Supporting Study material
Sustainable Development in Agriculture (Course code- CC- 05 GEO-SDA)

Introduction

Sustainable agriculture is farming in sustainable ways meeting society's present food and textile needs, without compromising the ability for current or future generations to meet their needs. It can be based on an understanding of ecosystem services. There are many methods to increase the sustainability of agriculture. When developing agriculture within sustainable food systems, it is important to develop flexible business process and farming practices. Agriculture has an enormous environmental footprint, playing a significant role in causing climate change (food systems are responsible for one third of the anthropogenic greenhouse gas emissions), water scarcity, water pollution, land degradation, deforestation and other processes; it is simultaneously causing environmental changes and being impacted by these changes. Sustainable agriculture consists of environment friendly methods of farming that allow the production of crops or livestock without damage to human or natural systems. It involves preventing adverse effects to soil, water, biodiversity, surrounding or downstream resources—as well as to those working or living on the farm or in neighboring areas. Elements of sustainable agriculture can include permaculture, agroforestry, mixed farming, multiple cropping, and crop rotation.

Definition

The term "sustainable agriculture" was defined in 1977 by the USDA as an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fibre needs
- enhance environmental quality and the natural resource base upon which the agriculture economy depends
- make the most efficient use of non-renewable 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.

Aims and objective

A common consensus is that sustainable farming is the most realistic way to feed growing populations. In order to successfully feed the population of the planet, farming practices must consider future costs–to both the environment and the communities they fuel. The fear of not being able to provide enough resources for everyone led to the adoption of technology within the sustainability field to increase farm productivity. The ideal end result of this advancement is the ability to feed ever-growing populations across the world. The growing popularity of sustainable agriculture is connected to the wide-reaching fear that the planet's carrying capacity (or planetary boundaries), in terms of the ability to feed humanity, has been reached or even exceeded.

Key principles

There are several key principles associated with sustainability in agriculture:

1. The incorporation of biological and ecological processes such as nutrient cycling, soil regeneration, and nitrogen fixation into agricultural and food production practices.
2. Using decreased amounts of non-renewable and unsustainable inputs, particularly environmentally harmful ones.
3. Using the expertise of farmers to both productively work the land as well as to promote the self-reliance and self-sufficiency of farmers.
4. Solving agricultural and natural resource problems through the cooperation and collaboration of people with different skills. The problems tackled include pest management and irrigation.

Major factors affecting the ecological balance and sustainability of agricultural resources are:

a) Land/soil related problems
• Soil degradation
• Deforestation
• Accelerated soil erosion
• Siltation of reserves
• Wind erosion
b) Irrigation related problems
• Rise in groundwater table & water logging
• Soil salinization & alkalization
• Over- exploitation of groundwater
c) Indiscriminate use of agro-chemicals
• Fertilizer pollution
• Pesticide pollution
d) Environmental pollution
• Greenhouse effect
• Depletion emissions
• Methane emission
• Eutrophication

Factors affecting types of farming

The type of farming practiced in a particular region is influenced by a range of factors that include:

1. **Climate**: Climate is one of the most important factors that influence the type of farming practiced in a particular region. Temperature, rainfall, and other climatic factors determine the type of crops that can be grown in a particular region. For example, regions with high rainfall and moderate temperatures are suitable for growing crops like rice, while regions with low rainfall and hot temperatures are suitable for growing crops like millet.
2. **Soil type**: The type of soil in a region also determines the type of crops that can be grown. Soil properties such as texture, fertility, and pH affect the growth of crops. For

example, crops like paddy require fertile, clayey soils, while crops like maize require well-drained soils.
3. **Topography**: The topography of a region, including the slope and altitude, affects the type of crops that can be grown. Regions with steep slopes are unsuitable for mechanized farming, while high-altitude regions are not suitable for certain crops.
4. **Water availability**: The availability of water for irrigation is an important factor in determining the type of farming system. Regions with abundant water resources are suitable for rice cultivation, while regions with low water resources are suitable for crops that require less water.
5. **Market demand**: The type of farming practised is also influenced by market demand. Farmers tend to produce crops that are in high demand in the market, to ensure profitability. For example, regions with high demand for vegetables are suitable for vegetable cultivation.
6. **Access to inputs**: The availability of inputs such as seeds, fertilizers, and pesticides can influence the type of farming practised. Regions with easy access to inputs are more likely to practice intensive farming, while regions with limited access to inputs may practice subsistence farming.
7. **Cultural factors**: Cultural factors such as traditions and customs can influence the type of farming practised. For example, in some regions, certain crops may have cultural significance, leading to their widespread cultivation.
8. **Economic factors**: The economic conditions of a region can influence the type of farming practised. Regions with strong economies are more likely to adopt modern farming methods, while regions with weak economies may continue to rely on traditional farming practices.

In summary, several factors influence the type of farming practised in a region, including climate, soil type, topography, water availability, market demand, access to inputs, cultural factors, and economic conditions. Understanding these factors can help farmers make informed decisions about the type of farming system to adopt.

Environmental factors

A farm that can "produce perpetually", yet has negative effects on environmental quality elsewhere is not sustainable agriculture. An example of a case in which a global view may be warranted is the application of fertilizer or manure, which can improve the productivity of a farm but can pollute nearby rivers and coastal waters (eutrophication). The other extreme can also be undesirable, as the problem of low crop yields due to exhaustion of nutrients in the soil has been related to rainforest destruction. In Asia, the specific amount of land needed for sustainable farming is about 12.5 acres which include land for animal fodder, cereal production as a cash crop, and other food crops. In some cases, a small unit of aquaculture is included.

Nitrates are used widely in farming as fertilizer. Unfortunately, a major environmental problem associated with agriculture is the leaching of nitrates into the environment. Possible sources of nitrates that would, in principle, be available indefinitely, include:

1. recycling crop waste and livestock or treated human manure[26]
2. growing legume crops and forages such as peanuts or alfalfa that form symbioses with nitrogen-fixing bacteria called rhizobia[27]

3. industrial production of nitrogen by the Haber process uses hydrogen, which is currently derived from natural gas (but this hydrogen could instead be made by electrolysis of water using renewable electricity)
4. genetically engineering (non-legume) crops to form nitrogen-fixing symbioses or fix nitrogen without microbial symbionts.

The last option was proposed in the 1970s, but is only gradually becoming feasible Sustainable options for replacing other nutrient inputs such as phosphorus and potassium are more limited.

Other options include long-term crop rotations, returning to natural cycles that annually flood cultivated lands (returning lost nutrients) such as the flooding of the Nile, the long-term use of biochar, and use of crop and livestock landraces that are adapted to less than ideal conditions such as pests, drought, or lack of nutrients. Crops that require high levels of soil nutrients can be cultivated in a more sustainable manner with appropriate fertilizer management practices.

Phosphate

Phosphate is a primary component in fertilizer. It is the second most important nutrient for plants after nitrogen, and is often a limiting factor. It is important for sustainable agriculture as it can improve soil fertility and crop yields. Phosphorus is involved in all major metabolic processes including photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis, and respiration. It is needed for root ramification and strength and seed formation, and can increase disease resistance.

Phosphorus is found in the soil in both inorganic and organic forms and makes up approximately 0.05% of soil biomass. Phosphorus fertilizers are the main input of inorganic phosphorus in agricultural soils and approximately 70%–80% of phosphorus in cultivated soils is inorganic. Long-term use of phosphate-containing chemical fertilizers causes eutrophication and deplete soil microbial life, so people have looked to other sources.

Phosphorus fertilizers are manufactured from rock phosphate.[36] However, rock phosphate is a non-renewable resource and it is being depleted by mining for agricultural use: peak phosphorus will occur within the next few hundred years, or perhaps earlier.

Potassium

Potassium is a macronutrient very important for plant development and is commonly sought in fertilizers. This nutrient is essential for agriculture because it improves water retention, nutrient value, yield, taste, color, texture and disease resistance of crops. It is often used in the cultivation of grains, fruits, vegetables, rice, wheat, millets, sugar, corn, soybeans, palm oil and coffee. Potassium chloride (KCl) represents the most widely source of K used in agriculture, accounting for 90% of all potassium produced for agricultural use The use of KCl leads to high concentrations of chloride (Cl^-) in soil harming its health due to the increase in soil salinity, imbalance in nutrient availability and this ion's biocidal effect for soil organisms. In consequences the development of plants and soil organisms is affected, putting at risk soil biodiversity and agricultural productivity. A sustainable option for replacing KCl are chloride-free fertilizers, its use should take into account plants' nutrition needs, and the promotion of soil health.

Soil

Land degradation is becoming a severe global problem. According to the Intergovernmental Panel on Climate Change: "About a quarter of the Earth's ice-free land area is subject to human-induced degradation (medium confidence). Soil erosion from agricultural fields is estimated to be currently 10 to 20 times (no tillage) to more than 100 times (conventional tillage) higher than the soil formation rate (medium confidence)." Almost half of the land on earth is covered with dry land, which is susceptible to degradation. Over a billion tonnes of southern Africa's soil are being lost to erosion annually, which if continued will result in halving of crop yields within thirty to fifty years. Improper soil management is threatening the ability to grow sufficient food. Intensive agriculture reduces the carbon level in soil, impairing soil structure, crop growth and ecosystem functioning, and accelerating climate change. Modification of agricultural practices is a recognized method of carbon sequestration as soil can act as an effective carbon sink. Soil management techniques include no-till farming, keyline design and windbreaks to reduce wind erosion, reincorporation of organic matter into the soil, reducing soil salinization, and preventing water run-off.[58][59]

Land

As the global population increases and demand for food increases, there is pressure on land as a resource. In land-use planning and management, considering the impacts of land-use changes on factors such as soil erosion can support long-term agricultural sustainability, as shown by a study of Wadi Ziqlab, a dry area in the Middle East where farmers graze livestock and grow olives, vegetables, and grains. Looking back over the 20th century shows that for people in poverty, following environmentally sound land practices has not always been a viable option due to many complex and challenging life circumstances. Currently, increased land degradation in developing countries may be connected with rural poverty among smallholder farmers when forced into unsustainable agricultural practices out of necessity.

Converting big parts of the land surface to agriculture has severe environmental and health consequences. For example, it leads to rise in zoonotic disease (like the Coronavirus disease 2019) due to the degradation of natural buffers between humans and animals, reducing biodiversity and creating larger groups of genetically similar animals.

Land is a finite resource on Earth. Although expansion of agricultural land can decrease biodiversity and contribute to deforestation, the picture is complex; for instance, a study examining the introduction of sheep by Norse settlers (Vikings) to the Faroe Islands of the North Atlantic concluded that, over time, the fine partitioning of land plots contributed more to soil erosion and degradation than grazing itself.

The Food and Agriculture Organization of the United Nations estimates that in coming decades, cropland will continue to be lost to industrial and urban development, along with reclamation of wetlands, and conversion of forest to cultivation, resulting in the loss of biodiversity and increased soil erosion.

Energy

In modern agriculture, energy is used in on-farm mechanisation, food processing, storage, and transportation processes. It has therefore been found that energy prices are closely linked

to food prices. Oil is also used as an input in agricultural chemicals. The International Energy Agency projects higher prices of non-renewable energy resources as a result of fossil fuel resources being depleted. It may therefore decrease global food security unless action is taken to 'decouple' fossil fuel energy from food production, with a move towards 'energy-smart' agricultural systems including renewable energy. The use of solar powered irrigation in Pakistan is said to be a closed system for agricultural water irrigation. .

Water

In some areas sufficient rainfall is available for crop growth, but many other areas require irrigation. For irrigation systems to be sustainable, they require proper management (to avoid salinization) and must not use more water from their source than is naturally replenishable. Otherwise, the water source effectively becomes a non-renewable resource. Improvements in water well drilling technology and submersible pumps, combined with the development of drip irrigation and low-pressure pivots, have made it possible to regularly achieve high crop yields in areas where reliance on rainfall alone had previously made successful agriculture unpredictable. However, this progress has come at a price. In many areas, such as the Ogallala Aquifer, the water is being used faster than it can be replenished.

According to the UC Davis Agricultural Sustainability Institute, several steps must be taken to develop drought-resistant farming systems even in "normal" years with average rainfall. These measures include both policy and management actions:

1. improving water conservation and storage measures
2. providing incentives for selection of drought-tolerant crop species
3. using reduced-volume irrigation systems
4. managing crops to reduce water loss
5. not planting crops at all.

Indicators for sustainable water resource development include the average annual flow of rivers from rainfall, flows from outside a country, the percentage of water coming from outside a country, and gross water withdrawal. It is estimated that agricultural practices consume 69% of the world's fresh water.

Importance

Rural economic development

Sustainable agriculture attempts to solve multiple problems with one broad solution. The goal of sustainable agricultural practices is to decrease environmental degradation due to farming while increasing crop–and thus food–output. There are many varying strategies attempting to use sustainable farming practices in order to increase rural economic development within small-scale farming communities. Two of the most popular and opposing strategies within the modern discourse are allowing unrestricted markets to determine food production and deeming food a human right. Neither of these approaches have been proven to work without fail. A promising proposal to rural poverty reduction within agricultural communities is sustainable economic growth; the most important aspect of this policy is to regularly include

the poorest farmers in the economy-wide development through the stabilization of small-scale agricultural economies.

In 2007, the United Nations reported on "Organic Agriculture and Food Security in Africa", stating that using sustainable agriculture could be a tool in reaching global food security without expanding land usage and reducing environmental impacts. There has been evidence provided by developing nations from the early 2000s stating that when people in their communities are not factored into the agricultural process that serious harm is done. The social scientist Charles Kellogg has stated that, "In a final effort, exploited people pass their suffering to the land." Sustainable agriculture mean the ability to permanently and continuously "feed its constituent populations".

There are a lot of opportunities that can increase farmers' profits, improve communities, and continue sustainable practices. For example, in Uganda Genetically Modified Organisms were originally illegal, however, with the stress of banana crisis in Uganda where Banana Bacterial Wilt had the potential to wipe out 90% of yield they decided to explore GMOs as a possible solution. The government issued the National Biotechnology and Biosafety bill which will allow scientists that are part of the National Banana Research Program to start experimenting with genetically modified organisms. This effort has the potential to help local communities because a significant portion live off the food they grow themselves and it will be profitable because the yield of their main produce will remain stable.

Not all regions are suitable for agriculture. The technological advancement of the past few decades has allowed agriculture to develop in some of these regions. For example, Nepal has built greenhouses to deal with its high altitude and mountainous regions. Greenhouses allow for greater crop production and also use less water since they are closed systems.

Desalination techniques can turn salt water into fresh water which allows greater access to water for areas with a limited supply. This allows the irrigation of crops without decreasing natural fresh water sources. While desalination can be a tool to provide water to areas that need it to sustain agriculture, it requires money and resources. Regions of China have been considering large scale desalination in order to increase access to water, but the current cost of the desalination process makes it impractical.

Women

Women working in sustainable agriculture come from numerous backgrounds, ranging from academia to labour. From 1978-2007, in the United States, the number of women farm operators has tripled. In 2007, women operated 14 percent of farms, compared to five percent in 1978. Much of the growth is due to women farming outside of the "male dominated field of conventional agriculture".

Growing your own food

Main article: Urban agriculture

The practice of growing food in the backyard of houses, schools, etc., by families or by communities became widespread in the US at the time of World War I, the Great Recession and World War II, so that in one point of time 40% of the vegetables of the USA was produced in this way. The practice became more popular again in the time of the COVID-19

pandemic. This method permits to grow food in a relatively sustainable way and at the same time can make it easier for poor people to obtain food.

Challenges

Sustainable agriculture faces several challenges and problems, which can have significant impacts on agriculture. *Here are some of the key issues and their impacts:*

1. **Soil degradation**: Soil degradation is a significant problem in many agricultural systems, leading to reduced productivity, increased erosion, and decreased nutrient availability. This can have a significant impact on crop yields and soil health, making it difficult to maintain sustainable production.
2. **Water scarcity and pollution**: Access to clean water is essential for agriculture, but many regions face water scarcity due to climate change and overuse. Water pollution from agricultural inputs such as pesticides and fertilizers is also a concern. This can have a significant impact on crop yields, soil health, and the availability of water resources for future generations.
3. **Climate change**: Climate change is expected to have significant impacts on agriculture, **including changes in temperature and rainfall patterns, increased frequency of extreme weather events, and rising sea levels**. These changes can affect crop yields, soil health, and the availability of water resources. This can lead to food insecurity and economic losses in the agricultural sector.
4. **Loss of biodiversity**: Agricultural practices can lead to the loss of biodiversity, both on farms and in surrounding areas. This can have **negative impacts on ecosystem services such as pollination and pest control**. This can lead to decreased productivity and increased vulnerability to pests and diseases.
5. **Land-use change**: Conversion of natural ecosystems to agriculture can lead to **loss of habitats and fragmentation of landscapes**. This can affect biodiversity, carbon sequestration, and soil health. This can lead to decreased productivity, increased greenhouse gas emissions, and decreased soil health.
6. **Food waste**: Food waste is a significant problem globally, with up to one-third of all food produced being lost or wasted. This has significant economic, environmental, and social impacts. This can lead to decreased productivity and increased economic losses in the agricultural sector.
7. **Unsustainable input use**: Overuse of pesticides, fertilizers, and other agricultural inputs can lead to environmental pollution, increased costs, and reduced long-term productivity. This can lead to decreased soil health and crop yields, as well as increased costs for farmers.
8. **Rural poverty**: Many small-scale farmers struggle to make a living from their farms, leading to poverty and food insecurity. This can result from a range of factors, including limited access to markets, lack of investment, and inadequate government support. This can lead to decreased productivity and increased social inequality.

In summary, the problems and challenges facing sustainable agriculture can have significant impacts on agriculture, including decreased productivity, decreased soil health, increased economic losses, increased vulnerability to pests and diseases, increased greenhouse gas emissions, and increased social inequality. Addressing these challenges will require changes in agricultural practices, policies, and systems, as well as broader social and economic transformation

Elements/components of sustainability

There are many ways to improve the sustainability of a given farming system, and these vary from region to region, However, there are some common sets of practices among farmers trying to take amore sustainable approach, in part through greater use of on-farm or local resources each contributing in some way to long- term profitability, environmental stewardship and rural quality of life.

contour bunding, graded bunding, vegetative barriers strip cropping cover cropping, reduced tillage etc help prevent loss of soil due to wind and water erosion

a)

b) Crop diversity- Growing a greater variety of crops on a farm can help reduce risks from extremes in weather, market conditions or crop pests. Increased diversity crops and other plants, such as trees and shrubs, also can contribute to soil conservation, wildlife habitat and increased populations of beneficial insects

b) Nutrient management- Proper management of nitrogen and other plant nutrients con improve the soil and protect environment. Increased use of farm nutrient sources such as manure and leguminous cover crops, also reduces purchased fertilizer costs.

c) Integrated pest management (IPM)- IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in way that minimizes economic, health and environmental risks.

d) Cover crops- Growing plant such as sun hemp, horse gram, pillipesara in the off season after harvesting a grain or vegetable crop can provide several benefits, including weed suppression, erosion control, and improved soil nutrients and soil quality.

e) Rotational grazing- New management- intensive grazing systems take animals out barn into the pasture to provide high-quality forage and reduced feed cost .

f) Water quality & water conservation- Water conservation and protection have important part of Agricultural stewardship. Many practices have been develop conserve Viz., deep ploughing, mulching, micro irrigation techniques etc.., protect quality of drinking and surface water .

g) Agro forestry- Trees and other woody perennials are often

h) underutilized on covers a range of practices Viz., ogi-silvicuture, silive-pastoral, agri-silvi-pagri-horticulture, Horti/silvipastoral, alley cropping, tree farming, lay farm that help conserve, soil and water.

Systems of Farming system

Systems of farming systems refer to the various ways in which different farming systems can be combined and integrated to create more sustainable and resilient farming systems. Some common systems of farming systems include:

Crop-Livestock Integration: This system involves the integration of crop and livestock production in a single farming system. Livestock can provide manure for crop production, while crop residues can be used as animal feed. This system can increase overall productivity, improve soil fertility, and reduce pest and disease pressure.

Agroforestry: Agroforestry involves the integration of trees with crops and livestock in a farming system. Trees can provide multiple benefits such as shade, windbreaks, soil conservation, and timber production, as well as providing habitats for wildlife. Agroforestry can increase overall productivity, improve soil health, and enhance biodiversity.

Conservation Agriculture: Conservation agriculture is a farming system that aims to reduce soil erosion, improve soil health, and conserve natural resources such as water and nutrients. This system involves minimal soil disturbance, the use of cover crops and crop residues to protect the soil, and crop rotation to improve soil fertility and reduce pest and disease pressure.

Sustainable Intensification: Sustainable intensification is a farming system that aims to increase productivity while minimizing negative environmental impacts. This system involves the use of technology and management practices to optimize the use of resources such as water and fertilizer, and the adoption of practices that enhance soil health and biodiversity.

Integrated Farming Systems: Integrated farming systems involve the integration of various agricultural activities such as crop production, livestock rearing, and fish farming in a single farming system. This system can increase overall productivity, reduce waste, and enhance biodiversity.

Multi-Cropping Systems: Multi-cropping systems involve the cultivation of two or more crops in a single field during the same growing season. This system can increase overall productivity, improve soil fertility, and reduce pest and disease pressure.

Mixed Farming Systems: Mixed farming systems involve the integration of different types of crops and livestock in a single farming system. This system can increase overall productivity, improve soil fertility, and reduce pest and disease pressure.

In summary, there are several systems of farming systems that can be combined and integrated to create more sustainable and resilient farming systems. These include crop-livestock integration, agroforestry, conservation agriculture, sustainable intensification, integrated farming systems, multi-cropping systems, and mixed farming systems. The choice of the most suitable system(s) of farming systems depends on the context, objectives, and available resources.