LECT 5. ENVIRONMENTAL SUSTAINABILITY

LEARNING OUTCOME:

- SOIL QUALITY AND LAND DEGRADATION
- AIR QUALITY AND AIR CONTAMINATION AND POLLUTION
Keeping the four ecosystem processes
- Effective energy flow
- Water
- Mineral cycles
- Viable ecosystem dynamics
in GOOD conditions
There is no bare ground.
Clean water flows in the farm's ditches and streams.
Wildlife is abundant.
Fish are prolific in streams that flow through the farm.
The farm landscape is diverse in vegetation.
"The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality; and support human health and habitation” (Karlen et. al., 1997)
The Concept of Soil Quality

- Various physical, chemical and biological soil properties interact in complex ways that determine a soil’s potential fitness for sustained production of healthy and nutritious crops,

- The integration of growth enhancing factors that make a soil productive is referred to as “Soil Quality”
People have different ideas of what a quality soil is. For example:

- **for people active in production agriculture**, it may mean highly productive land, sustaining or enhancing productivity, maximizing profits, or maintaining the soil resource for future generations;
- **for consumers**, it may mean plentiful, healthful, and inexpensive food for present and future generations;
- **for naturalists**, it may mean soil in harmony with the landscape and its surroundings;
- **for the environmentalist**, it may mean soil functioning at its potential in an ecosystem with respect to maintenance or enhancement of biodiversity, water quality, nutrient cycling, and biomass production.
Evolved in 1990’s in response to increase global emphasis on sustainable land use

Developed by Warkentin and Fletcher, 1977

The concept includes two areas of emphasis: EDUCATION and ASSESSMENT

- Soil quality kits, visual assessment procedures, video presentation were developed
- Assessment tools were developed as foundation for sustainable land management
Soil quality assessment and education are intended to provide better understanding and awareness that soil resources are truly living bodies with biological, chemical and physical properties and processes performing essential ecosystem services.
Why the Interest in Maintaining Soil Quality

- Increasing world demand for food, feed and fiber
- Increasing public demand for environmental protection
- Decreasing supplies of nonrenewable energy and mineral resources
Soil quality assessment is the process of measuring the management induced changes in soil as we attempt to get soil to do what we want it to do.

The ultimate purpose of assessing soil quality provide the information necessary to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms including people.

Soil quality assessments are conducted by evaluating *indicators*. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils.

They can also be morphological or visual features of plants.
Evaluating Soil
What Soil Does?

Healthy soil gives us clean air and water, bountiful crops and forests, productive rangeland, diverse wildlife, and beautiful landscapes.

Soil does all this by performing five essential functions:

- **Regulating water.** Soil helps control where rain, snowmelt, and irrigation water goes. Water and dissolved solutes flow over the land or into and through the soil.

- **Sustaining plant and animal life.** The diversity and productivity of living things depends on soil.
Filtering potential pollutants. The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.

Cycling nutrients. Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled through soil.

Supporting structures. Buildings need stable soil for support, and archeological treasures associated with human habitation are protected in soils.
The Inherent and Dynamic Quality of Soil

- Soil has both **inherent and dynamic qualities**. **Inherent soil quality is a soil’s natural ability to function.** For example, sandy soil drains faster than clayey soil. Deep soil has more room for roots than soils with bedrock near the surface. These characteristics do not change easily.

- **Dynamic soil quality** is how soil changes depending on how it is managed.
Management choices affect the amount of soil organic matter, soil structure, soil depth, water and nutrient holding capacity.

One goal of soil quality research is to learn how to manage soil in a way that improves soil function.

Soils respond differently to management depending on the inherent properties of the soil and the surrounding landscape.
Soil Quality Link to Sustainability

- Understanding soil quality means assessing and managing soil so that it functions optimally now and is not degraded for future use.

- By monitoring changes in soil quality, a land manager can determine if a set of practices are sustainable.
Soil quality cannot be measured directly, so we evaluate indicators. Indicators are measurable properties of soil or plants that provide clues about how well the soil can function. Indicators can be physical, chemical, and biological characteristics. Useful indicators:

- are easy to measure
- measure changes in soil functions
- encompass chemical, biological, and physical properties
- are accessible to many users and applicable to field conditions
- are sensitive to variations in climate and management.
Indicators can be assessed by qualitative or quantitative techniques. After measurements are collected, they can be evaluated by looking for patterns and comparing results to measurements taken at a different time or field.
### Example of Soil Quality Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Relationship to Soil Health</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SOIL ORGANIC MATTER (SOM)</strong></td>
<td>Soil fertility, structure, stability, nutrient retention, soil erosion</td>
</tr>
<tr>
<td><strong>PHYSICAL:</strong> Soil structure, Depth of soil, Infiltration and bulk density, Water holding capacity</td>
<td>Retention and transport of water and nutrients, habitat for microbes, estimate of crop productivity potential, compaction, plow pan, water movement, porosity, workability</td>
</tr>
<tr>
<td><strong>CHEMICAL:</strong> pH, Electrical Conductivity, Extractable N-P-K</td>
<td>Biological and chemical activity thresholds, plant and microbial activity thresholds, plant available nutrients and potential for N and P loss</td>
</tr>
<tr>
<td><strong>BIOLOGICAL:</strong> Microbial biomass C and N, Potentially mineralisable N, Soil respiration</td>
<td>Microbial catalytic and repository for C and N, soil productivity and N supplying potential, microbial activity measure</td>
</tr>
</tbody>
</table>
1. **Enhance organic matter:**

- Whether your soil is naturally high or low in organic matter, adding new organic matter every year is perhaps the most important way to improve and maintain soil quality.

- Regular additions of organic matter improve soil structure, enhance water and nutrient holding capacity, protect soil from erosion and compaction, and support a healthy community of soil organisms.
2. Avoid excessive tillage:

- Reducing tillage minimizes the loss of organic matter and protects the soil surface with plant residue.
- Tillage is used to loosen surface soil, prepare the seedbed, and control weeds and pests.
- But tillage can also break up soil structure, speed the decomposition and loss of organic matter, increase the threat of erosion, destroy the habitat of helpful organisms, and cause compaction.
- New equipment allows crop production with minimal disturbance of the soil.
3. Manage pests and nutrients efficiently:

- An important function of soil is to buffer and detoxify chemicals, but soil's capacity for detoxification is limited.
- Pesticides and chemical fertilizers have valuable benefits, but they also can harm non-target organisms and pollute water and air if they are mismanaged.
- Nutrients from organic sources also can pollute when misapplied or over-applied.
- Efficient pest and nutrient management means testing and monitoring soil and pests; applying only the necessary chemicals, at the right time and place to get the job done; and taking advantage of non-chemical approaches to pest and nutrient management such as integrated pest management, crop rotations, cover crops, and manure management.
4. Prevent soil compaction:

- Compaction reduces the amount of air, water, and space available to roots and soil organisms.
- Compaction is caused by repeated traffic, heavy traffic, or traveling on wet soil.
- Deep compaction by heavy equipment is difficult or impossible to remedy, so prevention is essential.
5. Keep the ground covered:

- Bare soil is susceptible to wind and water erosion, and to drying and crusting.

- Ground cover protects soil, provides habitats for larger soil organisms, such as insects and earthworms, and can improve water availability.

- Ground cover must be managed to prevent problems with delayed soil warming in spring, diseases
6. Diversify cropping systems:

- Diversity is beneficial for several reasons. Each plant contributes a unique root structure and type of residue to the soil.

- A diversity of soil organisms can help control pest populations, and a diversity of cultural practices can reduce weed and disease pressures.
Most of the world's soils that have been surveyed show some level of degradation due to human activities.

- Moderate: 46%
- Severe: 15%
- Light: 38%
- Extreme: 1%
Once the virgin land is used for agriculture – the quality of the soil resource will begin to degrade, the rate of decline will depend on the skill of the land manager.
Factors responsible for soil degradation

FACTORS OF SOIL DEGRADATION

NATURAL
- CLIMATE: Precipitation, Temperature regime, Evapotranspiration
- HYDROLOGY: Drainage pattern, depth of groundwater, overland flow
- TERRAIN: -slope steepness, length
- PARENT MATERIAL: -chemical composition of bedrock, physical properties
- VEGETATION: -plant species, diversity, density, composition

ANTHROPOGENIC
- POPULATION: Density, Lifestyle
- LANDUSE: Arable, Perennial, Pastures, urban, soil management
- LOGISTICS: Roads, waterways, industrial complex
- WASTE DISPOSAL: Industrial, urban, agricultural wastes
Processes of Soil Degradation

Changes in Soil Properties Due to

**Physical Processes**
- Decline in soil structure
- Densification
- Hydrothermal regime
- Slaking, crusting, compaction, hardening, erosion
- Sub-optimal temperature, anaerobiosis, drought, leaching

**Chemical Processes**
- Depletion of SOM
- Emission GH gases, decrease in biomass C
- Leaching
- Acidification
- Nutrient imbalance

**Biological Processes**
- Soil Fauna
  - Reduction in soil fauna
  - Increase in parasitic fauna
- Depletion of SOM
Causes of soil degradation worldwide for all land uses.

- Overgrazing (35%)
- Deforestation (30%)
- Agricultural activities (28%)
- Industrialization (1%)
- Overexploitation (7%)
1. Overgrazing

Overgrazing is what happens when there are too many animals on the land.
What grass plants need is sufficient recovery time between bites. Therefore, timing and grazing management, not numbers, is the critical factor.

But this is something that everybody already "knows"--that the solution to overgrazing is to reduce or eliminate the grazers.
Increasing the area available to the animals is not nearly as effective as shortening the time period during which the plant is exposed to grazing.
2. Deforestation

- The main contributors to land degradation are erosion and soil compaction, as a result of extensive removal of vegetation, exposure of the soils to heavy rainfall, increased evaporation, and later wind action.
The main reasons for vegetation removal are commercial logging and tree cutting to provide domestic fuel, as well as clearing of forests for commercial or subsistence cultivation.

Soils in many tropical areas rapidly decline in productivity after logging.
3. Agriculture

- Agriculture may last for a few hundred years or it may last for thousands of years. These terraces have been in place for thousands of years in Bali.
Agave production for tequila on these fields in Mexico may last for fewer than 50 years due to soil erosion which results in the loss of valuable topsoil.
Mechanisms of soil degradation worldwide for all land uses.

- Physical degradation (4%)
- Chemical degradation (12%)
- Water erosion (56%)
- Wind erosion (28%)
Water erosion is the wearing away of soil particles. Raindrops detach the soil particles. As infiltration is reduced, water moving down slope takes the soil with it.
Causes of Soil Erosion

- Impact of RAIN DROPS fall at 20 mph
Raindrops Cause

- Surface soil pores fill with soil particles reducing infiltration.
- Particles are separated due to beating of rain drops.
- Surface flow begins due to lack of infiltration
Erosion Types

- Sheet Erosion - thin film of water over the entire field moving down-slope
Sheet Erosion

NRCS Photo
Rill Erosion

collection of sheet erosion water into channels (rills) that erode the bottom and side of the rill.
Rill Erosion
Gully Erosion

- increasing size of rills eventually lead to a Gully or a channel too large for crossing by farm equipment.
Gully erosion, Iowa, NRCS photo.

Gully erosion, NSW, Australia.
Wind Erosion

Wind erosion is the detachment of soil particles by the wind and moving them to another location.
Chemical Degradation

- Chemical spills can pollute the soil beyond which it can recover naturally.
- Soil remediation can reclaim the soil, making it useful again.
Manure Spill

- Manure spills are chemical spills and they result in polluting soils, surface waters and groundwaters.
- Problems may occur during any of the steps of manure management including:
  - collection,
  - transfer,
  - Storage
  - application.
- If a manure spill reaches a stream it can create serious problems for aquatic life as well as for people and livestock.
Degradation of a resource can occur from overuse of any one of the many different resources required for sustainability of all resources.

Slide 14—Upper Klamath National Wildlife Refuge—Looking north (south of Rocky Point) on Upper Klamath NWR. With Klamath Basin irrigators receiving full water deliveries in 2002, all of Upper Klamath National Wildlife Refuge has once again been left totally dry at the onset of the fall waterfowl migration season.
Soil – A Sustainable Natural Resource

- Having a sustainable soil system is everyone's responsibility!
- Healthy soil gives us clean air and water, bountiful crops and forests, productive rangeland, diverse wildlife, beautiful landscapes and **beautiful soils**.
Global Warming
Air Pollution
Global Warming and Climate Change

- **Cause:**
  
  Increase in the concentration of greenhouse gases
  
  - Carbon dioxide
  - Nitrous oxide (N₂O)
  - Methane (CH₄)
  - CFC
Some light is reflected

Some heat escapes from the atmosphere

GHGs absorb some heat and radiate it back to earth

Long wave heat radiated from earth

Short wave light energy

Figure 1: The Structure of the atmosphere
Figure 2: Green House gases Impact
The Greenhouse Effect

Solar radiation: 343 Watts per m²

Some of the solar radiation is reflected by the atmosphere and the Earth's surface.

Outgoing solar radiation: 103 Watts per m²

Some of the infrared radiation passes through the atmosphere and out into space.

Outgoing infrared radiations: 240 Watts per m²

Solar radiation passes through the atmosphere.

Incoming solar radiation: 240 Watts per m²

About half the solar radiation is absorbed by the Earth's surface.

Absorption solar radiation: 168 Watts per m²

Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules.

Radiation is converted to heat energy, causing the emission of longwave (infrared) radiation back to the atmosphere.
Figure 2.2: Amounts of carbon in soil organic matter, terrestrial vegetation and animals and the atmosphere. (From Bolin, B. et al., 1986. *The Greenhouse Effects, Climate Change and Ecosystems*, SCOPE 29, Wiley, Chichester, other sources.)
Emission of Greenhouse Gases

- Carbon Dioxide
- Nitrous Oxide
- Methane
- CFC-12, CFC-11
A projection of future greenhouse gas emissions of developed and developing countries. Total emissions from the developing world are expected to exceed those from the developed world by 2015.
## Sources of GH Gases

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>13</td>
</tr>
<tr>
<td>Industrial processes</td>
<td>3</td>
</tr>
<tr>
<td>Waste</td>
<td>4</td>
</tr>
<tr>
<td>Land-use change and forestry</td>
<td>18</td>
</tr>
<tr>
<td>Energy</td>
<td>63</td>
</tr>
</tbody>
</table>
## Sources of Emission from Agriculture Sector (2006)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice (CH$_4$)</td>
<td>11</td>
</tr>
<tr>
<td>Fertilizers (N$_2$O)</td>
<td>37</td>
</tr>
<tr>
<td>Livestock (CH$_4$)</td>
<td>32</td>
</tr>
<tr>
<td>Residue burning/forest clearing</td>
<td>13</td>
</tr>
<tr>
<td>Manure management (CH$_4$, N$_2$O)</td>
<td>63</td>
</tr>
</tbody>
</table>

Emissions from agriculture activities are expected to increase due to increased demand of agric production (crops and meat) and population.

Global agricultural emissions were found to increase by 14 % from 1990 to 2005, and a 38 % rise is expected for the entire period 1990 to 2020.
Contribution of specific agric components on GHG emission

1. Agricultural soils
   - Nitrous oxide ($\text{N}_2\text{O}$) is the largest source produced naturally in soils through the processes of nitrification and denitrification.
   - Agricultural activity may add nitrogen to soils either directly or indirectly (N fertilizers and manures).
2. Livestock and manure management

- methane production
- fermentation or the natural digestive processes in ruminants, such as cattle and sheep, accounts for the majority of methane production
- Manure management includes the handling, storage and treatment of manure.
3. Rice cultivation

Flooded rice fields are the third largest source of methane emissions arising from anaerobic decomposition of organic matter.
Options of Mitigation

- Anthropogenic activities have the potential to impact the quantity of emissions through management of carbon and nitrogen flows and, thus, can be directed towards reducing (mitigating) emissions of greenhouse gases.

There are 2 big options
Can you suggest them?
Mitigation

Option I

- Reduce the amount of emissions (abatement)
Mitigation

Option II

- Enhance the absorption of carbon dioxide (C sequestration), storing carbon (C sinks)
Strategies that can be used

3 strategies
1. Increase carbon sequestration.
2. On-farm emission reductions.
3. Displacement of fossil fuels
What is Carbon Sequestration

The natural mechanism whereby trees and plants, through photosynthesis process, take carbon dioxide from the atmosphere and store it in their biomass and in soils. CS not only reduces the atmospheric content of carbon dioxide, it also improves the productivity of agricultural soils, reduces soil erosion, and chemical run-off caused by various farm operations like pesticides and fertilizer application.
The agricultural activities which will increase C sequestration include any practices that store carbon through cropland management “best practices”
Improved management practices that reduce on-farm GHG emissions include livestock and manure management, fertilizer management, and improved rice cultivation.
Livestock Management

- Reduce methane emissions from fermentation include enhancing the efficiency of digestion with improved feeding practices and dietary additives.
Manure Management

- capturing the methane emitted
Fertilizer Management

- Improving the efficiency of fertilizer application.
- Organic production.
- Improved water management in rice production.
Substitution of Fossil Fuels

- Biofuels
Impacts of climate change on food production
Potential direct effects on agriculture systems

Seasonal changes in rainfall and temperature could impact agro-climatic conditions;

- altering growing seasons,
- planting and harvesting calendars,
- water availability,
- pest, weed and disease populations.
- Evapotranspiration, photosynthesis and biomass production is altered.
- Stronger yield-depressing effects are found in tropical and sub-tropical regions for all crops.
Land suitability is altered
Increased CO$_2$ levels lead to a positive growth response in some crops under controlled condition.

“carbon fertilization effect”
STOP CLIMATE CHANGE 
BEFORE IT CHANGES YOU.
Air Pollution & Acid Rain
ii. Primary air pollutants

(a) Carbon monoxide (CO)

- produced from incomplete burning of fossil fuels (automobiles), although use of “catalytic converters” reduced CO emissions but number of cars has increased.
- produced also from “tobacco smoke” - affects ‘ non-smokers’
- CO remain attached to the haemoglobin for a long time → accumulates & reduce “oxygen carrying capacity of the blood.
- Exposure to 0.001 % CO in air for several hours → death.
- CO produced in heavy traffic causes:
  - headaches
  - drowsiness
  - blurred vision
- But CO is not a persistent pollutant
(b) Hydrocarbon (HC)

- Remnants in the fuel that did not burn completely.
- Main source → internal combustion engines
  - refineries
  - industry/factories

(c) Particulates

- Small pieces of solid material
- Sources: - from burning fossil fuels
  - farming operations
  - construction operations
  - building demolitions
- smoke particles from fires
  - bits of asbestos from brake linings
  - insulation
Particulates are irritants to eyes & nose and health and carcinogenic (if asbestos).

Particulates absorb potentially more harmful materials (sulfuric, nitric and carbonic acids)
- irritates lining of respiratory systems

Particulates in air cause
- haze
- smog

(d) Sulfur dioxide (SO₂)

Source – burning of S-containing fossil fuels
Sharp odour & irritates respiratory system, corrosive to lung tissues
Reacts with H₂O, O₂ and other materials → “S-containing acids”, can attach to particulates
(e) Oxides of nitrogen

Source: when there is combustion in the air, N & O molecules react:

\[ \text{N}_2 + \text{O}_2 \rightarrow 2\text{NO} \]
\[ 2\text{NO} - + \text{O}_2 \rightarrow 2\text{NO}_2 \]
mixtures of NO & NO\(_2\) → NO\(_x\)

Primary source: automobile engine.

NO\(_x\) are involved in production of secondary pollutants.