PRINCIPLES OF SUSTAINABLE AGRICULTURE

PRT 3006

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a. Course Outline

Jabatan : Jabatan Land Management
Nama Kursus : Principles of Sustainable Agriculture
Kod Kursus : PRT 3006
Jam Kredit : 2 (2+0)

Penerangan dan Ringkasan Kursus

Kursus ini merangkumi 2 jam kuliah seminggu. Selain mengikuti pembelajaran kuliah, pelajar juga perl menyiapkan satu kerja kursus.

b. About the Author (A)

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c. Course Objective

To give understanding on:
- principles of sustainable agriculture
- Component in sustainable agriculture.
- Challenges in sustainable agriculture and methods to overcome the problem.
d. Course Synopsis

A principle of sustainable agriculture course dealing with the application and management of sustainable agriculture in the field to produce more agriculture product while conserve environment, human health and economic value..
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f. Panduan Tugasan / Amali (jika berkenaan)
Format laporan akan diterangkan oleh tutor pada perjumpaan bersemauka. Nama dan No. matrik hendaklah ditulis dengan lengkap dan jelas pada setiap laporan amali.
g. Penilaian Kursus

Penilaian kursus ini terbahagi kepada:

(i) Kerja kursus keseluruhan
   Tugas (individu) 30 %

(ii) Peperiksaan pertengahan 30 %

(iii) Peperiksaan akhir 40%

Jumlah keseluruhan 100%

**Penilaian kursus berubah daripada semasa ke semasa bergantung kepada pensyarah/pengajar kursus semasa.**
Cadangan Jadual dan Aktiviti Pembelajaran

1. Perjumpaan Bersemuka
   a. Kuliah /Bimbingan 8 Jam
   b. Tutorial /Amali 24 Jam
   c. SCL/SMS/LMS (Form, VOD) 38 Jam

2. PTB / Kendiri
   Self-directed learning (Tugasan, Persediaan untuk perjumpaan) 22 Jam
   Ulang kaji 14 Jam
   Persediaan Penilaian 7 Jam

3. Penilaian
   Awal dan berterusan 2 Jam
   Akhir 3 Jam

Jumlah Jam Keseluruhan 118 Jam
h. Peperiksaan Pertengahan (jika berkenaan)
Peperiksaan pertengahan perlu diduduki oleh pelajar. Soalan peperiksaan yang akan dikemukakan berdasarkan modul yang dimiliki. Bentuk soalan adalah berbentuk kombinasi objektif dan subjektif/sesi. Peperiksaan ini merangkumi unit 1 hingga 3, walau bagaimanapun maklumat muktahir mengenai peperiksaan seperti berlaku soalan, bilangan soalan dan topik yang terlibat akan dimaklumkan kepada pelajar semasa perjumpaan bersemuka.

i. Peperiksaan Akhir (jika berkenaan)
Soalan peperiksaan ini akan merangkumi kesemua topik dalam modul, walau bagaimanapun penekanan ialah pada topik yang belum dinilai. Tutor di pusat pembelajaran akan dimaklumkan mengenai topik-topik ini atau pelajar boleh berhubung terus dengan pensyarah kursus untuk mendapatkan maklumat muktahir. Soalan peperiksaan akhir mesti berbentuk kombinasi objektif dan subjektif/sesi.
(Perhatian!!: bentuk soalan ini boleh berubah, maklumat terkini mengenai peperiksaan boleh berhubung terus dengan pensyarah/pengajar semasa perjumpaan bersemuka).
### Rujukan Utama


### Rujukan Tambahan

UNIT 1

INTRODUCTION

Introduction

In this section explanation about principle of sustainable agriculture will be done, which is:

1. History and evaluation in agriculture.
2. Impact or current issues on modern agriculture that make adoption of sustainable agriculture practices important.

Learning Outcomes

At the end of this unit the students are able to:

1. Correlate production factors in sustainable agriculture system.
2. Elaborate the main issue and agro-ecosystem mitigation steps in sustainable agriculture practice framework.
3. Explain the components of environment, economic and social in agriculture production system, marketing, and policy in facing challenges and role/position of sustainable agriculture in the future,
**TOPIC 1: AGRICULTURE**

- From the Latin word "agricultura"
- Ager = field and cultura = cultivation
- Since the beginning of human civilization
TOPIC 2: SUBSISTENCE AGRICULTURE

- Self sufficiency
- Sell/trade surplus
- Small area
- Primitive technology
- Low yield
- Example:
  - Shifting agriculture/ slash and burn
  - Clear forest area to grow crops
  - Land abandoned in a few years after soil fertility declined
TOPIC 3: GREEN REVOLUTION (1940 – 1970s)

- Increase in agriculture production to feed increasing population
- Through:
  - High yielding varieties
  - Irrigation
  - Mechanization
  - Synthetic chemicals (fertilizers and pesticides)
TOPIC 4: MODERN / COMMERCIAL AGRICULTURE

What are the impacts of conventional (modern) agricultural practices on the environment?

I. Land degradation
II. Emission of greenhouse gasses/g global warming (climate change)
III. Declining of genetic diversity (biodiversity)
IV. Excessive use of commercial fertilizer and pesticides (agrochemicals)
V. Deforestation; overgrazing
What are examples of land degradation process?

I. Soil erosion

II. Desertification

III. Compaction

IV. Frequent tilling

V. Water logging

VI. Acidification
VII. Crusting

VIII. Organic matter loss

IX. Nutrient runoff

X. Leaching of nutrients

XI. Accumulation of toxic materials (organic and inorganic)

I. Salinization
Emission of greenhouse gases

1. Carbon Dioxide (CO₂)
   - Natural and anthropogenic sources.
   - Recent increase due to fossil-fuel combustion and deforestation.

2. Methane (CH₄)
   - Natural and anthropogenic sources
   - About ¼ of current emission are anthropogenic (landfills, natural gas, agriculture)

3. Nitrous Oxide (N₂O)
   - Natural and anthropogenic sources
   - Nitrogen-based fertilizers

4. Other important greenhouse gases:
   - CFCs
   - Ozone
   - Water vapor
Global warming impacts:
- Increase temperature will enhance evaporation from oceans
  → increase water vapor in atmosphere → enhance greenhouse effect.
- Increase temperature will enhance evaporation → increase amount of low clouds → increase earth's albedo.
- CO₂ will dissolve into oceans
- Vegetation will remove CO₂ and grow more vigorously
- Decline of genetic diversity

Why is having a diverse genetic important?
- Different varieties adapted to different environmental factors (drought, different)
- Focusing on 1 variety = putting all eggs in 1 basket.
- Wild populations → great genetic diversity.
- Domesticated crops → less genetic diversity due to selective breeding which result in uniformity.
Excessive use of commercial pesticides and fertilizer

How excessive usage of fertilizer of pesticides and fertilizer affect the environment?

i. Genetic resistance to pesticides is developing in many insects.
ii. Health hazards.
iii. Pollution of soil and water.
iv. Broad spectrum insecticides kill beneficial insect too.
   - Used excessively as a preventive measure rather being applied in response to presence of pest.
v. Decrease organic matter in soil = less water-holding capacity
vi. Fertilizer in surface and ground water entering lakes and streams allows overgrazing of algae = eutrophication.

vii. Nitrate poisoning of groundwater / leafy vegetables
Others:

1. Forest fire / slash and burn

2. Deforestation

3. Overgrazing
   - What is overgrazing?
   - Happen when there are too many animals in an area.
   - Recovery of grass plant is slower than the grazing time.

   What is the solution?
   - Reduce the number of grazers.
   - Proper grazing management.
TOPIC 5: WHAT IS SUSTAINABLE FARMING?

Post modern agriculture

- The integration of agriculture technologies to produce quality food and fiber while maintaining or increasing soil productivity, farm profitability and environmental quality.

Additional References

UNIT 2
PRINCIPLE AND SYSTEM OF SUSTAINABLE AGRICULTURE

Introduction
Principle and system of sustainable agriculture is a study of understanding definition of sustainable agriculture, it principle and system that need to be done to ensure that the practices is perform properly in the field. These practices involve resource-conservation, social support, commercial competition and environmental sound.

Learning Outcomes
At the end of this unit, students will be able to:
1. Describe the definition of sustainable agriculture.
2. Explain the components of environment, economic and social in agriculture production system, marketing, and policy in facing challenges and role/position of sustainable agriculture in the future.
3. Understanding sustainable agriculture systems
TOPIC 1: SUSTAINABLE AGRICULTURE

- The word “sustain” from the Latin sustinere (sue) from below and (tenere) to hold.
  - To keep in existence or maintain, implies long-term support or permanence.
- Farming system that is “capable of maintaining their productivity and usefulness to society indefinitely.
- Meeting fundamental human needs while preserving the life-support systems of the planet.
- Produces abundant food without depleting the earth’s resources or polluting its environment.
- Agriculture of social values, one whose success is indistinguishable from vibrant rural communities, rich lives for families on the farms, and wholesome food for everyone.
- System must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. (Duesterhause 1990)
- Sustainable agriculture is a practices of various techniques and principles.
- The key issue in sustainable agriculture is that is no single approach that can be applied all over the world in a uniform manner.
- Different techniques and systems are applied, and adapted, in different ecological and socio-cultural systems.
- Sustainable agriculture is not merely to produce food but provides for other needs as well.
- “Better human nutrition is a more important goal than food production alone, and will not be achieved only through greater grain output.” (Uphoff, 2002)
- SA adopts the following ecological approach:
  - Recycles plant nutrients
  - Provide the most favorable soil conditions for plant growth.
    ▪ Protects soil from erosion
    ▪ Conserves and protects water
    ▪ Uses minimum tillage
    ▪ Minimize loss of energy and other growth factors among others,
      through microclimate management, water harvesting and better soil
      management.
- Integrates crop and livestock enterprises on the farm (enhance beneficial
  biological interactions and synergies)
  - Promotes biodiversity – diversify species and genetic resources.
- Sustainable agriculture or farming mean growing crops and livestock in ways
  that require:
  I. A whole-system approach with a goal towards continuing health of the
     land and people.
  II. Concentration on long-term solutions to problems instead of short-term
      treatment of symptoms.
  III. Sustainability that can be observed and measures; indicators that a farm
       or rural community is achieving 3 objectives of sustainability
       simultaneously, i.e.:
       ▪ Economic sustainability – economic profit
       ▪ Social sustainability – social benefits to the farm family and the
         community
       ▪ Environmental sustainability – environmental conservation
1. Economic Sustainability
   - Selecting profitable enterprises to ensure economic sustainability in term of economic components, agro-ecological approaches optimize the use of locally available resources.
   - The farm enterprises are consistently profitable from year to year.
   - Purchase of off-farm feed and fertilizer is decreasing.
   - Reliance on government payments is decreasing.

2. Social Sustainability
   - Socially, agro-ecological approaches build up and take advantage of local knowledge and practices.
   - The farm supports other businesses and families in the community.
   - Money circulates within the local economy.
   - Young people take over their parents’ farm and continue farming.
   - College graduates return to the community after graduation.

3. Environmental Sustainability
   - 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.
TOPIC 2: ELEMENTS OF SUSTAINABLE AGRICULTURE

- Element of sustainable agriculture is:
  - Environmentally sound
  - Economically viable
  - Socially just
  - Humane
  - Adaptable

- Sustainable agriculture can be viewed as ecosystem management of complex interactions among:
  - Soil
  - Water
  - Plants
  - Animals
  - Climate
  - People

- The goal is to integrate all these factors into a production system that is appropriate for the environment, the people, and the economic conditions where the farm is located.

- Farm acts as an ecosystem
  - On any farm, four major ecosystem processes are at work that, if
  - Functioning properly, will conserve the soil and water resources and
  - Eventually reduce the overall operating cost.
  - These natural processes — energy flow, water and mineral cycles, and
  - Ecosystem dynamic — are observable and manageable.
  - Effective ecosystem dynamic is indicated by high diversity of plants
    and animals both above and below ground.
  - "Diversity" refers not only to numbers of species, but also to genetic
defers to genetic diversity within species, and to a board age structure in each
population.
  - Greater diversity produces greater stability within the system and
minimizes pest problems.
 Principles of sustainable agriculture
   I. Prevent soil erosion
      - Covers crops
   II. Diversify crops
      - Crop rotation
      - Mixed cropping
   III. Fertilization
      - Reduce the use of chemical fertilizer
      - Green manures
      - Composts
IV. Weed management
V. Integrated Pest Management (IPM)
VI. Plant Disease Management
TOPIC 3: SUSTAINABLE AGRICULTURE SYSTEMS

- There are various sustainable agriculture systems:
  - Natural farming
  - Organic farming
  - Low-input agriculture
  - Alternative agriculture
  - Regenerative
  - Holistic farming
  - Biodynamic farming
  - Bio-intensive farming
  - Biological farming systems

- Example of sustainable agriculture systems
  1. Bio-dynamics
     - Biological dynamic agriculture, a.k.a. bio-dynamics, is a system of agricultural management based on a series of lectures given by Rudolf Steiner in 1924.
     - Over his lifetime, Dr. Steiner became concerned with the degradation of food produced through farming practices that increasingly relied on additions of inorganic fertilizers and pesticides.
     - Reputed to be the first alternative approach to agriculture,
     - Bio-dynamics has evolved over the last century to include many organic farming practices that have demonstrable benefits on land use and crop production
2. Natural farming
   - An ecological farming approach established by Masanobu Fukuoka (1913–2008), a Japanese farmer and philosopher
   - It is also referred to as "the Fukuoka Method", "the natural way of farming" or "do-nothing farming". The title refers not to lack of labour, but to the avoidance of manufactured inputs and equipment.
   - Natural farming can also be described as ecological farming and is related to organic farming, sustainable agriculture, agro-forestry, eco-agriculture and permaculture but should be distinguished from biodynamic agriculture.
   - The system exploits the complexity of living organisms that shape each particular ecosystem. Fukuoka saw farming not just as a means of producing food but as an aesthetic or spiritual approach to life.¹
   - Farmers could benefit from closely observing local conditions. Natural farming is a closed system, one that demands no inputs and mimics nature.

Conclusion

Sustainable agriculture is a better alternative to the current agriculture production system that not just focuses on crop production but also take into consideration the issue of environmental sustainability.

Additional References

UNIT 3
THE COMPONENTS OF SUSTAINABLE AGRICULTURE

Introduction
The component of sustainable agriculture is study to explain and describe how to perform sustainable practices, which considered economy, society, and environment sustainable while produce more profit.

Learning Outcomes
At the end of this unit, the students will be able to:
1. Identify and describe the components of sustainable agriculture, including the environment, economic and social aspects in agriculture production.
2. Explain the concepts of trade-offs between environmental and profitability and social sustainability.
TOPIC 1: ECONOMIC SUSTAINABILITY

- The challenge of farm economics as we enter the 21st century is to help farmers build a more sustainable agriculture.
- The environmental and social benefits of sustainable production methods do not always translate into economic gains.
- It depends on the farmer's management strength or weaknesses, decision making abilities, and marketing skills.
- Economic sustainability requires selecting profitable enterprises and doing comprehensive financial planning.
Indicators of economic sustainability

- The family savings or net worth is consistently going up and the family debt is consistently going down.
- The farm enterprise is consistently profitable from year to year
- Purchase of off-farm feed and fertilizer is decreasing
- Reliance on government payments is decreasing

The important criteria of economic sustainability

- The profitability of farming cannot be sustained through exploitation of the land or exploitation of other people.
- It must conserve and protect the natural resources upon which its long run productivity must depend.
- It must contribute to the social and cultural quality of life for farm families and rural residents as it provides an adequate supply of safe and healthy food and fiber for society in general
**TOPIC 2: ENVIRONMENT-PROFITABILITY TRADE-OFFS**

- Trade-offs between environmental and profitability effects offer a helpful way to think about environmental values without relying on direct monetary measures.
- Environmental-profitability trade-off analysis involves two measures:
  - An environmental one and a profitability one. Usually the environmental measure is in physical units (e.g., mass or density units), while the profitability one is in monetary units (e.g., revenues, costs, or net returns).
- Mapping alternative practices or policies by these two criteria can show which ones are "efficient" in the sense of giving the best profitability for a given level of environmental performance, or the best environmental outcome at a given profitability level.
TOPIC 3: SOCIAL SUSTAINABILITY

- The farm supports other businesses and families in the community.
- Money circulates within the local economy.
- The number of rural families is going up or holding steady.
- Young people take over their parents’ farms and continue farming.
- College graduates return to the community after graduation.

Additional References

UNIT 4
SOCIAL SUSTAINABILITY

Introduction
This topic will explain about the social sustainability which act as one of the component in sustainable agriculture. Social sustainability is a community action and ability to maintain and build its own resources and prevent and address problem in the future. There are many challenges to manage social sustainability such as global population growth, global climate and other environmental changes and others.

Learning Outcomes
At the end of this unit, the students will be able to:
1. Describe the definition of social sustainability in sustainable agriculture.
2. Explain the topic of food security and identify the main challenges that affects food production.
TOPIC 1: SOCIAL SUSTAINABILITY

Definition of social sustainability
- For a community to function and be sustainable, the basic needs of its residents must be met. A socially sustainable community must have the ability to maintain and build on its own resources and have the resiliency to prevent and/or address problems in the future.
- Two types or levels of resources in the community that are available to build social sustainability (and, indeed, economic and environmental sustainability):
  - individual or human capacity, and social or community capacity.
  - Individual or human capacity refers to the attributes and resources that individuals can contribute to their own well-being and to the well-being of the community as a whole. Such resources include education, skills, health, values and leadership.
  - Social or community capacity is defined as the relationships, networks and norms that facilitate collective action taken to improve upon quality of life and to ensure that such improvements are sustainable.
- To be effective and sustainable, both these individual and community resources need to be developed and used within the context of four guiding principles - equity, social inclusion and interaction, security, and adaptability.

What is social sustainability?
- The social preconditions for sustainable development or the need to sustain specific structures and customs in communities and societies (Sachs, 1999)
- The finality of development whilst economic and environmental sustainabilities are both goals of sustainable development and instruments to its achievement (Assefa and Frostell, 2007)
Why is social sustainability important?
- Emerging concept although least studied and often overlooked dimension of Sustainable Development
- At the heart of the sustainable communities agenda (Bristol Accord, 2005)

Social sustainability key themes and domains

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<th>Emerging</th>
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<td>Basic needs, including housing</td>
<td>Demographic change (ageing and international migration)</td>
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<td>Education and skills</td>
<td>Empowerment, participation and access</td>
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<td>Equity</td>
<td>Identity, sense of place and culture</td>
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<td>Employment</td>
<td>Health and safety</td>
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<td>Human rights</td>
<td>Social mixing and cohesion</td>
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<td>Poverty</td>
<td>Social capital</td>
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<td>Social justice</td>
<td>Well being, happiness and quality of life</td>
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TOPIC 2: FOOD SECURITY AND SAFETY

What is food security?
- In its narrowest definition, food security means that enough food is available, whether at the global, national, community or household level. Enough to meet economic demand and if so, at what price, or is it enough to meet energy and nutrient requirements.
- Originally, the term “food security” was used to describe whether a country had access to enough food to meet dietary energy requirements.
- The term food security at the national and global level tends to focus on the supply side of the food equation. This means availability.
- But availability won’t assure accessibility
World Hunger

Total = 925 million

- Developed countries: 19
- Near East and North Africa: 37
- Latin America and the Caribbean: 53
- Sub-Saharan Africa: 239
- Asia and the Pacific: 578

Source: FAO.
- FAO (1996):
  Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life.
Food Availability

- The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid).
- Food availability addresses the “supply side” of food security and is determined by the level of food production, stock levels and net trade.

Food Access

- Access means access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet.
- Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources).

Utilization

- Utilization of food is optimized through a combination of adequate diet, clean water, sanitation and health care in order to reach a state of nutritional well-being where all physiological needs are met.
- Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices and is especially important for infants and young children.
- For the broader household, food preparation, diversity of the diet and intra-household distribution of food are also important.

Stability

- Means that a population, household or individual has access to adequate food at all times. They should reduce their risk of losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity).
TOPIC 3: GLOBAL FOOD SECURITY CHALLENGES AND DRIVERS

Challenges

1. Global population growth
   - Coupled with demographic change, increasing affluence and urbanization, will lead to growth in demand for food and changing patterns of demand (increases in food consumption, especially of meat and dairy products).
   - Much of the expansion in population will occur in developing countries.

2. Global climate and other environmental changes
   - Direct or indirect impacts on food production and supplies include rising carbon dioxide and other greenhouse gases, leading to rising temperatures, changing rainfall patterns and increasing incidence of extreme weather events, rising sea level and ocean acidification.
   - Changing climate may also lead to changes in the distribution and/or severity of pests and has the potential for severe impacts on food production and animal welfare.

3. Environmental impact of farming and food
   - Negative impacts can include increasing water and land use, soil erosion and degradation, loss of biodiversity, as well as greenhouse gas emissions and water pollution.

4. Natural resources for agriculture are limited
   - Notably land, fresh water and energy, but also sources of other inputs such as mineral phosphate (an essential plant nutrient). Shortages of resources may be exacerbated by increasing competition, for example from urban and industrial development.
5. Social Drivers
   o Urbanization
   o Demographic change
   o Issues of land tenure
   o Governance and international security
   o Changing patterns of consumer needs
   o Preferences
   o Choices
   o Tastes
   o habits and practices
   o Affecting the demand for and consumption of different foods and patterns of waste.

6. Economic Drivers
   o Issues of trade
   o Land tenure
   o Food markets and their volatility
   o Supply and distribution
   o Regulation
   o Affordability and accessibility (particularly in the developing world) with associated globalization.
TOPIC 4: WORLD FOOD SECURITY

- Food Crisis: Impact on Food Security
  - The immediate problem is due to the increase in food prices, rather than a global shortage of food.
  - Food commodity prices increased by a staggering
    - 130% from 2002-2006
    - 58% from 2007-2008
    - 88% for cereals in 2008 alone.

- The price trend is increasing

Food Price Indices

January 2011
• Rice price increase accordingly
  It's not that a lot more people are eating a lot more rice, it's that more dollars are chasing the same bags of the stuff.
TOPIC 5: FOOD SECURITY IN MALAYSIA

- Brief facts of our population and staple food

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<th></th>
<th>2031</th>
<th>2050 (Est.)</th>
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<tr>
<td>Population</td>
<td>29.9 million</td>
<td>63 mill</td>
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<td>Rice yield</td>
<td>4-5 ton/ha</td>
<td>6-12 ton/ha</td>
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<tr>
<td>Consumption</td>
<td>82 kg/person/yr</td>
<td>?</td>
</tr>
</tbody>
</table>
Additional References

4. FAO Agricultural and Development Economics Division (June 2008). Food Security
UNIT 5
SOIL QUALITY & LAND DEGRADATION

Introduction
Soil quality refers fitness of a soil within natural or managed ecosystem boundaries to perform functions such as sustaining plant and animal productivity, maintain or enhance water and air quality and support human health and habitation (Doran et al., 1998). It reflects how well a soil can perform functions of maintaining biodiversity and productivity, partitioning water and solute flow, filtering and buffering, nutrient cycling, and providing support for plants and other structures. Soil management has major impact soil quality. Bad management practices will cause land degradation and loss of soil fertility.

Learning Outcome
At the end of this unit, the students are able to
1. Explain the concept of soil quality and its importance towards environmental sustainability.
2. Identify important soil quality indicators and components of soil quality management.
3. Describe the process of land degradation and factors that contributes towards land degradation.
**TOPIC 1: SOIL QUALITY**

**Environmental Sustainability**

- Keeping the four ecosystem processes in GOOD conditions:
  - Effective energy flow
  - Water
  - Mineral cycles
  - Viable ecosystem dynamics
- 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.

**Definition of Soil Quality**

“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;
o for consumers, it may mean plentiful, healthful, and inexpensive food
for present and future generations;
o for naturalists, it may mean soil in harmony with the landscape and its
surroundings;
o 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
  o Soil quality kits, visual assessment procedures, video presentation
    were developed
  o 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
- 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 provides 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 the 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 soils.
  - 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>Relation 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>

Soil Quality Management Component

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.
3. Manage pests and nutrients efficiently:
   o An important function of soil is to buffer and detoxify chemicals, but soil's capacity for detoxification is limited
   o Pesticides and chemical fertilizers have valuable benefits, but they also can harm non-target organisms and pollute water and air if they are mismanaged.
   o Nutrients from organic sources also can pollute when misapplied or over-applied.
   o 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:
   o Compaction reduces the amount of air, water, and space available to roots and soil organisms.
   o Compaction is caused by repeated traffic, heavy traffic, or traveling on wet soil.
   o Deep compaction by heavy equipment is difficult or impossible to remedy, so prevention is essential

5. Keep the ground covered:
   o Bare soil is susceptible to wind and water erosion, and to drying and crusting.
   o Ground cover protects soil, provides habitats for larger soil organisms, such as insects and earthworms, and can improve water availability.
   o 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.

Extreme (1%)

Severe

Moderate (46%)

Light (38%)
TOPIC 2 : LAND DEGRADATION

Land Degradation
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

- **NATURAL**
  - Climate
  - Morphology
  - Terrain
  - Parent material
  - Vegetation
    - Precipitation, Temperature regime, Evapotranspiration
    - Drainage pattern, depth of groundwater, overland flow
    - slope steepness, length
    - chemical composition of bedrock, physical properties
    - plant species, diversity, density, composition

- **ANTHROPOGENIC**
  - Population
    - Density, Lifestyle
  - Land use
    - 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

Chemical Processes:
- Siaking, crusting, compaction
- Compaction, hardening, erosion
- Sub-optimal temperature, anaerobiosis, drought, leaching

Biological Processes:
- Depletion of SOM
- Soil Fauna
- Emission GH gases, decrease in biomass C
- Leaching
- Acidification
- Nutrient imbalance
- Reduction in soil fauna
- Increase in parasitic fauna

Cause of Soil Degradation

Causes of soil degradation worldwide for all land uses.

- Industrialization (1%)
- Overexploitation (7%)
- Overgrazing (33%)
- Agricultural practices (18%)
- Desertification (8%)
- Degradation (8%)

48
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.
3. Agriculture

- Agriculture may last for a few hundreds of 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.
Soil Degradation Mechanisms

Mechanisms of soil degradation worldwide for all land uses.

1. Water Erosion
   - 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.
   - 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 downslope

Examples of sheet erosion (Source: NRCS Photo)

Rill Erosion
- Collection of sheet erosion water into channels (rills) that erode the bottom and side of the rill.
- Gully Erosion
  - Increasing size of rills eventually lead to a Gully or a channel too large for crossing by farm equipment.
2. Wind Erosion
   - Wind erosion is the detachment of soil particles by the wind and moving them to another location.

3. 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 and 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.
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

Additional References

UNIT 6
AIR QUALITY & AIR CONTAMINATION AND POLLUTION

Introduction
Air pollution is caused by the introduction of chemical, particulate matter or biological materials into the atmosphere, causing harm and discomfort for human and/or damage to the environment. The atmosphere is a complex and dynamic system that is essential for supporting life on Earth. The degradation of air quality (such as ozone layer depletion, acid rain, haze, etc.) caused by air pollutants has been a major concern in the 20th century. Currently, another major issue concerning air quality is global warming and its impact on climate change.

Learning Outcome
At the end of this unit, the students are able to
1. Explain the concept of global warming and climate change and its effect on environmental sustainability
2. Identify major sources of greenhouse gasses (GHGs) emissions and mitigation methods for GHGs level reduction.
3. Describes the primary air pollutants, its sources and harmful effect on the atmosphere.
TOPIC 1: AIR QUALITY

Global Warming and Climate Change

- Cause: Increase in the concentration of greenhouse gases
  - Carbon dioxide
  - Nitrous oxide (N₂O)
  - Methane (CH₄)
  - CFC
Figure 2: Greenhouse 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: 147 Watts per m²

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

Outgoing infrared radiation: 245 Watts per m²

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

Infrared radiation from the Earth's surface is absorbed by the greenhouse gases in the atmosphere.

Radiation is converted to heat energy, increasing the temperature of the Earth's surface.

Greenhouse Gases

Earth

Atmosphere
Emission of Greenhouse Gases
Total Greenhouse Gas Emission by Region: 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 ($\text{CH}_4$)</td>
<td>11</td>
</tr>
<tr>
<td>Fertilizers ($\text{N}_2\text{O}$)</td>
<td>37</td>
</tr>
<tr>
<td>Livestock ($\text{CH}_4$)</td>
<td>32</td>
</tr>
<tr>
<td>Residue burning/forest clearing</td>
<td>13</td>
</tr>
<tr>
<td>Manure management ($\text{CH}_4$, $\text{N}_2\text{O}$)</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**

- **Agricultural soils**
  - Nitrous oxide (N\textsubscript{2}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).

- **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.

- **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:
  - Option I: Reduce the amount of emissions (abatement)
  - Option II: Enhance the absorption of carbon dioxide (C sequestration), storing carbon (C sinks)

- Strategies that can be used
  - Increase carbon sequestration.
  - On-farm emission reductions.
  - 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”
On-farm Emissions Reductions

- 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 CO₂ levels lead to a positive growth response in some crops under controlled condition ("carbon fertilization effect").
Air Pollution & Acid Rain

Primary air pollutants

1. 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

2. Hydrocarbon (HC)
   - Remnants in the fuel that did not burn completely.
   - Main source: internal combustion engines, refineries, industry/factories

3. 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
4. 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

5. 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 & NO₂ → NOₓ
   - Primary source: automobile engine.
   - NOₓ are involved in production of secondary pollutants

Additional References
UNIT 7
WATER QUALITY

Introduction
Water quality refers to the physical, chemical and biological characteristics of water and is commonly measured as an indicator of ecosystems health, safety for human contact and drinking water suitability. Water is a basic need for all living organisms on Earth. Therefore, the contamination of water bodies such as river, lakes, etc will have negative impacts on the environment and human health. Some of the major causes of water pollution are; industrial and commercial activities (e.g. manufacturing, mining, and construction), runoff from agricultural areas, urban runoff and discharge of treated and untreated sewage.

Learning Outcome
At the end of this unit, the students are able to
1. Explain the concept of water quality and its importance towards the environment sustainability
2. Describes the major sources of water pollutants and how it affects water quality.
3. Identify major chemical contaminant in water quality for human consumption and its impact on human health.
TOPIC 1: WATER QUALITY

Water Quality as a Global Issue

- Agriculture, as the single largest user of freshwater on a global basis and as a major cause of degradation of surface and groundwater resources through erosion and chemical runoff, has cause to be concerned about the global implications of water quality.
- The associated agrofood-processing industry is also a significant source of organic pollution in most countries.

Water Quality as a Global Issue: Aquaculture is now recognised as a major problem in freshwater, estuarine and coastal environments, leading to eutrophication and ecosystem damage

- The principal environmental and public health dimensions of the global freshwater quality problem:
  - Five million people die annually from water-borne disease
  - Ecosystem dysfunction and loss of biodiversity
  - Contamination of marine ecosystems from land-based activities
  - Contamination of groundwater resources
  - Global contamination by persistent organic pollutants

- Experts predict that, because pollution can no longer be remedied by dilution (i.e. the flow regime is fully utilised) in many countries, freshwater quality will become the principal limitation for sustainable development in these countries early in the next century.

- This ‘crisis’ is predicted to have the following global dimensions:
Decline in sustainable food resources (e.g. freshwater and coastal fisheries) due to pollution
Cumulative effect of poor water resource management decisions because of inadequate water quality data in many countries
Many countries can no longer manage pollution by dilution, leading to higher levels of aquatic pollution
Escalating cost of remediation and potential loss of “creditworthiness”

Water Pollutants

• Biological Impurities
  o Bacteria, Virus, Parasites
    – Years ago, waterborne diseases accounted for millions of deaths. Even today in underdeveloped countries, an estimated 25,000 people will die daily from waterborne disease.
    – Effects of waterborne microorganisms can be immediate and devastating. Therefore, microorganisms are the first and most important consideration in making water acceptable for human consumption.

    – Generally speaking, modern municipal supplies are relatively free from harmful organisms because of routine disinfection with chlorine or chloramines and frequent sampling.
    – This does not mean municipal water is free of all bacteria. Those of us with private wells and small rural water systems have reason to be more concerned about the possibility of microorganism contamination from septic tanks, animal wastes, and other problems.

• Inorganic Impurities
Dirt and Sediment or Turbidity
- Most waters contain some suspended particles which may consist of fine sand, clay, soil, and precipitated salts. Turbidity is unpleasant to look at, can be a source of food and lodging for bacteria, and can interfere with effective disinfection.
- These substances are dissolved rock and other compounds from the earth. The presence and amount of total dissolved solids in water represents a point of controversy among those who promote water treatment products.

High Levels of Total Dissolved Solids (TDS) in Water
- High TDS results in undesirable taste which could be salty, bitter, or metallic.
- High TDS water is less thirst quenching.
- Some of the individual mineral salts that make up TDS pose a variety of health hazards. The most problematic are Nitrates, Sodium, Sulfates, Barium, Copper, and Fluoride.
- Some of the individual mineral salts that make up TDS pose a variety of health hazards. The most problematic are Nitrates, Sodium, Sulfates, Barium, Copper, and Fluoride.
- The EPA Secondary Regulations advise a maximum level of 500mg/liter (500 parts per million-ppm) for TDS. Numerous water supplies exceed this level. When TDS levels exceed 1000mg/L, it is generally considered unfit for human consumption.
- High TDS interferes with the taste of foods and beverages, and makes them less desirable to consume.
- High TDS make ice cubes cloudy, softer, and faster melting.
- Water with higher TDS is considered by some health advocates to have a poorer cleansing effect in the body than water with a low level of TDS. This is because water with low dissolved solids has a greater capacity of absorption than water with higher solids.

Toxic Metals or Heavy Metals
- Among the greatest threats to health are the presence of high levels of toxic metals in drinking water - Arsenic, Cadmium, Lead,
Mercury, and Silver. Maximum limits for each are established by the EPA Primary Drinking Water Regulations.

- Other metals such as Chromium and Selenium, while essential trace elements in our diets, have limits imposed upon them when in water because the form in which they exist may pose a health hazard. Toxic metals are associated with nerve damage, birth defects, mental retardation, certain cancers, and increased susceptibility to disease.

  - Asbestos
    - Exists as microscopic suspended mineral fibers in water.
    - Its primary source is asbestos-cement pipe which was commonly used after World War II for city water supplies. It has been estimated that some 200,000 miles of this pipe is presently in use to transport our drinking water. Because these pipes are wearing, the deadly substance of asbestos is showing up with increasing frequency in drinking water. It has been linked with gastrointestinal cancer.

  - Radioactivity
    - Even though trace amounts of radioactive elements can be found in almost all drinking water, levels that pose serious health hazards are fairly rare—for now.
    - Radioactive wastes leach from mining operations into groundwater supplies. The greatest threat is posed by nuclear accidents, nuclear processing plants, and radioactive waste disposal sites. As containers containing these wastes deteriorate with time, the risk of contaminating our aquifers grows into a toxic time bomb.

- Organic Impurities
  - Tastes and Odours
    - If your water has a disagreeable taste or odor, chances are it is due to one or more of many organic substances ranging from decaying vegetation to algae; hydrocarbons to phenols. It could also be TDS and a host of other items.

  - Pesticides and Herbicides
- The increasing use of pesticides and herbicides in agriculture shows up in the water we drink.
- Rain and irrigation carry these deadly chemicals down into the groundwater as well as into surface waters.
- As our reliance upon groundwater is escalating, so is its contamination. Our own household use of herbicide and pesticide substances also contributes to actual contamination.
- These chemicals can cause circulatory, respiratory and nerve disorders.

**Chlorine**

- Trihalomethanes (THM's) are formed when chlorine, used to disinfect water supplies, interacts with natural organic materials (e.g. by-products of decayed vegetation, algae, etc.). This creates toxic organic chemicals such as chloroform, and Bromodichloromethane.
- A further word about chlorine: "Scientists at Columbia University found that women who drank chlorinated water ran a 44% greater risk of dying of cancer of the gastrointestinal or urinary tract than did women who drank non-chlorinated water!"
- Chlorinated water has also been linked to high blood pressure and anemia. Anemia is caused by the deleterious effect of chlorine on red blood cells.
### Water Quality Recommendation for Human Drinking Water (Selected Contaminations)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Maximum Acceptable Concentration</th>
<th>Potential Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>0.01 (provisional)</td>
<td>Skin damage or problems with circulatory system; may have increased risk of cancer</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.003</td>
<td>Kidney damage</td>
</tr>
<tr>
<td>Chlorine</td>
<td>No health concerns at usual concentrations</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>0.05 (provisional)</td>
<td>Allergic dermatitis</td>
</tr>
<tr>
<td>Copper</td>
<td>0.02</td>
<td>Short-term exposure: gastrointestinal distress; Long-term exposure: liver or kidney damage; in cases of Wilson's disease consult physician about maximum acceptable concentration</td>
</tr>
<tr>
<td>Fluoride</td>
<td>1.5</td>
<td>Pain and tenderness of the bones; mottled teeth in children</td>
</tr>
<tr>
<td>Iron</td>
<td>No health concerns at usual concentrations</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.01</td>
<td>Infants and children: physical or mental development delays, slight attention span deficits and learning disabilities; Adults: kidney problems, hypertension</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.001 (total)</td>
<td>Kidney damage</td>
</tr>
<tr>
<td>Nitrate (as N)</td>
<td>50 (short term)</td>
<td>Infants &lt;6-month old: blue baby syndrome</td>
</tr>
<tr>
<td>Nitrate (as NO₃)</td>
<td>3 (short term), 0.2 (long term, provisional)</td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td>0.01</td>
<td>Hair or fingernail loss, numbness in extremities, circulatory problems</td>
</tr>
<tr>
<td>Sulfate</td>
<td>No health concerns at usual concentration</td>
<td></td>
</tr>
</tbody>
</table>
Additional References

UNIT 8
SUSTAINABLE AGRICULTURE PRACTICES

Introduction
Sustainable agriculture is an integrated farming system that practices ecological principles and emphasize on organisms-environment relationships, which over the long term will:

- satisfy human food and fiber needs
- enhance environmental quality and the natural resource base upon which the agricultural economy depends
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls
- sustain the economic viability of farm operations
- Enhance the quality of life for farmers and society as a whole.

There are various practices that can be used for sustainable agriculture. This section will discuss some of these practices.

Learning Outcome
At the end of this unit, the students are able to

1. Explain the concepts of sustainable agriculture and identify the practices used for sustainable agriculture

2. Describe what is Integrated Pest Management (IPM) and the practices used under IPM for sustainable agriculture.
TOPIC 1. SUSTAINABLE AGRICULTURE PRACTICES

Cover crops and green manures

- Perennial and biennial cereal crops, annual green manures, and annual cover crops are important for building soil in field-cropping systems.
- Each farmer will have to determine which cover crops are most appropriate to his or her system.

![Cover crops in an orchard reduce soil erosion.](NRCS photo by Gary Kramer, 2001)

**Manures**

- Manures are organic materials added to the soil to increase crop production.
- They are biological in origin.
- The organic matter content is bulky and large and the nutrient content is small.
- Since the manures contain nutrients in small quantities they have to be used in bulk.
- Since the manure contains a lot of organic matter, it increases the water holding capacity in sandy soils and drainage in clayey soils.
- Organic manures provide food for soil organisms like earthworms which are responsible for improving soil quality.
- Organic manures include
  - (i) Farmyard manure (FYM),
  - (ii) Compost,
  - (iii) Green manure,
  - (iv) Vermicompost
Farmyard Manure (FYM)
- This is the decomposed mixture of excreta (dung) and urine of farm animals like cow, horse, goat and sheep along with leftover hay and fodder.
- They are readymade manures and contain nitrogen, phosphorus and potassium.
- Farmyard manure when collected in the field and stored in an exposed condition over a long period shows considerable loss of ammonia which is a loss of fertilizing value.
- To prevent this loss the dung is stored in pits which are about a metre deep.
- When the pits are filled to the top, the surface is sealed with mud slurry.
- The manure is ready for use in about 4-5 months.
- Microbes play an important role in decomposing the dung and converting it into manure.

Compost
- This consists of a variety of farm wastes such as farm weeds, straw, sugarcane refuse, rotting vegetables, kitchen wastes, crop stubble, ground nut and rice husk.
- Composting is a biological process in which aerobic and anaerobic microorganisms decompose organic matter.
- A trench of suitable size 4-5 m long, 1.5 to 1.8 m broad and 1.0 to 1.8 m deep is dug.
- A layer of well mixed refuse of about 30 cm thickness is spread in the pit.
- A slurry of cow dung, earth and water is poured over this layer to keep it moist.
- Another layer of the mixed refuse is spread in the pit till the heap rises to a height of 45 to 60 cm above ground level.
- Finally the top is covered with a thin layer of mud.
- After 3 months of decomposition the layers are well mixed and covered again.
- 3 months later the compost is ready to be used in the fields.
Green Manure

- Green manuring is the practice of growing and ploughing in, the green crops, into the soil.
- It is a cheap and effective method that increases soil fertility as it can supplement farmyard and other organic manures and is more cost effective.
- Green manures add nitrogen and organic matter to the soil for improving crop productivity.
- They also improve soil aeration and drainage conditions.
- Both leguminous and non-leguminous plants are grown for making green manure.
- This type of manuring is used in fields in which crops like rice, maize, sugarcane, cotton, wheat etc., which require high nutrient input are raised.
- There is 30 - 50% increase in the crop yield by using green manure.
- The green manure crops are grown in the field for about 6 - 8 weeks and ploughed into the soil during the flowering stage.
- The plants are allowed to remain buried for about 1 - 2 months.
- During this period, the plant gets totally decomposed.
- The soil is then tilled and the next food crop is sowed.
- By alternating the green manure crop with food crop the nitrogen and organic content of the soil is maintained.

Vermicompost

- Vermicompost is a type of soil made by earthworms and microorganisms as they eat through organic wastes.
- The soil thus produced is mainly worm excreta and finely ground soil.
- Organic wastes can be collected and fed on by worms so that the end product is the broken down version of the original organic wastes.
- Worm castings (excreta) in the vermicompost have nutrients that are 97% utilizable by plants.
- Besides providing nutrients to plants, worms also upturn the soil thus making the soil lighter.
Composts, Manures, and Fertilizers

- Crop rotations, cover-cropping, and green-manuring are key strategies for soil building, which is the foundation of sustainable farming.
- However, modern production systems place high demands on land resources, requiring additional attention to soil fertility management.
- Manures and composts are ideal resources for nutrients cycling.
- Composts or aged manures are preferred.
- Compost is better than unaged manure and other organic amendments in that it has a good C/N ratio.
- Compost can be safely applied at rates of 12 tons per ha
- In sandy soils, compost’s stable organic matter helps absorbing and retaining water.
- Fresh plant material (green manure), on the other hand, retains its waxy leaf coating and cannot perform the same function until thoroughly digested by microbes.
- Several conventional fertilizers (such as ammonium sulphate) should be avoided in sustainable farming because of their harmful effects on soil organisms, structure and acidity.
- Additions of lime, phosphate rocks, and other fertilizers should be tested first to avoid soil imbalances and unnecessary expenditure.

Weed Management

- Weed management poses one of the greatest challenges to the crafting of sustainable production systems.
- However, weed populations tend to decline in severity as soil health builds.
- Basic understanding of weed ecology and the influence of cropping patterns on weed communities will help growers refine their use of cultural and mechanical techniques.
- In general, weed prevention in crops is based on developing a sound rotation, preventing existing weeds setting seed, and minimizing arrival of new weed seeds from outside the field.
- In a grazing system, weed management may be as simple as adding other animal species such as goats or sheep to a cattle herd to convert weeds into cash.
Insect Pest Management

- Insect pests can have a serious impact on farm income. In ecologically balanced farm production systems, insect pests are always present, but massive outbreaks resulting in severe economic damage are minimized.
- This results in good part from the presence of natural control agents — especially predatory and parasitic insects, mites, and spiders—that keep pest populations in check.
- To restore populations of beneficial insects, reduce pesticide use that harm them.
TOPIC 2. INTEGRATED PEST MANAGEMENT (IPM)

- IPM adopts cultural, physical, biological, and chemical practices to minimize crop losses.
- Monitoring, record keeping, and life-cycle information about pests and their natural enemies are used to determine which control measures are needed to keep pests below an economic threshold.
- Biological control — use of living organisms to control crop pests — is one of the pillars of IPM.
- Biocontrol agents may be predatory, parasitic, or pathogenic; they may also be either "natural" (such as wild beneficial insects) or "applied" (organisms are introduced).
- Biocontrol agents include insects, mites, bacteria, fungi, viruses, and nematodes (eg *Steinernema* species transmit pathogens to their prey as a form of indirectly applied biocontrol).
Examples of biocontrol agents
Plant Disease Management

- The first step towards preventing serious disease problems is the production of healthy plants nurtured by a microbially active soil.

- Healthy soil suppresses root diseases naturally; the primary means to create disease-suppressive soil is to add biologically active compost at appropriate rates with balanced mineral levels.

- Supplemental strategies include crop rotation, resistant cultivars, good soil drainage, adequate aeration, and clean seeds.

Resistant Plants and Cultivars

- One of the most important components in an integrated disease control program is the selection and planting of cultivars that are resistant to pathogens.

- The term resistance usually describes the plant host’s ability to suppress or retard the activity and progress of a pathogenic agent, which results in the absence or reduction of symptoms.

Site Selection

- Plant-pathogenic fungi such as Armillaria, Fusarium (the wilt-causing species), Plasmodiophora, Sclerotium, and Verticillium are true soil inhabitants and will persist in soil for many years, even in the absence of a plant host.

- Planting situations that create risks should also be avoided, such as pastures, foothills, riverbanks, grasslands, and other areas that support weeds and natural vegetation often are reservoirs of pathogens.

Exclusion

- The practice of keeping out any materials or objects that are contaminated with pathogens or diseased plants and preventing them from entering the production system.

- Growers should purchase seed that has been tested and certified to be below a certain threshold infestation level or that has been treated to reduce pathogen infestation levels.
Applying Control Materials

- Oils, plant extracts, and other natural plant products are being investigated for use as disease-control sprays.
- Bicarbonate-based fungicides have recently become available for control of plant disease, which shows acceptable activity against powdery mildew and a few other disease.
- However, it is unknown whether bicarbonate alone will provide season-long protection for an organically grown crop.

Cultural Practices

- Crop rotation — rotation using diverse crops, inclusion of cover crops, and appropriate use of fallow (host-free) periods all can contribute to the reduction of inoculum levels for soil borne pathogens and increase diversity in soil microflora.
- Other plants, besides being revenue-generating crops, also have suppressive effect on disease.
- For example, after broccoli and other crucifer crops are harvested and the plant residue is plowed into the soil, the decomposition of the broccoli stems and leaves release natural chemicals that can significantly reduce the number of Verticillium dahliae microsclerotia.
- Irrigation management is clearly an important factor when it comes to disease control.
- Regardless of the irrigation method, timing and duration of irrigations should satisfy crop water requirement without allowing for excess water.
- Bacterial foliar diseases are particularly dependent upon rain and sprinkler irrigation.
Additional References

UNIT 9

POSTHARVEST HANDLING

Introduction

Postharvest handling is the immediate stage of crop production after harvest, which includes cooling, cleaning, sorting and packing. Once removed or separated from the parent plant, the crop produce will begin to deteriorate. Effective postharvest handling can help to maintain the quality of the commodity and reduces postharvest losses.

Learning Outcome

At the end of this unit, the students are able to

1. Explain the concept of postharvest handling and its importance towards food safety and quality.
2. Describes the major sources of contamination during postharvest handling.
3. Identify major components of fresh commodity harvesting and handling.
**TOPIC 1: Food Safety**

**Food Safety**
- Source of danger
  - Biological
  - Chemical
- Microbe – high risk
- Human diseases
- Reduce storage/shelf life and quality

**Danger Levels for Commodities**

<table>
<thead>
<tr>
<th>Level</th>
<th>Commodity</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leafy Vegetables</td>
<td><em>Escherichia coli, Salmonella enterica, Shigella spp. Hepatitis A virus, Noro viruses (Cyclospora cayetanensis, Cryptosporidium, etc)</em></td>
</tr>
<tr>
<td>2</td>
<td>Berries</td>
<td><em>Cyclospora cayetanensis, Cryptosporidium parvum, Non viruses (frozen berries), Hepatitis A</em></td>
</tr>
<tr>
<td></td>
<td>Chives</td>
<td>Hepatitis A, virus <em>Shigella spp</em></td>
</tr>
<tr>
<td></td>
<td>Melons</td>
<td><em>Salmonella enterica, Escherichia coli</em></td>
</tr>
<tr>
<td></td>
<td>Sprouts</td>
<td><em>Salmonella enterica, Escherichia coli, Noro viruses</em></td>
</tr>
<tr>
<td></td>
<td>Tomato</td>
<td><em>Salmonella enterica, Hepatitis A virus</em></td>
</tr>
</tbody>
</table>

*Source: WHO, FAO (2008)*
Danger of Microbes in Fresh Produce

- Workers’ health
  - Sickness
  - Toilet facilities & clean water
- Usage patterns & practices
  - Raw material usage
  - Preparation practices
- Manure fertilizers
- Immature compost
- Other organic waste


Issues
1. High quality lettuce or other leafy green
2. Concern about dehydration, wilting
3. Rinse with water in tanks, crisping
4. Quality of water initially and after use?
5. More the water is used, more contaminated
When should hands be washed?

- Before handling food
- After
  - touching parts of the body
  - using the toilet
  - coughing, sneezing, using a handkerchief
  - using tobacco, eating, drinking
  - taking out the garbage,
  - picking up dropped items,
  - contacting cleaning chemicals

Danger in fresh produce: Chemicals

- Pesticides and heavy metals
  - Arsenic
  - Cadmium
  - Chromium
  - Copper
  - Lead
  - Mercury
  - Nickel
  - Selenium
  - Zinc
Handling Principles

- Harvest at mature stage
- Handle with care
- Protection from sunlight
- Simple and clean handling (workers hygiene)
- Careful choosing, classification & packaging
- Box arrangement
- Cool immediately
- Know the product and market needs
- Workers comfort

Handling Steps

- Harvest
- Selection (injuries, spoilt)
- Wash, dry
- Separate according to size/colour
- Packaging 'poly bag'
- Box, Pallet
- Pre-cooling, temporary storage
Field Packaging vs. Handling House Packaging

Packaging in field

Packaging in handling house

Field Harvest & Packaging

Handling House Harvest & Packaging
Malaysian Organic Scheme / Skim Organik Malaysia (SOM) Standard

Post Harvest
- Use potable water for washing of produce
- Manage waste from handling to have minimum effect on environment-compost
- Analyze water source once every 2 years - microbial, chemical and mineral pollutants to ensure it is potable
- Prohibit use of synthetic additives and irradiation to prolong storage or shelf life

Good Manufacturing Practices (GMP)
- Storage
- Packaging
- Transportation

Packaging
- Packaging materials clean and hygienic
- Cannot be treated with undesirable or prohibited substances
- Environmentally friendly packaging material
- Cannot be kept in containers, packaging or wrapping material used for conventional produce unless cleaned
- Prohibit PVC & chlorine based plastics unless no alternatives
- Styrofoam - prohibited for use as packaging-in direct contact with the organic produce

Storage of Organic Products
- Labeled and protected from co-mingling with non-organic products
- Protected from contact with non-permitted substances
- Cannot be stored together with non-organic products unless clearly identified, separated & measures taken to prevent mixing
- Storage areas cleaned using methods and materials permitted
• Prevent possible contamination from any pesticide or other treatment not listed

Harvesting
• Workers hygiene - prevent physical, microbiological & chemical contamination
• Identify farm produce from conventional farms, identified
• Label at all times to prevent co-mingling of organic produce

Conclusion
Postharvest handling can significantly affect the food production due to losses and quality degradation. Therefore, attention and appropriate management practices are needed to reduce postharvest losses.

Additional References
UNIT 10
CERTIFICATION SCHEME FOR GOOD AGRICULTURAL PRACTICES

Introduction

Good Agricultural Practices (GAP) is defined as a collection of principles applied in on-farm production and post-production processes with the intention of producing safe and healthy food and non-food agricultural products while maintaining economical, social and environmental sustainability. In Malaysia, there are some codes, standards and regulation have been developed to codify agricultural practices at farm level for a range of commodities. Skim Amalan Ladang Baik Malaysia (SALM) was developed to recognized farmers that practices GAP while Skim Organik Malaysia (SOM) was developed to recognize farmers that produce organic crops according to the SOM standards.

Learning Outcome

At the end of this unit, the students are able to

1. Explain the concept of good agricultural practices (GAP) and the need for certification for farmers that practices GAP.
2. Identify the major certification bodies for GAP in Malaysia and globally.
3. Describe the main elements and benefits for certification schemes used for GAP.
TOPIC 1: SALM (SKIM AMALAN LADANG BAIK MALAYSIA) / GOOD AGRICULTURE PRACTICE (GAP)

- Certification scheme designed by the Department of Agriculture to recognise farms that adopt GAP which, is implemented in an environmentally friendly way, ensures workers' welfare and safety and produces products that are of quality, safe and suitable for consumption. The scheme is developed based on Malaysian Standard MS 1784:2005 Crop Commodities — Good Agriculture Practices (GAP).
- Good Agriculture Practice is an integrated farming system aimed at managing all resources of crop production in a safe and sustainable way.
- The system is expected to increase farm productivity with the production of safe and quality food that takes into account workers' welfare, safety and health and protection of the environment.

Objectives of SALM/GAP
- GAP acts as a thrust to the Agro-Technological Extension System of the Department of Agriculture.
- GAP is adopted as a practice by producers in carrying out their farm activities.

Benefits of SALM/GAP
- Production of quality and safe crop produce, due to pesticide residues which are at the permitted level
- Reduction of pollution to the environment.
- Emphasis on the importance of integrated pest management
- Reduction of pesticide usage
- Guarantee of workers' safety and welfare
- Increase of crop yield
- Crop produce which are competitive at domestic and international markets
- Helps develop the national agricultural industry in an environmentally and sustainable way
Elements of SALM/GAP

- Traceability
- Record Keeping and Internal Audit
- Planting Materials and Root Stocks
- Site History and Site Management
- Soil and Substrate Management
- Fertiliser Management (Organic and Inorganic)
- Irrigation and Fertigation
- Crop Protection
- Harvesting
- Post Harvest Handling
- Pesticide Residue Analysis of Produce
- Waste and Pollution Management, Recycling and Re-Use
- Workers' Health, Safety and Welfare
- Environmental Issues
- Record of Complaints
- Legal Requirements
TOPIC 2: SKIM ORGANIK MALAYSIA (SOM)

- The standard of Organic Agriculture for Skim Organik Malaysia (SOM) is based on the Malaysian Standard MS 1529:2001 — The production, processing, labeling and marketing of plant based organically produced foods.
- In addition to this, the SOM Standard also encompasses rules or criteria which are derived from specific legal provisions of national laws to control hazards that impact the environment, food safety and workers' health and safety.

Benefits of SOM

- Benefit to Producers
  - Yield produced from farms that have been certified can be labelled as organic product and have the right to use the Malaysian Organic label on these products.
  - With this label, the products can be marketed as an organic product at a premium price.
- Benefit to Users
  - User have the assurance that the product bought are truly organic and does not have any unwanted chemical residue as the product has been endorsed as in compliance to the Malaysian Organic Standard.
- Benefit to the Environment and Workers
  - As the use of chemical fertiliser and pesticide are prohibited under the organic farming scheme, it directly translates that no contamination to the environment or the possibility of poisoning among manufacturers or workers can occur.
Elements of SOM

- Traceability
- Record Keeping
- General Production Management
- Responsibility for Organic Integrity
- Conversion
- Buffer Crop and Buffer Distance
- Land and Soil Management
- Water Management
- Crop Production
- Handling
- Storage
- Packaging
- Transport
- Workers' Health, Safety and Welfare
- Analysis of Produce
- Waste Management
- Record of Complaints
Conclusion

Certification is an important component in food production to ensure high quality products and product traceability. In line with the global trend, Malaysia has come up with schemes such as SALM and SOM to meet such demand.

Additional References