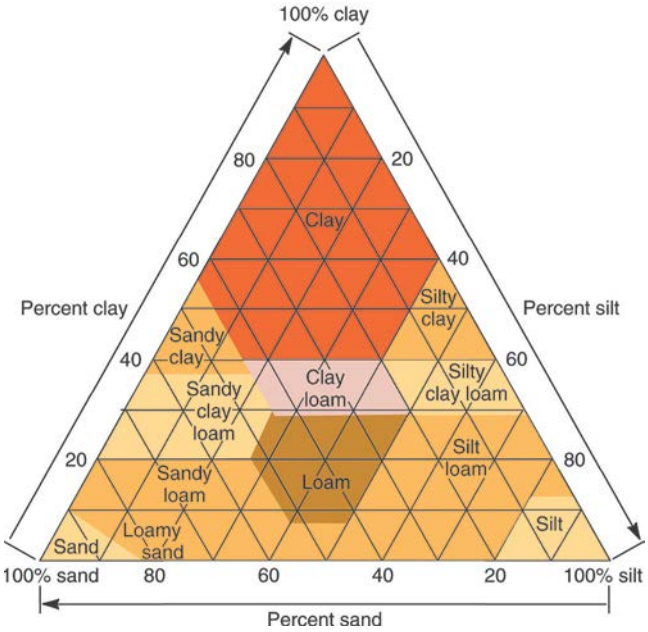
Approach and Tips

Quite frequently, the AP student is asked for soil characteristics, which include physical and chemical properties. Students should understand the various tests which determine a soil's physical and chemical properties. Not all soil tests listed in the table below need to be conducted, just make sure you have the students perform a variety of both chemical and physical tests. Students should be taught how to read a soil triangle, and understand how a soil's profile impacts vegetation. Students should be able to match a profile to a specific biome. Students should also conduct studies of weathering, including both physical and chemical weathering.

Soil Testing Options

Physical	Chemical
Texture – ribbon, sieve, sedimentation, particle size analysis	pH
Porosity	Ion exchange capacity
Water holding capacity	Macronutrients – NO_3^-, $PO4^{3-}$, K, S
Bulk density	Micronutrients – Fe, B, Co, Ca, Mg, Mn, Se, Al, Hg
Soil structure - friability	Organic content
Permeability	Salinity
Color	
Compaction	
Soil profile analysis	
Capillary action	

This chapter lends itself to many hands on activities. These activities enhance learning and play a key role in the students' learning. Since the chapter starts with a discussion of soil, each student should bring in a sample of soil from either their garden or yard. As an activity, have students conduct the "ribbon test." An example protocol for this test can be found on the NRCS website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/edu/
The more clay the soil has, the easier it will be to form a ribbon and the longer the ribbon they will be able to form. If the soil is homogenous, you can create unique soils by purchasing sand, silt, and clay from a variety of science vendors. You can then mix various samples to show how the textures and colors can vary dramatically.



Another activity is soil texture. It is determined by the ratio of sand to clay to silt. Have students bring in a bag of soil from their gardens. Students should place approximately 30 mL of their sample in a graduated cylinder and add enough water to reach the 50 mL mark. They should cover it with the palm of their hand or some Parafilm® and shake the sample vigorously. Students can use urine sample cups with screw caps to view the layers. Adding one drop of dish detergent will further allow the clay to collect at the top of the samples. Chemical texture tests can also be purchased from a variety of vendors. Place the cylinders in a place where they will not be disturbed and the next day have students examine the layers that have formed. Sand will be at the bottom of the graduated cylinder followed by silt and finally a top layer of clay. By calculating the percent of each layer, they will be able to see the layers of particles and make a loose determination, according to Figure 10.3, of what soil type they had. It is important to remember particle size and distribution of the layers.

How much clay and sand the soil contains will determine the length of time it will take water to drain. Use small paper cups with several holes punched in the bottom and soil samples of different types. Place the soil in the cup and pour a measured amount of water in the cup. Time how long it takes for the water to travel through the cup and how much water is retained in the soil sample. Soil with high clay content will take longer for the water to percolate through it. Sandy soils do not hold water. Soils that are composed of sandy loam are considered the best for farming. Alternately, a tube open at both ends can be covered with cheesecloth, and water can be timed to determine how quickly it will percolate through the soil. Permeability is the test of how quickly the water moves through the soil.

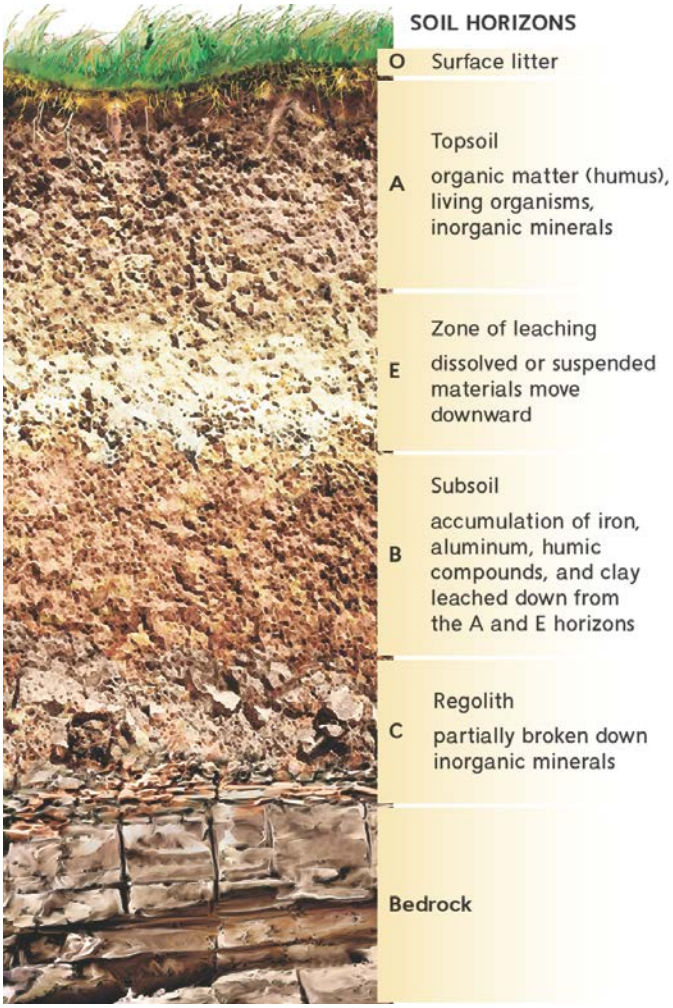
The soils you have collected can also be used to investigate erosion and runoff. Use a stream table or another large container to place your soil samples. You can plant grass seed to mimic crop placements and then have it “rain” at one end of the table. Is the soil held in place, or is it washed away over time? Does it form rills or gullies? Stress that water is not the only mechanism by which soil erodes. Discuss wind erosion and the methods used to reduce this from happening.

In addition to the physical soil properties, students need to familiarize themselves with chemical properties. NPK and pH are two chemical properties that students should know. Macronutrients and micronutrients are essential for plant growth. Knowledge of the three main macronutrients, NPK or the major components of inorganic fertilizers, is necessary to do well. Soil pH will indicate what plants may be grown or what needs to be added to the soil in order for other plants to grow. Try to avoid using the terms nitrogen, phosphorous, and potassium. Say nitrate, phosphate, and potassium ions so that students understand the nutrients are part of the biogeochemical cycles studied earlier in the year.

Students need to be familiar with a soil profile and the layers that make up a profile. See Figure 10.6 in the textbook. If you have a construction site nearby or even an eroded stream bed, layers of different colors can be observed. Each layer is made up of specific components. Emphasize that the substrate is important in determining soil type. The concept of soil fertility is crucial to agricultural production. Also, make sure students realize that soil formation is a very slow process.

Connecting agricultural topsoil loss with water and wind erosion is a fundamental concept. The use of irrigation to provide water to crops and the possibility of either water logging or salinization is important to know. Emphasize that not all land is arable and that desertification of land, particularly marginal land, can occur due to poor farming techniques as well as overgrazing.

Soil conservation methods need to be emphasized and described so that students will be able to explain when these methods are used and how these methods conserve soil. The ideas of crop rotation, letting a field go fallow, and the use of cover crops should be stressed. Ask the students why farmers use these methods and what happens to soil fertility when using these methods. They should be able to explain how soil fertility increases. Reference Chapter 14 to further describe weathering versus soil erosion. Strip cropping and intercropping can be used interchangeably. The definition of intercropping is growing more than one crop in the same field, especially in alternating rows or sections. Ensure that students are aware that methods to reduce soil erosion are the same as some of the methods to reduce pests.



Stress the importance of the use of pesticides as well as the different types of pesticides. Students need to know each major type of pesticide, including organophosphates, carbamates, and organochlorines, and how it is used. Environmental effects of pesticide use should be emphasized using DDT as a classic example. The concepts of bioaccumulation and biomagnification can be re-introduced using pesticides as the substance accumulating. Students can struggle differentiating biomagnification and bioaccumulation, so be sure to explain that a toxin *accumulates* in an organism and *magnifies* in a food web. Human exposure to pesticides should also be explained. Once again, a discussion can re-emphasize the concepts of an acute vs. a chronic effect. A discussion of pesticide alternatives including biological methods of control needs to be stressed. All AP students need to understand the concept of integrated pest management and how to apply this concept to a real life situation. Ensure that students are aware that the purpose of IPM is to reduce crop loss to an economically tolerable level, not to completely eradicate a pest. IPM often

involves using a non-persistent pesticide at first to lower the pest population, followed by the various non-pesticide control methods.

When discussing pesticides, explain that the term pesticide is an all encompassing term, while specific targeted pesticides have different names. Discuss the difference between the types of pesticides as well as natural pesticides. Describe various environmental effects that result from the use of pesticides. Pest resurgence and the concept of a pesticide treadmill are two very important ideas that need to be stressed.

Alternatives to modern mechanized monoculture agriculture should be stressed, including organic farming. Sustainability in reference to all resources is an idea that is integral to the study of environmental science. Continue to remind students that all agricultural practices have the goal of sustainability of the land and nutrients.

Organic farming and sustainable agriculture are more eco-friendly and leave soils healthier than intensive, chemical-based monoculture cropping. Differentiate between a natural fertilizer and a commercial fertilizer, and include the various benefits and drawbacks of each. It should enhance the argument that using natural fertilizer improves soil more than commercial fertilizer. Explain the requirements necessary in order for a product to be labeled organic. One method that can help with the concept of organic farming would be to have an organic food party. Each student can bring in an organic food to share with the class. Have each student explain the organic portions of their food. Stress that crop rotation and habitat diversification can keep pest populations from building up. Re-introduce the concept of genetic engineering and GMOs.

Common Mistakes and Misconceptions

Believe it or not, students confuse humus (decaying organic material) with hummus (food made from chick peas). They also do not realize that not all land is suitable for agricultural crop production. This is an important distinction of arable land. Another distinction that students fail to make is the difference between fertilizers and pesticides. Quite frequently students will think that pesticides run-off can lead to eutrophication. While they do run-off, causing their own multitude of problems, eutrophication is not one of them. Be clear so that students make the distinction. When comparing benefits and drawbacks for agricultural production, students overlook the realization that machines are needed for crop production and more importantly that these machines use fossil fuels. Students need to understand that the use of fertilizers, organic or inorganic can run-off into waterways and lead to eutrophication. The important connections between the hydrologic cycle and the nitrogen and phosphorus cycles are fundamental ideas that all AP students should understand.

Activities

Pesticide Label Lab Activity

Provide students with several samples of bottled pesticides or pesticide labels including insecticides, herbicides, miticides, rodenticides, nematicides, etc. Students should read the labels and identify health and environmental hazards; classify the pesticides as broad or narrow; and identify the targeted pest. Students should record their findings in a data table.

Toxicity of Pesticides Activity

A worksheet located at the end of this teacher's manual chapter is provided for the students to complete.

For materials, one "six pack" of plants can be obtained from a local nursery.

In step 4 of the procedure, have your class decide what "normal" is. I read the bottle and it will usually say "completely cover the plant with foam." So, this will be the normal dose.

Upon completion of step 6, discuss with the students why the manufacturer of the herbicide would like us to "completely cover the plant with foam" and the environmental effect the runoff pesticide will have.

Pesticide Pamphlet Activity

Each student is assigned a specific pesticide. Use the EPA website or perform a Google search for a list of pesticides. Students construct a tri-fold pamphlet. Items to be included on the pamphlet are: name, chemical formula or structural formula, type of pesticide, use, efficacy, hazardous information, environmental effects, first aid (if necessary), photos of usage, and a bibliography on the back page. Include any references to the material in the chapter that students have learned. Students can be very creative with this project. Include any published LD_{50} data as well.

Alternative Pesticide Remedy Presentations

Students will create presentations that discuss alternative methods of eradicating pests beyond chemical-based methods. Provide students with alternative methods, such as biological control, sterile-male technique, genetic engineering, natural repellents, photodegradable plastics, and changing harvesting methods

(crop rotation, planting periods, polyculture). Presentations must include an explanation of each method, targeted pest, advantages, disadvantages, and examples of how they have been used by consumers/farmers.

Supplemental Video

"Dirt", a film, takes a humorous look into the historical and current state of soil.

Questions for Review

1. What are the three main particles that make up soil in order from smallest to the largest?
   Clay, silt, and sand

2. Pesticides can be target specific. What type of pesticide would be used for the following species? (a) aphids eating a tomato plant, (b) dandelions growing in a lawn, (c) rats in a grain barn, (d) beetles eating raspberry bushes
   (a) insecticide, (b) herbicides, (c) rodenticides, (d) insecticides

3. What is the pesticide treadmill? How does it occur?
   The pesticide treadmill describes the increased use of pesticides as pests become resistant to the pesticide. When a pesticide is used on a particular pest, some pests survive to reproduce. The offspring become resistant to the pesticide. So there is a need to use newer and more effective pesticides.

4. How are biological organisms used to control pests in agriculture?
   Predators such as wasps, praying mantises, and ladybugs will kill certain pests in agricultural fields. Pathogens, including viruses and bacteria, can be used to eliminate pests as well.

5. What is IPM?
   Integrated pest management uses a combination of approaches to achieve pest reduction. It is an ecological approach that minimizes pesticide use and uses biological and physical methods.

6. What are three methods of soil conservation?
   Terracing, contour plowing, cover crops, reduction in tillage and strip farming are methods for soil conservation.

Practice Questions

Multiple Choice:

Directions for questions 1-5: The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

(A) contour plowing
(B) strip cropping
(C) no-till agriculture
(D) terracing
(E) shelter belts

1. shaping the land to create level platforms

2. used to prevent wind erosion

3. planting crops across the hill

4. planting different crops in alternating rows

5. planting crops without plowing the land

6. All of the following result in top soil loss except
   (A) gullying
   (B) sheet erosion
   (C) wind erosion
   (D) weathering of parent material
   (E) desertification

7. The soils in this biome have very little organic material and are composed of nutrient poor iron rich clays.
   (A) temperate rain forests
   (B) tropical rain forests
   (C) temperate grassland
   (D) temperate deciduous forest
   (E) taiga

8. The role of soil bacteria, algae, and fungi is
   (A) the depletion of nutrients from the soil.
   (B) the depletion of water from the soil making it unavailable for plants.
   (C) the decomposition and recycling of leaf litter to make nutrients available to plants.
   (D) to cause diseases in plants.
   (E) to not do anything beneficial in the soil.

9. Foods are grown in this deep organic rich soil horizon.
   (A) D
   (B) B
   (C) E
   (D) O
   (E) A

10. The neem tree is
   (A) native to North America
   (B) a natural insecticide
   (C) a fruit tree
   (D) a nut tree
   (E) a GMO

Free-Response Question:

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. Top soil is very important for agricultural production.

   (a) Describe the process of soil formation.

   (b) Identify and describe TWO chemical properties of soil and TWO physical properties of soil.

   (c) For one of the properties that you identified in (b) explain the importance of that property.

   (d) Identify two methods that will decrease the amount of soil erosion.

   (e) Suppose a farm is suffering from a pest resurgence. Suggest TWO methods to remediate this, other than the use of traditional pesticides.

Answers to Practice Questions

Multiple Choice:

1. D
2. E
3. A
4. B
5. C
6. D
7. B
8. C
9. E
10. B

Free-Response Question:

This question is based on 10 points.

1. (a) 1 point for explaining that chemical and physical weathering of parent material produces soil

   (b) 4 points total. 1 point for each property. Chemical properties include: pH, nitrogen, phosphorus, and potassium content. Physical properties include: texture, color, porosity, percolation.

   (c) 1 point for describing why the property mentioned in (b) is important.

Property	Importance
pH	acidic or basic soil supports different plants
nitrogen, phosphorus, and potassium content	nutrients essential for plant growth
texture	constituents of soil which will determine success of growth
color	indicates the parent material and amount of organic material present
porosity	indicates the space available for root growth
percolation	Determines the infiltration amount of water

(d) 2 points total. 1 point for each method. Methods include: strip cropping, terracing, no-till agriculture, wind breaks, contour plowing, drip irrigation

(e) 2 points total. 1 point for each method. Methods include: biological controls (any predator), viruses, bacteria, neem, or any other natural insecticide.

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (page 198)

(A) Very large farmed areas that have fertilizers applied introduce a large amount of nitrogen and phosphorous into the watershed. This excess nitrogen and phosphorous gets washed into the streams and rivers, and eventually makes it way to the ocean. Excess nutrients contribute to very large algae blooms that, when they die, can cause dead zones in the ocean. These areas of very low oxygen are fatal to sedentary benthic organisms.

(B) Ecosystem services that are lost by farming include: water that is used to support life in Brazil and in neighboring countries, and used for hydroelectric power, medicinal plants that are found nowhere else in the world, carbon storage, and biodiversity.

(C) Economic benefits of large-scale agriculture to the local Cerrado communities include high yields, cheap land, job opportunities, and favorable tax rates from a supportive government.

Use the Math (page 213)

Imports have increased by over $20 billion from 1960 to 2010 (from close to nothing to approximately $23 billion per year). From 1980 to 2010, the percent change is around 360% (~$5 billion to $23 billion). If pesticide prices remained constant, glyphosate probably contributed the most to the change, and atrazine probably contributed the least.

AP Connections Review Answers (pages 30-32)

Multiple-Choice

1. b. The E horizon is easily leached in temperate deciduous forests.

2. c. Terracing (cutting terraces into the steep slopes) will decrease erosion.

3. d. pH is the only chemical property listed. All other answers are physical properties.

4. c. The insecticide can protect the crop and improve land productivity. A farmer will use the pesticide, as the benefits outweigh the costs.

5. a. sand has the greatest porosity, it drains quickly and can deprive plants of moisture.

6. a. salinization, a type of chemical deterioration, can occur from salt-laden irrigation water on arid lands.

7. d. clay loam

8. c. mollisols are the dominant soil order found in the Farm Belt of the United States.

9. a. organophosphates are less persistent in the environment, breaking down in a few days, while organochlorines can persist in the soil for years, or decades

Data Analysis and Free-Response Questions

1A There was approximately 300,000 lbs of active ingredients applied in 1990 and 4,800,000 lbs applied in 2006. This is a 1500% increase.

1B The percentage of acres rose from approximately 11% to approximately 92% of acres: a 736% increase. It is less than the increase in active ingredients over the same amount of time.

1C If we consider the amount to be approximately 5,200,000 lbs in 2004, 3,500,000 lbs in 2005, and 4,600,000 lbs in 2006, the median amount of active ingredients is 4,600,000 lbs (2,090,909 kg). The mean amount of active ingredients from 2004 – 2006 is approximately 4,433,333 lbs (2,015,151 kg).

2A Integrated Pest Management (IPM) is a flexible, ecologically-based strategy that is applied at specific times and aimed at specific crops and pests. It minimizes the use of chemical pest controls, and relies on preventative practices that encourage beneficial organism diversity and enhanced plant vigor and defenses.

2B Answers may vary. A specific example of IPM from the text includes the introduction of *Compsilura* flies to feed on gypsy moth caterpillars. The gypsy moth caterpillar consumes fruit trees and ornamental plants. Unfortunately, the *Compsilura* flies are also very effective at controlling other moth species populations like the Cecropia moth whose population size has plummeted.

2C Answers will vary.

2D Environmental benefits of IPM include a decrease in the use of pesticides and herbicides, an increase in the diversity of organisms, and a more robust ecosystem.

Toxicity of Pesticides Activity Worksheet

*Student:*_____

Materials:

One “six pack” of plants from a local nursery
Bottle of spray herbicide

Procedure:

1. Take the six plants and cut the plastic so that they are apart from one another.

2. On one of the plastic containers, with a permanent marker, write control and set that one aside.

3. On a second container, write normal dose, on a third, write 1/2 normal, on a fourth, write 1/4 normal, on the fifth write 2 times normal, and on the last write 4 times normal.

4. Decide what is a normal dose?

5. Go outside or use a vent hood and spray the “normal” plant with the amount to “completely cover the plant with foam.” Then, spray the rest of the plants with the 1/2 normal, 1/4 normal, 2 times normal, and 4 times the normal amount.

6. Water all of the plants (including the control) and put them in the window until the plants have all died.

Questions:

1. Was the normal dosage effective in killing the plants?

2. Did lower amounts of pesticide still have the desired effect of killing the plants?

3. What are the environmental effects of this pesticide? Does using more than needed have an environmental footprint?

4. What is the most effective dose of this pesticide?

5. Are there any human health risks of being exposed to this pesticide?