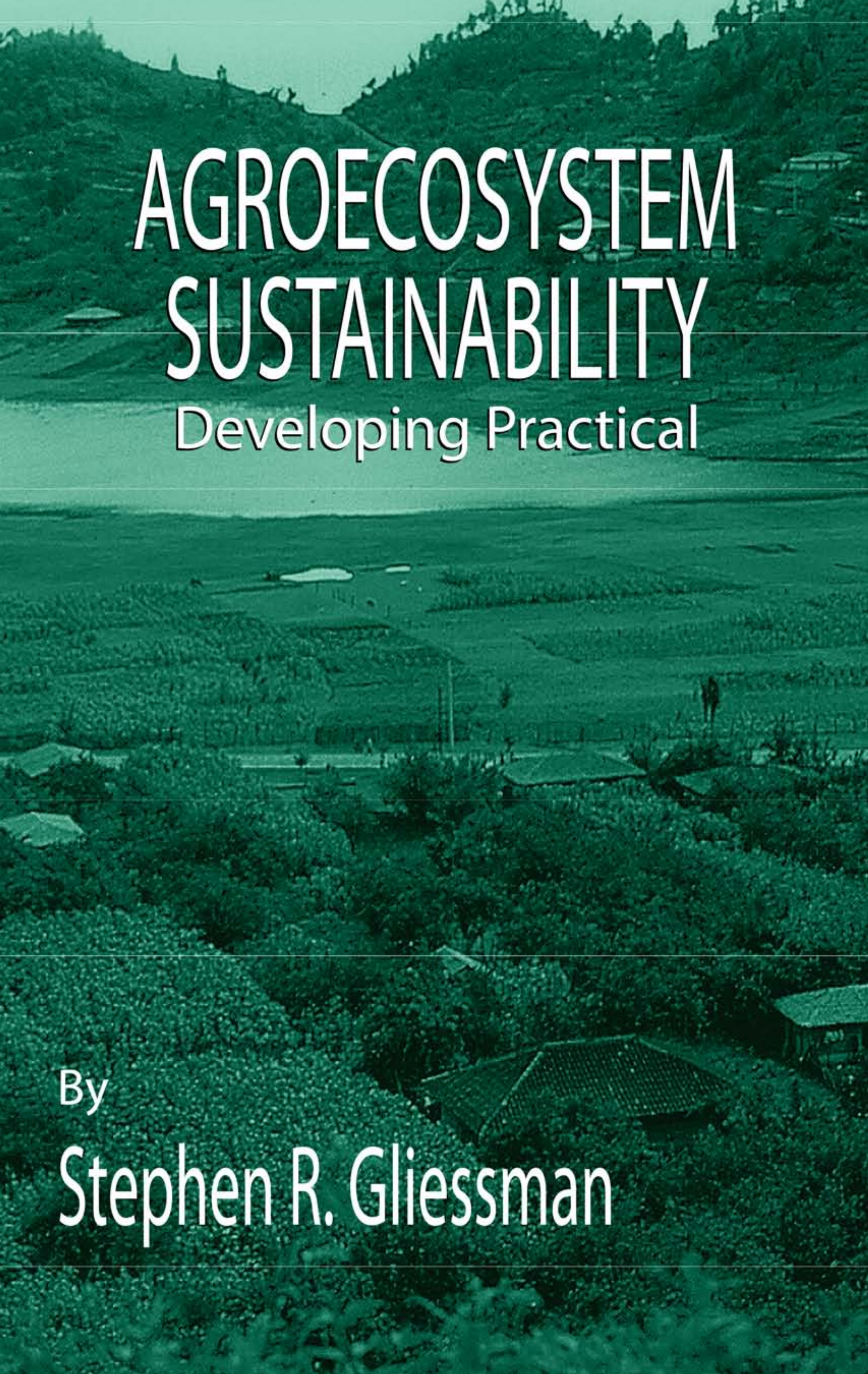

AGROECOSYSTEM SUSTAINABILITY

Developing Practical

By

Stephen R. Gliessman

AGROECOSYSTEM SUSTAINABILITY

Developing Practical Strategies

Advances in Agroecology

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Preface

Considerable evidence indicates that modernized, conventional agroecosystems around the world are unsustainable. Dependent on large, fossil-fuel-based, external inputs, they are overusing and degrading the soil, water, and genetic resources upon which agriculture depends. Although the deterioration of agriculture's foundation can be masked by fertilizers, herbicides, pesticides, high-yielding varieties, and water and fossil-fuel resources borrowed from future generations, it cannot be hidden forever, especially given increases in the human population, climate modification, and destruction of natural biodiversity and habitats.

It is against this background of concern that the science of agroecology and the concept of sustainability have arisen and evolved during recent decades. Agroecological research has always held sustainability of food production systems as its ultimate goal; recently agroecological and related research have turned toward making its connection to sustainability stronger and working on more practical strategies for shifting toward sustainability in agriculture.

This volume showcases the leading research in developing practical strategies. This research ranges from specific management practices that can enhance agroecosystem sustainability in a region to more global efforts to develop sets of sustainability indicators that can assess movement toward or away from sustainability.

Although the chapters in this volume represent disparate levels of focus and various disciplinary approaches, each chapter is part of the larger puzzle of achieving sustainability in agriculture, and springs from an agroecological framework. Modern agroecosystems have become unsustainable for a variety of reasons having to do with economics, history, social and political change, and the nature of technological development. Redirecting agriculture in a sustainable direction requires research and change in all these areas, but the basis of sustainability lies in ecological understanding of agroecosystems dynamics as represented by agroecology.

The chapters in this volume are organized into three sections: The first section presents the results of research in specific strategies for increasing the sustainability of farming systems. Particular problems or conditions facing farm managers are identified, and alternatives that employ an agroecological framework are applied. These strategies include adding self-reseeding annual legumes to a conventional crop rotation, manipulating the spatial distribution of natural biodiversity in vineyards to enhance natural pest control, applying agroforestry practices, and managing mulch.

The second section presents a variety of research approaches for assessing the level or degree of sustainability of farming systems. Each chapter in this section focuses on a particular agroecosystem level process or condition — ranging from nematode communities in the soil to nutrient cycling — that can be used to evaluate performance and sustainability as a function of farm design and management.

The third section takes sustainability analysis to its most holistic level through the presentation of research that combines the ecological foundations of sustainability with their social components. These chapters attempt to place agroecology in the social and cultural environment in order to influence people's decisions on how and why to design and manage agroecosystems.

Ultimately, this book emphasizes sustainability as a whole-system, interdisciplinary concept, and that it is the emergent quality of agroecosystems that evolves over time. Sustainability is the integration of a recognizable social system and its ecosystem setting; it results in a dynamic, continually evolving agroecosystem.

Stephen R. Gliessman

The Editor

With graduate degrees in botany, biology, and plant ecology from the University of California, Santa Barbara, Stephen R. Gliessman has over 25 years of teaching, research, and production experience in the field of agroecology. He has hands-on and academic experience in tropical to temperate agriculture, small farm to large farm systems, traditional to conventional farm management, and organic and synthetic chemical approaches to agroecosystem design and management. He is the founding director of the University of California, Santa Cruz Agroecology Program (one of the first formal agroecology programs in the world), and is the Alfred Heller Professor of Agroecology in the Department of Environmental Studies at UCSC. He dry farms organic wine grapes and olives with his brother in northern Santa Barbara County, California.

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Increasing Sustainability

CHAPTER 1

The Ecological Foundations of Agroecosystem Sustainability*

Stephen R. Gliessman

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1.1 INTRODUCTION

What is a sustainable agroecosystem? An easy way to answer this question is to give a definition: A sustainable agroecosystem maintains the resource base upon which it depends, relies on a minimum of artificial inputs from outside the farm system, manages pests and diseases through internal regulating mechanisms, and is able to recover from the disturbances caused by cultivation and harvest (Edwards et al., 1990; Altieri, 1995). Such a broadly applicable definition still begs many other questions: How do we identify an actually existing agroecosystem as sustainable or

* This chapter is adapted from Chapter 20 of *Agroecology: Ecological Processes in Sustainable Agriculture*, by Stephen Gliessman, CRC Press LLC, Boca Raton, FL, 2000.

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not? What particular facets of a system make it sustainable or unsustainable? How can we build a sustainable system in a particular bioregion, given realistic economic constraints? Generating the knowledge and expertise for answering these kinds of questions is one of the main tasks facing the science of agroecology today.

Ultimately, sustainability is a test of time; an agroecosystem that has continued to be productive for a long period of time without degrading its resource base — either locally or elsewhere — can be said to be sustainable. What constitutes a long period of time? How is it determined if degradation of resources has occurred? How can a sustainable system be designed when the proof of its sustainability remains always in the future?

Despite these challenges, we need to determine what sustainability entails. In short, the task is to identify parameters of sustainability — specific characteristics of agroecosystems that play key parts in agroecosystem function — and to determine at what level or condition these parameters must be maintained for sustainable function to occur. Through this process, we can identify what we will call indicators of sustainability — agroecosystem-specific conditions necessary for and indicative of sustainability. With such knowledge it will be possible to predict whether a particular agroecosystem can be sustained over the long-term, and to design agroecosystems that have the best chance of proving to be sustainable.*

1.2 LEARNING FROM EXISTING SUSTAINABLE SYSTEMS

The process of identifying the elements of sustainability begins with two kinds of existing systems: natural ecosystems and traditional agroecosystems. Both have stood the test of time in terms of maintaining productivity over long periods, and each offers a different kind of knowledge foundation. Natural ecosystems provide an important reference point for understanding the ecological basis of sustainability; traditional agroecosystems offer abundant examples of actually sustainable agricultural practices as well as insights into how social systems — cultural, political, and economic — fit into the sustainability equation. Based on the knowledge gained from these systems, agroecological research can devise principles, practices, and designs that can be applied in converting unsustainable conventional agroecosystems into sustainable ones.

1.2.1 Natural Ecosystems as Reference Points

Natural ecosystems and conventional agroecosystems are very different. Conventional agroecosystems are generally more productive but far less diverse than natural systems. Unlike natural systems, conventional agroecosystems are far from self-sustaining. Their productivity can be maintained only with large additional inputs of energy and materials from external, human sources; otherwise they quickly degrade to a much less productive level. In every respect, these two types of systems are at opposite ends of a spectrum.

The key to sustainability is to find a compromise between a system that models the structure and function of natural ecosystems and yields a harvest for human use.

* For recent reviews of different ways to apply sustainability analysis see Munasinghe and Shearer 1995; Moldan et al., 1997; OCED, 1998.

Such a system is manipulated to a high degree by humans for human ends, and is therefore not self-sustaining, but relies on natural processes for maintenance of its productivity. Its resemblance to natural systems allows the system to sustain human appropriation of its biomass without large subsidies of industrial cultural energy and detrimental effects on the surrounding environment.

Table 1.1 compares these three types of systems using several ecological criteria. As the terms in the table indicate, sustainable agroecosystems model the high diversity, resilience, and autonomy of natural ecosystems. Compared to conventional systems, they have somewhat lower and more variable yields, a reflection of the variation that occurs from year to year in nature. These lower yields, however, are usually more than offset by the advantage gained in reduced dependence on external inputs and an accompanying reduction in adverse environmental impacts.

From this comparison we can derive a general principle: the greater the structural and functional similarity of an agroecosystem to the natural ecosystems in its biogeographic region, the greater the likelihood that the agroecosystem will be sustainable. If this principle holds true, then observable and measurable values for a range of natural ecosystem processes, structures, and rates can provide threshold values or benchmarks that delineate the ecological potential for the design and management of agroecosystems. It is the task of research to determine how close an agroecosystem needs to be to these benchmark values to be sustainable (Gliessman, 1990).

1.2.2 Traditional Agroecosystems as Examples of Sustainable Function

Throughout much of the rural world today, traditional agricultural practices and knowledge continue to form the basis for much of the primary food production.

Table 1.1 Properties of Natural Ecosystems, Sustainable Agroecosystems, and Conventional Agroecosystems

	Natural Ecosystems	Sustainable Agroecosystems[a]	Conventional Agroecosystems[a]
Production (yield)	Low	low/medium	high
Productivity (process)	Medium	medium/high	low/medium
Species diversity	High	medium	low
Resilience	High	medium	low
Output stability	Medium	low/medium	high
Flexibility	High	medium	low
Human displacement of ecological processes	Low	medium	high
Reliance on external human inputs	Low	medium	high
Internal nutrient cycling	High	medium/high	low
Sustainability	High	high	low

[a] Properties given for these systems are most applicable to the farm scale and for the short to medium term time frame.

Modified from Odum (1984), Conway (1985), and Altieri (1995).

What distinguishes traditional and indigenous production systems from conventional systems is that the former developed primarily in times or places where inputs other than human labor and local resources were not available, or where alternatives have been found that reduce, eliminate, or replace the energy- and technology-intensive human inputs common to much of present-day conventional agriculture. The knowledge embodied in traditional systems reflects experience gained from past generations, yet continues to develop in the present as the ecological and cultural environment of the people involved go through the continual process of adaptation and change (Wilken, 1988).

Many traditional farming systems can allow for the satisfaction of local needs while also contributing to food demands on the regional or national level. Production takes place in ways that focus more on the long-term sustainability of the system, rather than solely on maximizing yield and profit. Traditional agroecosystems have been in use for a long time, and have gone through many changes and adaptations. The fact that they still are in use is strong evidence for social and ecological stability that modern, mechanized systems could well envy (Klee, 1980).

Studies of traditional agroecosystems can contribute greatly to the development of ecologically sound management practices. Indeed, our understanding of sustainability in ecological terms comes mainly from knowledge generated from such study (Altieri, 1990).

What are the characteristics of traditional agroecosystems that make them sustainable? Despite the diversity of these agroecosystems across the globe, we can begin to answer this question by examining what most traditional systems have in common. Traditional agroecosystems:

- Do not depend on external, purchased inputs
- Make extensive use of locally available and renewable resources
- Emphasize the recycling of nutrients
- Have beneficial or minimal negative impacts on both the on and off farm environment
- Are adapted to or tolerant of local conditions, rather than dependent on massive alteration or control of the environment
- Are able to take advantage of the full range of microenvironmental variation within the cropping system, farm, and region
- Maximize yield without sacrificing the long-term productive capacity of the entire system and the ability of humans to use its resources optimally
- Maintain spatial and temporal diversity and continuity
- Conserve biological and cultural diversity
- Rely on local crop varieties and often incorporate wild plants and animals
- Use production to meet local needs first
- Are relatively independent of external economic factors
- Are built on the knowledge and culture of local inhabitants

Traditional practices cannot be transplanted directly into regions of the world where agriculture has already been modernized, nor can conventional agriculture be converted to fit the traditional mold exactly. Nevertheless, traditional practices hold important lessons for how modern sustainable agroecosystems should be designed.

A sustainable system need not have all the characteristics outlined above, but it must be designed so that all the functions of these characteristics are retained.

Traditional agroecosystems can provide important lessons about the role that social systems play in sustainability. For an agroecosystem to be sustainable, the cultural and economic systems in which its human participants are embedded must support and encourage sustainable practices and not create pressures that undermine them. The importance of this connection is revealed when formerly sustainable traditional systems undergo changes that make them unsustainable or environmentally destructive. In every case, the underlying cause is some kind of social, cultural, or economic pressure. For example, it is a common occurrence for traditional farmers to shorten fallow periods or increase their herds of grazing animals in response to higher rents or other economic pressures and to have these changes cause soil erosion or reduction in soil fertility.

It is essential that traditional agroecosystems be recognized as examples of sophisticated, applied ecological knowledge. Otherwise, the so called modernization process in agriculture will continue to destroy the time tested knowledge they embody — knowledge that should serve as a starting point for the conversion to the more sustainable agroecosystems of the future.

1.3 CONVERTING TO SUSTAINABLE PRACTICES

Farmers have a reputation for being innovators and experimenters, willing to adopt new practices when they perceive some benefit will be gained. Over the past 40 to 50 years, innovation in agriculture has been driven mainly by an emphasis on high yields and farm profit, resulting in remarkable returns but also an array of negative environmental side effects. Despite the continuation of this strong economic pressure on agriculture, however, many farmers are choosing to make the transition to practices that are more environmentally sound and have the potential for contributing to long-term sustainability for agriculture (National Research Council, 1989; Edwards et al., 1990).

Several factors are encouraging farmers to enter into this transition process:

- The rising cost of energy
- The low profit margins of conventional practices
- The development of new practices that are seen as viable options
- Increasing environmental awareness among consumers, producers, and regulators
- New and stronger markets for alternatively grown and processed farm products

Despite the fact that farmers often suffer a reduction in both yield and profit in the first year or two of the transition period, most of those that persist eventually realize both economic and ecological benefits from having made the conversion (Swezey et al., 1994; Gliessman et al., 1996). Part of the success of the transition is based on a farmer's ability to adjust the economics of the farm operation to the new relationships of farming with a different set of input and management costs, as well as adjusting to different market systems and prices.

The conversion to ecologically based agroecosystem management results in an array of ecological changes in the system (Gliessman, 1986). As the use of synthetic