3.3

Environmental Issues in Modern Agriculture

Introduction: Environmental Issues in Modern Agriculture

OVERVIEW

This unit introduces students to the most common agricultural practices employed in conventional production, and the major agricultural, environmental, and human health concerns that have arisen as a result of their use over the last century.

Two lectures cover the socioeconomic factors that shape conventional modern agricultural production; key elements of modern agriculture and their environmental and human health impacts; and critical interactions between natural and agroecosystems. The lectures also present the set of alternative farming practices that have been used to avoid risks to environmental quality and human health. The lectures conclude with a discussion of the policy, regulatory, and economic factors that reinforce the conventional agriculture model and the policy and economic changes that need to take place in order to develop more sustainable productions systems.

Note: It is important to convey to students that many "conventional" farming operations, though not operating under National Organic Program organic certification, often integrate many of the "sustainable agriculture" practices outlined in this manual. Further, it is important to discuss that mere adherence to the minimum requirements of organic certification does not necessarily constitute sound agricultural practices. Students should understand that agriculture itself (whether "certified organic" or "conventional") is one of the most extensive and environmentally disruptive land use practices that human beings currently employ. Additionally, it is important to stress that it is often market pressures and the need to maintain a competitive advantage/economic viability that have encouraged individual farmers to adopt agricultural technologies that have later proven to have negative environmental or human health consequences. Lastly, though environmental degradation often results from the simple misuse or over-application of agricultural technologies (e.g., synthetic N-P-K fertilizers), certain agricultural technologies (e.g., GMOs and pesticides) currently pose either an unknown or well-substantiated environmental quality and/or human health risk.

MODES OF INSTRUCTION

> LECTURES (2 LECTURES, 50 MINUTES EACH)

Lecture 1 reviews a framework of analysis to understand the factors driving change in modern agricultural systems—technology and capital—and an explanation of how changes in production have impacted environmental and human health.

Lecture 2 includes an overview of alternative agricultural practices and concludes with an examination of the necessary policy and economic changes needed for their widespread adoption.

References given in the outlines are described in the References and Resources section.

LEARNING OBJECTIVES

CONCEPTS

- The environmental impacts of modern agriculture are the consequence of the paths of technological development taken in this country
- The “technology treadmill”: The technological package of modern agriculture as a system with its own internal logic, fueled and maintained by the techno-scientific and socioeconomic systems in which it is situated
- The development of agricultural mechanization, agricultural chemicals, and agricultural biotechnology and their impact
- The major environmental impacts and human health risks of modern agriculture: Water, soil, and air, biological diversity, and human health
- The barriers to adoption of conservation measures that would reduce these risks
- The set of organic/sustainable farming practices that are used to avoid risks to environmental quality and human health
- The policy and economic changes that need to take place in order to develop more sustainable productions systems

Lecture 1: Technological Innovations

A. The Shaping of Conventional Agriculture: Technological Innovations, Investment Capital, and the Technology Treadmill (see Cochrane 1993; FitzSimmons 1986; Heffernan et al. 1999)

1. The initial resistance of agriculture to the forces of capitalism
   a) Crop production as high-risk investment: Capital investors initially reluctant to invest in agriculture with productivity and profit being tied to biological processes and variables of natural environment
2. New agricultural technologies and capitalist investment
   a) As new agricultural technologies were developed and introduced into agriculture, capitalist investors found it more profitable to invest in the technologies rather than crop production itself
   b) Consequences
      i. Farmers become dependent upon constantly evolving inputs of agricultural technology
      ii. Agricultural technologies require substantial financial investment, thus requiring many farmers to obtain loans to reinvest in technology
      iii. Capital investors and technology manufacturers control agricultural technology
      iv. The restructuring of farm economics: New technology requires access to capital (loans, credit) for investment. This favors larger, well-capitalized farmers or farming corporations and puts smaller farmers at a competitive disadvantage, who often have to sell out, contributing to the growth in farm size and the loss of more small farms.
3. "The technology treadmill"
   a) The technology treadmill defined: The self-reinforcing cycle of technological dependency, driven by the application of technology and investment capital to agriculture
      i. Competition in the marketplace encourages the adoption of new agricultural technologies that allow for increases in efficiency or increases in the scale of production
      ii. Increased efficiency, increases in the scale of production convey a competitive advantage through the economies of scale
      iii. Crop prices are driven down because of efficiencies in production and the reduced costs per unit produced
      iv. This drives some small producers out of business because they cannot access the credit needed to invest in the latest technology that is now essential in competing in the market place
      v. Concurrently, this encourages producers to further increase the scale of production to have the size of operations necessary to cover their debts incurred through purchases of technology inputs
      vi. The agricultural technologies used in expanding the scale of production have had significant social and environmental consequences

B. Technological Innovations and Practices Used in Conventional Agriculture

1. Fossil fuel use in conventional agriculture
   a) Fossil fuel was first used on the farm to replace human labor and animal power. It was a great labor-saving device. It laid the foundation for monocultural production (through tractors) and long distance shipping of agricultural products.
   b) The influence of fossil fuel
      i. Economically subsidized in many ways: Highways; lower prices for larger volumes of fuel used; externalized environmental costs (e.g., CO_2, oil spills, etc.)
      ii. Inexpensive fossil fuel power makes long-distance, cross-country, and international transportation of food and fiber cost effective. Cost effectiveness of international import agriculture is further assured by lower costs of production in developing nations due to lower environmental and social justice standards.
      iii. Local and sustainable food systems cannot compete against large-scale agriculture with economically efficient long-distance food transport and the suite of externalized costs
2. Monoculture cropping systems (see Kimbrell 2002)
   a) Monoculture defined: The planting of genetically similar or uniform crop varieties over large tracts of land, sometimes without rotation to other crops in space or time
   b) Scale of monocultures: Monocultures can occupy hundreds to thousands of acres of land
   c) Known and potential agroecological risks:
      i. Agriculture as environmental degradation: With 600 million hectares worldwide, and 943,000 acres of arable land under cultivation in the U.S., it is the most extensive terrestrial-based activity
      ii. Agriculture has resulted in the conversion and degradation of grassland, woodland, and wetland ecosystems in the U.S. and around the world
      iii. Highly simplified agricultural ecosystems maintain large carrying capacity for "pest" organisms and low carrying capacity for natural predators of agricultural pests
      iv. Narrow and therefore vulnerable crop gene-pool
      v. Dependency on biocides to control pests
      vi. Soil loss and siltation of waterways through wind and water erosion in the absence of cover crops
      vii. Uninterrupted pest/host relationship resulting in buildup of pest and pathogen populations
3. Hybrid seed (see Kloppenburg 2004)
   a) History of seed production: Historically, farmers selected seed from the crop plants that produced well in a given area. This assured a locally adapted crop gene pool.
   b) Though rapidly changing, this is still the practice in most of the world today
   c) The development of off-farm selective breeding programs
      i. Geneticists began controlled breeding of corn varieties in the first half of the 20th century to improve yields
      ii. Hybrid seed varieties—a product of a forced cross between homogeneous inbred lines—have superior traits, such as uniformity in growth and yield, uniform ripening, better taste, consistent germination, and processing and shipping qualities
      iii. Traits in hybrid seeds can only be assured during the first generation, requiring farmers to buy hybrid seeds annually
      iv. This created a huge economic opportunity for seed companies by generating input dependence by farmers on these high-yielding seeds

v. It also meant that entire counties or states could have near-uniform and therefore vulnerable crop genetics

d) The adoption of hybrid seed

i. Government agencies and seed companies conducted extensive campaigns to "modernize" farmers by persuading them to buy "improved" seeds

ii. Farmers who were resistant, either because they suspected efforts to make them buy off-farm inputs, or because they simply saw no reason to change, were ridiculed

iii. As early adopters began to profit from improved seeds, they were able to outcompete their neighbors

iv. Early adopters of agricultural technologies began to buy their neighbors out, encouraging the concentration of ownership

e) Known and potential agroecological risks

i. The loss of genetic diversity of crop plants

ii. They may lack traits that have other ecological functions, such as disease resistance

iii. Narrow genetic base and therefore vulnerable to pests and pathogens

iv. Dependency on pesticide use

v. Loss of biodiversity of sexually reproduced crop plants

vi. Input dependence by farmers

4. GE: Genetically Engineered organisms (see Gurian-Sherman 2009; *www.centerforfoodsafety.org*; Kimbrell 2002)

a) What are genetically engineered (GE) organisms?

Genetic engineering (GE) is the transfer of genes from one organism to another through means that do not occur without human intervention. This involves isolating and then moving genes within and without different species by recombinant DNA techniques and other manipulation of the genetic construct outside the traditional practices such as sexual and asexual breeding, hybridization, fermentation, in-vitro fertilization and tissue culture.

b) Examples of GE technologies

i. Bt-producing crops, herbicide-resistant crops, vitamin-producing crops, pharmaceutical crops, GE animals (e.g., salmon)

ii. Terminator seeds: Despite the moratorium since 2001, there is increasing pressure to use them. (Watts and Vidal 2013).

c) Claims about benefits of GE crops

i. Feeding the world: However, malnutrition and hunger are largely problems of maldistribution of food and poverty, not of underproduction

ii. Reducing pesticide use: Bt crops appear to be reducing the use of pesticides. However, increasing insect resistant to Bt is a concern. In contrast, herbicide use has increased as GE crop plants have higher tolerances for herbicides (Benbrook 2012).

iii. Increasing yield: A recent Union of Concerned Scientists report states that looking at studies for the past 20 years, there has been little increase in yield from GE crops. They suggest overall yield increases in corn are based on non-genetic engineering approaches (Gurian-Sherman 2009).

iv. Other claims: Herbicide-resistant crops require less work, allowing farmers more time. However it puts farmers on the technological treadmill, having to pay more for input solutions to problems instead of managing problems by working within natural systems.

d) Worldwide increase in the use of GE technology

i. Herbicide-resistant crops (HRCs) and insect-resistant crops (Bt crops) accounted for 59 and 15 percent respectively of the total global area of all transgenic crops in 2000

ii. Worldwide, transgenic crops increased at a rate of 6% per year, for the past 17 years. As of 2012, there were 170.3 milling hectares in biotech crops (International Service for the Acquisition of Agri-Biotech Applications 2012).
iii. The U.S., Brazil, Argentina, and Canada, had the most acreage in GE crops in 2012. The most commonly grown crops worldwide are herbicide-tolerant soybeans (47% of biotech), stacked traits maize (23%) and Bt cotton (11%) (International Service for the Acquisition of Agri-Biotech Applications 2012).

e) Known and potential agroecological and human health risks
i. Potential human allergens: Viral vectors and antibiotic markers are used to verify successful trans-genetic engineering
ii. Potentially unknown viruses, toxins, and pathogens could be created by vector-mediated horizontal gene transfer and recombination
iii. The "escape" of trans-genetic genes via wind and insect pollination to wild plant weeds of the same species resulting in irreversible genetic pollution
iv. Additional farmer dependency on technological inputs
v. Ethical questions around intellectual property rights of germplasm
vi. Loss of genetic diversity of crop plants through the abandonment of regional selection of sexually reproduced seed
vii. Loss of effectiveness through rapid evolution of resistance of biocontrol pesticides for organic systems: Example, Bt corn
viii. Transfer of genes/contamination of non-GMO and certified organic crops
ix. Reduction of the fitness of non-target organisms through the acquisition of transgenic traits via hybridization
x. The rapid evolution of resistance of insect pests such as to Bt
xi. Soil accumulation of the insecticidal Bt toxin
xii. Disruption of natural control of insect pests through intertrophic-level effects of the Bt toxin on natural enemies of agricultural pests
xiii. Unanticipated effects on non-target herbivorous insects (e.g., monarch butterflies) through deposition of transgenic pollen on foliage of surrounding wild vegetation

f) GMOs as a crisis of democracy
i. FDA has made the regulatory determination that they are "substantially equivalent" to non-GMO foods and that minimal testing needs to be done, and they need not be labeled. Simultaneously, industry has pursued patent rights for GMOs, which require novelty.
ii. GMOs sold and in widespread use before long-term studies on ecological and human health risks were conducted
iii. Question: Do individuals have the right to be informed of the potential environmental quality and human health risks associated with GMO as with other products (e.g., tobacco, alcohol, gasoline)?

5. Synthetic pesticides: herbicides, insecticides, rodenticides, and fungicides (see Benbrook 1996; Kegley 1999, 2000; Reeves 1999; Kimbrell 2002)
a) Pesticides as "biocides": A pesticide is any substance or mixture of substances used to destroy, suppress, or alter the life cycle of any target organism. A pesticide can be a naturally derived or synthetically produced substance. Pesticides are not able to discriminate between target and non-target organisms with similar physiology.
b) Origins of synthetic biocides: Developed in WWI and WWII as warfare agents and later applied to agriculture
c) How pesticides work: The physiology of biocides (see *www.epa.nsw.gov.au/)*

i. Physical toxicity pesticides: Block the cellular processes of target organisms in a purely mechanical way. Examples include spray oils that clog the respiratory mechanism of insects.

ii Metabolic system inhibitors: There are many inhibitory pesticides in this category, such as rotenone and cyanide, that disrupt respiratory functions in animals; herbicides that inhibit seed germination or plant growth (especially at the root and shoot tips); and fungicides that inhibit germination of spores

iii. Protein synthesis and enzyme disruption: Proteins such as enzymes control many important cell functions. Many pesticides aim to disrupt enzyme processes or denature proteins. Examples include inorganic copper compounds, dithiocarbamate fungicides, phosphono amino acid herbicides such as glyphosate, and organophosphate insecticides.

iv. Hormonal system interference: Several pesticides simulate or otherwise interfere with hormones to disrupt hormone cycles. Examples are the phenoxy herbicides that interfere with plant growth hormones and insect growth regulators that interfere with cuticle formation in insects during molting.

v. Nervous system disruptors: These pesticides affect mainly animal groups such as insects, nematodes, and rodents. Some are narcotics such as some fumigant pesticides. Others disrupt the movement of nerve impulses, such as the organophosphate, carbamate, and pyrethroid pesticides.

vi. Photosynthetic inhibitors: Pesticides that disrupt photosynthesis prevent the plant from producing or storing energy and ultimately kill the plant. Examples include the triazine, substituted urea, and uracil herbicides.

vii. Some pesticides work in more than one way and fall into more than one of these categories. The modes of action of many pesticides are not fully understood.

d) Current trends in sales and use of biocides in agriculture (see Kegley 2000)

i. California: ~160 million pounds of active ingredients/year [1]

ii. U.S.: 1,133 million pounds active ingredients were estimated to have been used in 2006 and 2007 [2]

iii. Misleading terms: Active ingredients and "inert" ingredients. Pesticide formulation may contain 99% inert ingredients. Many inert ingredients have adverse health effects and may be active ingredients in other pesticide formulations.

e) Known and potential environmental and human health risks (see Kegley 1999, 2000; Reeves 1999; Moyers 1993)

i. Toxicity to non-target organisms, including natural enemies of agricultural pests

ii. Surface and groundwater pollution: Toxicity to aquatic wildlife and humans through drinking water

iii. Bio-accumulation in wildlife populations

iv. Effects on the physical environment (e.g., methyl bromide and ozone depletion)

v. Acute poisoning and occupational exposure of farmers and agricultural workers with known endocrine-disrupting compounds, known and suspected carcinogens, and nerve toxins. (3 million human pesticide poisonings, and 220,000 deaths attributed to pesticides worldwide/year.)

---

1 Californians for Pesticide Reform. 2010. Healthy children and green jobs: A platform for pesticide reform. San Francisco, CA. *pesticidereform.org/downloads/CPR-Platform-Nov-2010.pdf*

2 Grube, A, D. Donaldson, T. Kiely and L. Wu. 2011. Pesticides industry sales and usage: 2006 and 2007 market estimates. U.S. Environmental Protection Agency. *www.epa.gov/opp00001/pestsales/07pestsales/market_estimates2007.pdf*

vi. Dietary exposure to endocrine-disrupting compounds, known and suspected carcinogens and nerve toxins
vii. Potential synergistic effects of exposure to environmental toxins with similar mechanisms of toxicity
viii. Soil degradation: Reduce biological activity and diversity
ix. Developed resistance and resilience in pest populations
x. Dietary exposure and the safety of existing tolerance levels
xi. Pesticides disproportionately affect predaceous "beneficial organisms" over pests, creating resurgence in populations of pest organisms

f) The "logic" of pesticide use and the externalization of costs
i. For every $1 spent on pesticides there are $3 to $5 in return[3]

g) Estimates on financial costs to mitigate environmental damage
i. In the U.S., environmental costs are estimated to be around $10 billion, depending on assumptions (Pimentel 2005). These costs of production are not compensated for by the farmer or agrochemical company.

h) Legislation restricting the use of biocides (see Benbrook 1996)
i. The Food Quality Protection Act of 1996 (see *www.epa.gov/opppsps1/fqpa/*)
ii. Shortcomings of the FQPA (see *www.ecologic-ipm.com*)

6. Synthetically compounded N-P-K fertilizers (see also Supplement 4, Nitrate Contamination of Groundwater, in Unit 1.5, Irrigation—Principles and Practices)

a) What is synthetically compounded fertilizer? Synthesizing ammonia from nitrogen and hydrogen gas involves submitting nitrogen and hydrogen to at least 3,000 pounds per square inch of pressure, in the presence of osmium as a catalyst. Industrially produced synthetic ammonia is the principal source of the commercially available, industrially produced nitrogen and is the principal starting point from which all of the different kinds of industrially produced, so-called nitrogen "fertilizers" are made.

b) Known and potential agroecological and human health risks (see; U.S. Geological Survey 2010 , and Gliessman 2007)
i. The overapplication of synthetic N, P, and K nutrients are the most extensive form of "nonpoint source" (runoff) water pollution in the U.S.
ii Trends in nitrogen concentrations have changed little between 1993 and 2003. In places where there are changes, they tend to show increases rather than decreases (U.S. Geological Survey 2010).
iii. The overapplication of N-P-K fertilizers has greatly altered the global N and P cycles with unknown consequences (Gliessman 2007)
iv. Surface water contamination: N-P-K contamination leads to growth of algae and other plants (this process is called eutrophication). The plants utilize available oxygen and block sunlight penetration, harming fish and other marine organisms. This leads to "dead zones," e.g., in the Northern Gulf of Mexico (see Carpenter et al. 1998; Miller 2008; U.S. Geological Survey 2010).
v. Energy-intensive production: Nitrogen fertilizer requires large amounts of natural gas, both to contribute hydrogen to the nitrogen, but also adding heat manufacture it. Fertilizer prices tend to be in line with those of natural gas (see Miller 2008; Sawyer et al 2010).

---

3 United States Environmental Protection Agency. 2012. Agricultural Pesticides.*www.epa.gov/oecaagct/ag101/croppesticideuse.html*

vi. Drinking water contamination: Nitrate poisoning. Elevated nitrate levels in drinking water wells are common in agricultural areas and have resulted in a rare infant disease called methemoglobinemia ("blue-baby syndrome"; see *www.cdfa.ca.gov*).
   - In rural agricultural areas, 20% of shallow wells have nitrate levels above the federal drinking water standard (U.S. Geological Survey 2010)

vii. Excess nitrogen in crops can lead to increased susceptibility to pests and pathogens and poor post-harvest handling (Young, 1999)

viii. Soil degradation: Increased loss of soil organic matter; decreased soil biological activity and diversity; reduced aggregation and aggregate stability and the decline in desirable physical properties; increased soil erosion by wind and water; reduced nutrient availability through biological activity; increase susceptibility to pests and pathogens; increased dependence on synthetic chemical fertilizers and pest control agents to maintain productivity (Magdoff 2000)

7. Concentrated Animal Feeding Operations (Gurian-Sherman 2008 and Pew Commission on Industrial Farm Animal Production 2009)
   a) The number and size of Confined Animal Feeding Operations (CAFOs) have increased
      i. Hog operations went from over 500,000 in 1982 to 60,000 in 2006, with no decrease in production overall
      ii. The average size of a CAFO in 2004 was 12,000 animals in the Southern U.S.
   b) Large amounts of manure create concentration of nutrients, resulting in significant nutrient pollution of air, water, and groundwater (e.g., nitrate contamination and eutrophication of surface waters)
8. Agricultural water use (Reisner 1993)
   a) In the Western U.S., roughly 90% of water diversion and supply goes to agriculture (U.S. Department of Agriculture 2013)
   b) There are about 75,000 dams nationwide, and about 1500 in California
   c) Environmental consequences of dams and water diversion
      i. Dams degrade aquatic and riparian ecosystems by altering natural river flows, preventing flood flows necessary for the maintenance of habitat and wetlands, disrupting natural water temperatures, and reducing water quality
      ii. In California, dams block 90% of the anadromous fish habitat for Chinook salmon and steelhead trout (Patrick 2005)
   d) Groundwater depletion (see *water.usgs.gov/ogw/gwrp/stratdir/future.html*)
      i. The overdraft of groundwater is resulting in the depletion of underground aquifers, resulting in increased costs of harvest and eventual loss of the resource
      ii. Groundwater depletion in coastal areas may result in saltwater intrusion and salt contamination of ground water
      iii. Land subsidence: Land compaction and sinking due to water extraction can damage buildings and infrastructure, as well as permanently decreasing the storage capacity available
   e) Salinity problems
      i. Salinity results from the accumulation of salt in the soil, resulting from the use of irrigation in poorly drained soils
      ii. High soil salinity may result in the interference of water uptake and circulation leading to moisture stress in crop plants
      iii. More than half of irrigated agricultural lands in California are affected by elevated salinity (University of California Agricultural Issues Center 2009)

9. The environmental consequences of international trade liberalization policies (see Korten 2001)

   International trade liberalization policies (e.g., NAFTA and GATT) allow capital investors and U.S. and European food corporations to secure profits through the production of agricultural products in less developed nations (LDN). Costs of production in LDNs are much lower due to LDNs having lower environmental quality and social justice standards. These inexpensive products with many associated externalized costs are imported to the U.S. and Europe and sold at very low prices at large retail outlets.

10. Summary: Conventional agriculture, soil degradation, and the technology treadmill (see Magdoff 2000)

    Market competition and the absence of laws restricting the use of agrochemicals encourage the adoption of new agricultural technologies that allow for increases in the efficiency and scale of production (e.g., monocultures, pesticides, synthetic N-P-K fertilizers, hybrid and GMO seeds). Large-scale monocultures create a large carrying capacity for "pest" organisms and low carrying capacity for natural predators of agricultural pests by simplifying the agroecosystem and surrounding plant communities. This results in the population growth of pest organisms and the inability of natural predators of insect pests to effectively prevent pest outbreaks. Pesticides are therefore applied in an attempt to control pest populations.

    Pesticides disproportionately affect predaceous natural enemies of insect pests, resulting in the resurgence of insect pest populations and the development of genetic resistance of pests to pesticides. Pesticides become less effective and the intensity of pesticide use increases. The overuse of synthetic nitrate fertilizer may result in excessive vegetative growth and poor post-harvest quality, both of which are highly susceptible to pests. Pesticides are therefore applied in an attempt to control pest organisms.

    Synthetic N-P-K fertilizers do not replace the organic matter necessary to maintain the soil biological diversity and activity needed to maintain disease suppression and desirable physical properties of agricultural soils. The use of synthetic fertilizers and the absence of sound crop rotation and cover cropping may encourage soil erosion and compaction, reduce the water- and nutrient-holding capacities of soil, and result in poor growing conditions for crops, leading to an increased susceptibility to both pests and pathogens. Intensive use of fertilizers, new pesticides, and tillage are then required to maintain productivity of such systems. This often results in further soil degradation and the unintentional exposure of agriculture workers, wildlife, and the general public to elevated levels of pesticides and nitrates in food and groundwater.

    Agriculture itself (whether "certified organic" or "conventional") is one of the most extensive and environmentally disruptive land-use practices, where terrestrial plant and animal communities are converted to row crops and enormous amounts of water are diverted to supply needed irrigation water. Irrigation water has led to elevated salt levels, which may result in the interference of crop plants to access and regulate moisture. Water diverted from rivers has resulted in the degradation of these aquatic ecosystems through the erection of dams. Overdraft of underground aquifers for agricultural use has led to the depletion of this resource, and in coastal areas, to the intrusion of saltwater into agricultural wells.

    GMO crops pose an unknown environmental and human health risk, reduce the diversity of crop genetics and, where adopted, create further input dependence for farmers. Hybrid seed reduces the diversity of crop genetics and creates further input dependence for farmers.

Lecture 2: Alternatives to Conventional Agriculture

A. Viable Alternatives to Conventional Agriculture: Sustainable and "Organic" Agriculture Practices (see Pesticide Action Network of North America 2009; National Research Council 1989; Magdoff 2000; see also Part 1, Organic Farming and Gardening Skills and Practices)

1. Soil health management: Maintaining optimal soil chemical properties
   a) Nutrient budgeting based on balancing nutrient inputs with outputs: Matching crop demand with nutrient contribution of inputs. This approach attempts to assure that nutrient needs are met without creating nutrient excesses and their associated problems (e.g., nutrient runoff, leaching/nonpoint source pollution, pest susceptibility, and poor post-harvest quality).
   b) Practices
      i. Cover crops: Non-market crops, some of which are used to fix atmospheric nitrogen and carbon; cycle nutrient inputs and sub-soil nutrients (e.g., N and P respectively); stimulate soil biological activity; prevent nutrient leaching
      ii. Compost: Depending on compost feedstock, can be a source of N-P-K and micronutrients; stimulates soil biological activity necessary for nutrient release
      iii. Naturally occurring soil amendments and fertilizers: Supplies nutrients
      iv. Proper irrigation: Prevents leaching of mobile nutrients
2. Soil fertility management: Soil physical properties
   a) Perennial cover crop rotation: Allows soil to remain undisturbed and aggregate formation to proceed
   b) Properly timed and quantity of tillage: Prevents compaction of soil and unnecessary oxidation of soil organic matter (SOM)
   c) Cover crops: Prevent soil erosion; stimulate soil biological activity; allow soil to rest and aggregate formation to proceed
   d) Compost: Stimulates soil biological activity, diversity, and aggregate formation
   e) Proper irrigation: Prevents soil erosion
3. Non-toxic pest management
   a) Sound soil fertility management (see above)
   b) Polycultures: Diversity of crop plants maintains more even carrying capacity for pests and beneficial insects
   c) Biocontrol of pest organisms, e.g., using releases of predaceous, parasitic, and parasitoid insects to reduce pest populations
   d) Farmscaping: Non-crop vegetation used to encourage habitat for beneficial organisms and/or encourage pests away from market crop (trap crop)
   e) Cover crops: Rotating crops interrupts pest-host cycle and attracts natural enemies of agricultural pests; stimulates soil biological activity; allopathic control of pests
   f) Compost: Stimulates soil biological activity and diversity that encourage disease-suppressive qualities of soils
   g) Mating disruption: Pheromone releases timed with mating periods
4. Open-pollinated seed varieties: Maintain viability of regionally adapted (i.e., disease resistant) crop cultivars

B. Making Agriculture Practices in the U.S. More Environmentally Sound

(see Youngberg et al. 1993; Lockeretz 1997; Hassanein 1999)

1. Recognize what has driven change in agriculture over the past century: A complex interaction of social forces that have different impacts under different ecological conditions
2. Second step: Recognize that the primary instruments of change have been investment capital and technological developments
   a) Behind these instruments are a host of social structures that have influenced our relationship to food and food production: capitalist economics, national policies, changes in the agricultural workforce, reduction in food costs and increased availability of foods, changes in diet preferences, and attitudes toward the role of food in culture
3. To effect change, advocates will have to work intensively in particular areas but link up with others working on a broad range of reforms
4. Economics
   a) Support of policy initiatives that encourage local economic development that allows social and environmental values to be incorporated into the price structure of foods
5. Policy, science, technology, and education
   a) Continued educational efforts in informing consumers of the relationship between personal food choices, the food systems these choices support, and the associated social and environmental consequences
   b) Citizen participation in U.S. agricultural public policy (e.g., Farm Bill) in support of funding federal programs that financially support the adoption of conservation farming practices
   c) Citizen encouragement of agricultural public policies to fund federal programs for alternative agriculture, environmental, and food system research in U.S. agricultural colleges
   d) Consistent and sustained pressure on the public institutions that direct research trajectories (e.g., Land Grant institutions)
   e) Integration of conservation farming education into Cooperative Extension services
6. Policy: See Policy Initiatives in Unit 3.4, Sustainable Agriculture and Sustainable Food Systems
7. The importance of human values in shaping agriculture
   a) Recognize that attitudes toward food are shaped by broad social circumstances such as the cost of living, changes in the roles of women in society, food products advertising, the number of persons directly involved in food production, knowledge of food and agricultural systems and their social, environmental, and health consequences
   b) With knowledge of food and agricultural systems and the associated social, environmental, and health consequences, individuals may be compelled to emphasize locally produced seasonal and organic foods
   c) Education on food costs and fast foods may encourage more Americans to spend less money on food outside the home
   d) Re-emphasizing eating as a social act that builds family and community can assist the necessary changes in diet, the local agricultural economy, and the broader food system

Discussion Questions

ENVIRONMENTAL ISSUES IN MODERN AGRICULTURE, LECTURES 1 & 2

1. Why do you think it is important to understand the environmental impacts of the agriculture and food system?
2. What did you learn from these two lectures that was surprising to you? Why was it surprising? What did you previously assume to be true?
3. What are some of the most concerning issues raised? Why?
4. Are there any topics from these lectures that you are interested in learning more about? Why? How will you go about learning it?
5. How does learning about this material impact the way you intend to participate in the food system (as a farmer, activist, consumer, etc.)?

References & Resources

SUGGESTED READINGS FOR STUDENTS (DESCRIBED BELOW)

- Carpenter et al., 1998
- Teaching the Food System, 2010
- Gliessman, Stephen R., 2014. Chapters 1-2

PRINT REFERENCES & RESOURCES

Altieri, Miguel A. (ed.). 1995. *Agroecology: The Science of Sustainable Agriculture*. Boulder, CO: Westview Press.

> *Miguel Altieri is one of the pioneers in developing the discipline of agroecology, and this was the first text to lay out its major premises. Rather than present techniques for production, this text proposes an agricultural paradigm based on the science of ecology. The (second) edition contains updated essays, and still provides a thoughtful overview.*

Benbrook, Charles M. 1996. *Pest Management at the Crossroads*. Yonkers, NY: Consumers Union.

> *The clearest summary of environmental, health, policy and economic issues surrounding pest management in the U.S. Its chapters introduce IPM—with an emphasis on biointensive IPM, review of pesticide use and risk, and discussion of economic and policy obstacles to the adoption of IPM.*

Benbrook, Charles. M. 2012. Impacts of genetically engineered crops on pesticide use in the U.S.—the first sixteen years. *Environmental Sciences Europe,* 24(1), 1-13.

Carpenter, Stephen, Nina F. Caraco, David L. Correll, Robert W. Howarth, Andrew N. Sharpley, and Val H. Smith. 1998. *Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen*. Issues in Ecology 3.

> *Provides an introduction to the ecological impacts of nutrient run-off. Although the article's scope is much broader than agriculture, it explains the biochemical processes that occur when excess nutrients enter waterways; appropriate for non-science majors. Available from* www.esa.org/issues.htm

Cooper, Ann. 1999. *Bitter Harvest: A Chef's Perspective on the Hidden Dangers in the Foods We Eat and What You Can Do About It*. New York: Routledge.

> *Describes the health risks of modern industrial food and lax government oversight of food safety.*

Conway, Gordon, and Jules N. Pretty. 2009. *Unwelcome Harvest: Agriculture and Pollution*. Sterling, VA: Earthscan.

> *An exhaustive overview of the relationship amongst agrochemicals, environmental impacts, and social consequences from a global perspective.*

DANR (Division of Agriculture and Natural Resources). 1992. *Beyond Pesticides: Biological Approaches to Pest Management in California*. Oakland: University of California Division of Agriculture and Natural Resources.

> *A thorough analysis of the production-related problems of pesticide reliance in California; proposes in-creased funding for research and extension of biological methods of pest management in the state.*

FitzSimmons, Margaret. 1986. The new industrial agriculture: The regional integration of specialty crop production. *Economic Geography* 62 (4):334-353.

Gliessman, Stephen R. 2014. *Agroecology: The Ecology of Sustainable Food Systems, 3rd edition*. Boca Raton, FL: CRC.

> *This new edition of the bestselling textbook for courses in agroecology or sustainable agriculture updates the issues facing the sustainability of food systems, especially the strong movement from the "second green revolution" of biotechnology, the continued consolidation of the agricultural and food industries, the conflict with biofuels, and today's historical record of hungry and undernourished people worldwide. Presents recent research and provides new examples throughout, including innovative ways farms and other parts of the food system have introduced new alternative technologies to improve sustainability.*

Gurian-Sherman, Doug. 2008. *CAFOs Uncovered: The Untold Costs of Confined Animal Feeding Operations*. Cambridge, MA: Union of Concerned Scientists. *www.ucsusa.org/assets/documents/food_and_agriculture/cafos-uncovered.pdf*

Gurian-Sherman, Doug. 2009. *Failure to Yield: Evaluating the Performance of Genetically Engineered Crops*. Cambridge, MA: Union of Concerned Scientists. *www.ucsusa.org/assets/documents/food_and_agriculture/failure-to-yield.pdf*

Hassanein, Neva. 1999. *Changing the Way America Farms: Knowledge and Community in the Sustainable Agriculture Movement*. Lincoln, Nebraska: University of Nebraska Press

Heffernan, William D., Mary Hendrickson, and Robert Gronski. 1999. *Consolidation in the Food and Agriculture System*. National Farmers Union. *www.foodcircles.missouri.edu/whstudy.pdf*

> *Provides the clearest and most compelling evidence of the concentrated economic control that a small number of transnational corporations have over the processing and distribution of foodstuffs.*

International Service for the Acquisition of Agri-Biotech Applications. 2012. *Pocket K No. 16: Global Status of Commercialized Biotech/GM Crops in 2012*. *www.isaaa.org/resources/publications/pocketk/16/*

Kegley, Susan, Lars Neumister, and Timothy Martin. 1999. *Disrupting the Balance: Ecological Impacts of Pesticides in California*. San Francisco, CA: Californians for Pesticide Reform. *www.igc.org/cpr/publications/publications.html*

> *Reports in considerable detail the continuing impacts of agrochemicals on California's ecosystems.*

Kegley, Susan, Stephan Orme, and Lars Neumister. 2000. *Hooked on Poison: Pesticide Use in California 1991–1998*. San Francisco, CA: Californians for Pesticide Reform. *www.igc.org/cpr/publications/publications.html*

> *Drawing from California's pesticide database, reports patterns of pesticide use in the state by chemical, crop, and county.*

Kimbrell, Andrew, ed. 2002. *Fatal Harvest: The Tragedy of Industrial Agriculture*. Washington DC: Island Press.

> *A coffee table-sized book with many short essays and large photos describing the environmental and social consequences of our modern agricultural system. Provides a thorough identification of the range of consequences from this system. A lower-cost version without photos has all the essays, and would be an appropriate reader for undergraduates.*

Kloppenburg, Jack Ralph. 2004. *First the Seed: The Political Economy of Plant Biotechnology, 2nd edition*. Madison, WI: University of Wisconsin.

> *A brilliant historical analysis of seeds, plant breeding, genetic diversity, and the appeal of biotechnology to capitalism.*

Korten, David C. 2001. *When Corporations Rule the World*. Bloomfield, CT: Kumarian Press, Inc.

> *A central text in the emerging global Living Democracy Movements. Addresses the social and environmental consequences of economic globalization.*

Lockeretz, William, ed. 1997. *Visions of American Agriculture*. Ames. IA: Iowa State University Press.

> *A selection of writings by experts on social and economic evolution in the agricultural sector.*

Miller, G. T., and Scott E. Spoolman. 2012. *Living in the Environment, 17th edition*. Belmont, CA: Brooks/Cole Cengage Learning.

> *Undergraduate-level textbook in environmental science. Addresses prevalent environmental issues including problems in modern conventional agriculture and alternatives.*

National Research Council. 1989. *Alternative Agriculture*. Washington, D.C.: National Academy Press.

> *This book was significant because of the scientific legitimacy it accorded to the emerging sustainable agriculture movement. Its methodology was criticized by both conventional and alternative agriculture advocates. Although its findings and recommendations are not particularly provocative by today's standards, it marked an important milestone in efforts to promote alternative approaches to production.*

National Research Council. 1993. *Soil and Water Quality: An Agenda for Agriculture*. Washington DC: National Academy Press.

Provides the most scientifically thorough discussion of the soil and water conservation challenges facing agriculture in the U.S. Although written by scientists, its target audience is policymakers. Clear and well-organized.

Pesticide Action Network of North America. 2009. *Agroecology and Sustainable Development: Findings from the UN-led International Assessment of Agricultural Knowledge, Science and Technology for Development*. San Francisco, CA. *www.agassessment-watch.org/docs/PANNA_agroecology_Brief_20090505.pdf*

Pimentel, David 2005. Environmental and economic impacts of the application of pesticides primarily in the U.S. *Environment, Development and Sustainability.* 7, 229-252.

Patrick, Wesley S. 2005. *Evaluation and Mapping of Atlantic, Pacific and Gulf Coast Terminal Dams: A Tool to Assist Recovery and Rebuilding of Diadromous Fish Populations*. Department of Biology, East Carolina University. Proceedings of the 14th Biennial Coastal Zone Conference, New Orleans, Louisiana, July 17 to 21, 2005. *www.csc.noaa.gov/cz/CZ05_Proceedings/pdf%20files/Patrick.pdf*

Pew Commission on Industrial Farm Animal Production. 2009. *Putting Meat on the Table: Industrial Farm Animal Production in America.* A Project of The Pew Charitable Trusts and Johns Hopkins Bloomberg School of Public Health. *www.ncifap.org/_images/PCIFAPFin.pdf*

Pollan, Michael. 2002. Power Steer. *New York Times Magazine*, March 31.

Describes the modern beef production system, and its human health and environmental impacts.

Pretty, Jules N. 1995. *Regenerating Agriculture.* London: Earthscan.

Would serve well as a textbook for a sustainable agriculture class with a global perspective. Pretty does a good job integrating technical, social, and political changes that need to be put in place to make a transition to more environmentally friendly agriculture.

Reeves, Margaret, Kristin Schafer, Kate Hallward, and Anne Katten. 1999. *Fields of Poison: California Farmworkers and Pesticides*. San Francisco: Californians for Pesticide Reform.

The most complete discussion of California farmworker poisonings. Critiques the weak reporting and even weaker enforcement of farmworker protection laws.

Reisner, Mark. 1993. *Cadillac Desert: The American West and its Disappearing Water.* New York, NY: Penguin Group.

Robbins, John. 1987. Diet for A New America. Walpole NW: Stillpoint.

Discusses the human and environmental health impacts of modern agriculture and diet.

Röling, N.G., and M.A.E. Wagemakers, eds. 1998. *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty.* Cambridge: Cambridge University Press.

Essays explore in detail the social changes necessary to make the technical changes possible for sustainable agriculture. The emphasis and case studies are focused on Europe and the developing world, but the principles are relevant to all.

Sawyer, John, Mark Hanna, and Dana Petersen. 2010. *Energy Conservation in Corn Nitrogen Fertilization – Farm Energy.* Iowa State University – University Extension. *store.extension.iastate.edu/Product/Energy-Conservation-in-Corn-Nitrogen-Fertilization-Farm-Energy*

Schahczenski, Jeff, and Holly Hill. 2009. *Agriculture, Climate Change and Carbon Sequestration.* ATTRA–National Sustainable Agriculture Information Service. IP 338. *attra.ncat.org/publication.html*

Provides an overview of the relationship between agriculture, climate change and carbon sequestration. Investigates possible options for farmers and ranchers to have a positive impact on the changing climate and presents opportunities for becoming involved in the emerging carbon market.

Schlosser, Eric. 2001. *Fast Food Nation: The Dark Side of the All-American Meal.* Boston: Houghton Mifflin.

Contains great chapters on food safety, meat packing, and the implications of a fast food diet.

U.S. Department of Agriculture. 2013. *Irrigation & Water Use*. Economic Research Service. Updated June 7, 2013. *www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx#.U2WGuS8oyCQ*

U.S. Geological Survey. 2010. Nutrients in the Nation's Streams and Groundwater, 1992-2004. Reston, Virginia: USGS Circular 1350.

University of California Agricultural Issues Center. 2009. *Soil Salinization.* AIC White Papers on California Agricul-tural Issues. *aic.ucdavis.edu/publications/whitepapers/Soil%20Salinization.pdf*

USGS. 2000. *Water Quality in the Sacramento River Basin, California, 1994-1998*. Reston, Virginia.

Reports describe a thorough investigation into the water quality in U.S. and California rivers and streams.

Youngberg, Garth, Neill Schaller, and Kathleen Merrigan. 1993. The sustainable agriculture policy agenda in the United States: Politics and prospects. In *Food for the Future,* Patricia Allen, ed. New York: John Wiley.

Wright, Julia. 2009. *Sustainable Agriculture and Food Security in an Era of Oil Scarcity: Lessons from Cuba*. Sterling, VA: Earthscan.

Watts, Jonathon, and John Vidal. 2013. Unease among Brazil's farmers as Congress votes on GM terminator seeds. *The Guardian*. Thursday 12 December 2013. *www.theguardian.com/global-development/2013/dec/12/brazil-gm-terminator-seed-technology-farmers*

WEB-BASED RESOURCES

Action Group on Erosion, Technology and Concentration (formerly RAFI)

www.etcgroup.org

Dedicated to the conservation and sustainable advancement of cultural and ecological diversity and human rights. Supports socially responsible developments of technologies useful to the poor and marginalized and addresses international governance issues and corporate power.

The Organic Center

organic-center.org

Viewpoints on organic, conventional and genetically engineered farming systems.

Bullfrog Films

www.bullfrogfilms.com

Source of films on environmental issues.

Californians for Pesticide Reform

www.pesticidereform.org

A coalition of over 170 public interest groups dedicated to protecting human health and the environment from the dangers of pesticide use.

Center for Food Safety

www.centerforfoodsafety.org/

Analyzes biotechnology issues.

Extension Toxicology Network

ace.orst.edu/info/extoxnet/

A source of objective, science-based information about pesticides developed by toxicologists and chemists within the Extension Service of the land-grant universities; written for the non-expert. Information fully search-able and selectively retrievable.

Food Quality Protection Act (FQPA)

www.epa.gov/pesticides/regulating/laws/fqpa/

Viewpoints on the FQPA.

Heinz Center

triblive.com/news/allegheny/4957496-74/heinz-center-endowments#axzz2vhMuCVmI

The Heinz Center is a non-profit institution dedicated to improving the scientific and economic foundation for environmental policy through multisectoral collaboration among industry, government, academia, and environmental organizations.

Pesticide Action Network

www.panna.org

An excellent website containing the most recent compilations of studies on pesticide use in California and the U.S.

Sustainable Agriculture Education Association (SAEA)

sustainableaged.org/
(see "Curriculum Library")

Starting in 2014, SAEA will roll out a place where educators can share syllabi, class exercises, assignments, and information about

their degree programs.

Teaching the Food System. 2010. Agriculture and ecosystems: Background reading. A Project of the Johns Hopkins Center for a Livable Future.

www.jhsph.edu/research/centers-and-institutes/teaching-the-food-system/curriculum/_pdf/Agriculture_and_Ecosystems-Background.pdf

UC Sustainable Agriculture Research and Education Program—Agriculture Sustainability Initiative, UC Davis

www.sarep.ucdavis.edu

An excellent website for the discussion of the social, political, ecological, and agronomic aspects of "sustainable agriculture."

U.S. Geological Survey

water.usgs.gov/nawqa/

Accessible reports and maps on the water quality impacts of non-point source pollution from agriculture. These are appropriate for undergraduate students, and their maps make nice overheads for lectures.

U.S. Geological Survey

water.usgs.gov/ogw/gwrp/stratdir/future.html

The USGS Ground-Water Resources Program's efforts to examine and report on critical issues affecting the sustainability of the nation's groundwater resources.

Union of Concerned Scientists

www.ucsusa.org/food_and_agriculture/

Offers a large section on food and agriculture issues. The website includes a particularly useful section on genetic engineering, providing brief overviews as well as several reference documents.

VIDEOS

In Our Children's Food. 1993. PBS FRONTLINE special. Hosted by Bill Moyers (56 minutes).

Covers human health and environmental risks associated with pesticide exposure. Follows the politics of the development of the National Academy of Sciences' children's study: Pesticide residues in the diets of infants and children.

Oliver de Schutter: What is Agroecological Farming? 2012.

www.youtube.com/watch?v=938PECAJ920

Race to Save the Planet: Saving the Environment and Feeding the World. 1990. WGBH/PBS video.

Explores the human side of international environmental issues in agriculture and the delicate balance between progress and the preservation of the environment.

Diet for a New America. 1991. KCET /PBS video. Hosted by John Robbins (60 minutes).

From the John Robbins book of the same name. Discusses the human and environmental health impacts of modern agriculture and diet.

Playing with Poison. 2001. CBC's The Nature of Things. Force Four Entertainment (64 minutes).

American anthropologist investigates the side effects on children of pesticide use in Mexico's Yaqui Valley, one of Mexico's largest agricultural areas. Available from: www.bullfrogfilms.com

Queen of the Sun: What Are the Bees Telling Us? 2011. By Taggart Siegel and John Bets (83 minutes).

www.queenofthesun.com

An alternative look at the global bee crisis; includes interviews with beekeepers, scientists and philosophers from around the world, who reveal both the problems and the solutions in renewing a culture in balance with nature.

Symphony of the Soil. 2012. Directed by Deborah Koons Garcia (103 minutes)/

www.symphonyofthesoil.com

An artistic and scientific exploration of soil, examining its complex dynamics as well as the human relationship with soil, the use and misuse of soil in agriculture, deforestation and development, and the latest scientific research on soil's key role in ameliorating the most challenging environmental issues of our time. Filmed on four continents, featuring esteemed scientists and working farmers and ranchers.