A Curriculum in Sustainable Agriculture

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Abstract

Many institutions offer various courses and curricula related to sustainable agriculture yet there is no standard curriculum available for a degree in sustainable agriculture. An undergraduate curriculum in sustainable agriculture is presented here listing courses in general education, agronomic sciences, and sustainable agriculture. The courses intended to broaden the focus of sustainable agriculture include environmental sciences, resource economics, sustainable agriculture and environment, water pollution, air pollution, natural resource management, geographic information systems, and agricultural biotechnology. Brief contents for these courses are listed. This curriculum will prepare the students for careers (or graduate study) not only in the field of sustainable agriculture but also in agronomy, natural resource management, and environmental sciences.

Increasing environmental awareness and resource degradation from anthropogenic activities, including agriculture, have made us realize the importance of sustainable agriculture. Although the wide use of the term sustainable agriculture is relatively recent (10–15 yr), we have come to accept the fact that sustainable agriculture is no longer an option. Many institutions of higher education offer a variety of courses and curricula related to sustainable agriculture (Gates, 1996). These include soil ecology, soil fertility, cropping systems, alternative fertilizers, herbal studies, integrated pest management and sustainability of agricultural production, among others, both at the undergraduate and graduate levels. Much like the traditional disciplines (such as biology or chemistry), a standard (and yet flexible) curriculum for an undergraduate major in sustainable agriculture is needed. Well-defined concepts and goals of sustainable agriculture make it simpler to design and recommend such a curriculum.

Sustainable agriculture is a system of food and fiber production that improves the productivity of natural resources to meet the increasing demands of population and economic growth, produces food that is safe and nutritious, ensures adequate farm income, improves soil productivity and water resources and meets social and national expectations (NAP, 1991). The term low input sustainable agriculture (LISA) was introduced to describe systems that will achieve “sustainability that incorporates biologically based practices that result in lessened reliance on purchased agricultural inputs;” LISA is now being replaced by the term SARE (Sustainable Agriculture Research and Education). The various data bases that need to be emphasized for both sustainable agriculture and LISA include soil, weather, land use, hydrology, and socio-economic and ecological information. The recommended solutions to environmental and economic problems (STEEP) must consider tillage and plant management, plant design, erosion and run-off prediction and control, pest management and soil erosion/productivity relationships (NAP, 1991).

Ecological and Economical Concepts

Important components of sustainable agriculture include crop rotations, genetic resources, nutrient management, weed and insect control, livestock production, stewardship of natural resources, and costs and economic benefits (Ragland and Lal, 1993). In order to teach students sustainable agriculture we need to help them develop higher order (Bloom, 1974) thinking skills such as description, analysis, design, evaluation, and dissemination that will prepare them for a better understanding of the following ecological and economical concepts:

1. Role of animals in sustainable agriculture: Plant and animal complimentarity, enterprise diversification, animal-forage integration, forage farming, multiple animal cropping and manuring, and agroforestry.
2. Role of economics in sustainable agriculture: Enterprise or component analyses, whole farm analyses, macroeconomic analyses, profitability of adoption of integrated pest management (IPM), cost and social impact of additional machinery requirements, renewable vs. nonrenewable resource management costs, technological adaptation costs.
3. Role of ecology in sustainable agriculture: Ecosystems and holistic management, water, air, and soil pollution, carrying capacity of the earth, limits to food production, resource pollution and depletion, chemical toxicity, and health effects.

Abbreviations: LISA, low input sustainable agriculture; SARE, sustainable agriculture research and education; IPM, integrated pest management; EBPM, ecologically based pesticide management; ATTRA, appropriate technology transfer for rural areas.

5. Crop and pest management: Soil testing and plant analyses, rotation management, cover crop management, minimizing nutrient losses, cultural weed control, chemical and biological control (IPM and ecologically based pesticide management—EBPM), environmental responses (Hatfield and Karlen, 1994).

6. Sustainable agriculture and water quality: Supplementing precipitation, infiltration, soil water evaporation, modification of transpiration, soil storage increases, and percolation reducers.

**Recommended Curriculum**

Based on these goals and concepts the following curriculum for an undergraduate major in sustainable agriculture is suggested. The students should complete 2 yr of course work in general education requirements that include courses in English (12 semester credit hours - cr), Economics (6 cr), Humanities (6 cr), Mathematics including Statistics (9 cr), Zoology and Microbiology (8 cr), Chemistry (12 cr), Physics (8 cr), and Fine Arts (6 cr). Core agronomy courses should include: plant genetics and breeding, agronomic crops, soil science, soil fertility and plant nutrition, soil-water conservation, pesticides and weeds, and animal science with some on-farm practical experiences.

The above courses are normally available in most Colleges or Departments of Agriculture at higher education institutions. The required five to seven elective courses in sustainable agriculture should include the following courses at the upper division level:

- Environmental Science (4 cr)
- Resource Economics (3 cr)
- Sustainable Agriculture and the Environment (3 cr)
- Water Pollution (4 cr)
- Air Pollution (4 cr)
- Natural Resource Management (3 cr)
- Geographic Information Systems (3 cr)
- Agricultural Biotechnology (3 cr)

Most of these courses are being offered at this institution. Student interest in these nontraditional courses is increasing; they find these courses more "challenging and rewarding" as there is a greater need for systematic and critical thinking and integration of various disciplines by the students. We are pursuing grant opportunities to work with faculty from other nearby institutions to offer the remaining couple of courses through the use of satellite and Interactive Video Network. Offering of new courses with laboratory components is not always expedient because of limited resources. Many institutions offer excellent curricula in Natural Resource Management but with less emphasis on course work in agronomy, biotechnology, pollution science, and geographic information systems. An integration of these and many other courses is becoming essential and gaining importance for a sustainable global system. While some of the features and goals of the sustainable agriculture curriculum can be incorporated in a conventional agriculture curriculum, there is a need to broaden the currently available curricula at most institutions offering an agronomy track to emphasize the economical, environmental, and biotechnical issues.

**Course Content**

As some of these sustainable agriculture courses are relatively new (for many institutions), information as to their possible content is presented below for each of these courses. Although many books and references are available, only one reference for each course is listed here.

**Environmental Science:** (Miller, 1996)

Environmental problems and causes, population-production and pollution, ecosystems, geologic processes/the dynamic earth/ biogeochemical cycles, human population dynamics, deforestation and biodiversity, energy resources, risks-health-resources and pollution, agricultural activities and IPM, food resources, economics and environment, and politics and environment.

**Resource Economics:** (Tietenberg, 1988)

Resource exploitation and conservation, economic goods and resources, economic systems, growth, productivity and external costs, public and private policies, economic and political approaches to improving environmental quality and conserving resources, environmental ethics, achieving a sustainable global society.

**Sustainable Agriculture and the Environment:** (Ruttan, 1992)

Agroecology (farms as systems; ecological principles of crop and animal production), greenhouse gases and climate change, climate change models, climate change and agricultural production, forest response to climate change, agricultural impacts on climate change, information systems for soil management.

**Water Pollution:** (Laws, 1994)

Irrigation and salinity, fertilizers, pesticides, aerial input, heavy metals, land disposal of animal wastes, animal production and processing, acid deposition, industrial pollution, water pollution control, and safe drinking water acts/legislation.

**Air Pollution:** (Godish, 1991)

Meteorology, gaseous air pollutants, air pollution and plant metabolism, crop response to air pollutants, forest growth and air pollution, contribution of agriculture to air pollution, global climate change and precipitation, carbon dioxide and global warming, atmospheric photochemical reactions, air pollution control, and clean air acts/legislation.

**Natural Resources Management:** (Miller, 1992)

Human population, land and soil, water, air, energy, minerals, oceans, fisheries, forests, wildlife, ecosystem management, and microcomputer applications in resource management.

**Geographic Information Systems:** (Reichhardt, 1996)

Electromagnetic radiation, remote sensing of agricultural and natural resources, natural resource inventory, monitoring and management, environmental concerns, construction and use of computer-based information systems, collection, manipulation and display of geographical data, applications in agricultural practices (farm run-off, groundwater monitoring, air quality modeling, oil spills, and pollution hot spots), global positioning system, and field applications.
Agricultural Biotechnology: (Krimsky and Wrubel, 1996)

Scientific research, technical development, commercialization, social, economical and environmental innovations in: Herbicide resistant crops, insect resistant crops, disease-resistant crops, transgenic plant products (foods and pharmaceuticals), microbial and ecologically based pesticides, N₂-fixing bacteria, frost-inhibiting bacteria, animal growth hormones (bovine somatotropin), and transgenic animals.

This curriculum will prepare the students for careers (or for graduate study) not only in the field of sustainable agriculture but also in agronomy, natural resource management, and environmental sciences.

Resources in Sustainable Agriculture

Gates (1996) provides a comprehensive listing of the programs at various institutions, where courses are offered in sustainable agriculture, along with the names and addresses of the contact persons. A few of these institutions include Univ. of California (Berkeley, Fresno, Davis), Iowa State Univ., Kansas State Univ., Cornell Univ., Univ. of Maine, Univ. of Maryland, Slippery Rock Univ., and Virginia Polytechnic Institute and State University; many other institutions are doing research and extension work in sustainable agriculture. There are many other sources of information dealing with sustainable agriculture. The Sustainable Agriculture Network (1996) publishes a directory with much practical information for farmers, ranchers, educators, students, and others interested in sustainable agriculture. The Sustainable Agriculture Network is a cooperative effort of the university, government, business, and private organizations interested in exchange of information on sustainable agriculture. The internet address for this network is san@nalusda.gov; Mr. Andy Clark is the current SAN Coordinator. Other organizations interested in sustainable agriculture include Earthwatch, Natural Organic Farmers Association, Rodale Institute, Conservation Tillage Information Center, Appropriate Technology Transfer for Rural Areas (ATTRA), and the Water Quality Information Center. The National Agricultural Library (10301 Baltimore Blvd., Beltsville, MD 20705-2351, (301)504-6559) continues to be the primary clearing house for useful information in this emerging area of study. The National Agricultural Library also has an Alternative Farming System Information Center (internet address: afsic@nalusda.gov).

These resource centers are continually adding to their capacity to update information sources to support curriculum in sustainable agriculture. The address for U.S. Department of Agriculture’s SARE Program office is: USDA/CREES, South Building, Room 3863, Washington, DC. 20250; the NE Regional Coordinator for SARE is Dr. F. Magdoff who can be reached at msimpson@moose.uvm.edu.

References

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Inquiry Learning: A Paradigm from an Entomology Course

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Abstract

Inquiry should be an important component of all science courses. Learning about how scientists have approached problems with actual examples helped students to understand the nature of scientific thinking. Guided-inquiry activities in a structured format with familiar or readily observable scientific phenomena reinforced student understanding of the inquiry process and also stimulated increased interest in science.

The National Research Council (NRC) in its new science education standards (1996) emphasizes the importance of incorporating inquiry into science education. The NRC defines inquiry in the following way:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.

Inquiry may vary from what some have called open inquiry in which the students formulate and investigate their own questions to guided inquiry in which the instructor provides various levels of structure to the inquiry activities. I find that some degree of structure is helpful for nonscience majors.

It is generally agreed that there is no single scientific method by which scientists conduct their investigations in a lock-step progression (Ayala et al., 1989), and it is important to emphasize this point to students. However, the process that has come to be known as the scientific method is a useful model for student investigation of scientific phenomena. Throughout the following discussion, the term scientific method will refer to the traditional sequence of steps (observation, causal question, hypothesis, predictions [expected outcomes of experiments], experimentation, conclusion). Gibbs and Lawson (1992) presented an excellent discussion of the scientific method and a framework for its application. In their paper, they analyzed a series of studies by Caro on the ethology of storing in gazelles, Gazella thompsoni (Artiodactyla:Bovidae). Stotting is a visual display in which the students formulate and investigate their own hypotheses that have not yet been proposed and remind them that there might be testable hypotheses that have not yet been proposed, that stabilimenta may have different roles for different spider species, or that they may have multiple roles for the same species. I try to emphasize that it is this complexity that makes biology so fascinating.

The spider’s web represents considerable resources from the spider in terms of the amino acids in the silk—an investment worthy of being protected. Eisner and Nowicki suggested that the stabilimentum functions as a visual marker to warn visually oriented animals such as birds of the presence of the web so the web is not destroyed. They reasoned that the framework to introduce inquiry learning into a summer insect field biology course for education majors and in-service teachers.

Preliminary Homework Assignment

During the first week of class, I give the students a homework assignment to ensure that they understand the approach of the scientific method. I assign pages 139 to 141 of the Gibbs and Lawson paper that describe their framework and also a short paper by Eisner and Nowicki (1983) that deals with the role of stabilimenta in the orb webs of some spiders (Argiope sp.; Araneae:Araneidae). Stabilimenta are visual adornments that occur in the webs of some orb weaving spiders (Fig. 2). They may take different shapes in the webs of different species of spiders. Also, spiders of some species spin stabilimenta of different shapes at different ages of their lives. Stabilimenta are commonly spun as vertical or diagonal strands, as near circular patches, or in an X pattern. I ask the students to find examples of the components of the scientific method in the Eisner and Nowicki paper and state the components in the Gibbs and Lawson format with the appropriate key words. After the students have done the homework, we discuss the various hypotheses investigated by Eisner and Nowicki, and I give them my own rendering of the homework. I also give them a list of other hypotheses that have been proposed and remind them that there might be testable hypotheses that have not yet been proposed, that stabilimenta may have different roles for different spider species, or that they may have multiple roles for the same species. I try to emphasize that it is this complexity that makes biology so fascinating.

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Fig. 1. Summary of key words and scientific processes (modified from Gibbs and Lawson, 1992).

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if stabilimenta do perform this protective function, then birds approaching webs with stabilimenta will take evasive action. They also conducted a series of manipulative experiments to test the protection hypothesis. For example, they placed artificial paper stabilimenta (Fig. 3) in webs without stabilimenta and looked at the relative rates at which these webs were destroyed during the night and daytime when compared to webs without stabilimenta. These examples of Eisner and Nowicki's application of the scientific method in the Gibbs and Lawson format with the key words follow:

**Hypothesis.** If stabilimenta are visual markers that serve as deterrents to potentially destructive, visually oriented animals such as birds,

**Experiment 1.** and we observe birds on the wing,

**Expected Outcome.** then the animals will take evasive action when approaching webs with stabilimenta.

**Actual Outcome.** Birds were observed to approach and then to avoid webs with stabilimenta.

**Experiment 2.** And if we compare the durability of webs with and without stabilimenta,

**Expected Outcome.** then webs with stabilimenta and those without will have equal durability during the night, but webs with stabilimenta will be torn down less frequently during the daytime than those without stabilimenta.

**Actual Outcome.** Webs with artificial stabilimenta were torn down with equal frequency during hours of darkness but less frequently during hours of daylight when compared to webs without stabilimenta.

**Conclusion.** Therefore, the hypothesis is supported.

After the homework exercise, the students have a pretty good concept of the application of the scientific method. We are then ready to proceed with actual inquiry exercises. My course is a field course involving hands-on activities with living insects (Hall, 1994/1995), but the approach I will describe also is adaptable to laboratory situations using a variety of organisms.

**Guided Inquiry**

Students are reminded that organisms that do not reproduce do not contribute their genes to the next generation. Therefore, there is a premium on traits that increase the chance of producing offspring (and also those that increase the fitness of those progeny). They also are reminded that these traits may be either physical (color or structural) or behavioral. The following statement by Lloyd (1980) sets the stage for inquiry activities:

> More often than not when you observe an insect in the field, what it is doing at the moment is the best thing it can possibly be doing at that moment for maximizing its long-run reproduction.

I tell the students that we will refer to any characteristic that contributes to an insect's long-run reproduction as being adaptive and that many of an insect's activities will be related to one of the following:

1. Feeding
2. Avoiding enemies
3. Mating (including finding a mate and the mating process)
4. Reproducing (e.g., finding host, giving birth, etc.)
5. Enhancing survival of young
6. Avoiding unfavorable environments

We observe a variety of structural characteristics and behaviors of insects during the course. Students are instructed to assume that Lloyd's statement is true in each case and to attempt to apply the scientific method. It is emphasized that not all behaviors or structures may be adaptive, but that we are assuming that they are in order to invoke the opportunity for scientific inquiry. The following rubric is then practiced periodically throughout the course:

1. Upon observing an insect structure or behavior, ask "How is it adaptive?"
2. Formulate testable hypotheses to explain how it is adaptive. (Students are encouraged to use the list above to help them in generating hypotheses.)

3. Suggest experiments to test each hypothesis.

4. Predict possible outcomes of the experiments and state the significance of each for supporting or contradicting hypotheses.

5. If possible, conduct the experiments. (Due to course time constraints, this is often impossible. In some cases, I provide data from published studies)

6. If experiments are done, compare actual outcomes with predicted outcomes.

7. Formulate probable conclusions or additional hypotheses.

Obviously, this is only one of many possible approaches to incorporating inquiry learning, but I believe it has provided valuable learning experiences for the students. During the course, students go through at least the mental process of the scientific method repeatedly. I believe this mental exercise combined with the hands-on activities helps the students develop the higher-level cognitive skills. These inquiry activities also greatly increase student interest in science. Another advantage to inquiry learning is that it is readily adaptable to students of different grade levels or those with different levels of scientific backgrounds. The questions researched, types of data collected, and the sophistication of data analysis can be adjusted according to the course objectives and student level.

Assessment of inquiry activities and other teaching approaches that attempt to teach more than mere memorization of facts is difficult. One of the course requirements is preparation of an extensive course portfolio that is worth one-third of the course grade. A major section of the portfolio is composed of student worksheets related to the inquiry activities. Students also are required to write summaries of what they have learned during each exercise. Admittedly, grading of this section of the portfolios is somewhat subjective, but probably not much more so than some of the essay questions we give our students on examinations.

References


