Course Syllabi and Curricula

Curriculum for Environmentally Sound Sustainable Agriculture

David Pimentel, Cornell University, 1996

Concepts and Perspectives

The goal of environmentally sound sustainable agriculture is to utilize land, water, energy, and biological resources in an ecologically sound manner in order to produce abundant food, forage crops, and livestock as economically as possible. Knowledge of all the interacting segments in agroecosystems is essential. Improvements focus on reducing the inputs of agrochemical and other fossil energy inputs while conserving soil, water, and biological resources.

The more biological resources and other natural resources can be utilized in an ecologically sound manner, the less energy and inputs will be needed for maximum food production. With this concept and perspective in mind, a curriculum for environmentally sound sustainable agriculture is designed for a full academic year. (Articles followed by ⛰ are available in this compendium's Selected Readings package.)

Contents

I. Environmental Problems Faced by Agriculture

A. Pollution and contamination by pesticides, fertilizers, and manures
   1. Water, food, soil, and atmosphere
   2. Extent of pesticide, fertilizer, and manure pollution

B. Soil erosion and degradation
   1. Extent of soil erosion on croplands and pastures
      a. On-site effects
      b. Off-site effects

C. Water overuse in rivers, lakes, and groundwater and pollution
   1. Extent of overuse
   2. Extent of pollution

D. Negative impacts on biodiversity
   1. Pest problems
   2. Pesticide resistance problems in pests
   3. Natural enemies destroyed
   4. Bee kills and reduced pollination
   5. Wildlife killed
   6. Crops and natural vegetation affected

II. Role of Land in Food Production

A. More than 99% of U.S. and world food comes from the land and less than 1% from oceans and other aquatic systems

B. Limits to the intensification of agriculture

C. Distribution problems with land in U.S. and developing countries

III. Soil Resources

See D. Pimentel, et al., "Environmental & Economic Costs of Soil Erosion and Conservation Benefits," *Science* 267 (24 February 1995), 1117–1123.

A. Role of a productive soil in agriculture
   1. Support of the crop plant
   2. Nutrients
   3. Moisture

B. Qualities of a productive soil
   1. Water
   2. Nutrients
   3. Organic matter
   4. Soil biology
   5. Soil depth
   6. Soil structure

C. Soil erosion and reduced productivity
   1. Discuss impacts of soil erosion on each item listed under section B.
   2. Role of slope
   3. Role of vegetation

D. Soil conservation for cropland
   1. Vegetative cover
   2. Mulches
      a. Biomass
      b. Living mulches
      c. Plastic sheets
   3. No-till planting
   4. Ridge-till planting
   5. Contour planting
   6. Cover crops
   7. Grass strips
   8. Crop rotations
   9. Strip cropping
   10. Perennial crops
   11. Terraces
   12. Agroforestry
   13. Combinations of the above
   14. Costs and benefits of conservation

IV. Water Resources

See D. Pimentel et al., "Water Resources in Food and Energy Production," *BioScience* 32, no. 11 (1982) 861–867.

A. Hydrologic cycle

B. Water use by crops
1. Vital role of water in photosynthesis
2. Quantity of water transpired by various crops per ha during growing season
3. Loss of water by evaporation from soil
4. Loss of water by run-off

C. Water use by agricultural production
1. Irrigation
2. Overuse of rivers, lakes, and aquifers
3. Total water use by agriculture
4. Water quality and use

D. Water pollution
1. Pesticides, fertilizers, and livestock wastes
2. Soil sediments
3. Salinization and water logging

E. Rainfall limits to crop production
1. Requirements for various crops
2. Effects of climatic conditions on rainfall needs for crops
3. Distribution patterns and effects

F. Water conservation
1. Vegetative cover to reduce water runoff
2. Mulches
   a. Biomass
   b. Living mulches
   c. Plastic sheets
3. No-till planting
4. Ridge-till planting
5. Contour planting
6. Cover crops
7. Grass strips
8. Crop rotations
9. Strip cropping
10. Perennial crops
11. Terraces
12. Pastures and rangelands (regulated grazing intensity)
13. Combinations of the above
14. Crop types cultured
15. Costs and benefits of conservation

G. Conservation of irrigation water
1. Flood irrigation
2. Surge-flood irrigation
3. Sprinkler irrigation
4. Low pressure sprinkler irrigation
5. Above ground water delivery to individual crop plants
6. Drip irrigation
7. Costs and benefits of various irrigation procedures
8. Crops cultured and weather requirements

V. Fertilizer Nutrients

See David Pimentel, "Conservation of Fertilizers and Livestock Manure: Pollution Prevention" (Ann Arbor: National Pollution Prevention Center for Higher Education, University of Michigan; 1997).

A. Nutrient cycles and nutrient (N, P, K, Ca, etc.) requirements of crops

B. Amounts of nutrients removed by crop harvest

C. Amounts of nutrients in crop residues

D. Amounts of nutrients lost because of erosion

E. Nitrogen lost by leeching

F. Nitrogen lost by volatilization

G. Nutrients lost by various methods utilized in manure management

H. Nutrients (nitrogen) lost by composting

I. Pollution of ground water and eutrophication in aquatic ecosystems

J. Environmental costs and benefits of fertilizer use in crop production

K. Conserving nutrients in agricultural production
   1. Soil and water conservation techniques
   2. Conserving crop residues
   3. Conserving livestock manure
   4. Use of legumes and other green manures
   5. Agroforestry methods
   6. Use of mulches; limits of mulch sources in a sustainable system
   7. Slash-and-burn agriculture; land requirements for fallow
   8. Soil testing to determine nutrient needs
   9. Limit nutrient applications to the needs of the crop
   10. Number of fertilizer applications to meet crop needs
   11. Role and benefits of cover crops
   12. Integrated nutrient management

L. Organic agriculture
   1. Nitrogen sources (livestock manure, dried blood, alfalfa meal)
   2. Rock phosphate
   3. Phosphate (powdered granite)
   4. Limestone

VI. Climate

A. Sunlight
   1. Time periods
   2. Shading tolerance

B. Rainfall requirements for crops
   1. Distribution
   2. Evaporation

C. Temperature requirements for crops
   1. Favorable temperature periods
   2. Impact on evaporation from crops and land

D. Carbon dioxide

E. Ozone and air pollution effects on crops

F. Global warming and potential effects
   1. Temperature and growing season
   2. Rainfall and evaporation rates

VII. Biodiversity and Biological Resources

See M. G. Paoletti et al., "Agroecosystem Biodiversity: Matching Production and Conservation Biology," *Agriculture, Ecosystems and Environment* 40 (1992) 3–23.

A. Biodiversity in crop, pasture, and forest systems
   1. Compared with natural systems in temperate and tropic regions
   2. Small versus large organisms
   3. Biomass of crops and small and large organisms per hectare
   4. Livestock biomass
   5. Organisms above and below ground

B. Role of biodiversity in agriculture and forestry
   1. Recycling organic matter (crop residues and livestock wastes)
   2. Pollination by bees
   3. Chemical degradation
   4. Pest control by natural enemies (insects, plant pathogens, weeds)
   5. Soil formation
   6. Soil and water conservation
   7. Plant breeding
   8. Genetic engineering
   9. Nitrogen fixation

C. Loss of forests to the spread of agriculture

D. Loss of biodiversity and threat to agriculture and forestry

E. Interactions of agriculture with natural ecosystems

VIII. Pests and Pest Management

See D. Pimentel et al., "Environmental and Economic Costs of Reducing Pesticides Use," *BioScience* 41, no. 6 (June 1991): 402–409 , and "Environmental and Economic Costs of Pesticide Use," *BioScience* 42, no. 10 (November 1992): 750–760 .

A. Extent of pesticide use in the U.S. and world
   1. Herbicides
   2. Insecticides
   3. Fungicides

B. Crop losses from pests in the U.S. and world
   1. Pest insects
   2. Diseases
   3. Weeds

C. Environmental impacts and costs of pesticide use in U.S. and world
   1. Human health
   2. Livestock health and poisonings
   3. Fish kills
   4. Bird kills
   5. Destruction of beneficial natural enemies
   6. Pesticide resistance in pests
   7. Ground and surface water contamination
   8. Crop losses from pesticides
   9. Increased pest problems because of pesticide use
   10. Wildlife losses
   11. Internalize environmental costs

D. Judicious and reduced use of pesticides
   1. IPM
   2. Using pesticides only when necessary

E. Non-chemical substitutes for pesticides
   1. Natural enemies and biological controls
   2. Crop rotations
   3. Mechanical cultivation for weed and insect control
   4. Use of microbes for pest control
      a. Bacteria
      b. Viruses
      c. Fungi
      d. Protozoans
      e. Nematodes
   5. Soil management
   6. Water management
   7. Timing of planting
   8. Crop combinations
   9. Trap crops
   10. Fertilizer management
   11. Short-season crops
   12. Combinations of these non-chemical controls

IX. Energy Resources

See D. Pimentel et al., "Renewable Energy: Economic and Environmental Issues," *BioScience* 44, no. 8 (Sept. 1994): 536–547 ⛰; and D. Pimentel, G. Berardi, and S. Fast, "Energy Efficiency of Farming Systems: Organic and Conventional Agriculture," *Agriculture, Ecosystems, and Environment* 9 (1983): 358–372 ⛰.

A. Fossil fuel use in agriculture and food system

B. Fossil energy resources and the future in U.S. and world
   1. Oil resources
   2. Natural gas resources
   3. Coal resources
   4. Nuclear energy resources

C. Energy use
   1. Crop production (several crops and listing of inputs)
   2. Livestock production and combined with crops and pastures (milk, chicken, beef, sheep)
      a. Grain-fed systems
      b. Grass-fed systems
   3. Food processing and packaging
   4. Distribution and cooking

D. Energy needed to replace hand labor and increase crop productivity
   1. Labor substitute
   2. Productivity inputs

E. Energy conservation
   1. Soil and water conservation
   2. Nutrient conservation
      a. Erosion control
      b. Crop residue conservation
      c. Effective use of manure
      d. Green manure crops
      e. Cover crops
   3. Reduced pesticide use
      a. Natural enemies and biological controls
      b. Crop rotations
      c. Mechanical cultivation for weed and insect control
      d. Use of microbes for pest control
      e. Soil management
      f. Water management
      g. Timing of planting
      h. Crop combinations
      i. Trap crops
      j. Fertilizer management
      k. Short-season crops
      l. Combinations of these non-chemical controls
   4. Storage methods
   5. Local production of crops and livestock

F. Renewable energy systems
   1. Human labor
   2. Draft animal power
   3. Biomass energy
   4. Ethanol production (a total loss)
   5. Wind power
   6. Solar thermal
   7. Solar ponds
   8. Hydropower
   9. Hydrogen use
   10. Photovoltaics
   11. Costs and benefits

X. Socioeconomics of Agriculture

See David Pimentel, "Environmental and Economic Benefits of Sustainable Agriculture," in *Socio-economic and Policy Issues for Sustainable Farming Systems,* 5–20 (Padova,Italy: Cooperativa Amicizia, 1993) .

A.Costs and benefits of various crop production systems
1. Intensive agriculture
2. Sustainable agriculture
3. Organic agriculture
4. Traditional agriculture

B. Livestock production
1. Confined production systems
2. Free range systems
3. Grass-fed livestock production

C.Production of nutrients and costs using various technologies
1. Protein production
   a. Crops
   b. Animal products
   c. Aquaculture
2. Vitamin C
   a. Citrus
   b. Tomato
   c. Potato
3. B vitamins
   a. Grain
   b. Potato
   c. Animal products
   d. Traditional versus intensive agriculture

XI. Social Changes in Agriculture, 1900 to Date

See D. Pimentel, "The Global Population, Food, and the Environment," Chapter 15 in *Perspectives on Ecological Integrity*, edited by L. Westra and J. Lemons (Dordrect, Netherlands: Kluwer Academic Publishers, 1995) 239–253.

A.Labor involved in farming

B. Land acres per farm

C.Energy use per farm

D.Fertilizer and pesticide use per hectare

E. Water use or irrigation per hectare

F. Horsepower per hectare
1. Animal power
2. Tractor power

G.Rural community change

H. U.S. human population growth
1. 1930 = 130 million people
2. 1995 = 263 million people
3. Next 60 years = projected to double to 520 million

I. Loss of agricultural land to urbanization and highways

J. Loss of agricultural land to erosion and salinization

XII. Landscape Ecology

See David Pimentel, "Farms and Greenbelts" (Ann Arbor: National Pollution Prevention Center for Higher Education, University of Michigan, 1997).

A. Agriculture

B. Forestry

C. Protected national parks (biodiversity)

D. Other land uses (e.g., urban)

E. Urbanization
1. Social problems
2. Pollution
3. Greenbelts
4. Automobile pollution and gridlock

F. Rural communities
1. Urban sprawl
2. Loss of agricultural and forest land
3. Depressed rural towns

XIII. Systems Approach to Agriculture

A. Integrated resource management

B. Multidisciplinary approach

C. Integrating crop and livestock production

XIV. Genetic Engineering and Biotechnology

See D. Pimentel et al., "Benefits & Risks of Genetic Engineering in Agriculture," *BioScience* 39, no. 9 (October 1989) 606–614  .

A. Potential benefits to agriculture

B. Limits for use in crop and livestock production

C. Potential problems for agriculture
1. Bovine growth hormone
2. Herbicide resistance in crops and the environment
3. Transgenic crops and the environment
4. Negative social and economic effects

Food, Agriculture, and Society

Allison Power, Cornell University

I. Introduction

A. Patterns of food production and issues in agricultural development
B. Traditional farming systems in the tropics
C. Population and hunger
D. Historical perspectives on U.S. agriculture

II. Productivity

A. Plant genetic resources
B. Crop domestication
C. Discussion: Conservation of genetic resources
D. Crop ecology
E. Annual and perennial cropping systems
F. Animals in sustainable agriculture
G. Discussion: The cattle battle

III. Sustainability and Stability

A. Pest dynamics
B. Biological control
C. Pesticides and integrated pest management
D. Discussion: Pros and cons of pesticide use
E. Sustainability and water use
F. Energy use in agriculture
G. Soil erosion and conservation tillage
H. Discussion: Arid land agriculture
I. Biotechnology in agriculture
J. Socioeconomic impacts of biotechnology
K. Discussion: Biotechnology and sustainable agriculture

IV. Equitability

A. The green revolution
B. Discussion: Food aid policies and hunger
C. Issues in sustainable development
D. Central America: A case study
E. Discussion: Role of NGO's in sustainable development
F. Looking to the future