Agroecology

The environmental impacts of the Green Revolution, which emphasized increasing crop yields often at the expense of the environment, led ecologists to encourage agroecology, a sustainable approach that protects not only the environment but small shareholders. The movement has grown worldwide with positive effects particularly in developing countries, where it has not only ecological impacts but social and economic effects as well.

Agroecology is defined most simply as "the application of ecology in agriculture." Whereas many of the principles of agroecology are as old as agriculture itself, interest in the topic has expanded in response to industrialized agriculture's negative environmental and social impacts. The Green Revolution in agriculture that occurred from the 1940s to the 1970s promoted the adoption of new technologies for boosting crop yields through monoculture systems, improved crop varieties, chemical fertilizers, synthetic pesticides, and irrigation. Although this strategy increased production in an effort to feed a growing population, a number of unintended consequences emerged. New high-yielding varieties displaced traditional varieties that were well adapted to local conditions and served as a source for genetic diversity. The focus on specific grain crops such as corn, wheat, and rice reduced the nutritional quality of the human diet because these replaced fruits, vegetables, and traditional crops. Environmental impacts are the most publicized consequences: biodiversity and habitat loss in the landscape; pollution of water resources from pesticides, nutrients, and sediment; reduction in water quantity from irrigation; and others. The growing environmental movement of the 1960s raised awareness of these issues. Agroecology emerged as an approach that would support production of food and other materials while also protecting the environment and small shareholders.

Charles Francis, a US expert on sustainable agriculture, and his colleagues expanded the area of agroecology as the "integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions" (Francis et al. 2003, 100). This broader focus on food systems establishes agroecology as an integrated and multidisciplinary field that encourages involvement from sociologists, economists, regional planners, policy makers, and public health experts. Interest in agroecology is likely to grow because society needs creative and sustainable solutions to balance the need for greater food security with the limited availability of natural resources to produce food.

Historical Context

The emergence of agroecology as a unique discipline dates to the early part of the twentieth century. Scientists explored early topics such as crop ecology (Klages 1928), crop-environment interactions (Papadakis 1970), and ecology in agriculture (Hanson 1939). Agroecology gained a strong foothold in the 1970s, as scientists publicized the impacts of industrialized agriculture. Miguel Altieri, a US agroecologist and a sustainable agriculture advocate, published *Agroecology: The Science of Sustainable Agriculture* in 1987. Steven Gliessman, another US expert in agroecology, published his textbook *Agroecology: Ecological Processes in Sustainable Agriculture* in 1998. Alexander Wezel (2009), a French agroecologist, and his colleagues chronicled the development of agroecology primarily as a scientific discipline in the 1970s and earlier, as a set of practices in the 1980s, and as a social

movement in the 1990s. Broader definitions that encourage the integration of multiple disciplines have emerged in the twenty-first century.

A number of topics related to agroecology are worth defining because they have contributed to the development of the field and will likely impact directions. *Sustainable agriculture* seeks to meet the needs of humans today without compromising the needs of future generations by integrating goals for environmental stewardship, economic viability, and social equity. Many of the practices recommended for sustainable agriculture align with those in agroecology, but the concept of sustainable agriculture is used less in the context of traditional agricultural systems, practices, and knowledge. *Organic agriculture* refers to a very specific set of farming standards that limit the use of pesticides, chemical fertilizers, and other synthetic inputs. The Agricultural Marketing Service of the US Department of Agriculture and international bodies regulate the marketing term. Products labeled "organic" often receive a premium price. *Multifunctionality in agriculture* developed out of the recognition that agricultural landscapes can provide multiple noncommodity outputs including ecological functions (e.g., biodiversity, water protection, and habitat) and cultural functions (e.g., recreation, visual quality, and education) that traditional markets do not capture. Policies to encourage multifunctionality often promote landscape features and practices that could support agroecology. Other holistic approaches such as *permaculture* and *biodynamic agriculture* overlap with agroecology, drawing in a diverse audience to include residential gardeners, collective farms, and concerned consumers. These approaches share knowledge on the ecology of agriculture in simple and small-scale formats.

Contemporary Approaches, Impacts, and Challenges

Contemporary agroecology includes a broad set of approaches and methods, most of which seek to mimic the characteristics of natural ecosystems. In general, the methods intend to reduce reliance on off-farm resources, avoid synthetic inputs, minimize toxic materials, conserve energy, and protect natural resources such as soil and water. Reduced tillage minimizes the regular disturbance of the system, resulting in lower energy requirements, reduced soil erosion, and conservation of soil moisture. Diversification of the agroecosystem through crop rotations and polycultures helps to reduce pests by disrupting their life cycles, to improve soil fertility when nitrogen-fixing legumes are included, and generally to increase resilience against local disturbances. Cover crops can also contribute to biodiversity and nutrient cycling while suppressing weeds. Crop species that are well adapted to the given environment can reduce the need for irrigation and other inputs. Perennial crops, including trees, minimize disturbance of the system while providing additional benefits such as carbon sequestration, soil stabilization, and microclimate control. Integrating livestock into the agroecosystem improves soil organic matter and enhances nutrient cycling because animals process plant material into readily available nutrient forms in their manure. From the social perspective, agroecology seeks to support the livelihoods of farmers, to protect the welfare of farm workers, and to strengthen the rural communities in which they live.

The impacts of agroecology on the environment are intended to be positive when compared with conventional systems. Critics of conventional industrial agriculture say it displaces natural habitats, depletes the soil of nutrients and organic matter, pollutes and depletes water resources, and contributes to greenhouse gas emissions (agriculture and food systems globally contribute one-third of emissions). Agroecology is one strategy for protecting natural resources through appropriate design and management of a production system.

The approach is not without challenges, however. The knowledge required to manage such a complex system is vast. Current institutional support to help build the knowledge base through research and extension activities is lacking. Farmers themselves, along with some key advocates, share much of the knowledge. Agroecology can also be more labor intensive, particularly in the start-up phases. The availability of skilled laborers is limited in some regions. Finally, profitability can be a challenge in countries where government subsidies provide support for commodity crops and associated inputs, but not for

agroecology production. Farmers of diversified and small-scale production systems may find it difficult to compete under such conditions. They are often pushed into high-value markets with a more elite or wealthier customer base. The outputs (such as organic foods) are not equally available to all consumers, particularly the members of disadvantaged communities.

International Distribution

The roots of agroecology, as well as current applications, can be found across the globe. Much of the focus in the literature is on developing countries, but the growing interest in healthy food systems is driving a greater awareness in developed countries.

United States and Canada

Ecologists led the rise of agroecology in the 1970s in the United States, where the conflict with industrial agriculture was most intense and visible. Several key advocates have promoted agroecology for decades and continue to contribute to the field through writings, research, and curriculum development: Miguel Altieri at the University of California at Berkeley; Steven Gliessman at the University of California at Santa Cruz; Charles Francis at the University of Nebraska; and John Vandermeer at the University of Michigan. A number of land grant institutions provide some curricular offerings in agroecology or related topics through a dedicated major, a specialization within a major, or individual courses. Increasingly, other institutions throughout the United States and Canada, including liberal arts colleges and community colleges, offer programs in agroecology to meet the demand growing from greater public awareness of the role of agriculture in environmental and social issues.

Many of the publications on agroecology originate from US authors, yet developing countries (particularly those in Latin America) are the target for much of the research in the articles. One reason may be that experts rarely consider the applications of agroecology from the United States and Canada to be transformative. Few examples exist of whole farms planning to closely mimic the natural environment. Instead, US agriculture has focused on implementing individual, specific practices such as cover cropping, intercropping, and crop rotations, which are often promoted for commercial organic production systems. Some of the more aggressive applications include integrated crop-livestock systems, urban food production systems, and perennial polycultures for grain or biofuels. The growing public interest in local foods in the United States could have important implications for the future of agroecology as consumers request higher environmental standards from the nearby farmers providing their food.

Latin America

Latin America has played an important role in the development of the international agroecology scene in two ways. For one, the region includes a number of sites that have been the focus of research and the source of models of integrated systems relying on local knowledge. A second role is in the grassroots political movements driven by peasant farmers, such as the Campesino a Campesino (Farmer to Farmer) movement that Eric Holt-Giménez, an internationally known researcher in agroecology, documented. These movements call for agricultural reform through a return to sustainable agriculture practices, local knowledge protection, and food sovereignty for the poor.

In some ways, Latin America serves as a nexus of agroecology between the developing and developed world. These countries offer innovative solutions, host development projects, and lead reforms. In Havana, Cuba, the transition from reliance on imported foods and agricultural inputs to local, organic food production following the collapse of the Soviet Union may be one of the most inspiring examples of widespread transformation to agroecology production. The Tropical Agriculture Research and Higher Education Center, or CATIE (Centro Agronómico Tropical de Investigación y Enseñanza), in Turrialba, Costa Rica, is recognized globally for programs and expertise in agroecology, particularly for its emphasis on social issues such as poverty alleviation and rural development. A number of current agroecology experts have trained at the center.

Europe

In many European countries, agroecology is being applied at a broad scale in a comprehensive and integrated manner responsive to local and regional landscape characteristics. Policies to subsidize landscape features that improve ecological and cultural functions while still encouraging productivity have embraced the concept of multifunctionality of agriculture. Many of the programs emphasize landscape design (i.e., including noncrop habitats), as opposed to field-scale management practices. Several European researchers are contributing to the broader conversation about agroecology. Eduardo Sevilla-Guzman's research group at Spain's University of Cordoba focuses on the sociological perspective of agroecology, engaging small-scale farmers and supporting rural development through participatory approaches. Alexander Wezel at ISARA-Lyon in France studies the history and applications of agroecology around the world. The Nordic Agroecology

University Network (AGROASIS) is a collaboration between several institutions to provide education in agroecology. Wageningen University in the Netherlands offers programs that bridge disciplines through applied research and education based on a theme of "healthy food and living environment."

Asia

In Asia, the most interesting applications of agroecology occur in and around urban centers. High population densities require innovative approaches to growing food and reusing resources, in some cases integrating crops, livestock, and aquaculture. In urban areas, agroecology combines with landscape ecology, integrating and protecting production functions as part of the urban planning process. Peri-urban zones, which juxtapose urban and rural areas, contain agritourism enterprises that often emphasize sustainability. In rural areas, protecting the heritage of traditional practices that relied upon complex nutrient cycling and waste management is the primary focus, providing important lessons for agroecology today. Water and air quality are specific issues that could strengthen the importance of agroecology in Asia in the coming years, along with the threat that climate change poses to food security in densely populated areas.

Africa

For Africa, agroecology offers an opportunity to deal with human hunger in a more sustainable manner that could also support self-reliance and community empowerment. The lack of organized agricultural policy that could subsidize sustainable approaches has limited the widespread adoption of agroecology in Africa. Instead, food insecurity has led to exploitation of resources, causing a decline in soil fertility and crop yields. To date, most international efforts to assist African communities in dealing with the immediate threat of starvation have relied on Green Revolution technologies such as nonlocal varieties, irrigation, and synthetic pesticides and fertilizers. Recently, however, results of a countrywide study in Malawi provided evidence of the benefits of sustainable approaches, even in terms of food provision. Monitoring the impacts of a broad government program to provide farmers with improved maize seed and synthetic nitrogen fertilizer, the research team of US ecologist Sieglinde Snapp and her colleagues found that adding diversity to the system (in the form of rotations including legumes) increased yield consistency, grain quality, production profitability, fertilizer efficiency, and farmer preference compared with synthetically fertilized monoculture systems. This study challenges the notion that agroecology is inconsistent with the need for high production to feed the world (Snapp 2010).

Australia

Agroecology has existed in Australia for decades, mostly through alternative sustainable farming practices. The Australian ecologists Bill Mollison and David Holmgren formalized the permaculture approach (or "permanent agriculture") in the 1970s as a way to promote ecological principles through productive perennial habitats that are diverse and resilient. Permaculture, which is often implemented as part of the homestead, can become a lifestyle for some advocates. Biodynamic farming, a related holistic and organic approach focusing on a closed system of nutrient cycling, is popular in Australia (see, e.g., Biodynamic Agriculture Australia, a nongovernmental organization that promotes the concepts). Australia was also an early leader in the organic agriculture movement, with the first organic society, the Australian Organic Farming and Gardening Society.

Controversy and Debates in Agroecology

The debates between proponents of industrial agriculture and advocates of agroecology have simmered throughout the decades. The primary point of contention has been the extent to which agroecology could actually meet the global food needs if implemented on a broader scale. Governments justified the Green Revolution based on the assumption that the growing population required high-yielding grain crops that could be stored for extensive periods. Critics have brought the sustainability of this strategy into question. With the growing awareness of the impacts of agriculture on climate change, water quality, and other environmental issues, the controversy has evolved to consider the best strategies for conserving biodiversity and protecting natural resources. The question then becomes whether it is better to intensify production in an effort to conserve land elsewhere ("land sparing"), or to reduce the negative impacts of agriculture locally ("wildlife-friendly farming").

The controversy between industrial agriculture and agroecology extends beyond environmental issues to include societal issues. One debate relates to the importance of protecting local knowledge, conserving local genetic resources, and supporting farmer livelihoods in developing countries. Critics have accused agribusinesses of exploiting the diverse crop genetic resources to improve the performance of marketable crop varieties. Governments have encouraged indigenous farmers to purchase the

"improved" varieties. Farmers often abandon local and adapted crops, along with the local knowledge to manage such systems. Agroecologists, on the other hand, view the genetic resources and local knowledge as an essential part of the agroecosystem and a contributor to livelihoods of small farmers.

Another debate revolves around the issue of human health related to food consumption. Historically, proponents of traditional agricultural systems compared systems based on metrics of quantity (producing calories, or high grain yields) and not quality (nutritional value). Agroecology advocates argue that much of the grain that conventional systems produce is destined for livestock feed or highly processed foods (particularly in the United States with the focus on corn), so the efficiency is low in terms of human consumption and food quality. The recent concerns about the quality of the human diet have fueled this argument, as health experts call for diets with more fruits and vegetables to reduce obesity and related illnesses.

The controversies related to production, environmental impacts, and social implications become particularly heated when government subsidies and incentives are considered. In the United States, for example, agroecologists and other critics question policies originally designed to avoid food shortages and support farmers, for their unbalanced support of large, commodity-based production systems. Agroecology advocates argue governments should remove or redistribute subsidies and incentives to align with the public benefits provided by agriculture. Furthermore, a large portion of the agricultural subsidies go to wealthy individuals and corporations that are not based in rural communities where the land is located. Predicting the broader implications of an overhaul of these policies, however, is a great challenge.

Outlook

Governments are exploring agroecology as a realistic solution for balancing food production and environmental health, with increasing consideration of the noncommodity outputs provided by agroecosystems. The expansion of the definition of agroecology to encompass the entire food system will encourage multidisciplinary approaches that consider social and political issues. An important contemporary concern is the need to develop appropriate assessment and monitoring strategies in order to evaluate the impacts, beyond yield alone, of different types of farming systems. These assessments will consider "ecosystem services" provided by agroecosystems, as well as impacts on food security, human health, and farmer livelihoods. The results of these assessments could help guide agricultural policy.

The outlook for the discipline of agroecology is bright. United Nations Special Rapporteur Olivier De Schutter's report to the United Nations on the "right to food" specifically identified agroecology as an appropriate strategy to improve food availability for vulnerable groups (De Schutter 2010). And since vulnerable groups have been identified in cities throughout the world, even in developed countries, urban agriculture is a particularly interesting application of agroecology to address food insecurity and obesity while promoting neighborhood revitalization. With dense populations, the urban environment offers unique opportunities to provide healthy foods, reuse organic waste products, reduce transportation and processing, educate consumers about food and nutrition, and create jobs.

The future of agroecology will most certainly be guided by *sustainability*, as the environmental implications of agricultural activities must be balanced with the need to feed the world. Research related to climate change—both mitigation and adaption—will be critical in the coming years. How can agroecosystems be designed to sequester carbon? What cropping systems will be adapted to future conditions? To what extent will agriculture compete for fresh water resources? Answers to these questions will certainly require collaboration across disciplines. Although agroecology initially gained strength directly from the negative outcomes of industrialized agriculture, this discipline has the potential to dissolve some of the tensions between agriculturalists and environmentalists as we face an uncertain future dealing with food insecurity, climate change, and limited resources.

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See also Adaptive Resource Management (ARM); Agricultural Intensification; Best Management Practices (BMP); Biodiversity; Ecosystem Services; Global

Climate Change; Human Ecology; Irrigation; Nutrient and Biogeochemical Cycling; Permaculture; Soil Conservation; Urban Agriculture

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