5.7 SUSTAINABLE AGRICULTURE

College Board Topics 5.5, 5.6, 5.14, and 5.15

Related Reading: 225-237 and254 -260

From The Course Description

ENDURING UNDERSTANDING

STB-1

Humans can mitigate their impact on land and water resources through sustainable use.

LEARNING OBJECTIVE

STB-1.E

Describe sustainable agricultural and food production practices.

ESSENTIAL KNOWLEDGE

STB-1.E.1

The goal of soil conservation is to prevent soil erosion. Different methods of soil conservation include contour plowing, windbreaks, perennial crops, terracing, no-till agriculture, and strip cropping.

STB-1.E.2

Strategies to improve soil fertility include crop rotation and the addition of green manure and limestone.

STB-1.E.3

Rotational grazing is the regular rotation of livestock between different pastures in order to avoid overgrazing in a particular area.

SUGGESTED SKILL

Environmental Solutions

7.C

Describe disadvantages, advantages, or unintended consequences for potential solutions.

SUGGESTED SKILL

Environmental Solutions

7.D

Use data and evidence to support a potential solution.

SUGGESTED SKILL

Environmental Solutions

7.E

Make a claim that proposes a solution to an environmental problem in an applied context.

From The Course Description

ENDURING UNDERSTANDING

EIN-2

When humans use natural resources, they alter natural systems.

LEARNING OBJECTIVE

EIN-2.G

Describe the benefits and drawbacks of different methods of pest control.

ESSENTIAL KNOWLEDGE

EIN-2.G.1

One consequence of using common pest-control methods such as pesticides, herbicides, fungicides, rodenticides, and insecticides is that organisms can become resistant to them through artificial selection. Pest control decreases crop damage by pest and increases crop yields.

EIN-2.G.2

Crops can be genetically engineered to increase their resistance to pests and diseases. However, using genetically engineered crops in planting or other ways can lead to loss of genetic diversity of that particular crop.

ENDURING UNDERSTANDING

STB-1

Humans can mitigate their impact on land and water resources through sustainable use.

LEARNING OBJECTIVE

STB-1.C

Describe integrated pest management.

ESSENTIAL KNOWLEDGE

STB-1.C.1

Integrated pest management (IPM) is a combination of methods used to effectively control pest species while minimizing the disruption to the environment. These methods include biological, physical, and limited chemical methods such as biocontrol, intercropping, crop rotation, and natural predators of the pests.

LEARNING OBJECTIVE

STB-1.D

Describe the benefits and drawbacks of integrated pest management (IPM).

ESSENTIAL KNOWLEDGE

STB-1.D.1

The use of integrated pest management (IPM) reduces the risk that pesticides pose to wildlife, water supplies, and human health.

STB-1.D.2

Integrated pest management (IPM) minimizes disruptions to the environment and threats to human health but can be complex and expensive.

From The Course Description

ENDURING UNDERSTANDING

EIN-2

When humans use natural resources, they alter natural systems.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EIN-2.E Describe different methods of irrigation.	**EIN-2.E.1** The largest human use of freshwater is for irrigation (70%). **EIN-2.E.2** Types of irrigation include drip irrigation, flood irrigation, furrow irrigation, drip irrigation, and spray irrigation.
EIN-2.F Describe the benefits and drawbacks of different methods of irrigation.	**EIN-2.F.1** Waterlogging occurs when too much water is left to sit in the soil, which raises the water table of groundwater and inhibits plants' ability to absorb oxygen through their roots. **EIN-2.F.2** Furrow irrigation involves cutting furrows between crop rows and filling them with water. This system is inexpensive, but about 1/3 of the water is lost to evaporation and runoff. **EIN-2.F.3** Flood irrigation involves flooding an agricultural field with water. This system sees about 20% of the water lost to evaporation and runoff. This can also lead to waterlogging of the soil.

ESSENTIAL KNOWLEDGE

EIN-2.F.4

Spray irrigation involves pumping ground water into spray nozzles across an agricultural field. This system is more efficient than flood and furrow irrigation, with only 1/4 or less of the water lost to evaporation or runoff. However, spray systems are more expensive than flood and furrow irrigation, and also requires energy to run.

EIN-2.F.5

Drip irrigation uses perforated hoses to release small amounts of water to plant roots. This system is the most efficient, with only about 5% of water lost to evaporation and runoff. However, this system is expensive and so is not often used.

EIN-2.F.6

Salinization occurs when the salts in groundwater remain in the soil after the water evaporates. Over time, salinization can make soil toxic to plants.

EIN-2.F.7

Aquifers can be severely depleted if overused for agricultural irrigation, as has happened to the Ogallala Aquifer in the central United States.

Potential problems related to industrialized agriculture

- Industrial agricultural practices stemming from the Green Revolution pose a variety of potential environmental problems.
  - Increased soil degradation (erosion from tillage, salinization and water logging from irrigation, nutrient depletion from monocultures and limited fallow periods)
  - Increased dependence on inorganic fertilizers to realize the genetic potential of high yield crop varieties and mitigate nutrient depletion of soils caused by monocultures.
  - Increased dependence on irrigation to realize the genetic potential of high yield crop varieties and expand agricultural productivity in dryland farming regions.
  - Increased need for synthetic pesticides to combat increasing crop losses caused by pesticide resistant pests, exacerbated by monocultures.
  - Increased mechanization of farming and greater dependence on fossil fuels needed to farm on the industrial scales that keep farming profitable with the increased inputs needed for modern agriculture.
- The practices listed above have led to a worldwide increase in food production since the Green Revolution, but have led many to question the sustainability of these practices in the long run.
  - Has led to a return some traditional practices and development of new approaches to farming in order to improve the sustainability of modern agriculture

Addressing soil erosion

- ***Conservation Tillage or No-till farming*** reduces plowing (tilling) of fields after harvesting the previous seasons crops.
  - Replaces traditional tillage with small holes drilled through crop residues and into the top soil in which seeds are plant and the then covered by a No-till Drill.

- Benefits of Conservation Tillage and No-Till Farming
  - Eliminates the soil loosening process of tilling, thereby reducing erosion
  - Leaves crop residues on the field to better hold soil and resist erosion
  - Improves soil structure by increasing organic matter content and reducing soil compaction which increases moisture retention.
  - Increased organic matter, less compaction, and less disturbance of soil increases soil biota and speeds nutrient cycling
  - Increases carbon sequestration in soil
  - Reduces fossil fuel dependence, pollution and costs while reducing wear and tear on machinery and requiring less time and labor

- Drawbacks of Conservation Tillage and No-Till Farming
  - May lead to increased use of herbicides to control weeds that are no longer removed by tilling the fields
  - May lead to increased use of fertilizers since these weeds compete with crops and remove nutrients from the soil

Traditional Tilling

No-Till Farming

Addressing Soil Erosion

- ***Contour Plowing***
  - Plowing a field with the contours of the land, perpendicular to the slope, rather than up and down the slope.
  - Slows runoff moving down slope, thereby decreasing water erosion
- ***Terracing***
  - Cuts steep hillsides into a series of giant steps, each step is a small flat area suitable for farming with minimal runoff to cause water erosion.
- ***Shelter Belts***
  - Planting rows of trees or small shrubs around the edge of fields to act as wind breaks and slow wind erosion over large flat expanses of fields




- ***Cover Crops***
  - Non crop species, or secondary crops planted during off-seasons, to cover the soil and slow wind and water erosion. Many cover crops are grasses and grains that grow at high density with extensive root networks.
  - Often used as green manure, leguminous, nitrogen-fixing plants (peas and clover) can add nitrogen to the soil, and can help with weed and insect pest management.

Addressing Nutrient Depletion from Soils

- ***Crop Rotation***
  - Alternating the species of crop grown in fields from one season of the year to the next.
  - Crop rotation can minimize nutrient loss from soils (different crops use nutrients at different rates), and, in some cases return nutrients to the soil (nitrogen fixing crops)
  - Can also limit erosion compared to traditional approaches of allowing fields to lie ***fallow*** (empty)
  - Corn and wheat farmers often grow nitrogen-fixing soy beans (a legume) from one year to the next.
- ***Intercropping***
  - Planting different crops in alternating bands or other spatial arrangements throughout their fields.
  - Slows nutrient depletion compared monocultures since crops are using different nutrients at different rates
  - Reduces the chance of one nutrient from becoming a limiting nutrient for crop growth

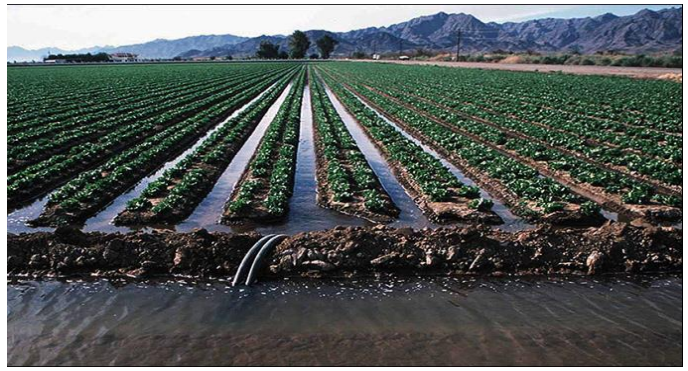
Addressing Nutrient Depletion from Soils

- ***Green Manure and Compost***
  - Many cover crops are used as ***green manure***. Prior to planting with the main crop, cover crops are plowed into the soil where soil organisms decompose the organic material and release nutrients into the A horizon for crops to use.
  - Similar to green manure, ***compost*** is decomposed organic matter that is produced in controlled settings and then applied to fields and gardens.
  - Green manure and compost offer benefits beyond inorganic fertilizers because they add a full array of soil nutrients, including micronutrients (not just one targeted nutrient), and they improve the structure of soil and increase its water holding capacity.

- ***Limestone ($CaCO_3$)***
  - Adding crushed limestone to soil can raise the pH of soils and thereby increase the availability of existing soil nutrients for plants by improving the cation exchange capacity of the soil.

Improving Irrigation

- ***Furrow Irrigation***
  - Simple, cheap, traditional approach
  - Furrows are between crop rows and water is diverted into the furrow.
  - Water loss from evaporation and runoff can be up to 30%, making furrow irrigation very inefficient
- ***Flood Irrigation***
  - Entire fields are flooded and water is allowed to infiltrate into the soil.
  - Even watering of all plants depends on precisely leveled fields to prevent ***waterlogging*** where water pools
  - Water loss from runoff and evaporation can be up to 20%



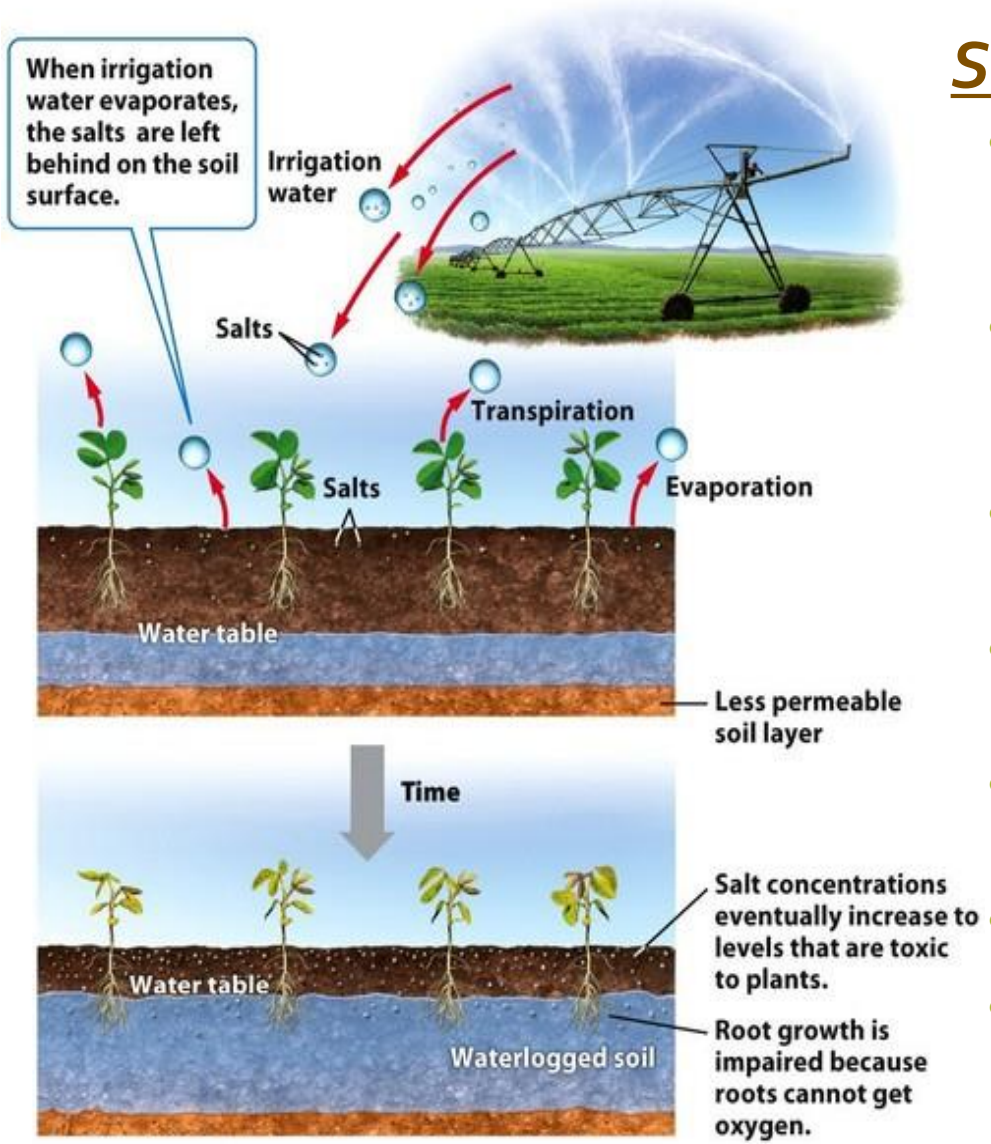
- ***Spray***
  - Ground or surface water is pumped into spray nozzles.
  - Less water loss than furrow or flood irrigation, but more expensive, requiring pumps, extensive piping and ongoing energy costs
- ***Drip***
  - Small holes in narrow hoses drip precise amounts of water directly into the root zones of plants
  - Most efficient, but most costly.

The results of poor irrigation practices

Waterlogging

- Overwatering can saturate the soil, and raise the water table, filling all soil pore space with water.
- Doesn't allow air into pores, so roots can't take in O_2 they need for respiration
- Common in low lying areas of fields irrigated with flood irrigation
- **Solution**: drip irrigation, or soil aeration - poking holes or cores in soil to allow air in & water to drain through soil

The results of poor irrigation practices



Soil Salinization

- Groundwater for irrigation has low concentrations of naturally occurring salts. Heavy irrigation dissolves salts deep in the soils.
- Rapid evaporation in arid climates brings these salts to the surface and deposits them in the topsoil as the water evaporates.
- Synthetic fertilizers can worsen soil salinization problems since these products are themselves ionic salts
- Over time, salt can reach toxic levels, dehydrating plant roots (osmotic water loss) & preventing germination.
- **Solutions**: Expensive, so prevention with efficient drip irrigation using low salt water is best
- Avoid water thirsty crops in arid regions.
- Flooding with large volumes of fresh water, stop irrigating and allow rain to flush out salts, plant with salt tolerant crops such as barley.

Integrated Pest Management (IPM)

- IPM seeks to reduce (not necessarily eliminate) the use of chemical pesticides and their impacts.
  - Uses biological and physical means of pest control in addition to limited use of chemical pesticides.
  - Goal is to reduce crop damage to economically tolerable levels, not eliminate all pests
  - Reduces or prevents the pesticide treadmill, impacts on non-target organisms, and toxicity to humans.
- Biological Pest Controls:
  - Pest predators and parasites (cat/dog, lady bugs, preying mantis, parasitic wasps, specific strains of bacteria/fungi that can be sprayed on crops.
    - Concerns about introduced species becoming pests themselves (cane toads)
  - Releasing sterile males of the pest species reduces mating success of pest population as a whole.
  - GM Crops with genetically enhanced pest resistance
- Physical Pest Controls:
  - Traps (insect traps with pheromone baits), weed block fabric/plastic, crop rotation, intercropping, tilling (weeds)

Integrated Pest Management (IPM)

- Chemical pesticides are still part of integrated pest control, but their use is limited.
  - Ideally narrow spectrum, low persistence pesticides are selected
  - Used in specific, targeted applications during specific times of the growing season or to address specific problems not readily controlled by other means.
  - Broad spectrum pesticides may harm non-target species, including species previously introduced for biological control of the pest species.

- Drawbacks of IPM:
  - Can be complex. Requires close observation of fields and crops, and extensive knowledge of species and their ecological interactions.
  - Can be expensive, or have a high up front cost, depending on the combination of methods applied.
  - Can be slow. Spraying with chemical pesticides generally has an immediate impact on the size of the pest population.
    - Recruiting a large enough population of predators to regulate pest populations may take more than one growing season.

Video Resources

- Agriculture
  - https://www.youtube.com/watch?v=OGfo4jPEaTo&feature=emb_logo