COMMENTARY

Incorporating agroecology into the conventional agricultural curriculum

Miguel A. Altieri and Charles A. Francis

Abstract. *Agroecology is the development and application of ecological theory to the management of agricultural systems, according to the specific land and other resources available. Beyond the biological and climatic dimensions of agriculture and ecology, there is growing appreciation of the influence of social, economic, and political factors on the structure and success of farming systems. This broader field is becoming known as "agroecology and sustainable development." Expansion of the conventional curriculum to include integrative themes is essential because of the need for students to appreciate a whole farm focus for analysis, to understand the impact of socio-economic factors, and to further develop their abilities to link people and environment. Two courses are proposed and described in detail. "Biology of Agroecosystems" includes study of system structure and function, cycles and interactions among components, system development and performance, and the importance of resource conservation and use. "Agroecology and Sustainable Agricultural Development" includes a survey of systems around the world, an evaluation of resources and their use, the environmental impact of agriculture, the relationships between society and agriculture, the applications of agroecology to rural development, and some projections of alternative future strategies for food production. Future agricultural professionals need to understand how improvement of agroecosystems is closely linked to economic, cultural, and political systems, and how they are both enhanced and constrained by factors beyond biology and climate.*

Key words: sustainable agriculture, resource efficiency, cropping systems, agricultural education

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Introduction

Environmental consequences of agriculture in the U.S. and elsewhere have attracted public attention to unintended impacts of some crop and animal production practices. Regulations on use of pesticides, water, and fertilizers present new challenges to producers, who must modify their practices to conform to the goals of a broader society. A major concern today is to maintain a productive and profitable agriculture while eliminating or minimizing the negative long-term environmental and social costs associated with some widely used technologies, such as fertilizers and chemical pesticides (National Research Council, 1989). There is growing awareness that agriculture must compete for scarce resources, and that our current system does not use some of these resources as efficiently as other industries. This competition threatens the sustainability of food production systems (Francis et al., eds., 1990).

One reason that it has been difficult for specialists in agriculture to focus on broader impacts of production systems is our narrow education and training in specific disciplines. We now recognize that challenges in agricultural production and resource use efficiency are more than technical problems. Given a growing appreciation of the impact of agriculture on the environment, it is logical to broaden our horizons in education to include "agroecology." Narrowly defined, this is the development and application of ecological theory to the management of agricultural systems, according to the specific resources available, especially land; agroecology provides a framework within which interdisciplinary activities can occur (Altieri, 1987).

As we examine the multiplicity of complex, interacting, and long-term concerns affecting agriculture, it becomes apparent that even this focus is too narrow. In addition to biological, climatic, and environmental dimensions of food production, there are economic, social, and political factors operating as well. Agriculture is a biological and ecological activity that interacts closely with the socioeconomic systems that prevail around the globe, and cannot be separated from them (Pierce, 1990). Research, education, and field activities in this complex arena are increasingly being identified under the banner of agroecology and sustainable development (Altieri and Hecht, 1990). It is this perspective that is needed in the education of the next generation of professional agriculturists.

This paper outlines the potential role that agroecology can play in broadening a conventional agricultural curriculum. The goal is to incorporate ecological principles and knowledge into the study of cropping and farming systems, so that professionals are well prepared for the future design and management of a sustainable agriculture. These professionals will need the skills to:

- Enhance agricultural productivity to satisfy food, feed, and fiber needs, increase rural income, and at the same time conserve the natural resource base;
- Introduce ecological rationality and methods into agriculture to minimize chemical inputs and costs, complement watershed and field conservation programs, plan systems according to local resources and land capabilities, and make efficient use of water, nutrients, and genetic resources; and
- Discover long-term policies concerning pricing, taxation, land and resource use planning, research, and educational activities that will promote a stable, resource efficient, and equitable agriculture.

These skills are not readily acquired in today's conventional agricultural curriculum. An application of broad thinking in agroecology can help us design a curriculum to build this capacity in students, making them better prepared to face future challenges in agricultural development.

Agroecological Focus in Education

Most U.S. academic institutions have developed an educational program in the context of capital-intensive agriculture and an infrastructure that provides access to all needed inputs. Both research and education have focused mostly on individual components of a system, such as recommending a specific fertilizer, insecticide, planting date or plant density. Design of courses has followed classical disciplinary lines, with emphasis in any specific course on the soils, the crops, the insects, the plant pathogens, or the water resources. Often there is little attempt to establish the linkages among these components, nor are the complexities of cropping and crop/animal systems made obvious. As we search for ways to control or remediate the most limiting factors to production, our research and education are focused on specific constraints and the yield response to a particular input. Rarely is the goal to study the complex interactions within an ecosystem and its overall productivity (Altieri, 1987).

There is growing recognition of the need to analyze larger units of study than the individual species or even the cropping system in one field. We still appreciate the need to delve in more detail into the integrative processes that govern productivity and sustainability, such as nutrient cycling, water use and balance, energy flow in systems, and competition among crops and pest species. It is equally important to appreciate and analyze larger units of study, such as the total farming system under control of one operator, or the economic and ecological impacts of different input use strategies on a watershed or an effective market region.

Scientific specialization in agriculture has become more a barrier than a bridge for building understanding of complex phenomena or systems. Even when a group of specialists comes together to teach about production systems, an integrated approach is limited by their lack of a common conceptual framework and language. An agroecological approach makes it possible to evaluate and integrate the many disparate elements of agricultural systems into a unified study of how those systems work, and how they affect the biological, economic, and social environment. This approach can help link issues that lie at the interface of ecological, economic, biological, and social systems.

In an agroecological approach to teaching agriculture, there are several ways in which these systems can be conceived:

- Each as a hierarchical system within an agricultural region that is composed of various subsystems (crops, animals, crop/animal systems, whole farm systems, watershed), with vertical and horizontal interactions among those elements or subsystems, and with outputs from one subsystem serving as inputs to other subsystems (Hart, 1980). In a broad sense, the agricultural system is composed of biological and socioeconomic subsystems with inputs and outputs of money, materials, energy, and information. Models of these systems are useful to help students visualize relationships among subsystems and assign values to resource flows among components.
- As a biophysical system with interactions among abiotic and biotic components, emphasizing feedbacks and understanding of cycles, flows, and population fluctuations. The internal structure of an agroecosystem resulting from the assemblage of various components affects the response of the system to different stresses. By focusing on the interdependence of biotic and abiotic processes, it is possible to study and understand how system performance is affected by the infusion or extraction of large amounts of energy, biomass, and nutrients (Gliessman, 1990).
- As a system where management and other decisions by farmers are affected by natural as well as socioeconomic factors. Farmers' perceptions and risk-averting strategies become fundamental to system performance. Indigenous knowledge about plants, soils, environment, and ecological processes gains increased significance within the agroecological approach. Study of how farmers' rationale and technical knowledge can be used within development schemes provides another dimension to the educational process (Altieri and Hecht, 1990).

In summary, the unique nature of education in agriculture using an agroecological frame of reference requires that students acquire a broader vocabulary and appreciation of a wider range of information resources that help them understand the linkages among components and the total complexity of agricultural systems.

Specific Methods of Analysis

The move toward an agroecological perspective in education involves an appreciation of a wider complement of methods and components than our conventional approach by discipline. From the descriptive statistics of research results to evaluation of the impact of alternative practices, the methods used by agronomists, animal scientists, economists, and sociologists need to be understood and incorporated. This is one reason for interdisciplinary teaching of an agroecology curriculum. The goals of education in agricultural systems can only be met with approaches that do the following:

- Focus on whole-farm systems rather than using a disciplinary analysis that emphasizes one crop or process; understanding of single crops or processes still is critical to provide building blocks for systems, and these topics also must have high priority in the curriculum.
- Incorporate some sociological methods to evaluate the impacts of both socioeconomic and biophysical production factors on productivity and profitability.
- Use the agroecosystem as the unit of study and concentrate on interactive and integrative processes, such as nutrient cycling, rather than on simple cause-effect relationships, such as corn yield response to levels of applied nitrogen.
- Depend on multidisciplinary teams in teaching, and encourage students to gain the interpersonal skills needed to function well in groups.
- Emphasize the linkages between basic and applied science, between research and development, between people and their environment, and between planning and decision making in agriculture (di Castri and Headley, 1986).

Perspectives on Curriculum Design

As we design a set of courses and a series of topics in each course, it is useful to keep in mind some principles on which agroecology is based and how these influence educational approaches. To present an integrative and practical series of topics and activities, our educational philosophy must be based on the following ideas:

- Transcending the dichotomy of teaching independent courses on agricultural production (technical or discipline-based production sciences) and evaluation of impacts (socioeconomic or impact sciences); emphasis should go beyond limiting factors and focus on system design, performance, and response under a range of circumstances.
- Emphasizing the interdependence and integration of economic, cultural, environmental, social, and technical spheres of interest.
- Studying farms and farm families not as isolated units, but as integral components of communities, watersheds, and a larger socioeconomic system.
- Emphasizing the study of systems at different levels of complexity inherent in agroecosystems; moving from simple cause-effect relationships, we can evolve from a problem-solving mentality to one of "situation improvement" or "ecological enhancement."
- Recognizing the uniqueness of each farm, as well as the need for localized and specific responses that are consistent with the economic, resource, and social environment in which each family finds itself.
- Incorporating students' and farmers' knowledge, innovations, and preferences as part of the total information resource base on which to build improved and sustainable agroecosystems.

The design of a specific course or series of courses depends on applying these ideas to the choice of topics, methods of teaching, and ways of involving students in the process of education. Because of the broad and integrative nature of the subject matter, it is important to explore a wide range of information resources and of ways to integrate them into the classroom and laboratory program.

Components of a Curriculum

We suggest two types of courses as contributions from agroecology that would be appropriate to a conventional agricultural curriculum. As a first step, the topics listed here in two courses could be incorporated into a single course that includes both the structure and functions of agroecosystems and the role they play in sustainable development. Some components could be included in other courses in the curriculum, and additional units could be introduced as appropriate. In developing a comprehensive program, these topics could be expanded into more than the two suggested courses.

First course: Biology of agroecosystems

Structure of agroecosystems: description of different biotic and abiotic components of agroecosystems, different types of regional systems, factors and determinants of productivity, trophic webs, biophysical features of soils, and ecophysiology of plants, animals and microorganisms.

Agroecosystem functions: physiological and ecological processes in agroecosystems (energy flow, water balance, nutrient cycling, trophic relationships, competition, decomposition); ecological and energetic efficiency of agricultural systems; species interactions and role of organisms in agroecosystem processes.

Development and performance of agroecosystems: biological changes and process rates in agroecosystems with time and management; response of different biotic and abiotic components to management; crop responses to multiple factors and different cropping designs and management options; effect of management on microclimate, edaphic factors and species population growth, development, and survival.

Optimization and conservation: how to guide management in a way that promotes beneficial ecological interactions, ensuring productivity, resource conservation, and environmental integrity.

Agroecological methodologies and mensuration: systematization of information on complex interactions in systems, hypothesis formulation, design of on-station and on-farm experiments, establishment of inter-relationships, multi-factorial analysis of data, evaluation of biological parameters, and ecological impacts of agricultural systems.

Second course: Agroecology and sustainable agricultural development

Agricultural systems of the U.S. and the world: biophysical, socioeconomic and management characteristics; development and comparative analysis of systems of varied structures under a range of resource endowment situations.

Resources available for agriculture: relationships among land, energy, population, and other resources and the agricultural potential of different regions; national and regional production trends, policy scenarios, and changes in food demand and distribution.

Environmental impacts of agriculture: pesticide pollution, soil erosion, salinization, eutrophication, water contamination.

Social and economic aspects of agriculture: status of family farms, role and potential dominance of agribusiness, politics of agricultural research, implications of biotechnology and other advances in science.

Relationships between agriculture and society: interactions and issues between urban and rural systems, agricultural technology and public health, gender issues in agriculture, agricultural literacy in total population.

Concept and dynamics of agroecosystems: agriculture as an ecological system; ecological processes such as nutrient cycling, water balance, population regulation.

Principles of soil management and biology: study of major soil types, strategies for providing fertility, physical characteristics as influenced by management, microbiological dimensions of soils and cropping systems.

Ecology and management of pest populations: interactions of crops with weeds, plant pathogens, insects, and nematodes; dynamics of pest populations and effects of different management strategies; genetic resistance or tolerance in crops; interactions of pest populations with fertility, water regime, crop rotations, physical design of cropping patterns.

Alternative systems of agricultural production: multiple cropping, rotations, cover cropping, agroforestry systems, minimum and zero tillage; living mulches.

Organic farming systems: characteristics, management and economic performance; current research results and production trends; conversion studies; marketing system for organic products.

Agroecosystem analysis and system design: diagnosis of field problems, farmers' preferences and experiences; design of technologies and systems tailored to each farmer's needs and resource base.

Measuring the performance of agriculture: economic, resource, and ecological indicators (including social equity, stability of production, sustainability, productivity); accounting for long-term environmental and social costs of agriculture.

Traditional farming systems of the Third World: analysis of sustainable farming systems; ethnoecology of systems; collection and evaluation of indigenous farmer knowledge; studies of subsistence farming systems.

Applying agroecology to rural development in the Third World: use of low-input technologies and local resources; renewable resources and efficiency of small farm systems.

Challenges and requirements of sustainable agriculture: definition of sustainability; technical and social dimensions, policy changes and economic incentives; new directions in research and extension.

Future of agriculture: long-term analysis of agriculture; evaluation of internal and external forces on agriculture; growing role of private sector; North-South issues and other geopolitical questions; global climate change.

Conclusions

We consider it important to incorporate agroecology and sustainability into the educational process in agriculture. The degradation of soils and depletion of other natural resources impose high economic, ecological, and social costs on society in the long term, even though many of these changes are not easily detected or understood in the short term. These impacts of agriculture are occurring despite several decades of applying modern science to improving system performance.

Agricultural professionals need to understand that improvement of agroecosystems is closely linked to interacting economic, cultural, and political systems. National or international economic or policy changes can dramatically influence the options available to individual farmers. Problems of rural development involve more than narrow technical questions; they must be dealt with at the local as well as the regional, national, and international levels.

Awareness of broad socioeconomic and political issues is important for agricultural professionals and should be built into our curricula. Yet a strong ecological and technical science background is still fundamental in agriculture, since improved production practices and rural development involve physical interventions and management of resources. To educate people about the intricacies of sustainable systems requires a broad appreciation of production, of resources, of conservation and environmental impacts, and of the complex socioeconomic goals and factors that influence farmers' decisions. This is the rationale for including a strong complement of agroecology in the conventional agricultural curriculum.

References

1. Altieri, M.A. 1987. Agroecology: The Scientific Basis of Alternative Agriculture. Westview Press, Boulder, Colorado.
2. Altieri, M.A., and S.B. Hecht. 1990. Agroecology and Small Farm Development. CRC Press, Boca Raton, Florida.

3. di Castri, F., and M. Headley. 1986. Enhancing the credibility of ecology: Is interdisciplinary research for land use planning useful? GeoJournal 13:299-32.
4. Francis, C.A., C.B. Flora, and L.D. King (eds). 1990. Sustainable Agriculture in Temperate Zones. John Wiley & Sons, New York, N.Y.
5. Gliessman, S.R. 1990. Agroecology: Researching the Ecological Basis for Sustainable Agriculture. Ecological Studies No. 78, Springer-Verlag, New York, N.Y.
6. Hart, R.D. 1980. Agroecosistemas. CATIE, Turrialba, Costa Rica.
7. National Research Council, Board on Agriculture. 1989. Alternative Agriculture. National Academy Press, Washington D.C.
8. Pierce, J. T. 1990. The Food Resource. Longman Scientific and Technical Publishing Co., New York, N.Y.

Book Reviews

Ecological Literacy. Education and the Transition to a Postmodern World. 1992. By David W. Orr. State University of New York Press, Albany. 210 pp. $29.50 hardcover; $14.95 paper.

A book dealing with education pertinent to environmental problems is timely. A recent national survey of college students conducted by the University of California at Los Angeles reported that the environment is the primary concern of incoming freshmen; many universities have responded to this interest by setting up environmental studies curricula. Yet little attention has been given to how interrelations of agriculture and environmental deterioration should be addressed at the college level. A recent review of the federal Sustainable Agriculture Research and Education program (NRC, 1991) said almost nothing about education. It was not even clear whether the education component of this program refers to farmers, other working adults, or students in Colleges of Agriculture or other university settings.

Ecological Literacy is a wide-ranging collection of essays by an author with considerable experience in environmental education. Orr co-founded the Meadowcreek Project, an innovative non-profit environmental education organization in Fox, Arkansas, and now is Professor of Environmental Studies at Oberlin College.

The book is organized into three sections: The Issue of Sustainability; Education; and What Knowledge? For What Purposes? The first section defines the scope and depth of the "crisis of sustainability." It reviews criticism of industrialized societies and literature about detrimental human effects on the biophysical environment. The second section explores ramifications of Orr's belief that "educational institutions are potential leverage points for the transition to sustainability" (p. 84). He argues that sustainability requires changes in the content and process of education, and a "recovery of civic competence" (p. 84). One chapter in this section is an exhaustive syllabus of almost every imaginable topic related to living well and responsibly. The third section deals with a few specific "pathologies of knowledge" (p. 156) that arise from misdirected generation of knowledge. The three examples Orr examines are the assumption that we can manage our planet, the failure of social sciences to contribute to understanding and resolving the crisis of sustainability, and a proposal for a high-technology perennial-based agricultural system from two U.S. Department of Agriculture researchers (Rogoff and Rawlins, 1987). The final chapter includes several alternative visions of the future of U.S. agriculture that contrast with the proposal Orr trounces.

Ecological Literacy is mainly about problems of modern (or perhaps more precisely, "postmodern") industrialized societies, and how education could contribute to solutions. It is related only peripherally to ecology, as most ecologists would understand the term. Orr's syllabus for ecological literacy includes readings by very few professional ecologists, and "ecological literacy" seems to be a misnomer for the concept he promotes. It has more to do with what Orr wants ecology to be than what it is. For instance: "The form and structure of any conversation with the natural world is that of the discipline of ecology as a restorative process and healing art" (p. 91).

Orr pleads for greater understanding of environmental and political issues, and the interconnections between these topics and technical issues, to produce citizens who take their stewardship responsibilities seriously. He tries to link a staggering array of social problems—from terrorism to anomie—with ecological literacy. These connections are the weakest part of the book; they depend too much on idealism and emotional appeal.

I agree with much of Orr's assessment of what is wrong with modern society, but I am unconvinced that his prescription matches the ailments. To me, the basic question for "ecological literacy" is whether greater awareness of social and environmental problems will lead people to be willing to pay the costs of fixing those problems and to forego the benefits of consumerism. This book is a cornucopia of alternatives that could ameliorate the crisis of sustainability, but the jury is still out on what will induce people to choose these kinds of options. Orr's arguments for a rich experiential humanistic education are persuasive, but I think the likely consequences are overstated. (Orr, too, acknowledges that education is only one of several influences on behavior).

The first section of this book adds little to its overall message. Here Orr details the evils of modern society, but they have already been described by the authors listed in his syllabus. Unfortunately, ideas that were plausible in the original sometimes seem fatuous second-hand, when quoted without explanation. For example, it is unclear what Wendell Berry meant by writing that good solutions generically "have wide margins" and "exist in proof" (p. 62). Likewise, the reader might wonder how to use recommendations such as "design should be co-evolutionary" and "design should follow a sacred ecology" (p. 33, quoted from John and Nancy Todd). Perhaps because Orr is trying to cover too much ground, his analyses sometimes seem simplistically distilled into "good