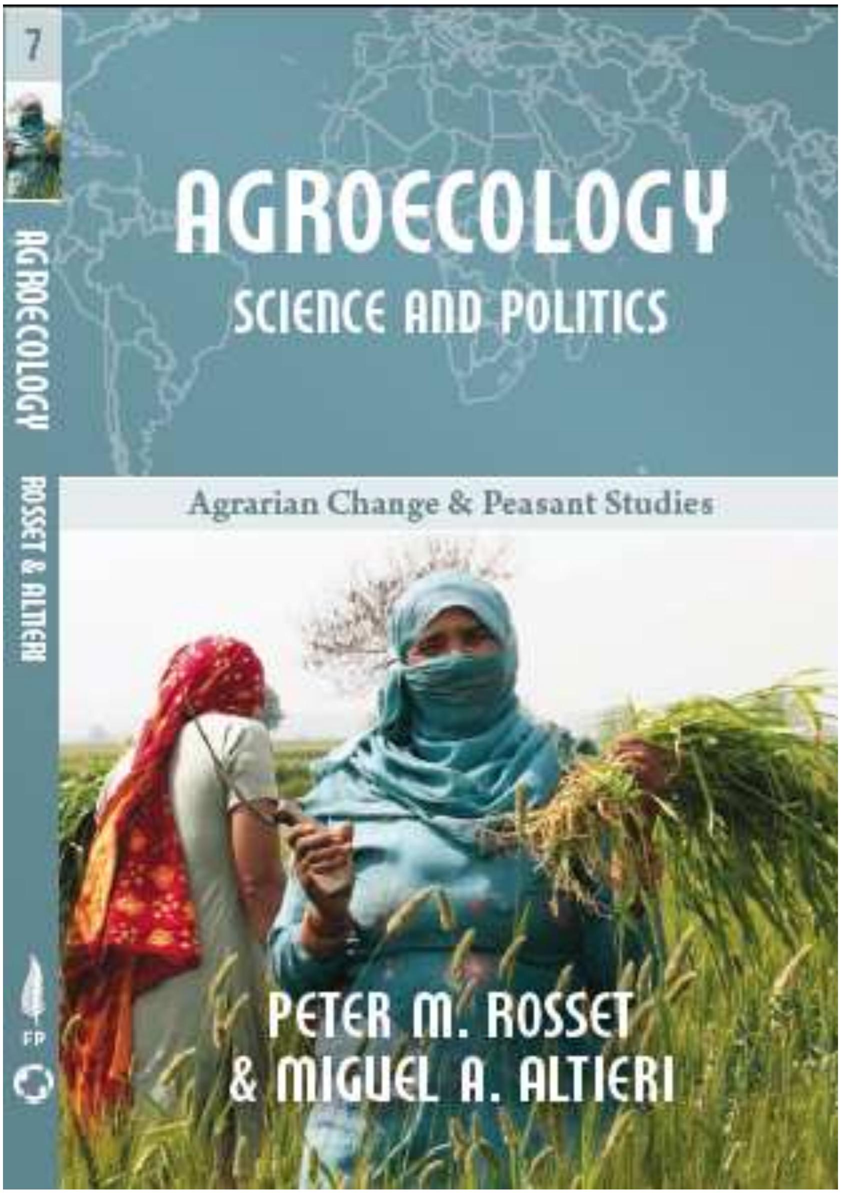
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AGROECOLOGY
ROSSET & ALTIERI
FP
AGROECOLOGY
SCIENCE AND POLITICS
Agrarian Change & Peasant Studies
PETER M. ROSSET
& MIGUEL A. ALTIERI

Agrarian Change and Peasant Studies Series

Our global food system is largely based on unsustainable industrial agricultural practices, is a major source of greenhouse gas emissions, is controlled by a handful of large corporations and produces unhealthy food. Agroecology is a solution to these increasingly urgent problems.

After decades of being dismissed by mainstream institutions and defended in obscurity by grassroots movements, some scientists and farmers, agroecology is suddenly in fashion. The United Nations Food and Agriculture Organization, government agencies and even corporations are jumping on the bandwagon. But, are they for the same agroecology as developed by pioneering farmers, scientists and peasant social movements, or are they seeking to co-opt the concept and give it different content? Rosset and Altieri, two of the world's leading agroecologists, outline the principles, history and currents of agroecological thought, the scientific evidence for agroecology, how to bring agroecology to scale, and the contemporary politics of agroecology.

Peter M. Rosset is professor of agroecology at El Colegio de la Frontera Sur (ECOSUR Advanced Studies Institute) in Chiapas, Mexico and CAPES visiting professor in the Geography Department of the Federal University of Ceará (UFC) in Brazil. He is co-coordinator of the Land Research Action Network (LRAN). Miguel A. Altieri is emeritus professor of agroecology at the University of California at Berkeley, and founder and past president of the Latin American Scientific Society for Agroecology (SOCLA).

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AGROECOLOGY

ROSSET & ALTIERI

FP

Advance Praise for *Agroecology*

This is a timely and excellent book by two world leaders of agroecological thought and practice. In this highly readable book, Peter Rosset and Miguel Altieri offer a clear analysis of the principles of agroecology and its potential to address major social, economic and environmental challenges of food and farming in the 21st century. Most notably, the book demonstrates the importance of social organization, peasant agroecology schools and social movements for bringing agroecology to scale. By focusing on the contested nature of the science of agroecology and its contemporary politics, the authors invite the reader to embrace an agroecology that transforms — rather than conforms with — the dominant agri-food regime. A stimulating read!

—Michel Pimbert, Centre for Agroecology, Water and Resilience, Coventry University

Agroecology: Science and Politics *by Peter Rosset and Miguel Altieri will be an important book that does an excellent job at summarizing what agroecology is as a science, a practice and a movement, as well as the debates that are currently going on regarding agroecology.*

— Ivette Perfecto, George W. Pack Professor of Natural Resources, University of Michigan

This small book has a very important message for the agroecology movement as well as for each of us as agroecologists. The scientific basis of agroecology and how agroecology confronts the industrial agriculture model is now broadly accepted, but how this approach can overcome the political and economic power of this model is much more controversial. This book clearly and forcefully states that agroecology must also address the politics of the food system, who has power and control, and how what might be called political agroecology must be included so that deep change can occur. We must heed this call to action!

— Steve Gliessman, Professor Emeritus of Agroecology, UC Santa Cruz, author of *Agroecology: The Ecology of Sustainable Food Systems*

In this short, straightforward book, two of the world's foremost experts in agroecology team-up to lay out the historical, scientific, and political basics of agroecology. As this timely publication makes clear, the recent rise of agroecology in official discourses on hunger and climate change is not just because of agroecology's relevance to the urgent challenges of our time — it is a reflection of the struggle between farmers and scientists committed to a socially and ecologically rational food system, *and the powerful forces of agribusiness-as-usual currently destroying the planet and impoverishing rural communities. A must-read for all food and environmental activists.*

— Eric Holt-Giménez, Food First/Institute for Food and Development Policy, author of *A Foodie's Guide to Capitalism: Understanding the Political Economy of What We Eat*

There's a battle for the soul of "agroecology," a term that the high technologists of the food system would like to steal. Rosset and Altieri don't just explain what agroecology is, and why it's important in fighting climate change and hunger, but why its power derives from its deeply political anti-capitalist roots. This short introduction is an invaluable defence of agroecology's political past, and a tool for its future.

— Raj Patel, author of *Stuffed and Starved: The Hidden Battle for the World Food System*

At a time when dead zones the size of New Jersey drape over the Gulf Coast and more than 50 million hectares of tropical forests and grasslands have been converted to GMO *soy and corn in South America, when a mere 167,000 farms produce most of American grains, a rethink is most definitely in order. Agroecology should really be called recuperative agriculture for its ability to recover abused agricultural landscapes, to make agriculture safe and and social and ecological haven for people communities, and biodiversity. It does so while capturing carbon, improving soils, producing nutricious (and delicious) food and bettering livelihoods. Few books are more urgently needed now than this one.*

— Susanna Hecht, Luskin School of Public Policy, UCLA, and Graduate School of International Development Studies, Geneva, author of T*he Fate of the Forest: Developers, Destroyers and Defenders of the Amazon*

AGROECOLOGY

Agrarian Change and Peasant Studies: Little Books on Big Issues

AGROECOLOGY

SCIENCE AND POLITICS

Peter Rosset and Miguel Altieri

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Series Editors' Foreword

Agroecology: Science and Politics by Peter Rosset and Miguel Altieri is the seventh volume in the Agrarian Change and Peasant Studies Series from ICAS (Initiatives in Critical Agrarian Studies). The first volume is Henry Bernstein's *Class Dynamics of Agrarian Change,* followed by Jan Douwe van der Ploeg's *Peasants and the Art of Farming,* Philip McMichael's *Food Regimes and Agrarian Questions,* Ian Scoones' *Sustainable Livelihoods and Rural Development,* Marc Edelman and Saturnino M. Borras Jr.'s *Politics of Transnational Agrarian Movements,* and Henry Veltmeyer and Raul Delgado Wise's *Agrarian Change, Migration and Development*. Together, these seven books reaffirm the strategic importance and relevance of applying agrarian political economy analytical lenses in agrarian studies today. They suggest that succeeding volumes in the series will be just as politically relevant and scientifically rigorous.

A brief explanation of the series will help put the current volume by Rosset and Altieri into perspective in relation to the ICAS intellectual and political project.

Today, global poverty remains a significantly rural phenomenon, with rural populations comprising three-quarters of the world's poor. Thus, the problem of global poverty and the multidimensional (economic, political, social, cultural, gender, environmental and so on) challenge of ending it are closely linked to rural working people's resistance to the system that continues to generate and reproduce the conditions of rural poverty and their struggles for sustainable livelihoods. A focus on rural development thus remains critical to development thinking. However, this focus does not mean de-linking rural from urban issues. The challenge is to better understand the linkages between them, partly because the pathways out of rural poverty paved by neoliberal policies and the war on global poverty engaged in and led by mainstream international financial and development institutions to a large extent simply replace rural with urban forms of poverty.

Mainstream approaches in agrarian studies are generously financed and thus have been able to dominate the production and publication of research and studies on agrarian issues. Many of the institutions (such as the World Bank) that promote this thinking have also been able to acquire skills in producing and propagating highly accessible and policy-oriented publications that are widely disseminated worldwide. Critical thinkers in leading academic institutions are able to challenge this mainstream approach, but they are generally confined to academic circles with limited popular reach and impact.

There remains a significant gap in meeting the needs of academics (teachers, scholars and students), social movement activists and development practitioners in the Global South and the North for scientifically rigorous yet accessible, politically relevant, policy-oriented and affordable books in critical agrarian studies. In response to this need, ICAS launched this series. The idea is to publish "state of the art small books" that explain a specific development issue based on key questions, including: What are the current issues and debates in this particular topic and who are the key scholars/thinkers and actual policy practitioners? How have such positions developed over time? What are the possible future trajectories? What are the key reference materials? And why and how is it important for NGO professionals, social movement activists, official development aid circle and nongovernmental donor agencies, students, academics, researchers and policy experts to critically engage with the key points explained in the book? Each book combines theoretical and policy-oriented discussion with empirical examples from different national and local settings.

The series will be available in multiple languages in addition to English, starting with Chinese, Spanish, Portuguese, Bahasa, Thai, Japanese, Korean, Italian and Russian. The Chinese edition is in partnership with the College of Humanities and Development of the China Agricultural University in Beijing, coordinated by Ye Jingzhong; the Spanish edition with the PhD Programme in Development Studies at the Autonomous University of Zacatecas in Mexico, coordinated by Raúl Delgado Wise, EHNE Bizkaia in the Basque country coordinated by Xarles Iturbe; Fundacion Tierra in Bolivia coordinated by Gonzalo Colque, the Portuguese edition with the Universidade Estadual Paulista, Presidente Prudente (UNESP) in Brazil, coordinated by Bernardo Mançano Fernandes, and the Universidade Federal do Rio Grande do Sul (UFRGS) in Brazil, coordinated by Sergio Schneider; the Indonesian edition with University of Gadjah Mada in Indonesia, coordinated by Laksmi Savitri; the Thai edition with RCSD of University of Chiang Mai, coordinated by Chayan Vaddhanaphuti; the Italian edition coordinated by Alessandra Corrado at the University of Calabria; the Japanese edition with Kyoto University, coordinated by Shuji Hisano of Kyoto University, Koichi Ikegami of Kinki Universit, and by Sayaka-Funada-Classen; the Korean edition with Research Institute of Agriculture and Peasant Policy and coordinated by Wongkyu Song; and the Russian edition with the Russian Presidential Academy of National Economy and Public Administration (RANEPA), coordinated by Teodor Shanin and Alexander Nikulin.

Given the objectives of the Agrarian Change and Peasant Studies Series, one can easily understand why we are delighted to have as Book 7 the work by Rosset and Altieri. The first seven volumes fit together well in terms of themes, accessibility, relevance and rigour. We are excited about the bright future of this important series! Finally, Book 7 is being released with financial support from and in collaboration with the Rosa Luxemburg Foundation and the Transnational Institute (TNI).

Saturnino M. Borras Jr., Ruth Hall, Christina Schiavoni,
Max Spoor and Henry Veltmeyer
ICAS *Book Series Editors*

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We owe many thanks to a long line of agroecologists among the ranks of peasant and indigenous farmers, maverick scientists and grassroots social movements, who together have created the *agroecology* that we describe and defend in this text. In particular we give thanks to La Vía Campesina, the transnational social movement that today is providing vision and mobilizing leadership to the agroecology movement, and which has clearly spelled out that agroecology and agrarian reform are the key ingredients in building food sovereignty.

Peter Rosset gives special thanks to the academic colleagues and graduate students of the Research Group on the Massification of Agroecology at El Colegio de la Frontera Sur (ECOSUR) in Chiapas, México, for creating an ideal environment for advancing our collective, conceptual thinking on scaling and territorializing agroecology; to the National Association of Small Farmers of Cuba for their stirring real-world example of bringing agroecology to scale; to the Zapatista agroecology promoters in Chiapas who have shown the centrality of agroecology to building autonomy; and to the Landless Workers' Movement of Brazil for identifying agroecology as a key strategy for confronting agribusiness and the devastation of extractive capitalism in the countryside. He also thanks CAPES in Brazil for the Visiting Professor Fellowship that partially supported his work on this book.[1]

Miguel Altieri wishes to thank the many students and colleagues at the University of California at Berkeley and at many other universities, and the members of the Latin American Scientific Society for

Agroecology (SOCLA), who pushed him to widen his approach to agroecology to include social, cultural and political dimensions in his research, teaching and outreach. He gives special thanks to Clara Nicholls, colleague and companion, for her support during many agroecological crusades around the world.

We are deeply indebted to the many farmers in Latin America and other parts of the world, who tend the land with so much wisdom and skill, and who through their examples have showed us that agroecology is the path toward diverse, productive and resilient systems.

Note

1. *Professor Visitante do Exterior, Processo CAPES PVE-Edital* 65/2014, n. 23038.010102/2013-34, in the Geography Department of the *Universidade Federal de Ceará* (UFC).

Introduction

Agroecology at a Crossroads

Over the past few years "agroecology" has come to be *the* word used in debates about agricultural technology, though its exact meaning varies a lot depending on who is speaking. While some may wish to deny this, agroecology has a strong political element that is inseparable from its technical-biological aspects. The very nature of the debates makes it clear that now is the time for a book that summarizes the science and politics of this controversial field.

Agroecology is variously known as the *science* that studies and attempts to explain the functioning of *agroecosystems*, primarily concerned with biological, biophysical, ecological, social, cultural, economic and political mechanisms, functions, relationships and design; as a set of *practices* that permit farming in a more sustainable way, without using dangerous chemicals; and as a *movement* that seeks to make farming more ecologically sustainable and more socially just (Wezel, Bellon, Doré et al. 2009). The global corporate food system is largely based on unsustainable industrial agriculture practices, is a major source of greenhouse gas emissions, is controlled by a handful of large corporations and produces increasingly unhealthy food (Lappé, Collins and Rosset 1998; Patel 2007; ETC Group 2009, 2014). Agroecology offers various points of entry for beginning to transform that system. Yet for decades, "agroecologists," as we call agroecological researchers, academics, non-governmental organizations (NGOs), ecological farmers, peasants and activists, were ignored or ridiculed by the establishment, labelled as dreamers, preachers, radicals, charlatans or worse (Giraldo and Rosset 2016, 2017).

But this has changed drastically. Seemingly out of nowhere, mainstream universities, research centres, private companies, government agencies and multilateral institutions have "discovered" agroecology as a potential source of solutions to pressing problems of the global food system, ranging from greenhouse gas emissions and climate change to soil erosion and yield decline. The versions of agroecology that they promote, with allusive titles like "climate smart agriculture" (Delvaux, Ghani, Bondi and Durbin 2014; Pimbert 2015) and "sustainable intensification" (Scoones 2014) tend be quite different from the agroecology put forth by its original proponents (Carroll, Vandermeer and Rosset 1990; Altieri 1995; Gliessman 1998; and many others) in both *technical* and *political* content, setting the stage for controversy and dispute over what is *really* agroecology.

In Rome, Italy, on September 18–19, 2014, the Food and Agriculture Organization of the United Nations (FAO) held its first-ever official event on agroecology. At the International Symposium on Agroecology for Food Security and Nutrition some 400 participants heard from more than fifty experts, including academic professors, researchers, the private sector, government officials and leaders of civil-society organizations and social movements. "Today a window was opened in what for 30 years has been the cathedral of the Green Revolution,"[1] said FAO Director-General José Graziano da Silva in his closing remarks to the symposium. "Agroecology continues to grow, both in science and in policies. It is an approach that will help to address the challenge of ending hunger and malnutrition in all its forms, in the context of the climate change adaptation needed." He added that the problems facing the world are so great that we must pursue *all approaches,* affirming that "agroecology represents a promising option and is one possibility among others, such as GMOs and reducing the use of chemicals" (FAO 2015), thus echoing the position of the World Bank and Monsanto. This view is diametrically opposed by agroecologists, who typically argue that GMOs and agroecology are incompatible and cannot coexist (Altieri and Rosset 1999a,b; Altieri 2005; Rosset 2005).

Highlighting the high-level nature of the new debate on agroecology, the closing roundtable discussion featured interventions by the agriculture ministers of France, Senegal, Algeria, Costa Rica, Japan, Brazil and the European Union. And highlighting the controversial nature of agroecology, the United States representation to the FAO had earlier tried to block the symposium from taking place at all, eventually allowing it go forward based on an agreement with FAO that it would be "technical and not political in nature" and that there would no sessions concerned with trade policy, GM crops or the concept of "food sovereignty" put forth by social movements.

At this landmark event, it was clear that agroecology is currently more or less divided into two camps. The institutional camp sees it essentially as a set of additional tools for industrial food production, which is under attack for greenhouse gas emissions and is facing declining productivity and rising production costs due to the ecological degradation it causes to productive resources such as soil, water, functional biodiversity, etc. They see agroecological tools as ways to make this "dominant model" a little bit more sustainable, without challenging underlying relations of power nor the structure of large-scale monoculture. The other camp, made up of many scientists, activists, ecological farmers, NGOs and social movements, sees agroecology as the alternative to industrial food production and as a lever for the transformation of the food system into something that is better for people and the environment (LVC 2014).

Agroecology is at a crossroads, facing a major struggle over its possible cooptation by the mainstream. To paraphrase a quote sometimes attributed to Gandhi: "First they ignore you, then they laugh at you, then they fight you, then they try to co-opt you, and finally they appropriate your idea, removing the original content and replacing it with their own, and take credit for it." Agroecology has advanced along this continuum, moving through the stages of being ignored, laughed at and fought, and now rapidly faces attempts at co-optation. While those who might co-opt agroecology like to deny that it has any political content, agroecology advocates have always stressed its inherently political nature. This was made clear just five months after the FAO event. In a counterpoint to that symposium, social movements, led by the global peasant alliance La Vía Campesina (LVC), held their own International Forum on Agroecology on February 24–27, in Nyéléni, Mali, in West Africa (IPC 2015). The idea was to respond to the perceived threat of cooptation by developing a shared vision of agroecology for transformation and to agree to work together across sectors (farmers, workers, indigenous peoples, nomads, fisherfolk, consumers, the urban poor, etc.) and continents to defend agroecology and to build it "from below." In the declaration from that meeting, the delegates said: "*Agroecology is political*; it requires us to challenge and transform structures of power in society. We need to put the control of seeds, biodiversity, land and territories, waters, knowledge, culture and the commons in the hands of the peoples who feed the world" (LVC 2014).

They laid out a vision of agroecology that is very different from the institutional views seen at the FAO Symposium:

> Agroecology is the answer to how to transform and repair our material reality in a food system and rural world that has been devastated by industrial food production and its so-called Green and Blue Revolutions. We see agroecology as a key form of resistance to an economic system that puts profit before life.... The real solutions to the crises of the climate, malnutrition, etc., will not come from *conforming* to the industrial model. We must *transform* it and build our own local food systems that create new rural-urban links, based on truly agroecological food production by peasants, artisanal fishers, pastoralists, indigenous peoples, urban farmers, etc. We cannot allow agroecology to be a tool of the industrial food production model: we see it as the essential *alternative* to that model, and as the means of *transforming* how we produce and consume food into something better for humanity and our Mother Earth. (LVC 2014)

With agroecology given increasing prominence by both the institutions above and the movements below, universities are rushing to offer agroecology curricula and government ministries to create agroecology departments, programs and policies. But which view of agroecology will be represented? Which will receive the research dollars and the production credits for farming? Who will get these credits, the corporate giants of the food system or family and peasant farmers? Will the food system be transformed, with more healthy food for all, or will business as usual continue with a light veneer of "greenwashing" in the form of lip service on climate change, and organic processed food from the multinationals directed at niche markets of wealthy consumers who want and can afford healthier food?

Thus, we are at an opportune moment for this book, in which we summarize the scientific basis (Chapter 1) and history (Chapter 2) of agroecology, including evidence that food production based on agroecological principles can be more productive, have lower costs, reduce negative environmental impacts and increase the long-term sustainability of agriculture (Chapter 3). We examine the social and organizational basis for bringing agroecology up to scale at a territorial level (Chapter 4). And finally we delve into the politics of agroecology, focusing primarily on the crossroads described above (Chapter 5). A final caveat is that, while the more scientific and technical principles of agroecology can be applied equally to small- and to large-scale systems of production (Altieri and Rosset 1996), in keeping with the focus of this series of "small books that summarize the state of the art on large topics" relevant to Agrarian Change and Peasant Studies, we limit our scope to peasant and family farm agroecology. Space does not permit a larger and extensive critique of the corporate, industrial food system and the Green Revolution to which agroecology responds. This, however, has been covered extensively elsewhere (see Lappé at al. 1998; Patel 2007, 2013; ETC Group 2009, 2014; and many others).

Note

1. The "Green Revolution" loosely refers to the packet of "modern," industrial farming technologies, like hybrid seeds, chemical fertilizers and pesticides, that were "exported" from the U.S. to Third World agriculture, particularly during the 1960s and 1970s, with many negative consequences in terms of social differentiation and the loss of productive capacity of agroecosystems (Patel 2013). While food production apparently soared over those years, it was narrowly based on a handful of crops and concentrated among a minority of producers, with the unfortunate outcome that world hunger also increased during the same period of time. Agroecology is often proposed as the main alternative to address the shortcomings of Green Revolution practices (Lappé et al. 1998: Ch.5).

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Chapter 1

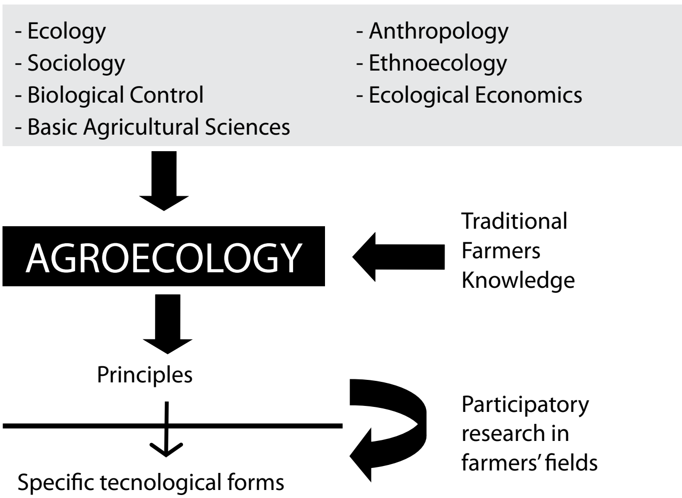
The Principles of Agroecology

The true roots of agroecology lie in the ecological rationale of indigenous and peasant agriculture still prevalent in many parts of the developing world (Altieri 1995). For agroecologists,[1] a starting point in the development of new agricultural systems is the very systems that traditional farmers have developed and/or inherited throughout centuries (Altieri 2004a). Such complex farming systems, adapted to the local conditions, have helped small farmers to sustainably manage harsh environments and meet their subsistence needs without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science (Denevan 1995). Guided by an intricate knowledge of nature, traditional farmers have nurtured biologically and genetically diverse smallholder farms with a robustness and built-in resilience necessary to adjust to rapidly changing climates, pests and diseases, and more recently to globalization, technological penetration and other modern trends (Toledo and Barrera 2009; Ford and Nigh 2015). Although many of these systems have collapsed or disappeared, the stubborn persistence of millions of hectares under ancient, traditional management in the form of raised fields, terraces, polycultures, agroforestry systems, integrated rice-duck-fish systems, etc. document a successful indigenous agricultural strategy and are a tribute to the "creativity" of traditional farmers. These microcosms constitute a legacy that offers promising models for a new agriculture, as they promote biodiversity and thrive without external inputs, sustaining year-round yields in the midst of climatic variability.

Some western scientists have started recognizing the value of indigenous land-use practices and their crucial role in climate change adaptation/mitigation and the provisioning of water, food and energy to cities (De Walt 1994). Many agroecologists argue that indigenous knowledge systems can support rapid adaptation to complex and urgent crises and inspire the new models of agriculture that humanity needs in this era of rapid ecosystem degradation and climate change. The virtues of traditional agroecosystems, where sustainability and resiliency are based on complex ecological models, represent a rich resource for agroecologists to understand the mechanisms at work in diversified agroecosystems and hence derive key principles for designing novel agroecosystems (Altieri 2002).

Agroecology combines indigenous knowledge systems about soils, plants and so on with disciplines from modern ecological and agricultural science. By promoting a dialogue of wisdoms and integrating elements of modern science and ethnoscience, a series of principles emerge, which when applied in a particular region take different technological forms depending on the socio-economic, cultural and environmental context (Figure 1-1). Agroecology does not promote technical recipes but rather principles; thus, it is not an agriculture of inputs but rather of processes. In order for the technologies derived from the application of principles to be relevant to the needs and circumstances of small farmers, the technological generation process ideally must result from a participatory or farmer-led research process in which farmers along with researchers provide

Figure 1-1 The Principles of Agroecology



input into the research questions and the design, running and evaluation of field experiments.

Agroecological Features of Traditional Farming Systems

Traditional farming systems have emerged over centuries of cultural and biological co-evolution and represent the accumulated experiences of peasants interacting with the environment without access to external inputs, capital and so-called scientific knowledge. Using inventive self-reliance, experiential knowledge and locally available resources, peasants have developed farming systems based on the cultivation of a diversity of crops, trees and animals deployed in time and space, which have allowed them to maximize harvest security under marginal and variable environments and with limited resources and space (Wilken 1987). The development of such systems has been guided by knowledge based not only on observation but also on experimental learning. This approach is apparent in the selection and breeding of local seed varieties and in the testing of new cultivation methods to overcome particular biological constraints. Most traditional farmers have an intimate knowledge of their surroundings, especially within a local geographical and cultural radius (Brokenshaw, Warren and Werner 1980).

Despite the myriad agricultural systems and historical and geographical particularities, most traditional agroecosystems exhibit the following six remarkably similar features:

1. high levels of biodiversity, which plays a key role in regulating ecosystem functioning and also in providing ecosystem services of local and global significance;
2. ingenious landscape, land and water resource management and conservation systems that are used to improve the efficiency of agroecosystems;
3. diversified agricultural systems that provide a broad variety of products to local and national food sovereignty and livelihood security;
4. agroecosystems that exhibit resiliency and robustness to cope with disturbance and change (human and environmental),

minimizing risk in the face of variability and stochasticity;
5. agroecosystems nurtured by traditional knowledge systems featuring many farmer innovations and technologies; and
6. strong cultural values and collective forms of social organization, including customary institutions for agroecological management, normative arrangements for resource access and benefit sharing, value systems, rituals, etc. (Denevan 1995; Koohafkan and Altieri 2010).

Genetic Diversity

Worldwide, small farmers maintain no less than two million crop varieties and about 7,000 animal breeds in some 350 million farms (ETC Group 2009). Many traditional agroecosystems are located in centres of crop diversity, thus containing populations of variable and adapted land races as well as wild and weedy relatives of crops. The ecological ranges of wild relatives may exceed those of the crops derived from or otherwise related to them. Cycles of natural hybridization and introgression often occur between crops and wild relatives, increasing the variability and the genetic diversity of seeds available to farmers (Altieri, Anderson and Merrick 1987). Through the practice of "non-clean" cultivation, many peasant farmers increase the gene flow between crops and their relatives and also encourage specific "weeds" (also known as *quelites, arvenses,* etc.) used for food, fodder and green manure. The presence of these plants in peasant agroecosystems may represent progressive domestication (Altieri et al. 1987).

Many farmers plant multiple varieties of each crop in their fields and regularly exchange seeds with neighbours. For example, in the Andes, farmers cultivate as many as fifty potato varieties in their fields (Brush 1982). Similarly, in Thailand and Indonesia, farmers maintain many rice varieties in their paddies that are adapted to a wide range of environmental conditions, and they also regularly exchange seeds with neighbours (Swiderska 2011). The resulting genetic diversity heightens resistance to diseases and other biotic stresses and enhances the nutritional diversity available to rural populations (Clawson 1985). Researchers have shown that the use of within-field crop genetic diversity reduces disease severity, and this method has been used commercially in some crops (Zhu et al. 2000).

Crop Species Diversity

A salient feature of traditional farming systems is their degree of plant diversity in the form of polycultures (also known as intercropping or companion planting) and/or agroforestry patterns. Polycultures involve spatial diversification of cropping systems that allows the cultivation of two or more crops simultaneously on the same field (Francis 1986). Long-tested intercropping systems involve mixtures of annual crops in various spatial and temporal designs. They commonly include a legume and a cereal, which leads to greater biological productivity than each species grown separately, because legumes fix nitrogen and because the mixture can use resources more effectively and convey associational resistance to pests (Vandermeer 1989). Agroforestry uses mixtures of annuals with perennials or perennials with animals, sometimes containing more than a hundred annual and perennial plant species and several animal species per field. Besides providing useful products (construction materials, firewood, tools, medicine, livestock feed and human food), trees frequently minimize nutrient leaching and soil erosion, add organic matter and restore key nutrients by pumping them from the lower soil strata (Sanchez 1995). Trees also buffer microclimatic conditions, protecting crops and soils against climatic extremes like storms and droughts, which are likely to increase under climate change (Verchot et al. 2007). In multistrata silvopastoral systems (integration of trees and livestock) the presence of N-fixing legumes tree species improves pasture production and nutrient cycling and eliminates the need of chemical N fertilizers. Deep-rooted trees help to recover nutrients and water from deeper soil layers and increase carbon sequestration both below and above ground. Tree cover also provides better environmental conditions and delivers more biomass, nutrients and shade to the animals, reducing stress and improving production and body condition (Murgueitio et al. 2011).

In polyculture systems, plant species are grown in close proximity so that beneficial interactions occur between them, thus offering a number of ecosystem services to farmers. The higher species richness improves soil organic matter, soil structure, water retention capacity and soil cover, protecting soils from erosion and suppressing weeds, all favourable conditions for crop production. Crop diversity also enhances arthropod diversity and microbiological activity involved in improved nutrient cycling, soil fertility and pest regulation. Studies reveal that resiliency to climate disasters is closely linked to farms with increased levels of biodiversity (Vandermeer et al. 1998, Altieri et al. 2015).

Integration of Livestock

In many regions, mixed crop–livestock systems are the backbone of peasant agriculture. In well-integrated systems, locally adapted races of livestock provide draft power to cultivate the land and manure to fertilize the soil, and crop residues are a key feed resource for livestock. Resources (crop residues, manure, power and cash) produced in such systems benefit both crop and livestock production, leading to greater farm efficiency, productivity and sustainability (Powell, Pearson and Hiernaux 2004).

In Asia, many rice farmers integrate various species of fish and ducks with their crop. Fish consume insect pests that attack the rice plant as well as weeds that choke the plants and the rice leaves infected by sheath blight disease, thus reducing the need for pesticides. These systems exhibit a lower incidence of insect pests and plant diseases when compared to monoculture rice farming. Further, the fish oxygenate the water and move the nutrients around, also benefiting the rice. *Azolla* species fix nitrogen (243–402 kg/ha), some of which (17–29 percent) is used by the rice. The ducks consume the *Azolla* before it covers the whole surface and triggers eutrophication, in addition to consuming snails and weeds. Clearly, the complex and diverse food webs of microbes, insects, predators and associated crop plants promote a number of ecological, social and economic services that are beneficial to farmers and local communities (Zheng and Deng 1998).

Ecological Role of Biodiversity in Agroecosystems

Biodiversity in agroecosystems includes the crops, livestock, fish, weeds, arthropods, birds, bats and microorganisms present. It is affected by human management, geographical location and climatic, edaphic and socioeconomic factors. There are several classifications of biodiversity components of agroecosystems in relation to the role they play in the functioning of cropping systems (Swift and Anderson 1993; Moonen and Barberi 2008).

Functional diversity refers to the variety of organisms and the ecosystem services they provide for the system to continue performing and enhance its responses to environmental change and other perturbations. An agroecosystem that contains a high degree of functional diversity is usually more resilient against various types and degrees of shock (Lin 2011). In general, there are many more species than there are functions, and thus redundancy is built into the agroecosystem. Biodiversity enhances ecosystem function because those components that appear redundant at one point in time may become important when some environmental change occurs. In such situations, the redundancies of the system allow for continued ecosystem functioning and provisioning of ecosystem services (Cabell and Oelofse 2012). Also, a diversity of species acts as a buffer against failure due to environmental fluctuations by enhancing the compensation capacity of the agroecosystem; if one species fails, others can play the same role, thus leading to more predictable aggregate community responses or ecosystem properties (Lin 2011; Rosset et al. 2011). A community of organisms in an agroecosystem becomes more complex when a larger number of different plant species are included, leading to more interactions among arthropods and microorganisms, components of above and below-ground food webs. As diversity increases, so do opportunities for coexistence and beneficial interference between species that can enhance agroecosystem sustainability (Malezieux 2012). Diverse systems encourage complex food webs, which entail more potential connections and interactions among members, creating many alternative paths for energy and material flow. For this reason, a more complex community typically exhibits more stable production and fewer fluctuations in the numbers of undesirable organisms (Power and Flecker 1996). Ecologists, however, correctly affirm that diversity does not always promote ecosystem stability (Loreau and Mazancourt 2013).

Our current understanding of the relationship between biodiversity and ecosystem function in natural ecosystems (Tilman, Reich and Knops 2006) can inform agroecosystem management at multiple spatial and temporal scales. Current literature on biodiversity and ecosystem function tells us that biodiversity (or species richness) *per se* is not the most important metric, but functional diversity is — the representation of species that perform different ecological functions (Moonen and Barberi 2008), such as enhancing nutrient cycling or controlling pests. One explanation is that certain species affect ecological processes more than others. In agroecosystems, a common example is the ability to improve soil fertility by intercropping legumes with grasses (two different plant functional groups) because grass-legume competition for soil nitrogen increases legume nitrogen fixation. Therefore, designing high quality matrices is not a simple question of adding more species to agroecosystems but involves understanding biological interactions and managing them to optimize multiple goals (Loreau et al. 2001).

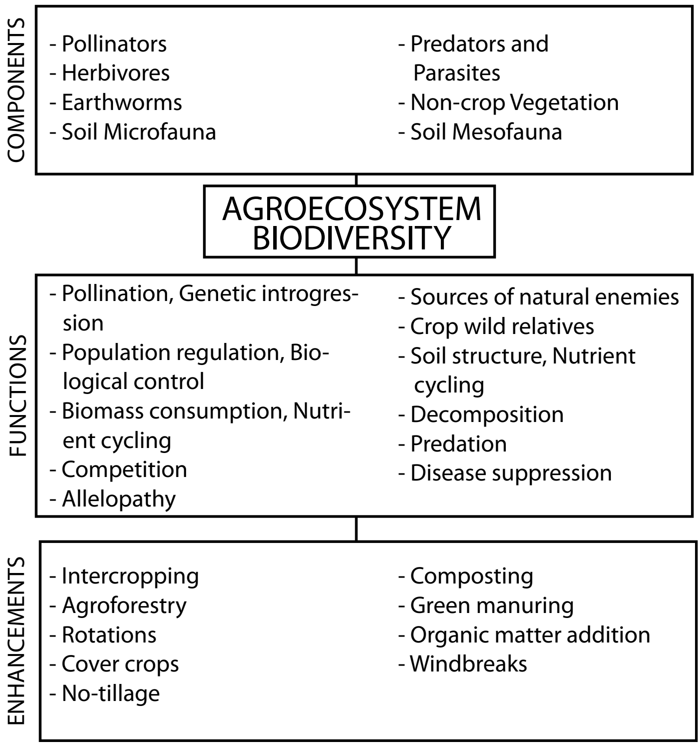
The exploitation of interactions mediated by biodiversity in real situations involves agroecosystem design and management strategies aimed at optimizing functional biodiversity via the following three approaches (Hainzelin 2013):

1. enhancement of above-ground biodiversity, at different scales over space and time, to intensify biological cycles of nutrients and water, while aiming for increasing production of harvested biomass (food, fibre, energy, etc.) without external inputs. This strategy requires planning annual and perennial combinations with complementarity of canopy architectures and root systems among species, to maximize the capture of solar radiation, conservation of water and uptake of nutrients, while harbouring beneficial biota such as predators and pollinators;
2. use of crop diversification in time and space to enhance natural biological control of insect pests, promote allelopathic effects to suppress weeds and stimulate antagonists to reduce soil borne pathogens, thus diminishing losses of harvested crop biomass, without use of pesticides; and
3. stimulation of functional below-ground biodiversity via soil organic management practices, which in turn aids in amplifying biogeochemical cycles in the soil, recycling nutrients from deep

profiles and increasing beneficial microbial activity for optimal crop nutrition and health without fertilizers.

Thus, the optimal behaviour of agroecosystems depends on the level of interactions between the various members of the functionally diverse biota, which initiates synergisms, which, in turn, subsidize agroecosystem processes. The key is to identify the type of biodiversity that is desirable to maintain and/or enhance in order to carry out ecological services and then to determine the best practices that will encourage the desired biodiversity components (Figure 1-2; Altieri and Nicholls 2004).

Figure 1-2 Function of Biodiversity Components and Strategies for Enhancement



The Ecological Matrix

Many small-scale peasant farming systems contain plots embedded in natural or secondary forest communities, with the surrounding landscape determining to a large degree the levels of biodiversity in these agroecosystems (Perfecto, Vandermeer and Wright 2009). In many traditional rural communities, crop-production units and adjacent ecosystems often are integrated into a single agroecosystem at the landscape level. Many peasants utilize, maintain and preserve within or adjacent to their properties, areas of natural ecosystems (forests, hillsides, lakes, grasslands, stream ways, swamps, etc.) that contribute valuable food supplements, construction materials, medicines, organic fertilizers, fuels, religious items, and so on. Plant gathering as practised by a number of rural inhabitants has an economic and ecological basis, as collected wild plants provide essential supplies of food, raw materials for cottage industries and other resources, especially during times of low agricultural production. Wild plant ecosystems also provide ecological services to peasants such as habitats for wildlife and natural enemies of agricultural pests, leaf litter to enhance organic matter and residues for mulching for fields, etc. (Wilken 1987; Altieri, Anderson and Medrrick 1987).

Spillover effects from adjacent natural areas to managed fields may greatly influence insect diversity and food web interactions. There is clear evidence that plants around the cultivated field provide important resources to increase the abundance and impact of natural enemies of pests in adjacent crop fields. Habitats associated with agricultural fields may provide resources for beneficial arthropods that are unavailable in the crop habitat, such as alternate hosts or prey, food and water resources, shelter, favourable microclimates, overwintering sites, mates and refuge from pesticides (Bianchi, Booij and Tscharntke 2006). Of course care must be taken if weed borders harbour pests and diseases. Unfortunately, agricultural intensification has led to considerable losses in habitat diversity with great effects on the occurrence of general biodiversity. In fact, the advancement of monocultures is altering global agricultural landscapes and the ecosystem services they provide. For example, in four

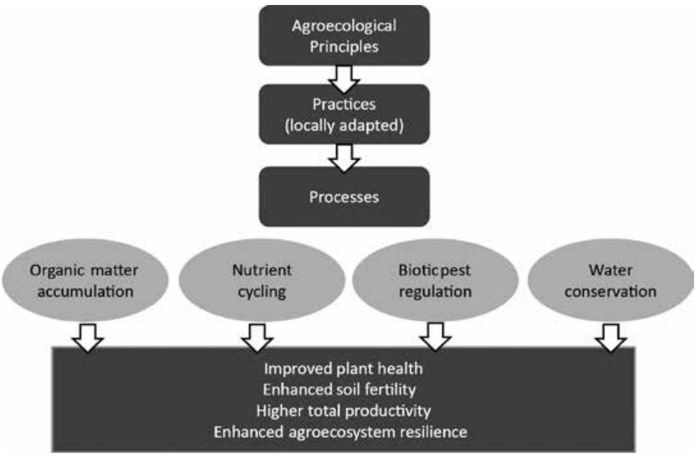
U.S. Midwest states, biofuel-driven growth in corn planting resulted in lower landscape diversity, decreasing the supply of pest natural enemies to soybean fields and reducing biocontrol services by 24 percent. This loss of biocontrol services cost soybean producers in these states an estimated $58 million per year in reduced yield and increased pesticide use (Landis et al. 2008).

Restoring landscape diversity can enhance biological control of insect pests in agroecosystems. For example, old fallow strips adjacent to annual crop fields of oilseed rape increase parasitism rates of the main insect pest by a factor of three (Tschanrtke et al. 2007). In Hawaii the presence of nectar-source plants in sugar cane field margins allowed population levels to rise and increased the efficiency of the sugar cane weevil parasite, *Lixophaga sphenophori* (Topham and Beardsley 1975). The authors suggest that the effective range of the parasite within cane fields is limited to about 45–60 metres from nectar sources present in the field margins. In California farmers tested prune trees as refuges for parasitoids (*Anagrus epos*) of leafhoppers affecting vineyards; but researchers determined that the effect of prune refuges was limited to few vine rows downwind and *A. epos* exhibited a gradual decline in vineyards with increasing distance from the refuge (Corbett and Rosenheim 1996). This finding poses an important limitation to the use of adjacent vegetation as habitat for natural enemies, as generally the colonization of predators and parasitoids seems to be limited to field borders leaving the central rows of crops void of biological control protection. To overcome this limitation, Nicholls, Parrella, and Altieri (2001) tested whether the establishment of a vegetational corridor inside the field enhanced movement of beneficial insects beyond the "normal area of influence" of adjacent habitats or refuges. Findings from this study suggest that the creation of corridors across vineyards can serve as a key strategy to allow natural enemies emerging from riparian forests to disperse over large areas of otherwise monoculture systems. Such corridors should be composed of locally adapted plant species exhibiting sequential flowering periods, which attract and harbour an abundant diversity of predators and parasitoids throughout the growing season. Thus, these corridors or strips, which may link various crop fields and riparian forest remnants, can create a network that allows many species of beneficial insects to disperse throughout whole agricultural regions, transcending farm boundaries.

Principles for the Design of Diversified Farming Systems

Capitalizing on the ecological mechanisms that enhance favourable natural processes and biological interactions in traditional agriculture, an important goal of agroecologists is to assemble crops, animals and trees in new spatial/temporal schemes, so that such diversified designs allow farms to sponsor their own soil fertility, crop health and productivity (Vandermeer et al. 1998). Clearly, ecosystem bundles are not sustained by just adding companion species at random; most associations that agroecologists promote have been tested by farmers for decades if not centuries, and farmers have maintained them because such systems strike a balance between farm-level productivity, resilience, agroecosystem health and livelihoods. Agroecologists use well-established ecological principles for the design and management of diversified agroecosystems, where external inputs are replaced by natural processes such as natural soil fertility, allelopathy and biological control (Table 1-1). When applied in a given location, principles take different technological forms or

Figure 1-3 Agroecosystem Functioning



Source: Nicholls, Altieri and Vazquez 2016

Table 1-1 Agroecological Principles

1. Enhance the recycling of biomass, with a view to optimizing organic matter decomposition and nutrient cycling over time
2. Strengthen the "immune system" of agricultural systems through enhancement of functional biodiversity — natural enemies, antagonists, etc., by creating appropriate habitats
3. Provide the most favourable soil conditions for plant growth, particularly by managing organic matter and by enhancing soil biological activity
4. Minimize losses of energy, water, nutrients and genetic resources by enhancing conservation and regeneration of soil and water resources and agrobiodiversity
5. Diversify species and genetic resources in the agroecosystem over time and space at the field and landscape level
6. Enhance beneficial biological interactions and synergies among the components of agrobiodiversity, thereby promoting key ecological processes and services

Source: Altieri 1995

Table 1-2 Contribution of Management Practices to Agroecological Principles

Management Practice	Principle to Which They Contribute*					
	1	2	3	4	5	6
Compost	x		x			
Cover crops/green manures	x	x	x	x	x	x
Mulching	x		x	x		
Crop rotation	x		x	x	x	
Microbial/botanical pesticides		x				
Insectary flowers		x			x	x
Living fence posts		x	x		x	x
Intercropping	x	x	x	x	x	x
Agroforestry	x	x	x	x	x	x
Integration of crops & livestock	x		x	x	x	x

Source: Nicholls, Altieri and Vazquez 2016
** Numbers refer to the principles shown in Table 1-1*

practices depending on the local socio-economic needs of farmers and their biophysical circumstances, resources on hand, etc. Once applied, the practices set in motion ecological interactions that drive key processes for agroecosystem function (nutrient cycling, pest regulation, productivity, etc.) (Figure 1-3). Each practice is linked to one or more principles, thus contributing to their manifestation in the function of the agroecosystems (Table 1-2).

A key principle in agroecology is the diversification of the agroecosystem, favouring in-field diversity as well as landscape heterogeneity. This principle is based on observations and experimental evidence that demonstrate the following trends: (a) when agroecosystems are simplified, entire functional groups of species are removed, shifting the balance of the system from a desired to a less desired functional state, affecting the capacity to respond to changes and to generate ecosystem services; and (b) the higher the vegetational diversity of agroecosystems, the greater the capacity of the agroecosystem to buffer against pest and disease problems and against shifting rainfall and temperature patterns (Loreau et al. 2001).

Diversification occurs in many forms at the field level (mixtures of varieties, rotations, polycultures, agroforestry, crop-livestock integration) and at the landscape level (hedgerows, corridors, etc.), giving farmers a wide variety of options and combinations for the implementation of such a strategy (Table 1-3). Ecological properties emerge in diversified agroecosystems that allow the system to function in ways that maintain soil fertility, crop production and pest regulation. Well-designed biodiverse farms optimize the application of agroecological principles, thus increasing agroecosystem functional diversity as the foundation for soil quality, plant health, crop productivity and system resilience (Nicholls, Altieri, and Vazquez 2016).

Research has shown that diversified agroecosystems can reverse the long-term downward trends in yields observed in many monocultural systems, as a variety of crops deployed in temporal and spatial schemes responds differently to external shocks. In one review, researchers found that when compared with conventional monocultures, diversified farming systems supported substantially greater biodiversity, soil quality and water-holding capacity in surface soils, and exhibited greater energy-use efficiency and resilience to climate change. Relative to conventional monocultures, diversified farming systems also enhance the regulation of weeds, diseases and

Table 1-3 Temporal and Spatial Strategies

Crop Rotations
Temporal diversity in the form of cereal-legume sequences, where nutrients are conserved and provided from one season to the next, and the life cycles of insect pests, diseases and weeds are interrupted.
Polycultures
Cropping systems in which two or more crop species are planted within certain spatial proximity, which result in biological complementarities that improve nutrient use efficiency and pest regulation, thus enhancing crop yield stability.
Agroforestry Systems
Trees grown together with annual crops, in addition to modifying the microclimate, maintain and improve soil fertility as some trees contribute to nitrogen fixation and nutrient uptake from deep soil horizons, while their leaf litter helps replenish soil nutrients, maintain organic matter, and support complex soil food webs.
Cover Crops and Mulching
The use of pure or mixed stands of grass and legumes, e.g., under fruit trees can reduce erosion and provide nutrients to the soil and enhance biological control of pests. Flattening cover crop mixtures on the soil surface in conservation farming reduces soil erosion and lowers fluctuations in soil moisture and temperature, improves soil quality and enhances weed suppression, resulting in better crop performance.
Crop-Livestock Mixtures
High biomass output and optimal nutrient recycling can be achieved through crop-livestock integration. Animal production that integrates fodder shrubs planted at high densities, intercropped with improved, highly productive pastures and timber trees, all combined in a system that can be directly grazed by livestock, enhances total productivity without need for external inputs.

Source: Altieri 1995; Gliessman 1998

arthropod pests while increasing pollination services (Kremen and Miles 2012).

Agroecological systems are designed with an emphasis on the adaptation and application of the principles in accordance with local realities. For example, in one location soil fertility may be enhanced through worm composting, while in another location it might be through planting green manures. The choice of practices depends on such factors as local resources, labour, family conditions, farm size and soil type. This is quite different from the type of commercial organic farming, common especially in Northern countries that is based on recipe-like substitution of toxic inputs with less noxious ones from approved lists, which are also largely purchased off farm. This "input substitution" retains dependency on the external input market and the ecological, social and economic vulnerabilities of monocultures (Rosset and Altieri 1997).

In contrast to input substitution, "agroecological integration" is achieved through the functional diversification of the agroecosystem, such that off-farm inputs are reduced to a minimum (Rosset et al. 2011). Pests may be controlled through intercropping, for example, rather than with a conventional chemical or an organic-approved, alternative biological pesticide. Soil fertility would not be maintained with a chemical fertilizer nor with an organic substitute purchased off-farm, such as commercial compost, manures or biofertilizers, but rather through some combination of worm composting of crop residues, constant incorporation of organic matter into the soil, pasturing animals on crop residues and using their manure as fertilizer, intercropping with nitrogen-fixing legumes and the promotion and maintenance of an active soil biology (Rosset et al. 2011; Machín Sosa et al. 2013). Such agroecological systems have been shown to restore even severely degraded soils (Holt-Giménez 2006).

Farms can have a greater or lesser degree of agroecological integration, ranging from an industrial monoculture (negligible agroecological integration), to a monoculture-based organic farm with input substitution (low level of integration), to a nearly autonomous, complex peasant agroforestry system with multiple annual crops and trees, animals, rotational schemes and perhaps even a fish pond, where pond mud is collected to be used as an additional crop

Table 1-4 Strengths and Weaknesses of Different Approaches to Agriculture

Aspect	Conventional Agriculture	Agroecology
Inputs	Potent	Weak
Synergisms	Absent	Powerful
Capacity to restore degraded soils	Absent (but offers ever higher doses of inputs as a way to mask problems)	High

Source: Rosset et al. 2011

fertilizer (high level of agroecological integration). A high degree of agroecological integration brings into play powerful synergisms between system components that can generate much higher levels of total production per unit area with fewer or zero off-farm inputs, often with a lower input of labour per unit of production as well (Rosset et al. 2011). More research is however needed to understand the ecology of complex system (how the components are interacting) in order to observe the general patterns that emerge.

An undue emphasis on alternative off-farm inputs often puts so-called sustainable agriculture in a poor competitive position *vis-à-vis* conventional industrial agriculture, because alternative inputs are weaker than conventional inputs (e.g., a chemical poison with immediate knockdown of pests compared to a slow acting biological pesticide). This is shown schematically in Table 1-4. This is one of the reasons why organic farming in wealthier countries consistently fails to out-yield conventional agriculture, while in the South, peasant agroecological systems average a higher level of total productivity than conventional monocultures (Rosset 1999b; Badgley et al. 2007; Rosset et al. 2011).

Overyielding

Significant production increases have often been reported in intercropping systems compared to monocultures (Francis 1986; Vandermeer 1989). Enhanced production in these polycropping systems may result from a variety of mechanisms, such as more efficient use of resources (light, water, nutrients), reduced pest damage, enhanced weed control, reduced soil erosion and improved water infiltration (Francis 1986). The mechanisms that result in higher productivity in diverse agroecosystems are called facilitation. Facilitation occurs when one crop modifies the environment in a way that benefits a second crop, for example by lowering the population of a critical herbivore or by releasing nutrients that can be taken up by the second crop (Lithourgidis et al. 2011). This is why overyielding often results despite competition between the intercropped plants, as facilitation can overcome competition, particularly weak competition. Pest and pathogen incidence is generally lower in intercrops. As well higher total resource use efficiency results from growing together crops with different root systems and leaf morphologies, which reduces the competition between them, as they exploit different strata of light and water. Resource capture, resource conversion efficiency and other factors have also been suggested as mechanisms underlying yield advantages.

One school of thought concerning the resource use of intercropping systems argues that a combination of two contrasting species, usually a legume and a cereal, would lead to greater overall biological productivity than each species grown separately, because the mixture can use resources more effectively than separate monocultures (Vandermeer 1989). Huang et al. (2015) explored how corn-fava bean, corn-soybean, corn-chickpea and corn-turnip intercropping affected yield output and nutrient acquisition in agricultural fields in northwest China. The authors found that intercropping increased total production in almost all instances over their monoculture counterparts. Furthermore, the intercropping systems more efficiently exploited nitrogen from the soils and partially return it via decomposing biomass, leading to better resource use efficiency in the intercropped systems.

Pest Regulation

Over the last forty years, many studies unequivocally suggest that diversification schemes enhance natural enemies and reduce herbivore pest abundance as well as crop damage, from a combination of bottom-up and top-down effects (Altieri and Nicholls 2004). In a meta-analysis of twenty-one studies comparing pest suppression in polycultures versus monocultures, Tonhasca and Byrne (1994) found that polycultures significantly reduced pest densities (64 percent). In a later meta-analysis spanning 148 comparisons, Letourneau et al. (2011) found a 44 percent increase in abundance of natural enemies, a 54 percent increase in herbivore mortality and a 23 percent reduction in crop damage on farms with species-rich vegetational diversification systems than on monoculture farms. Clearly there are cases when pest problems arise under certain crop combinations.

Plant pathologists have also observed that mixed cropping systems can decrease pathogen incidence by slowing down the rate of disease development and by modifying environmental conditions so that they are less favourable to the spread of certain pathogens (Boudreau 2013). For soil-borne or splash-dispersed diseases, Hiddink, Termorshuizen and Bruggen (2010) reviewed thirty-six studies, concluding that mixed cropping systems reduced disease in 74.5 percent of cases in comparison to monocultures. Host dilution was frequently proposed as the mechanism for reducing disease incidence of both soil-borne and splash-dispersed pathogens. Other mechanisms, such as allelopathy and microbial antagonists, are thought to affect disease severity in diversified farming systems. Such effects lead to less crop damage and contribute to higher yields in mixed crops as compared to the corresponding monocultures.

Weed ecologists have found that intercrops are often superior to sole crops in terms of weed suppression, as intercrop combinations can exploit more resources than sole crops. Greater total yields and less weed growth may be achieved through intercropping as these systems increase resource preemption by the intercrop, resulting in greater quantities of resources captured by crops and less for weeds, or alternatively an intercrop component may release allelopathic substances that inhibit weed germination and growth, or may effectively shade out weeds (Liebman and Dyck 1993).

Diversity and Resiliency to Climate Change

Data from ninety-four experiments on mixed cropping sorghum and pigeon pea showed that for a particular "disaster" level, a sole pigeon pea crop would fail one year in five, a sole sorghum crop would fail one year in eight, but intercropping would fail only one year in thirty-six (Willey 1979). Polycultures exhibit greater yield stability and less productivity declines during a drought than do monocultures. Natarajan and Willey (1986) examined the effect of drought on enhanced yields with polycultures by manipulating water stress on intercrops of sorghum and peanut, millet and peanut, and sorghum and millet. All the intercrops overyielded consistently at five levels of moisture availability, ranging from 297 to 584 mm of water applied over the cropping season. Interestingly, the rate of overyielding actually increased with water stress, such that the relative differences in productivity between monocultures and polycultures became more accentuated as stress increased. One possible explanation is that polycultures tend to be in soils with a higher content of organic matter (Marriott and Wander 2006), which enhances moisture holding capacity, leading to higher available water for crops, which positively influences resistance and resilience in drought conditions. Hudson (1994) showed that as soil organic matter content increased from 0.5 to 3 percent, available water capacity more than doubled. In a thirty-seven-year trial, Reganold (1995) found significantly higher soil organic matter levels and 42 percent higher surface soil moisture content in organically managed plots than in conventional plots.

Many intercropping systems improve water use efficiency compared to monocultures. Morris and Garritty (1993) found that intercrops greatly exceed water-utilization efficiency over sole crops, often by more than 18 percent and by as much as 99 percent. They do so by promoting the full use of soil water by plant roots, increasing the water storage in the root zone and reducing the inter-row evaporation, and also by controlling excessive transpiration and creating a special microclimate advantageous to plant growth and development.

In hillside situations prone to tropical storms, intercrops can significantly protect soil from erosion as their complex canopies afford better soil cover. More complex canopies and plant residues reduce the impact of heavy rains, which otherwise would detach soil particles, making them prone to erosion. Surface runoff is slowed by the soil cover, allowing improved moisture infiltration. Not only does the above-ground growth provide soil protection, but also the root system helps stabilize the soil by infiltrating the profile and holding it in place (Altieri et al. 2015).

Agroecological Conversion of Farms

The challenge to align commercial agricultural systems with ecological principles is immense, especially in the current context of modern agriculture, where specialization, short-term productivity and economic efficiency are emphasized (Horowith 1985). Despite such constraints, many small, mid-sized and even large-scale farmers initiate the agroecological conversion of their farming systems. Within three years or so, these farmers observe several beneficial changes in soil properties, microclimatic conditions, plant diversity and associated beneficial biota, slowly creating the foundations for enhanced plant health, crop productivity and resiliency.

Many authors have conceptualized conversion as a transitional process with three marked steps or phases (McRae et al. 1990; Gliessman 1998):

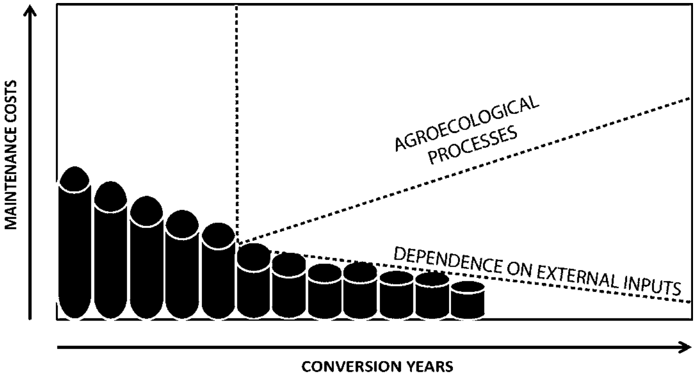
1. increased efficiency of input use through integrated pest management (IPM) and/or integrated soil fertility management;
2. input substitution or substitution of environmentally benign inputs (botanical or microbial pesticides, biofertilizers, etc.); and
3. system redesign: diversification with an optimal crop/animal assemblage, which encourages synergism so that the agroecosystem may sponsor its own soil fertility, natural pest regulation and crop productivity.

Many of the practices that are currently being promoted as components of sustainable agriculture fall in the first two phases, both of which offer clear benefits in terms of lower environmental impacts as they decrease agrochemical input use and often provide economic advantages compared to conventional systems. Incremental changes are likely to be more acceptable to farmers as drastic modification may be viewed as highly risky. But does the adoption of practices that increase the efficiency of input use or that substitute biologically based inputs for agrochemicals, but that leave the monoculture structure intact, really have the potential to lead to the productive redesign of agricultural systems (Rosset and Altieri 1997)? A true agroecological conversion calls into question monoculture and the dependence on external inputs.

In general, the fine-tuning of input use through approaches such as integrated pest management does little to transition farmers toward an alternative to high-input systems. In most cases IMP translates to "intelligent pesticide management," as it results in selective use of pesticides according to a pre-determined economic threshold, which pests often surpass in monoculture situations. The input substitution used by the large majority of commercial organic farmers follows the same paradigm of conventional farming — overcoming the limiting factor but with biological or organic inputs (Rosset and Altieri 1997). Many of these alternative inputs have become commodified; therefore farmers continue to be dependent on input suppliers. In California, many organic farmers cultivating grapes and strawberries apply between twelve and eighteen different types of biological inputs per season. In addition to increasing costs, many products used for one purpose affect other aspects of the system. For example, sulphur, which is widely used to control foliar diseases of grapes, can also wipe out populations of *Anagrus* parasitic wasps, key regulators of leafhopper pests. Thus, farmers become trapped in an "organic treadmill." Gliessman (2010) argues that improvements in efficiency of input use and input substitution are not enough to address the challenges facing modern agriculture. Instead, he argues, farming systems must be redesigned based on a new set of ecological relationships. This entails approaching conversion as an ecological transition of agriculture based on notions of agroecology and sustainability.

Ultimately, system redesign consists in the establishment of an ecological infrastructure that, through plot- to landscape-scale diversification, encourages ecological interactions that generate soil fertility, nutrient cycling and retention, water storage, pest/disease regulation, pollination and other essential ecosystem services. The associated cost (labour, resources, money) to redesign the ecological infrastructure of the farm (living fences, rotation, insect habitats, etc.) tends to be high in the first three to five years (Nicholls, Altieri and Vazquez 2016). Once the rotation and other vegetational designs (cover crops, polycultures, field borders, etc.) start lending ecological

Figure 1-4 Agroecological Processes



services to the farm, key ecological processes (nutrient cycling, pest regulation, etc.) are set in motion, and the need for external inputs, including labour, and thus maintenance costs, start decreasing as the functional biodiversity of the farm slowly sponsors ecological functions (Figure 1-4).

Changes in Soil Biology

After three to four years of the agroecological conversion process, changes in soil properties become apparent. In general, organically managed soils exhibit greater biological activity than conventionally managed soils. In a long-term and well-controlled study conducted in Switzerland, researchers found that the crop roots colonized by mycorrhizae in organic farming systems were 40 percent longer than in conventional systems. Of particular significance is the fact that, under water stress conditions, plants colonized by vesicular-arbuscular mycorrhizae (VAM) usually exhibit significantly higher biomass and yields compared to non-mycorrhizal (NM) plants, as VAM colonization increases water use efficiency (Li et al. 2007). Also found in Switzerland, biomass and abundance of earthworms were higher by a factor of 1.3 to 3.2 in the organic plots as compared with conventional. Activity and density of predators such as carabids, staphylinids and spiders in the organic plots was almost twice that of the conventional plots (Mader et al. 2002). The percentage of nitrogen, phosphorus and potassium, organic matter and some micronutrients increase with time, reaching values significantly higher than at the start of the conversion. Many studies have revealed better performance of organic agriculture than conventional systems for various metrics of sustainability, including species richness and abundance, soil fertility, nitrogen uptake by crops, water infiltration and holding capacity, and energy use and efficiency (e.g., Pimentel et al. 2005).

Evolution of Yields

In terms of productivity, the Mader et al. (2002) study in Central Europe showed that mean organic crop yields were 20 percent lower on average than conventional over a period of twenty-one years. However, in the organic systems, the energy that produced a unit of crop dry matter was 20–56 percent lower than conventional and correspondingly 36–53 percent lower per unit of land area (Mader et al. 2002). Yields usually decline during the first three to five years of conversion and then rise again, but as a 2015 meta-analysis suggests, organic yields are only 19.2 percent (±3.7 percent) lower than conventional yields, a smaller yield gap than previous estimates. The researchers found no significant differences in yields for leguminous versus non-leguminous crops, perennials versus annuals or developed versus developing countries (Ponisio et al. 2015). It should be noted that the discussion of yield gaps in organic farming is a bit misleading as far as agroecology goes, as yield gap studies usually compare organic monoculture to conventional monoculture and not complex agroecological systems. Higher productivity systems are found not in monocultures, but rather under more diverse and complex intercropping, agroforestry and integrated crop-livestock systems, all of which typically produce more total output per unit area than any kind of monoculture system, organic or conventional (Rosset 1999b).

Nevertheless, when large-scale cropping systems are subject to organic management for at least three years (under either a manure-based organic system or a legume-based organic system), crops exhibit similar yields as the conventional fields, as demonstrated in another long-term experiment, the thirty-year farming systems trial (FST) run by the Rodale Research Institute in Pennsylvania.

Due to the fact that soil health (measured as carbon content) in the organic systems increased over time, while the conventional systems remained essentially unchanged, organic corn yields were 31 percent higher than in years of drought, a direct result of higher soil organic matter and associated enhanced soil water storage (Rodale Institute 2012).

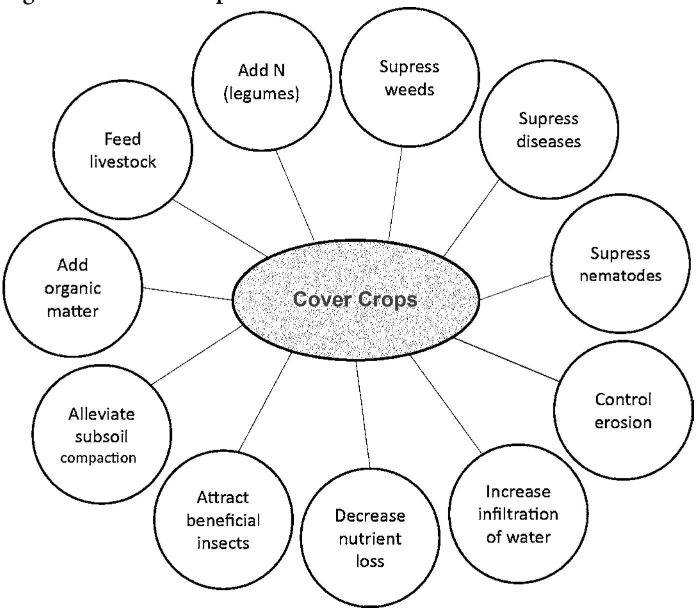
Once agroecosystems reach the last stage of the conversion process (system redesign) and polycultural cropping systems become prevalent, total production output increases at the farm level. Ponisio et al. (2015) found that two agricultural diversification practices, multi-cropping and crop rotation, substantially reduce the yield gap when the methods were applied in organic systems. When total output is considered rather than yield from a single crop, small diversified farms that simultaneously produce grains, fruits, vegetables, fodder and animal products are much more productive per unit area than large farms systems that produce a single crop (Rosset 1999b).

Syndromes of Production

One of the frustrations of research during the conversion process has been the inability to demonstrate that, and/or how, low-input practices outperform conventional practices in experimental comparisons that incrementally reduce chemical inputs while increasing organic practices, despite the success in practice of many well established organic and low-input production systems. A potential explanation for this paradox was offered by Andow and Hidaka (1989) in their description of "syndromes of production." These researchers compared the traditional shizeñ system of rice production with the contemporary Japanese high-input system. Although rice yields were comparable in the two systems, management practices were radically different in almost every respect: irrigation method, transplanting technique, plant density, fertility source and quantity, and management of insects, diseases and weeds. Andow and Hidaka (1989) argue that systems like shizeñ function in a qualitatively and completely different way than conventional systems. The broad array of different cultural technologies and pest management methods result in functional differences that cannot be accounted for by any single practice. Thus, a production syndrome is a set of management practices that are mutually adaptive and lead to high performance. However, subsets of this collection of practices may be substantially less adaptive, so there is no way to do incremental comparisons. The interaction and synergisms among practices lead to improved system performance that cannot be explained by the additive effects of individual practices. In other words, each production system represents a distinct group of management techniques and by implication, ecological relations. Thus, they are different syndromes (Nicholls et al. 2016).

Depending on how it is applied and complemented or not by other methods, one particular practice can sometimes act as an "ecological turntable" by activating key processes such as recycling, biological control, antagonism, allelopathy, etc., all essential for the health and productivity of a particular farming system. Cover crops, for example, can exhibit several multiple effects simultaneously (Figure 1-5), including suppressing weeds, soil-borne diseases and pests, protecting the soil from rain and runoff, improving soil ag-

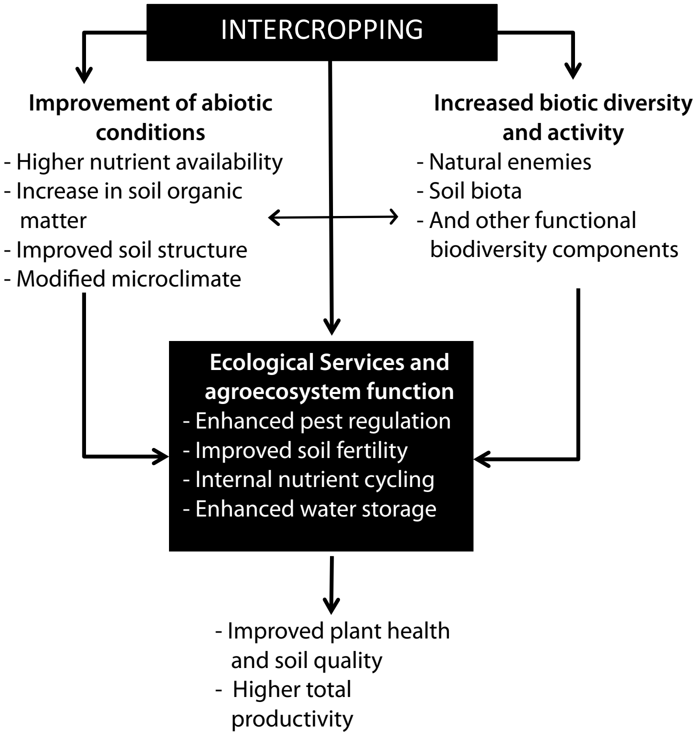
Figure 1-5 Cover Crop Functions



gregate stability, adding active organic matter, fixing nitrogen and scavenging for nutrients (Magdoff and van Es 2000).

Clearly, each production system represents a distinct group of management practices and by implication, ecological relations. This highlights the fact that agroecological designs are site-specific; what may be applicable elsewhere are not the techniques but rather the ecological principles that underlie sustainability. It is of no use to transfer technologies from one site to another if the set of ecological interactions associated with such techniques cannot be replicated (Altieri 2002). What can be transferred are the underlying principles.

Figure 1-6 Improving Agroecosystem Performance



Intentional Diversification

Inspired by the diversified cropping systems of traditional agriculture, agroecologists often attempt to assemble integrated combinations of crops (and livestock and/or trees in many cases) on the same piece of land, inducing changes in soil organic matter and nutrient content and in microclimate (changes in light, temperature and humidity). In addition, certain crop mixes enhance key functional biodiversity components (i.e., predators and parasitoids, pollinators, decomposers such as earthworms and other below-ground soil biodiversity, etc.), by creating more suitable habitat conditions for beneficial biota, which provide key ecological services (Figure 1-6). For example, introducing legumes in the mixture improves soil fertility through biological nitrogen fixation, benefitting associated cereals, or one crop in the mixture provides early season alternative food sources for natural enemies of pests of the other crop in the mixture. Similarly, enhanced soil carbon and structure due to the action of VAM and/or earthworms increase water storage and water use efficiency, enhancing the capacity of crop mixes to tolerate drought.

Crop diversification is therefore an effective strategy for introducing more biodiversity into agroecosystems to increase the number and level of ecosystem services provided. Higher species richness of planned and associated biodiversity improves nutrient cycling and soil fertility, limits nutrient leaching losses, reduces the negative impacts of pests, diseases and weeds and enhances the overall resilience of the cropping system. Further studies to improve our understanding of the ecological interactions in diversified farming systems will provide still greater basis for designing efficient systems with potential for wider applicability both in temperate and tropical agriculture.

Note

1. When we refer to “agroecologists” in this book, we use the term broadly to encompass people who study and/or promote agroecology and the agroecological transformation of farming and food systems, be they academics, researchers, extensionists, activists, advocates and/or farmers, peasants or consumers, including their leaders.

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Chapter 2

History and Currents of Agroecological Thought

Agroecological principles and practices lie in the accumulated knowledge and practice of peasant and indigenous agriculture around the world, even though peasants and indigenous people did not historically use this word. But to trace the origins of agroecology as it is used by academics, practitioners and social movement activists, we need to examine currents of thought espoused by diverse people at different points in recent history and in varied geographical regions.

Historical Foundations

Rudolf Steiner (1993), an early theorist in Germany, laid the foundation for a somewhat esoteric ecological approach to agriculture, now called biodynamic farming, that according to followers increases soil fertility and plant health using preparations from healing plants, minerals and cow manure applied to the soil and crops to strengthen self-sustaining farming. Biodynamic farmers conceive the farm as a whole and see it as an organism that must be managed with a holistic approach.

Another influential source of holistic agricultural thought has been organic farming, which was conceived as an alternative to the conventional agricultural approach. Sir Albert Howard, an organic farming pioneer, was sent to India by British colonial authorities to improve the farming practices of the "natives." Yet years spent conducting agricultural research and observations on the subcontinent only convinced him that traditional farming practices used by Indian peasants were far more sophisticated and effective than contemporary practices in Europe. Out of this experience he developed the philosophy and concept of organic farming, which he promoted in his classic book, *An Agricultural Testament* (1943). Howard's emphasis was on soil fertility and the need to effectively recycle waste materials, including night soil, onto farmland. Howard's concept of soil fertility centred on building soil humus, with an emphasis on how soil life was connected to the health of crops, livestock and humankind. Many people think that Howard was inspired by Franklin Hiram King (1911), who documented how the traditional farming systems of China, Korea and Japan stood the test of time through resilient indigenous agricultural strategies. Lady Eve Balfour helped to popularize organic farming with the publication of *The Living Soil* (Balfour 1949). Jerome Rodale, and later his son Robert Rodale, publishers and early converts to organic farming, were instrumental in the diffusion and popularization of organic concepts in the U.S. (Heckman 2006).

Another current of thought that influenced the emergence of agroecology was the early work of academics and researchers, including agronomists, geographers, entomologists, ecologists and others, in Europe and North America. According to Wezel et al. (2009), the term "agroecology" was firstly used by Bensin, a Russian agronomist, who suggested the term in 1930 to describe the use of ecological methods in research on commercial crop plants. At the end of the 1960s, the French agronomist Hénin (1967), inspired by Bensin's work, defined agronomy as being "an applied ecology to plant production and agricultural land management."

In the 1950s, the German ecologist and zoologist Wolfgang Tischler published a book which was probably the first to be actually titled "agroecology" (1965). He presented results of agroecological research, in particular on pest management, and discussed unsolved problems concerning soil biology, insect community interactions and plant protection in agricultural landscapes.

In the early 1900s, the Italian scientist Girolamo Azzi (1928) defined "agricultural ecology" as the study of the physical characteristics of environment, climate and soil, in relation to the development and yield quality of agricultural plants. He emphasized that while meteorology, soil science and entomology are distinct disciplines, their study in relation to the potential responses of crop plants converges in agroecology, a science that illuminates the relationships between crop plants and their environment. Later, Alfonso Draghetti (1948) published the seminal book *Farm Physiology Principles*, which views a farm as a functional unity (living body) where all parts (organs) are connected through an organization (physiology) provided by the farmer's design and management. This physiology allows circulation and re-cycling of materials in a synergistic framework between complementary components according to their functional roles of "organs." Soil fertility maintenance is the main "physiological" objective for ensuring long-term productivity, or agroecosystem health, while crop rotations and mixed farming with farmyard manure are the main "organs" that supply organic matter to soil.

In the U.S., an early and important book on agroecology was published by agronomist Karl Klages (1928), who suggested that, in order to understand the complex relationships between a crop plant and its environment, consideration must be given to the physiological and agronomic factors influencing the distribution and adaptation of specific crop species. Later Klages (1942) broadened his definition to include the historical, technological and socioeconomic factors that determined what crops could be produced in a given region and in what amount.

The decades of the 1970s and 1980s saw a gradual shift toward an ecosystem approach to agriculture, with an enormous expansion of agronomic literature with an agroecological perspective, including works such by Altieri, Letourneau and Davis (1983), Conway (1986), Dalton (1975), Douglass (1984), Gliessman, Garcia and Amador (1981), Hart (1979), Loomis, Williams and Hall (1971), Lowrance, Stinner and House (1984), Netting (1974), Spedding (1975), van Dyne (1969) and Vandermeer (1981). After the publication in 1979 of Cox and Atkins' book *Agricultural Ecology* and of *Agroecology: The Scientific Basis of Alternative Agriculture* by Altieri (1987), interest in agroecology grew more rapidly, especially among agronomists who saw the value of ecology in guiding agricultural design and management and also among ecologists who began to use agricultural systems as study plots to test ecological hypotheses.

Tropical ecologists were among the first to stress the fragility of agroecosystems and warn of the dangers of introducing modern intensive agricultural technology into tropical areas. Janzen's (1973) article on tropical agroecosystems was the first widely read evaluation of why tropical agricultural systems might function differently from those of the temperate zones, challenging agricultural researchers to rethink the ecology of tropical agriculture. The work of Gliessman and his group in the 1970s in the Mexican tropics focused on understanding the ecological bases of traditional Mexican agriculture, drawing from the scholarship of Efraím Hernández-Xolocotzi (1977). This empirical information, based on observation and practice and also integrating cultural aspects, was viewed as a source of knowledge to conceptualize and apply agroecology (Mendez, Bacon and Cohen 2013). Tropical ecologists warned that replacement of polycultures by monocultures in the tropics increased the probabilities of deforestation, soil erosion, nutrient depletion, crop disease, pest incidence, loss of genetic diversity, etc. (Janzen 1973; Igzoburike 1971; Dickinson 1972; Gliessman, Garcia, and Amador 1981). A central idea of many ecologists was that a tropical agroecosystem should mimic the ecological functioning of local ecosystems, thus exhibiting tight nutrient cycling, complex structure and enhanced biodiversity. The expectation is that such agricultural mimics, like their natural models, can be productive, pest-resistant and conservative of nutrients (Ewell 1986). This approach of nature mimicry is being tested at the Land Institute, in the Kansas prairies, through the development of mixed crop perennials.

Rachel Carson's *Silent Spring* (1962), which raised questions about the secondary impacts of insecticides in the environment, fuelled environmental groups that called for the development of alternative forms of agriculture that would reduce the agrochemical load on ecosystems, wildlife, food and people. One response was the development of biological control and pest management approaches to crop protection which initially were in theory and practice based entirely on ecological principles, as described and theorized by Altieri, Letourneau and Davis (1983); Browning (1975); Levins and Wilson (1979); Metcalf and Luckman (1975); Price and Waldbauer (1975); and Southwood and Way (1970). Many insect ecologists warned that the instability of agroecosystems, manifested as the worsening of most insect pest problems, was increasingly linked to the indiscriminate use of pesticides and to the expansion of crop monocultures. They advised the restoration of vegetational diversity within and around agroecosystems as a key strategy to enhance habitat and alternative food sources for predators and parasitoids of insect pests. During the 1980s there was a virtual explosion of research documenting that diversification of cropping systems (variety mixtures, polycultures, agroforestry systems, etc.) often leads to reduced herbivore-pest populations and reduced pest damage through natural enemy enhancement and a combination of other factors (Altieri and Nicholls 2004, Letourneau et al. 2011).

The books of Altieri (1987, 1995), Carroll, Vandermeer and Rosset (1990) and Gliessman (1998) contributed to the evolution of agroecology from its beginnings as a predominantly ecological- and agronomic-based science toward an approach grounded in transdisciplinary and participatory research through engagement with social scientists, dialogue with other knowledge systems (mainly peasants and indigenous people) and direct involvement of local agricultural communities. These and other books and papers published in the two ensuing decades moved the agenda from that of agroecologists as scientists conducting research based mostly on the experimental ecological or agricultural production sciences, to a field of inquiry that ought to be as much social science or politically driven as it is natural science driven.

Finally, agroecology as a scientific discipline went through a strong change, moving beyond the field or agroecosystem scale towards a broader focus on the whole food system, defined as a global network of food production, distribution and consumption (Gliessman 2007; van der Ploeg 2009). This entails a new and larger definition of agroecology as "the integrative study of the ecology of the entire food systems, encompassing ecological, economic and social dimensions, or more simply the ecology of food systems" (Francis et al. 2003). Thus, a new current of research among agroecologists is to carefully analyze the current global food system and explore local alternatives for more socially just and economically viable forms of food provisioning and access.

Rural Development

Agroecology's re-emergence in the late 1970s and early 1980s was influenced by a number of intellectual currents that had relatively little to do with formal agronomy and ecology. Diverse disciplines such as anthropology, ethnoecology, rural sociology, development studies and ecological economics started to be reflected in the intellectual pedigree of agroecology (Hecht 1995). Latin America was the region of the world where agroecology expanded rapidly, initially adopted by hundreds of NGOs concerned about the ecological and social consequences of the Green Revolution. For the most part, resource-poor farmers gained very little from the Green Revolution, as the new technologies were not scale-neutral (Pearse 1980). The farmers with the large and better-endowed lands gained the most, whereas farmers with fewer resources often lost, and income disparities were often accentuated (Lappé, Collins and Rosset 1998: Ch. 5). Not only were technologies inappropriate for poor farmers, but peasants were excluded from access to credit, information, technical support and other services that would have helped them use and adapt these new inputs if they so desired (Pingali, Hossain and Gerpacio 1997). Non-governmental organizations felt the urgent need to combat rural poverty and to conserve and regenerate the deteriorated resource base of small farms and saw in agroecology a new approach to agricultural research and resource management that lent itself to a more participatory approach for technology development and dissemination (Altieri 2002). They argued that to be of benefit to the rural poor, agricultural research and development should operate on the basis of a "bottom-up" approach, using and building upon the resources already available: local people, their knowledge and their autochthonous natural resources. It must also seriously take into consideration, through participatory approaches, the needs, aspirations and circumstances of smallholders (Richards 1985).

Studies of indigenous knowledge and technologies and rural development theory became crucial ingredients for the growth of agroecology. Building on the work of anthropologists, sociologists, geographers and ethnoecologists such as Hernández Xolocotzi (1977), Grigg (1974), Toledo et al. (1985), Netting (1993) and van der Ploeg (2009), agroecologists argued that a starting point in the development of new pro-poor agricultural development approaches are the very systems that traditional farmers have developed and/or inherited throughout centuries (Astier et al. 2015). The ensemble of traditional crop management practices used by many resource-poor farmers have represented a rich resource for modern workers seeking to create novel agroecosystems well adapted to the local biophysical and socioeconomic circumstances of peasants. The "farmer first" approach championed by Chambers (1983) inspired many agroecologists to include local communities at all stages of projects (design, experimentation, technology development, evaluation, dissemination, etc.) as a key element in successful rural development. By now, it is well recognized by agroecologists that the inventive self-reliance of rural populations is a resource that must be urgently and effectively mobilized. Since the early 1980s, hundreds of agroecologically based projects have been promoted by NGOs throughout Latin America and other parts of the developing world that incorporate elements of both traditional knowledge and modern agricultural science. A variety of projects emerged featuring resource-conserving yet highly productive systems (Altieri 1999). Agroecology is highly knowledge intensive and is based on techniques that cannot be delivered top-down but must be developed on the basis of farmers' knowledge and experimentation. For this reason agroecology emphasizes the capability of local communities to experiment, evaluate and scale-up innovations through farmer-led and farmer-to-farmer research and grassroots extension approaches. Technological approaches emphasizing diversity, synergy, recycling and integration, and social processes that value community involvement, point to the fact that human resource development is the cornerstone of any strategy aimed at increasing options for rural people and especially resource-poor farmers (Holt-Gimenez 2006; Rosset 2015). In general, data show that over time these agroecologically managed systems exhibit stable levels of total production per unit area, produce economically favourable rates of return, provide a return to labour and other inputs sufficient for a livelihood acceptable to small farmers and their families, and ensure soil protection and conservation as well as enhanced biodiversity (Pretty 1995; Uphoff 2002).

The expansion of agroecology in Latin America initiated an interesting process of cognitive, technological and socio-political innovation intimately linked to new political scenarios, like the emergence of progressive governments and the resistance movements of peasants and indigenous people. Thus, the new agroecological scientific and technological paradigm is today being built in constant reciprocity with social movements and political processes (Martínez-Torres and Rosset 2010, 2014; Rosset and Martínez-Torres 2012; Machado and Machado Filho 2014). The technological dimension of the agroecological revolution emerges from the fact that, contrary to Green Revolution approaches that emphasized seed-chemical packages and "magic bullet" recipes, agroecology works with principles that take multiple technological forms according to the local socio-economic needs of farmers and their biophysical circumstances. Agroecological innovations are born *in situ* with the participation of farmers in a horizontal manner, and technologies are not standardized but rather flexible and respond and adapt to each particular situation.

The following epistemological innovations have characterized the agroecological revolution in the region (Altieri and Toledo 2011):

- agroecology integrates natural and social processes, joining political ecology, ecological economics and ethnoecology among the hybrid disciplines;
- agroecology uses a holistic approach; therefore it has long been considered to be transdisciplinary, as it integrates the advances and methods of several other fields of knowledge around the concept of the agroecosystem viewed as a socio-ecological system;
- agroecology is not neutral and is self-reflexive, giving rise to a critique of the conventional agricultural paradigm;
- agroecology recognizes and values local wisdom and traditions, creating a dialogue with local actors via participatory research that leads to a constant creation of new knowledge;
- agroecology adopts a long-term vision that sharply contrasts with the short-term and atomistic view of conventional agronomy; and
- agroecology is a science that carries an ecological and social ethics with a research agenda of creating nature friendly and socially just production systems.

Peasant Studies and Re-Peasantization

The relevance of peasant studies to contemporary agroecology is significant. Eduardo Sevilla Guzmán and other rural sociologists have traced the origins of agroecological thought in social science and social theory to neo-Narodnism and libertarian heterodox Marxism (Guterres 2006; Sevilla Guzmán 2006, 2011; Sevilla Guzmán and Woodgate 2013), in particular marked by the seminal thought of Chayanov (see van der Ploeg 2013). Sevilla Guzmán and van der Ploeg (2009, 2013) are probably the leading contemporary proponents of this school of analysis, which has its foundations in agrarian social thought and movements that emerged in opposition to early processes of agricultural industrialization and has developed in an ongoing dialectic between capitalist modernization and resistance to it. Thus, agroecology is viewed as an applied science embedded in a social context, problematizing capitalist relations of production and allying itself with agrarian social movements. In this regard agroecology was greatly influenced in Latin America by the ongoing debates between *descampesinistas* ("de-peasantizers"), who predicted the eventual disappearance of the peasantry (*campesinado*), and the *campesinistas* ("peasantists"), who believed that the peasantry could continue to reproduce itself at the margins of the capitalist economy.

Jan Douwe van der Ploeg (2009) puts forth a theoretical proposition about the peasantries of today. Rather than defining "peasant," he chooses to define what he calls "the peasant condition," or the "peasant principle," characterized by the constant struggle to build autonomy:

> Central to the peasant condition, then, is the struggle for autonomy that takes place in a context characterized by dependency relations, marginalization and deprivation. It aims at and materializes as the creation and development of a self-controlled and self-managed resource base, which in turn allows for those forms of co-production of man and living nature that interact with the market, allow for survival and for further prospects and feed back into and strengthen the resource base, improve the process of co-production, enlarge autonomy and, thus reduce dependency.... Finally, patterns of

> cooperation are present which regulate and strengthen these interrelations. (2009: 23)

Two characteristics stand out on this definition. The first is that peasants seek to engage in co-production with nature in ways that strengthen their resource base (soil, biodiversity, etc.). The second is precisely the struggle for (relative) autonomy, via the reduction of dependence in a world characterized by inequality and unequal exchange. According to van der Ploeg (2010), peasants may pursue agroecology to the extent that it permits them to strengthen their resource base and become more autonomous of input and credit markets (and thus indebtedness) while improving their conditions. This use of agroecology to move along a continuum from dependency toward relative autonomy — from being the entrepreneurial farmers they in some cases had become, toward being peasants again — is one axis of what he calls "re-peasantization" (2009). Another axis of re-peasantization is the conquest of land and territory from agribusiness and other large landowners, whether by land reform, land occupations or other mechanisms (Rosset and Martínez-Torres 2012).

When farmers undergo a transition from input-dependent farming to agroecology based on local resources, they are becoming "more peasant." Agroecological practices are similar to, and frequently based upon, traditional peasant practices, so in this transition re-peasantization takes place. And in marking the difference between the ecological and social wasteland of agribusiness land, and ecological farming on land recovered by peasants, they are reconfiguring territories as peasant territories, as they re-peasantize them through agroecology. Conversely, when peasants are drawn into greater dependence, use of industrial agricultural technologies, market relations and the debt cycle, this is one axis of "de-peasantization." Another axis of de-peasantization is when land grabbing corporations or states displace peasants from their land and territories and reconfigure these as territories for agribusiness, mining, tourism or infrastructure development (Rosset and Martínez-Torres 2012).

The twin processes of re- and de-peasantization move back and forth over time as circumstances change (van der Ploeg 2009). During the heyday of the Green Revolution in the 1960s and 1970s, the peasantry was incorporated *en masse* into the system, many of them becoming entrepreneurial family farmers. But today, faced with growing debt and market-driven exclusion, the net tendency is the reverse, according to van der Ploeg (2009, 2010). He presents convincing data to show that even those farmers in Northern countries most integrated into the market are in fact taking (at least small) steps toward becoming "more peasant" through relatively greater autonomy from banks, input and machinery suppliers and corporate intermediaries. Some even become organic farmers. In other words, there is a net retreat from some or many elements of the market (Rosset and Martínez-Torres 2012).

Numerical re-peasantization can be seen in the end of the long-term decline in the number of farms and the number of people dedicated to agriculture, and even a visible up-tick, in countries like the United States and Brazil (Rosset and Martínez-Torres 2012). In fact, what one observes is an increase in both the number of small family-size farms and an increase in large-scale commercial farms (agribusiness), with a decline in the numbers of intermediate size classes. In other words, in today's world, we are essentially losing the middle (entrepreneurial farmers) to both re-peasantization and de-peasantization. And we are increasingly witnessing a global territorial conflict, material and immaterial, between agribusiness and peasant resistance (Rosset and Martínez-Torres 2012). In this context we see the post-1992 emergence of La Vía Campesina (LVC), arguably the world's largest transnational social movement (Desmarais 2007; Martinez-Torres and Rosset 2010), promoting agroecologically diversified farming, as a key element in resistance, re-peasantization and the reconfiguration of territories (Sevilla Guzmán and Alier 2006; Sevilla Guzmán 2006). Of course, this somewhat stylized dichotomy should in no way be taken to imply that there is no longer a significant number of medium-scale farmers who still maintain both agribusiness and peasant identities.

Many organized peasant- and indigenous-based agrarian movements, such as LVC, consider that only by changing the export-led, free-trade-based, industrial agriculture model of large farms can the downward spiral of poverty, low wages, rural-urban migration, hunger and environmental degradation be halted (LVC 2013). These movements embrace the concept of agroecology as a pillar of food sovereignty which focuses on local autonomy, local markets and community action for access and control of land, water, agrobiodiversity, etc., which are of central importance for communities to be able to produce food locally.

Many peasant and indigenous organizations have adopted agroecology as the technological basis of small-scale farming and actively promote it among its thousands of members via farmer-to-farmer networks and grassroots educational processes (LVC 2013; Rosset and Martínez-Torres 2012). The following are the five main reasons why agroecology has been embraced by many social rural movements:

1. agroecology is a socially activating tool for the transformation of rural realities through collective action and is a key building block in the construction of food sovereignty, meaning healthy food for peasant and farm families and for local markets;
2. agroecology is a culturally acceptable approach as it builds upon traditional and popular knowledge and promotes a dialogue of wisdoms with more Western scientific approaches;
3. agroecology allows human beings to live in harmony with, and take care of, our Mother Earth;
4. agroecology provides economically viable techniques by emphasizing the use of indigenous knowledge, agrobiodiversity and local resources, avoiding dependence on external inputs, thus helping to build relative autonomy; and
5. agroecology helps peasant families and communities adapt to and resist the effects of climate change.

Despite its advantages and interest on the part of rural movements to promote agroecology, it faces both internal and external barriers (discussed in Chapter 4).

Other Currents of Alternative Agriculture

There are many manifestations of alternative agriculture, which depend to a greater or lesser extent on the implementation of agroecological principles and practices. They include biodynamic agriculture, organic farming, permaculture, natural farming and others. All mobilize agroecological principles through a diverse range of alternative practices designed to reduce dependence on synthetic chemical pesticides, fertilizers and antibiotics in order to cut production costs and reduce the adverse environmental consequences of industrial agricultural production.

Organic Farming

Organic farming, for example, is practised in almost all countries of the world, and its share of agricultural land and farms is growing, reaching a certified area of more than 30 million hectares globally. Organic farming is a production system that sustains agricultural productivity by avoiding or largely excluding synthetic fertilizers and pesticides. Instead, organic farmers rely heavily on the use of crop rotations, cover cropping and green manuring, crop residues, animal manures, legumes, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insect pests, weeds and diseases (Lotter 2003).

Scientists in Switzerland conducted a twenty-one-year comparison of the agronomic and ecological performance of organic and conventional farming systems. They found crop yields to be 20 percent lower in the organic systems, although input of fertilizer and energy was reduced by 31–53 percent and pesticide input by 98 percent. Researchers concluded that the enhanced soil fertility and higher biodiversity found in organic plots rendered these systems less dependent on external inputs (Mader et al. 2002).

Organic farming based on agroecological principles builds up soil organic matter and soil biota, sequesters carbon, minimizes pest, disease and weed damage, conserves soil, water, and biodiversity resources, and promotes long-term agricultural productivity with produce of optimal nutritional value and quality (Lampkin 1992).

Unfortunately about 80 percent of the certified organic farming systems are managed as monocultures, which are highly dependent on external (organic/biological) inputs to subsidize functions of pest control and soil fertility. As mentioned in Chapter 1, adoption of such practices, with the structure of monoculture left intact, does little to move toward a durable alternative to high-input systems, or toward the more productive redesign of farming systems. Farmers following this regime are trapped in an input substitution process that keeps them dependent on suppliers (many of a corporate nature) of a variety of typically expensive organic inputs (Rosset and Altieri 1997).

A broader critique of "conventional" organic farming by agroecologists revolves around the issue that, in addition to not challenging the monocultural nature of plantations and the heavy reliance on external inputs, many organic farmers also rely on foreign and/or expensive certification labels, or fair-trade systems destined only for agro-export, making them dependent on volatile international markets (Holt-Gimenez and Patel 2009). There is no question that the demand for organic food is increasing, but it is mostly confined to populations with high income levels, particularly in the industrialized world. Exploiting market niches available in the globalized economy to market organics privileges those with access to capital and perpetuates an "agriculture of the poor for the rich." The "*cibo pulito, justo e buono*" ("clean, fair and good food") that the slow food movement promotes and the fair trade coffee, bananas and other products are mainly enjoyed by the opulent in the North. As Southern countries enter the organic market, production is mostly for agroexport and thus contributes very little to the food sovereignty or security of poor nations. As organic products are increasingly traded as international commodities, their distribution is slowly being taken over by the same multinational corporations that dominate conventional agriculture. Even the food movements in the U.S. and Europe that support sustainable agriculture via eating fresh locally produced food have left off their radar the people of colour and from low-income neighbourhoods who live in food deserts and who therefore have been systematically deprived of access to such healthy and so-called sustainable food (Holt Giménez and Shattuck 2011). By not limiting the maximum amount of land that a particular farmer or company could certify as organic, now big corporations have joined the fad and are displacing small organic farmers (Howard 2016). In California, over half of the value of organic production comes from the 2 percent of growers who grossed over US$500,000 each. Growers grossing

$10,000 or less comprise 75 percent of all growers and only 5 percent of sales. In California, only 7 percent of the organic food that people buy comes from small, local farms; 81 percent of organic food sales involve large-scale processors, distributors, wholesalers or brokers. The consolidation of multiple farms, packing plants and regional hubs under a single corporation requires the adoption of conventional big business practices. This system is excellent for consolidating wealth and power at the apex of a pyramid, but it is antithetical to the goals of community and local control that were part of the original inspiration of the organic movement. As is already being observed, once bigness dominates the organic industry, local community values are inevitably left behind while targeting niche markets for the well-off (Guthman 2014).

In addition, most certification protocols do not include social considerations to differentiate organic produce. Today in California, it is possible to buy organic produce that may be environmentally produced but at the expense of the exploitation of farmworkers (Cross et al. 2008; Guthman 2014). Generally, there are no major differences in living conditions, labour practices or pay for a farmworker working in an organic versus a conventional farm operation. Might this be a reason why, for example, farmworker unions have not wholeheartedly endorsed organic farming? There is no question that organic agriculture must be both ecologically and socially sustainable. For this to happen, organic techniques must be embedded in a social organization that furthers the underlying values of social and ecological sustainability.

The "technological determinism" of the organic farming school that emphasizes input substitution and export markets epitomizes those groups that have a relatively benign view of capitalist agriculture. They ignore the fact that organic products are increasingly traded as international commodities for the consumption of the rich and that their production and distribution is slowly being taken over by the same multinational corporations that dominate conventional agriculture (Rosset and Altieri 1997; Howard 2016). Ignoring the complex issues surrounding commercial and agroexport-oriented organic agriculture is undermining the original agrarian vision of organic farming, which saw a renaissance of a diversified and small scale agriculture in order to strengthen local production-consumption circles. This narrow acceptance of the present structure of agriculture as a given condition restricts the real possibility of implementing alternatives that challenge that structure. Merely introducing alternative agricultural technologies will do little to change the underlying forces that led to monoculture production, farm size expansion and mechanization in the first place (Altieri 2012).

Fair Trade

In their attempt to obtain better prices for small farmers and thus reduce poverty, the so-called "fair trade" movement leads a worldwide movement for ethical consumption with commodities that include coffee, cocoa, tea, bananas and sugar. Fair trade experienced rapid market expansion when large corporations and brands, including Costco, Sam's Club, Seattle's Best, Dunkin Donuts, Starbucks and McDonalds, began offering fair trade certified coffee (Jaffee 2012; Jaffee and Howard 2016). These companies were certified with the U.S. fair trade seal regardless of their dismal labour or environmental records. In 2005 the fair trade market ballooned to $500 million, the fastest growing segment of the specialty coffee market. To reach such amounts, the fair trade focuses on exports and contributes little to local food sovereignty or security, at times creating social stratification in rural communities as relatively few families benefit from the good prices. Fair trade companies have not joined other social movements demanding structural change — like getting agriculture out of the World Trade Organization and abolishing the NAFTA and other regional free trade agreements — therefore not supporting rural social movements and government policies for a more local and socially just sustainable food production (Holt Giménez and Shattuck 2011).

Conservation Biologists

Conservation biologists have traditionally considered agriculture as an enemy of nature conservation, but they have slowly accepted the fact that agriculture, which occupies about 1.5 billion hectares of land worldwide, has become a major force in modifying the biosphere, and therefore they have to deal with it. In the search for better outcomes for local and global biodiversity, and influenced by conventional agronomists who argued that, thanks to the Green Revolution, which intensified production thus requiring less land, millions of hectares of forests and associated wildlife were saved, many conservationists embrace the concept of "land sparing." This is the idea that conventional intensification means more food can be produced on less land, thus "sparing" land for conservation. This ignores the fact that industrial agriculture and plantations and corporate-driven ranching are among the main destroyers of biodiversity worldwide. In contrast, the "land sharing" concept is that agroecological farming contributes to a mosaic or matrix in which the landscape is shared by agriculture and biodiversity (Perfecto, Vandermeer and Wright 2009; Grau, Kuemmerle and Macchi 2013). Kremen (2015) argues that the land-sparing/land-sharing dichotomy limits the realm of future possibilities to just two out of many options for conservation.

Eco-Agriculture

Many people interested in promoting wildlife-friendly farming methods embrace the concept of eco-agriculture, which argues that wildlife preservation can be accomplished mainly through agricultural intensification, especially in the biodiversity hotspots of the Global South, where most of the poor concentrate and have little choice but to exploit wild habitats for survival (McNeely and Scherr 2003). Eco-agriculture promoters claim that the best way to reduce the impact of agricultural modernization on ecosystem integrity is to intensify production with emerging technologies in order to increase yields per hectare, and in this way spare natural forests and other wildlife habitats from further agricultural expansion. For the eco-agriculturists, it makes no difference if the best results to preserve birds or other animals are derived from landscapes inclusive of large high-input and high-yielding monocultures with protected areas of natural habitat set aside for biodiversity conservation, or of small diversified farms (i.e., coffee agroforests) surrounded by a matrix of natural vegetation. The end goal is wildlife preservation, as long as it is achieved at a "reasonable" environmental and social cost. True, exclusive attention to increasing yields for meeting food needs can exert a very high toll on the environment, but a sole focus on preserving nature may condemn millions to hunger and poverty (Altieri 2004).

The land sparing versus sharing debate has been highly successful in generating much needed discussion about two of the most pressing problems of our time — feeding a growing human population and conserving biodiversity (Fischer et al. 2014). Limiting the debate to two conservation mechanisms fits into discourses on food production and land scarcity but says nothing about food sovereignty or about who controls the land, other resources and the food system. It can help to identify trade-offs but cannot tell us which of these trade-offs are socially desirable. Its answers on biodiversity are only as good as the ways in which biodiversity is defined and measured.

Nature's Matrix

Perfecto, Vandermeer and Wright (2009) propose "nature's matrix" as a more viable conservation strategy, as it considers that biodiversity conservation, food production and food sovereignty (i.e., the rights of food producers and consumers) are all interconnected goals. The matrix quality model challenges the assumption that agriculture is the enemy of conservation. It is the kind of agriculture, not the simple fact of its existence, that matters. In summary, contrary to the conventional wisdom that industrial agriculture is needed to produce enough food to feed the world, the empirical evidence suggests that peasant and small-scale family farm operations adopting agroecological methods can be as (or more) productive than industrial agriculture. An agricultural matrix composed of small-scale sustainable farms can thus create a win-win situation that addresses both the current food crisis and the biodiversity crisis.

Ecofeminism

Carolyn Merchant, Vandana Shiva and other ecofeminists have long argued that modern, Western science has its epistemological origins in the not-unrelated material relations of colonialism, capitalism and patriarchy and that it is intimately related to both the epistemological and physical forms of violence that these have engendered throughout modern history (Merchant 1981; Mies and Shiva 1993). They equate reductionist science and the brute force technical domination of Nature with patriarchal forms of thought and point to the similarities between the domination of Nature and the domination of women by men (also see Levins and Lewontin 1985). They posit ecofeminism in particular, and ecological, holistic thinking in general, as representing a more female rationality of living together with Nature, similar to what has more recently come to be known in South America as the indigenous rationality of *buen vivir,* or "living well" with each other and with Mother Earth (Giraldo 2014). If industrial monoculture is the epitome of patriarchal thought applied to agriculture, then agroecology as its opposite has real feminist roots (Shiva 1991, 1993; Siliprandi 2009).

More recently many authors have observed that women peasants and farmers are often the visible or invisible protagonists of processes of agroecological transformation (Siliprandi 2015; Siliprandi and Zuluaga 2014). Women are taking public leadership roles in a number of social movement processes, though they are often underrepresented compared to male leaders. But even when they are not in visible leadership roles, when one scratches beneath the surface of successful processes of agroecological transformation, it is typically the women inside the peasant household who first pushed to put an end to the use of dangerous pesticides and to produce healthy food — women concerned about the health and nutrition of their families.

Around the world, including inside the peasant or farmer household, patriarchy, sexism, inequality between men and women, and domestic violence affect the quality of life, not only of women but of the entire family. Conventional Green Revolution agriculture based on monocultures, chemical inputs and mechanization offers no place for members of the family other than the male head of household. It is the man alone who manages the machinery, who applies the pesticides and who collects the income from the year's harvest. This ends up reinforcing his powerful role within the family unit. Many times the man makes all decisions within the family, exclusively. Other family members are left to be only his helpers.

The broad experience of Cuba has shown that agroecology is beginning to alter these trends for the better. Agroecology increases and diversifies incomes of peasant families and also generates a diversity of responsibilities for the entire extended family. During the transformation from a monoculture to an agroecologically diversified farm, the duties and responsibilities of the members of the peasant household are diversified as well. When the farm is dedicated to a commercial monoculture, it is typically the man who makes all the decisions, buys the inputs, prepares the land, harvest, sells the crop, and pockets the income. But after agroecological transformation and the associated diversification of crops, trees and livestock, and responsibilities for caring for them, each member now has their own role to play, and at times, an independent income. For example, the women, besides taking responsibility for the animals, may also sow plants and vegetables in the backyard. Often, they are also responsible for vermiculture (worm composting), even forming small vermiculture collectives with neighbouring women. It is also common that young people have their own projects, such as raising specific animals, from which they hope to earn an income. The elderly may have orchards, and they sometimes make and sell preserves. All of these opportunities on farms that follow agroecological practices encourage the (re)integration of the entire extended peasant family, and each family member gains important relative autonomy, decision-making authority over their specific areas and even often their own income. The cumulative effect is to reduce, in relative terms, the omnipotent, patriarchal power of the man within the family, compared to what is typical on conventional, monocultural farms (Machín Sosa et al. 2010, 2013).

Feminism has been an important current in agroecological thought and can also be an essential part of agroecological processes, and these processes can contribute as well to a strengthened feminism.

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Chapter 3

The Evidence for Agroecology

Most analysts today agree that increasing food production will be a necessary but not a sufficient condition to prevent future hunger around the world. Hunger results from underlying inequities in the dominant capitalist system that deprive poor people of economic opportunity, access to food and land and other resources vital for a secure livelihood (Lappé, Collins and Rosset 1998). Focusing narrowly on increasing food production cannot alleviate hunger because it fails to alter the tightly concentrated distribution of economic power that determines who can buy food or have access to seeds, water and land to produce it. Increasing food production to meet future needs must therefore be combined with strategies that at the same time improve the livelihoods of smallholder farmers and preserve ecosystems. A series of reports argue that agroecology can provide the basis for such strategies because of its coherent principles for designing diversified, resilient and productive farming systems strongly rooted both in science and in practice (de Schutter 2011). Available and convincing data from a plethora of studies shows that, over time, agroecological systems exhibit more stable levels of total production per unit area than high-input systems, produce economically favourable rates of return, provide a return to labour and other inputs sufficient for a livelihood acceptable to small farmers and their families, and ensure soil and water protection and conservation as well as enhanced biodiversity (Altieri and Nicholls 2012).

Today there are myriad examples of successful agricultural systems characterized by a tremendous crop and animal diversity maintained and enhanced by soil, water and biodiversity management regimes nourished by agroecology, many based on the rationale of complex traditional farming systems (Altieri and Toledo 2011). Such agricultural systems not only have fed much of the world population for centuries and continue to feed people in many parts of the world, especially in developing countries, but also hold many of the potential answers to the production and natural resource conservation challenges affecting today's rural landscapes (Koohafkan and Altieri 2010). Emerging research is documenting how smallholder agroecological production worldwide contributes substantially to food security and sovereignty, rural livelihoods and local and even national economies, yet these contributions have not been adequately appreciated (Uphoff 2002; Altieri, Rosset and Thrupp 1998).

Extent and Significance of Peasant Agriculture

Most developing countries have a significant peasant population made up of hundreds of ethnic groups with histories that can be traced back more than 10,000 years of practicing traditional agriculture. Globally there are about 1.5 billion smallholders, family farmers and indigenous people on 350 million small farms, while 410 million practise gathering in forests and savannas; 190 million are pastoralists and well over 100 million are artisanal fisherfolk. At least 370 million of these are indigenous people, occupying about 92 million farms (ETC Group 2009). It is estimated that 70–80 percent of the world's food is still produced by small-scale food producers in plots averaging 2 hectares in size. Farms smaller than one hectare account for 72 percent of all farms, but control only 8 percent of agricultural land (Wolfenson 2013). Furthermore, most of the food consumed in the world today is derived from 5,000 domesticated crop species and 1.9 million peasant-bred plant varieties, mostly grown without agrochemicals or the high input techniques of conventional agriculture, on these same small farms (ETC Group 2009).

In Latin America, small farms (average size 1.8 ha) run by peasants represent over 80 percent of the total holdings and provide 30–40 percent of the region's agricultural GDP. Peasant production units account for no less than 16 million small farms, contributing to approximately 41 percent of the agricultural output for domestic consumption, according to official statistics, which typically massively underestimate peasant production, and are responsible for producing at the regional level 51 percent of the maize, 77 percent of the beans and 61 percent of the potatoes (Ortega 1986). The contribution to food security of this small-farm sector is today as crucial as twenty-five years ago. In Brazil alone, there are about 4.8 million peasant and family farmers (about 85 percent of the total number of farmers), who occupy 30 percent of the total agricultural land in the country. Such small farms control about 33 percent of the area sown to maize, 61 percent of that under beans, and 64 percent of that planted to cassava, thus producing 84 percent of the total cassava and 67 percent of all beans (Altieri 2002). In Ecuador, the peasant sector occupies more than 50 percent of the area devoted to food crops such as maize, beans, barley and okra. In Mexico, peasants occupy at least 70 percent of the area cultivated to maize and 60 percent of the area under beans (Altieri 1999). In Cuba, peasant farmers produce almost two-thirds of the country's food, on only one-third of the land (Rosset et al. 2011).

Africa has approximately 33 million small farms, representing 80 percent of all farms on the continent. The majority of African farmers (many of them are women) are smallholders, with two-thirds of all farms below 2 hectares. Most small farmers practise low-resource agriculture, producing the majority of grains, almost all root, tuber and plantain crops, and the majority of legumes consumed in the region (Pretty and Hine 2009). In Asia, China alone accounts for almost half the world's small farms (on 193 million hectares), followed by India, with 23 percent, and Indonesia, Bangladesh and Vietnam. Of the majority of more than 200 million rice farmers who live in Asia, few cultivate more than 2 hectares of rice. China has probably 75 million rice farmers who still practise methods similar to those used more than a thousand years ago. Local cultivars, grown mostly on upland ecosystems and/or under rain-fed conditions, make up the bulk of the rice produced by Asian small farmers. Smallholder farmers in India possessing on average 2 ha of land each make up about 78 percent of the country's farmers while owning only 33 percent of the land, but they are responsible for 41 percent of national grain production. As on other continents, Asian small farmers significantly contribute to both household and community food security as their total farm outputs tend to be high (UN-ESCAP 2009).

Assessing the Impact of Agroecological Interventions

The first global assessment of agroecologically based projects and/or initiatives throughout the developing world encompassed 286 sustainable agriculture projects in fifty-seven poor countries covering 37 million hectares (3 percent of the cultivated area in developing countries). Researchers found that such interventions increased productivity on 12.6 million farms, with an average crop-yield increase of 79 percent (Pretty, Morrison and Hine 2003). Sustainable agricultural practices led to 50–100 percent increases in per hectare cereal production (about 1.71 Mg per year per household — an increase of 73 percent) in rain-fed areas typical of small farmers living in marginal environments; that is an area of about 3.58 million hectares, cultivated by about 4.42 million farmers. In fourteen projects where root crops were main staples (potato, sweet potato and cassava), the 146,000 farms on 542,000 hectares increased household food production by 17 tons per year (increase of 150 percent). Such yield enhancements are a true breakthrough for achieving food security among farmers isolated from mainstream agricultural institutions (Pretty et al. 2003).

A more recent large-scale study points to the same conclusions. Research commissioned by the Foresight Global Food and Farming Futures project of the U.K. government (2011) reviewed forty projects in twenty African countries where sustainable agriculture intensification was developed during the 2000s. The projects included crop improvements (particularly improvements through participatory plant breeding on hitherto neglected orphan crops), integrated pest management, soil conservation and agroforestry. By early 2010, these projects had documented benefits for 10.39 million farmers and their families and improvements on approximately 12.75 million hectares. Crop yields more than doubled on average (increasing 2.13-fold) over a period of three to ten years, resulting in an increase in aggregate food production of 5.79 million tons per year, equivalent to 557 kg per farming household.

Africa

There is a growing body of evidence emerging from Africa demonstrating that agroecological approaches can be highly effective in boosting production, incomes, food security and resilience to climate change and in empowering communities (Action Aid 2011). Christian Aid (2011) found that in 95 percent of sustainable agriculture projects cereal yields improved by 50–100 percent. Total farm food production increased in all surveyed farms. The additional positive impacts on natural, social and human capital also helped to build the asset base so as to sustain these improvements in the future. The enhanced food outputs reported in the above studies resulted mainly from diversification schemes that included a range of new crops, livestock or fish that added to the existing staples or vegetables already being cultivated. These new system enterprises or components included aquaculture for fish raising; small patches of land used for raised beds and vegetable cultivation; rehabilitation of formerly degraded land; fodder grasses and shrubs that provide food for livestock (and increase milk productivity); raising of chickens and zero-grazed sheep and goats; new crops brought into rotations with maize or sorghum; and/or adoption of short-maturing varieties (e.g., sweet potato and cassava) that permit the cultivation of two crops per year instead of one (Pretty, Toulmin and Williams 2011).

Another meta-analysis, conducted by UNEP–UNCTAD (2008) assessing 114 cases in Africa, revealed that a conversion of farms to organic methods increased agricultural productivity by 116 percent. In Kenya, maize yields increased by 71 percent and bean yields by 158 percent. Moreover, increased diversity in food crops available to farmers resulted in more varied diets and thus improved nutrition. Also the natural capital of farms (soil fertility, levels of agrobiodiversity, etc.) increased with time after conversion.

One of the most successful diversification strategies has been the promotion of tree-based agriculture. Agroforestry of maize associated with fast growing and N-fixing shrubs (e.g., *Calliandra* and *Tephrosia*) has spread among tens of thousands of farmers in Cameroon, Malawi, Tanzania, Mozambique, Zambia and Niger, resulting in a maize production of 8 t/ha compared with 5 t/ha obtained under monoculture (Garrity 2010). By mid-2009, over 120,000 Malawian farmers received training and tree materials from the national agroforestry program, reaching 40 percent of Malawi's districts and benefiting 1.3 million of the poorest people. Research shows that agroforestry systems resulted in increased yields, from 1 t/ha to 2–3 t/ha of maize, among farmers who cannot afford commercial nitrogen fertilizers.

Another agroforestry system in Africa is one dominated by *Faidherbia* trees, which improve crop yields and protect crops from dry winds and the land from water erosion. In the Zinder Regions of Niger, there are now about 4.8 million hectares of *Faidherbia*-dominated agroecosystems. The foliage and pods from the trees also provide much-needed fodder for cattle and goats during the long Sahelian dry seasons. Encouraged by the experience in Niger, about 500,000 farmers in Malawi and the southern highlands of Tanzania maintain *Faidherbia* trees in their maize fields (Reij and Smaling 2008).

In southern Africa, conservation agriculture is an important and partially agroecological innovation based on three agroecological practices: minimum soil disturbance, permanent soil cover and crop rotations. These systems have spread in Madagascar, Zimbabwe, Tanzania and other countries reaching no less than 50,000 farmers, who have dramatically increased their maize yields to 3–4 MT/ha higher than conventional. Improved maize yields increase the amount of food available at the household level and also increase income levels (Owenya et al. 2011). In Sub-Saharan Africa, 80 percent of smallholder farmer have less than two hectares of land and therefore are no longer able to have three-quarters of their land sitting idle (i.e., in a fallow) every year and still feed their families with what's left. Under these conditions, the introduction of a series of leguminous green manure/cover crops is a key strategy, as these cover crops can produce over 100 tons of biomass (green weight) on two hectares of land, which is more than enough to maintain the fields' fertility and to gradually restore the soil. Even more important, most of the green manure/cover crops also produce high-protein food, which usually can be consumed or sold in local markets (Reij, Scoones and Toulmin 1996).

In Sub-Saharan Africa, 40 percent of the farmland is located in semi-arid and dry sub-humid savannahs increasingly subjected to frequent occurrence of water scarcity. An old water harvesting system known as *zai* is being revived in Mali and Burkina Faso. The *zai* are pits or holes typically 10–15 cm deep and filled with organic matter (Zougmore, Mando and Stroosnijder 2004). The application of manure in the pits further enhances growing conditions and simultaneously attracts soil-improving termites, which dig channels and thus improve soil structure so that more water can infiltrate and be held in the soil. In most cases farmers grow millet or sorghum or both in the *zai*. At times the farmers sow trees directly together with the cereals in the same *zai*. At harvest, farmers cut the stalks off at a height of about 50–75 cm, which protects the young trees from grazing animals. Farmers use anywhere from 9,000 to 18,000 pits per hectare, with compost applications ranging from 5.6 to 11 t/ha (Critchley, Reij and Willcocks 2004). Over the years, thousands of farmers in the Yatenga region of Burkina Faso have used this locally improved technique to reclaim hundreds of hectares of degraded lands as the pits efficiently collect and concentrate runoff water and function with small quantities of manure and compost. Cereal yields obtained on fields managed with *zai* are consistently higher (870–1,590 kg/ha) than those obtained on fields without *zai,* which average 500–800 kg/ha (Reij 1991).

In Eastern Africa, an agroecologically based pest management strategy known as "push–pull" has been widely disseminated. The strategy consists in intercropping maize with a repellent plant (*Desmodium*), which repels (pushes) pests such as stem borers, bordered by Napier grass, which lures (pulls) stem borers so they lay their eggs in the grass instead of the maize, thus acting as a trap crop. Napier grass also produces a gummy substance that traps freshly hatched stem borers so only a few survive to adulthood. The system not only controls pests but has other benefits as well, because *Desmodium* can be used as fodder for livestock. The push-pull strategy doubles maize yields and milk production while, at the same time, improves the soil and controls Striga, a parasitic weed. The system has already spread to more than 10,000 households in East Africa (Khan et al. 1998).

Asia

Pretty and Hine (2009) evaluated sixteen agroecological projects/initiatives spread across eight Asian countries and found that some 2.86 million households have substantially increased total food production on 4.93 million hectares, resulting in greatly improved household food security. Proportional yield increases are greatest in rain-fed systems, but irrigated systems have seen small cereal yield increases combined with added production from additional productive system components (such as fish in rice, vegetables on dykes).

The system of rice intensification (SRI) is an agroecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients (Stoop, Uphoff and Kassam 2002). It has spread throughout China, Indonesia, Cambodia and Vietnam, reaching more than a million hectares, with average yield increases of 20–30 percent. The benefits of SRI, which have been demonstrated in over forty countries, include increased yield at times more than 50 percent, up to 90 percent reduction in required seed and up to 50 percent savings in water. SRI requires more knowledge and skill on the part of farmers and initially more labour per hectare, but greater labour intensity is compensated by farmers achieving higher returns. SRI principles and practices have also been adapted for rain-fed rice as well as for other crops, such as wheat, sugarcane and teff, among others, with yield increases and associated economic benefits (Uphoff 2003).

In what can probably be considered the largest study undertaken on sustainable agriculture in Asia, Bachmann, Cruzada and Wright (2009) examined the work of MASIPAG, a network of peasant farmers, peasant organizations, scientists and NGOs. By comparing in the Philippines 280 full organic peasant farmers, 280 in conversion to organic, and 280 conventional peasant farmers, these researchers found that food security is significantly higher for organic farmers. Results of the study, summarized in Table 3-1, show good outcomes, particularly for the poorest in rural areas. Full organic farmers eat a more diverse, nutritious and secure diet, with substantially better reported health outcomes. The study reveals that the full organic farmers have considerably higher on-farm diversity, growing on average 50 percent more crop species than conventional farmers, better soil fertility, less soil erosion, increased tolerance of crops to pests and diseases, and better farm management. The group also has, on average, higher net incomes.

Zero Budget Natural Farming (ZBNF) is a grassroots peasant

Table 3-1 Farmer-Led Sustainable Agriculture

More Food Secure
88% of organic farmers find their food security better or much better than in 2000 compared to only 44% of conventional farmers. Of conventional farmers, 18% are worse off. Only 2% of full organic farmers are worse off.
Eating an Increasingly Diverse Diet
Organic farmers eat 68% more vegetables, 56% more fruit, 55% more protein rich staples and 40% more meat than in 2000. This is an increase between 2 and 3.7 times higher than for conventional farmers.
Producing a More Diverse Range of Crops
Organic farmers on average grow 50% more crop types than conventional farmers.
Experiencing Better Health Outcomes
In the full organic group, 85% rate their health today better or much better than in 2000. In the reference group, only 32% rate it positively, while 56% see no change and 13% report worse health.

Note: Main findings of the MASIPAG study on farmers practising farmer-led sustainable agriculture
Source: Bachmann, Cruzada and Wright 2009

agroecology movement in Karnataka, India, that has spread massively (no less than 100,000 farmers) in the southern Indian states of Tamil Nadu, Andhra Pradesh and Kerala. The main agroecological practices promoted by the ZBNF include effective spacing of crops, contouring and bunds to conserve water, intensive mulching, the addition of microbial cultures to enhance decomposition and nutrient recycling, use of local seeds, integration of crops, trees and livestock (mainly cows), extensive intercropping and crop rotations, among others. A recent survey found that by adopting ZBNF practices over time 78.7 percent of the farmers saw improvements in yield, 93.6 percent in soil conservation, 76.9 percent in seed diversity, 91.1 percent in quality of produce, 92.7 percent in seed autonomy, 87.8 percent in household food autonomy and 85.7 percent in income, while 90.9 percent experienced reduced farm expenses and 92.5 percent a reduced need for credit. Clearly these results show that ZBNF works not just in agronomic terms but also brings about a variety of social and economic benefits (Khadse et al. 2017).

Latin America

Since the early 1980s in Latin America, small farmers, often and especially in the early years in partnership with NGOs and other organizations, have promoted and implemented alternative, agroecological practices featuring resource-conserving yet highly productive systems (Altieri and Masera 1993). An analysis of several agroecological field projects in operation during the 1990s, involving almost 100,000 farming families/units covering more than 120,000 hectares of land, showed that traditional crop and animal combinations can often be adapted to increase productivity when the agroecological structuring of the farm is improved and labour and local resources are efficiently used (Altieri 1999). In fact, most of the agroecological technologies that were promoted improved agricultural yields, increasing output per area of marginal land from 400–600 to 2,000–2,500 kg/ha, also enhancing the overall agrobiodiversity and its associated positive effects on food security and environmental integrity. Some approaches emphasizing green manures and other organic management techniques have increased maize yields from 1–1.5 t/ha (a typical highland peasant yield) to 3–4 t/ha (Altieri and Nicholls 2008).

An IFAD (2004) study which surveyed twelve farmer organizations that comprise about 5,150 farmers covering close to 10,000 hectares, showed that small farmers who shifted to organic production in all cases obtained higher net revenues relative to their previous situation. Many of these farmers produce coffee and cacao under very complex and biodiverse agroforestry systems. In addition to the *campesino a campesino* movement (described below), perhaps the most widespread agroecological effort in Latin America promoted by peasant organizations and NGOs is the rescuing of traditional or local crop varieties (*variedades criollas*), promoting *in-situ* conservation of genetic diversity via community seed banks and exchange through hundreds of seed fairs (*ferias de semillas*), notoriously in Mexico, Guatemala, Nicaragua, Peru, Bolivia, Ecuador and Brazil. For example, in Nicaragua the project *Semillas de Identidad*, which involves more than 35,000 families on 14,000 hectares, have already recuperated and conserved 129 local varieties of maize and 144 of beans (Altieri and Toledo 2011).

Campesino a Campesino in Central America

The first peasant-driven process of technological sharing and dissemination in contemporary agroecology took place in the highlands of Guatemala, where Kaqchikel farmers developed a horizontal learning methodology they called Campesino a Campesino (farmer to farmer, or peasant to peasant). When they later visited Mexican farmers in Tlaxcala (Vicente Guerrero), who had created a school of soil and water conservation, rather than try to convince the Mexicans of their innovations, the Kaqchikel farmers insisted they experiment with new ideas on a small scale first to see how well they worked. When the innovations proved successful, Mexican farmers shared their new knowledge with others. As these exchanges expanded, a grassroots Campesino a Campesino (CAC) agroecology movement grew up in southern Mexico and war-torn Central America over several decades (Holt-Gimenez 2006). In the midst of the Sandinista epoch in Nicaragua, the CAC practices were introduced through the Union Nacional de Agricultores y Ganaderos of Nicaragua. By 1995, about 300 agroecological promotors influenced about 3,000 families. In 2000, about 1,500 promotors were working with almost one-third of the Nicaraguan peasant families (Holt-Gimenez 2006). Today it is estimated that about 10,000 families in Nicaragua, Honduras and Guatemala practise the Campesino a Campesino method.

It was via the CAC method that soil conservation practices were introduced in Honduras, where hillside farmers adopting the various techniques tripled or quadrupled their yields, from 400 kg/ha to 1,200–1,600 kg/ha. This tripling in per-hectare grain production has ensured that the 1,200 families that participated in the program have ample grain supplies for each ensuing year. The adoption of velvet bean (*Mucuna pruriens*) as a green manure, which can fix up to 150 kg of nitrogen per hectare as well as produce 35 tons of organic matter, helped triple maize yields to 2500 kg/ha. Labour requirements for weeding were cut by 75 percent and herbicides eliminated entirely (Bunch 1990). Taking advantage of well-established CAC networks, the spread of a simple technology (*Mucuna* cover cropping) has occurred rapidly. In just one year, more than 1,000 peasants recovered degraded land in the San Juan watershed of Nicaragua (Holt-Gimenez 2006). Economic analyses of these projects indicate that farmers adopting cover cropping have lowered their utilization of chemical fertilizers (from 1,900 kg/ha to 400 kg/ha) while increasing yields from 700kg to 2,000kg/ha, with production costs about 22 percent lower than those of farmers using chemical fertilizers and monocultures (Buckles, Triomphe and Sain 1998).

Cuba

In Cuba in the 1990s, the Asociacion Cubana de Agricultura Organica, an NGO formed by scientists, farmers and extension personnel, helped establish three integrated farming systems called "agroecological lighthouses" in cooperatives in the province of Havana. After the first six months, all three pilot co-ops had incorporated agroecological innovations (i.e., tree integration, planned crop rotation, polycultures, green manures, etc.) to varying degrees, which, with time, led to enhancement of production and biodiversity and improvement in soil quality. Several polycultures, such as cassava-beans-maize, cassava-tomato-maize and sweet potato–maize, were tested in the cooperatives. Productivity evaluation of these polycultures indicated 2.82, 2.17 and 1.45 times greater total productivity than monocultures, respectively (SANE 1998).

At the Cuban Instituto de Investigacion de Pastos, analysis of the agroecological integration of crops and livestock in a 75 percent pasture/25 percent crop agroecological module, revealed that total production increases over time and that energy and labour inputs decrease, as the biological structuring of the system begins to sponsor the productivity of the agroecosystem. Total biomass production increased from 4.4 to 5.1 t/ha after three years of agroecological integration. Energy inputs decreased, which resulted in enhanced energy efficiency (Table 3-2). Human labour demands for management also decreased over time from 13 hours of human labor/day to 4–5 hours. This is important because there is a common myth that agroecology is always labor intensive and thus can only work when abundant labour is available, yet agroecology can also be labour saving, especially

Table 3-2 Productivity and Efficiency of Crop Integration in Cuba

Productive Parameters	1st Year	3rd Year
Area (ha)	1	1
Total production (t/ha)	4.4	5.1
Energy produced (Mcal/ha)	3797	4885
Protein produced (Kg/ha)	168	171
Number of people fed by 1 ha.	4	4.8
Inputs (energy expenditures, Mcal)		
– human labour	569	359
– animal work	16.8	18.8
– tractor energy	277.3	138.6

Note: Results of the 75% animal/25% crop integrated module in Cuba after three years of conversion. Source: SANE *1998*

over time as synergistic processes (like shading-out weeds) replace human labour (like weeding), as argued by Funes-Monzote (2008). Such models were promoted extensively in other areas of the island through field days and farmers cross visits (SANE 1998).

A later study conducted by Funes-Monzote et al. (2009) showed that small farmers using agroecologically integrated crop-livestock farming systems were able to achieve a three-fold increase in milk production per unit of forage area (3.6 t/ha/year) as well as a seven-fold increase in energy efficiency. Energy output (21.3 GJ/ha/year) was tripled and protein output doubled (141.5 kg/ha/year) via diversification strategies of specialized livestock farms (Table 3-3).

After the CAC methodology was adopted by the Asociación Nacional de Agricultores Pequeños, the national peasant organization (and member of La Vía Campesina) in Cuba, these and other agroecological practices were scaled out to between a third and a half of all peasant farmers in the island nation (Rosset et al. 2011). A study found that agroecological practices are now used on 46–72 percent (depending on which combinations of practices) of peasant farms, which are responsible for more than 70 percent of domestic food production, e.g., 67 percent of roots and tubers, 94 percent of small livestock, 73 percent of rice, 80 percent of fruits and most

Table 3-3 Results of Two Cuban Small-Scale Farms

	Cayo Piedra, Matanzas	Del Medio, Sancti Spiritus
Area (ha)	40	10
Energy (GJ/ha/year)	90	50.6
Protein (Kg/ha/year)	318	434
People fed/ha/year (calories)	21	11
People fed/ha/year (protein)	12.5	17
Energy efficiency (output/input)	11.2	30
Land equivalent ratio	1.67	1.37

Note: Cayo Piedra farm typically includes between 10 and 15 different species in crop rotations (maize, beans, sugar beets, cabbage, potatoes, sweet potatoes, taro, carrot, cassava, squash and pepper) and permanent crops such as banana and coconut. Del Medio farm is a highly diversified farm with more than 100 species of crops, animals, trees, and other wild species that are being managed using permacultural practices. Source: Funes-Monzote, Monzote, Lantinga et al. 2009

of the honey, beans, cocoa, maize, tobacco, milk and meat production (Funes Aguilar et al. 2002; see also Machin Sosa et al. 2013; Rosset et al. 2011; Funes Aguilar and Vázquez Moreno 2016). Small farmers using agroecological methods obtain yields per hectare sufficient to feed about fifteen to twenty people per year with energy efficiencies of no less than 10:1 (Funes-Monzote 2008).

Andean Region

Several researchers and NGOs have studied pre-Columbian Andean technologies in search of solutions to contemporary problems of high-altitude farming. A fascinating example is the revival of an ingenious system of raised fields that evolved on the high plains of the Peruvian Andes about 3,000 years ago. According to archeological evidence, these *waru waru* platforms of soil surrounded by ditches filled with water were able to produce bumper crops despite floods, droughts and the killing frost common at altitudes of nearly 4,000 metres (Erickson and Chandler 1989). In 1984, several NGOs and state agencies assisted local farmers in reconstructing ancient systems. The combination of raised beds and canals has proven to have important temperature-moderation effects, extending the growing season and leading to higher productivity on the *waru warus* compared to chemically fertilized normal pampa soils. In the Huatta district, reconstructed raised fields produced impressive harvests, exhibiting a sustained potato yield of 8–14 t/ha a year. These figures contrast favourably with the average potato yields in Puno of 1–4 t/ha a year. In Camjata the potato fields reached 13 t/ha a year and quinoa yields reached an acceptable level of 2 t/ha a year in *waru warus*.

Elsewhere in Peru, several NGOs in partnership with local government agencies engaged in programs to restore abandoned ancient terraces. For example, in Cajamarca, in 1983, EDAC-CIED together with peasant communities initiated an all-encompassing soil conservation project. Over ten years they planted more than 550,000 trees and reconstructed about 850 hectares of terraces and 173 hectares of drainage and infiltration canals. The end result were about 1124 hectares of restored terraces, benefiting 1247 families. Potato yields went from 5 t/ha to 8 t/ha and oca yields jumped from 3 t/ha to 8 t/ha. Enhanced crop production, fattening of cattle and raising of alpaca for wool increased the income of families from an average of $108 year in 1983 to more than $500 in the mid-1990s (Sanchez 1994a). In the Colca valley of southern Peru, a local government program sponsored terrace reconstruction in 30 hectares by offering peasant communities low-interest loans and seeds or other input. First-year

Table 3-4 Yields on New Bench Terraces vs. Sloping Fields

Crop[a]	Terraced[b] (kg/ha)	Sloping[c] (kg/ha)	% Increase	N
Potatoes	17,206	12,206	43	71
Maize	2,982	1,807	65	18
Barley	1,910	1,333	43	56
Barley (forage)	25,825	23,000	45	159

Note: First year per hectare yields of crops on new bench terraces, compared to yields on sloping fields (kg/ha)
a – all crops treated with chemical fertilizers;
b – water absorption terraces with earthen walls and inward platform slope;
c – fields sloping between 20% and 50% located next to terraced fields for control;
N – number of terrace/field sites. Source: Treacey 1989

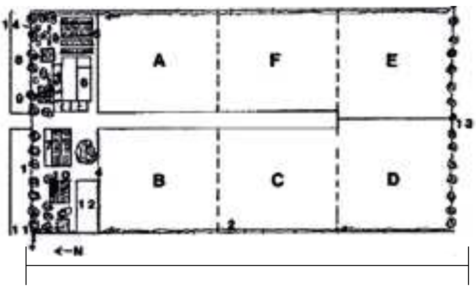
yields from new bench terraces showed a 43–65 percent increase of potatoes, maize and barley, compared to the crops grown on sloping fields (Table 3-4). The native legume *Lupinus mutabilis* was used as a rotational or associated crop on the terraces; it fixes nitrogen, which is available to companion crops, minimizing fertilizer needs and increasing production (Treacey 1989). NGOs have also evaluated traditional farming systems above 4,000 metres, where maca (*Lepidium meyenii*) is the only crop capable of offering farmers secure yields, especially when grown after fields have been fallowed for five to eight years (SANE 1998).

Chile

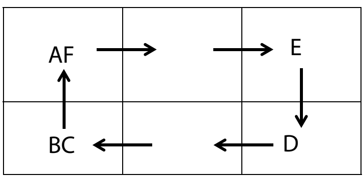
Since 1980, the Centre for Education and Technology (CET), a Chilean NGO, has engaged in a rural development program aimed at helping peasants reach year-round food self-sufficiency while rebuilding the productive capacity of their small landholdings (Altieri 1995). The approach consisted in setting up several 0.5 hectare model farms, which consist of a spatial and temporal rotational sequence of forage and row crops, vegetables, forest and fruit trees, and animals. Components are chosen according to crop or animal nutritional contributions to subsequent rotational steps, their adaptation to local agroclimatic conditions, local peasant consumption patterns and finally, market opportunities. Most vegetables are grown in heavily composted raised beds located in the garden section, each of which can yield up to 83 kg of fresh vegetables per month, a considerable improvement to the 20–30 kg produced in spontaneous gardens tended around households. The rest of the 200-square metre area surrounding the house is used as an orchard and for animals (cows, hens, rabbits and Langstroth beehives). Vegetables, cereals, legumes and forage plants are produced in a six-year rotational system designed to provide the maximum variety of basic crops in six plots, taking advantage of the soil-restoring properties of rotations (Figure 3-1). Relatively constant production is achieved in the half hectare (about 6 t/year of useful biomass from thirteen different crop species) by dividing the land into six rotational plots. Fruit trees were planted as fencerows producing more than a ton of fruits. Milk and egg production far exceeds that on conventional farms. A nutritional analysis of the system showed that after a typical family of five has fed itself, the farm produces a 250 percent surplus of protein, 80 and 550 percent surpluses of vitamin A and C, respectively, and a 330 percent surplus of calcium. A household economic analysis indicates that the balance between selling surpluses and buying preferred

Figure 3-1 Integrated Half Hectare farm in Chile, Six-Year Rotational Design

1 Fruit trees	6 House	11 Pigs
2 Irrigation	7 Chickens, Lumber pile	12 Compost pile
3 Grape arbor	8 Water well	13 Trees
4 Espaliered berries	9 Oven	14 Bee hives
5 Vegetables	10 Cows	



A Corn Beans Potatoes	F Pasture (3rd year)	E Pasture (2nd year)
B Favas or Peas Tomatoes Onions Squash	C Oats/Clover Soybeans Peanuts Sunflowers	D Wheat and Pasture (1st year)



Source: Altieri 1995

Table 3-5 Productivity of Integrated Chilean Peasant Farm

Production	
Rotation	3,16 t
Home garden	1,12 t
Fruits	0,83 t
Milk	3.200 l
Meat	730 kg
Eggs	2.531 u
Honey	57 kg

Marketable Surplus Nutritional Output (after family consumption)	
Protein	310%
Calories	120%
Vit. A	150%
Vit. C	630%
Ca	400%
P	140%

Note: Productivity of a half hectare integrated Chilean peasant farm after 3 years of agroecological management. Source: Altieri 1995

items provides a net income beyond consumption of US$790 while dedicating only a relatively few hours per week to the farm. The time freed up is used by farmers for other on-farm or off-farm income generating activities (Table 3-5).

Brazil

The state government extension and research service EPAGRI (Empresa de Pesquisa Agropecuaria e Difusao de Technologia de Santa Catarina) works with farmers in the southern Brazilian state of Santa Catarina. The technological focus is on soil and water conservation at the micro-watershed level using contour grass barriers, contour ploughing and green manures. Some sixty cover crop species have been tested with farmers, including both leguminous plants such as velvet bean, jack bean, lablab, cowpeas, many vetches and crotalarias, and non-legumes such as rye, oats and turnips. The cover crops are intercropped or planted during fallow periods and are used in cropping systems with maize, onions, cassava, wheat, grapes, tomatoes, soybeans, tobacco and orchards (Derpsch and Calegari 1992). The major on-farm impacts of the project have been on crop yields, soil quality and moisture retention and labour demand. The reduced need for most weeding and ploughing has meant significant labour savings for small farmers. From this work, it has become clear that maintaining soil cover is more important in preventing erosion than terraces or conservation barriers. EPAGRI has reached some

38,000 farmers in sixty micro-watersheds since 1991, supplying them with 4300 tons of green manure seed (Guijt 1998). By using cover crop mixtures including legumes and grasses mulch, biomass can reach 8,000 kg/ha and a mulch thickness of 10 cm, leading to 75 percent or more inhibition of weed emergence. Consequently, maize yields have risen from 3 to 5 t/ha and soybeans from 2.8 to 4.7 t/ha without using herbicides or chemical fertilizers (Altieri et al. 2011).

In the savannahs of the Brazilian *cerrados,* where soybean monoculture dominates, many problems associated with inappropriate land development have become evident. A key to stable production in the *cerrados* is soil conservation and soil fertility replenishment, as the maintenance and increase of soil organic content is of paramount importance. For this reason NGOs and government researchers have concentrated efforts on promoting the use of green manures such as *Crotalaria juncea* and *Stizolobium atterrimum*. Researchers have shown grain crops following green manure yielded up to 46 percent more than monocultures during normal rainy seasons. Although the most common way of using green manures is to plant a legume after the main crop has been harvested, green manures can also be intercropped with long cycle crops. In the case of the maize–green manure intercrop, the best performance is observed when *S. atterrimum* is sown thirty days after the maize (Spehar and Souza 1999).

A more recent project, led by the NGO AS-PTA (Agricultura Familiar e Agroecologia) in the semarid region of Paraiba, covers fifteen municipalities involving fifteen rural worker unions, 150 community associations and one regional organization of ecological farmers. Through agroecological innovation networks that entail more than five thousand families in the Borborema region, the project has been able to build eighty community seed banks, distribute 16,500 kgs of locally produced native seeds among 1,700 families, produce more than 17,900 tree saplings, which have been planted in more than 30 kms of living fences, and have supplied more than a hundred farms with fruit trees. The project also installed about 556 cisterns for water harvesting, allowing the production of vegetables in intensive gardens in periods of drought (Cazella, Bonnal and Maluf 2009).

Measuring the Performance of Diversified Farming Systems

Despite much debate about the relationship between farm size and productivity (Dyer 1991; Dorward 1999; Lappé, Collins and Rosset 1998: Ch. 6), agroecologists have shown that on the whole small family farms are much more productive than large farms if total output is considered rather than yield from a single crop (Rosset 1999b). Measurement of the yield of one crop species does not reflect a true measure of the productivity of diversified farms. In such farms total output — everything that is produced on the farm — should be the real measure of the productivity of land. Measuring just the yield of a single crop biases comparisons in favour of monoculture farms, which produce just maize on each hectare, for example, versus agroecological farms, which may produce dozens of different products on the same hectare. For the latter, measuring the production a single crop ("yield") makes no sense, as their true productivity is the sum of all they produce on each hectare.

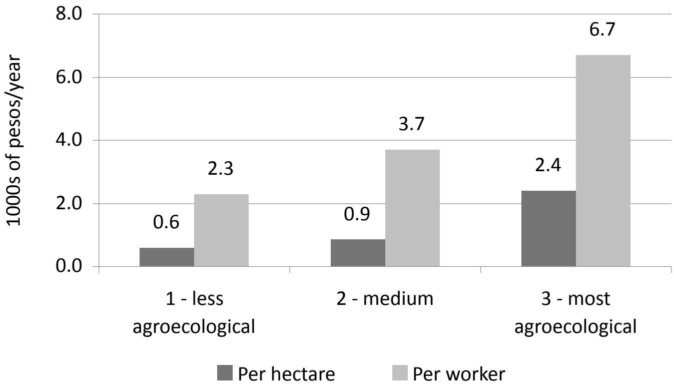
Integrated farming systems in which the small-scale farmer produces grains, fruits, vegetables, fodder and animal products out-produce yield per unit of single crops such as corn (monocultures) on large-scale farms. A large farm may produce more corn per hectare than a small farm in which the corn is grown as part of a polyculture that also includes beans, squash, potato and fodder. But when total output is measured, small biodiverse farms are more productive than large monoculture farms. In polycultures developed by smallholders, productivity, in terms of harvestable products per unit area, is higher than under sole cropping with the same level of management. Productivity advantages can range from 20 percent to 60 percent, because polycultures reduce losses due to weeds, insects and diseases and make more efficient use of the available resources of water, light and nutrients (Beets 1990). An important tool to assess such yield advantages is the land equivalent ratio (LER). Providing that all other things are equal, the LER measures the yield advantage obtained by growing two or more crops as an intercrop compared to growing the same crops as a collection of separate monocultures. The LER is calculated using the formula LER= Σ (Ypi/Ymi), where Yp is the yield of each crop in the polyculture, and Ym is the yield of each crop or variety in the sole crop or monoculture. For each crop (i) a ratio is calculated to determine the partial LER for that crop, then the partial LERs are summed to give the total LER for the intercrop. A LER value of 1.0, indicates no difference in total productivity between the intercrop and the collection of monocultures. Any value greater than 1.0 indicates a production advantage for the intercrop. A LER of 1.5, for example, indicates that the area planted to monocultures would need to be 50 percent greater than the area planted to intercrops, for the two to produce the same combined total production (Vandermeer 1989).

The practice of growing *milpa* (maize combined with beans, squash and other plant species) is the foundation of food security in many Mesoamerican rural communities (Mariaca Méndez et al. 2007). A study by Isakson (2009) shows that although most peasants are well aware of the potential to increase their returns from cash crops or other alternative economic activities, 99 percent of the households surveyed maintained that the practice of *milpa* was central to their family's food security. Clearly, assessing the value of the *milpa* in pure cash-return economic terms misses this dimension. The contribution of the *milpa* to the food security of the peasantry represents much more than the calories it generates. It provides a near guarantee that a family's basic sustenance needs will be met. In Mexico, 1.73 hectares of land has to be planted with maize to produce as much food as 1 hectare planted with the traditional *milpa*. In addition, a maize–squash–bean polyculture can produce up to 4 t/ha of dry matter that can be used as fodder or plowed into the soil, compared with 2 t/ha in a maize monoculture. In Brazil's drier environments, maize is replaced by sorghum in the intercrops, without affecting the productive capacity of cowpeas or beans and giving LER values of 1.25–1.58. This system exhibits a greater stability of production as sorghum is more tolerant to drought (Francis 1986).

Another way to compare performance of monoculture versus polyculture farms is to account for direct energy inputs used in the production of crops and animals. Research indicates that small peasant and organic farms are more energy efficient than conventional monoculture systems. The energy return to labour expended in a typical highland Mayan maize farm is high enough to ensure continuation of the present system. To work a hectare of land, which normally yields 4,230,692 calories per year, requires some 395 hours of labour; an hour's labour produces about 10,700 calories. A family of three adults and seven children eat about 4,830,000 calories of maize per year; thus current systems provide food energy for a typical family of five to seven people (Wilken 1987). Also in these systems, favourable rates of return between inputs and outputs in energy terms are realized. On Mexican hillsides, maize yields in hand-labour-dependent swidden systems are about 1,940 kg/ha, exhibiting an output/input ratio of 11:1. In Guatemala, similar systems yield about 1,066 kg/ha of maize, with an energy efficiency ratio of 4.84:1. When animal traction is utilized, yields do not necessarily increase, but the energy efficiency ratio drops to values ranging from 3.11:1 to 4.34:1. When fertilizers and other agrochemicals are introduced, yields can increase to levels of 5–7 t/ha, but energy ratios are highly inefficient, at less than 2.5:1 (Pimentel and Pimentel 1979).

A comparison carried out in the U.K. of seven organic and conventional crops showed a higher energy demand for machinery for all organic products. However, the higher energy demand for machinery did not outweigh the energy savings from foregoing synthetic fertilizers and pesticides (Lotter 2003). According to Pimentel et al.

Figure 3-2 Production during 2008 from 33 Farms in Sancti Spíritus Province, Cuba, 2008



Note: Categories rank the degree of agroecological integration (1 = low, 2= medium, 3 = high). Source: Machín Sosa et al. 2013

(2005), the total energy use per unit of product was lower for organic systems in all cases except for carrots, where a high energy demand for flame weeding was assumed. On average, the total energy demand for organic products was 15 percent lower. The reduced dependency on energy inputs in organic farming reduces vulnerability to rising energy prices and hence volatility of agricultural input prices.

In Cuba, Machín Sosa et al. (2013) and Rosset et al. (2011) compared the total economic productivity of thirty-three farms at three levels of agroecological integration, ranging from very low to high (Figure 3-2). They found that the more agroecological the farm, the higher the total productivity per unit area, in line with other findings reported above. Interestingly, they also found that the productivity of labour was greater in the more agroecological farms, suggesting that ecological functions provide services that would require labour in monocultural farms (like intercropped tall stature crops or trees shading-out weeds and reducing the need for weeding).

Resiliency to Climatic Variability

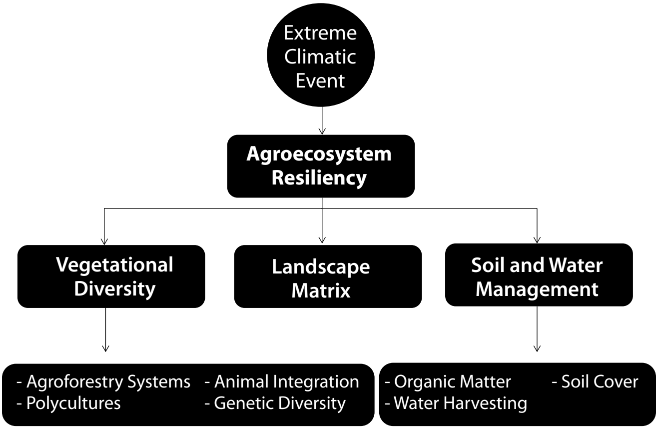
Many researchers have found that, despite their high exposure to climate risks, indigenous peoples and local communities are actively responding to changing climatic conditions and have demonstrated their resourcefulness and resilience in the face of climate change. Strategies such as maintaining genetic and species diversity in fields and herds provide a low-risk buffer in uncertain weather environments (Altieri and Nicholls 2013). By creating diversity temporally as well as spatially, traditional farmers add even greater functional diversity and resilience to systems with sensitivity to temporal fluctuations in climate. A review of 172 case studies and project reports from around the world shows that agricultural biodiversity as used by traditional farmers contributes to resilience through a number of, often combined, strategies: the protection and restoration of ecosystems, the sustainable use of soil and water resources, agroforestry, diversification of farming systems, various adjustments in cultivation practices and the use of stress tolerant crops (Mijatovic et al. 2013).

A survey conducted in Central American hillsides after Hurricane Mitch showed that farmers using diversification practices such as cover crops, intercropping and agroforestry suffered less damage from the hurricane in terms of crop losses, soil erosion and formation of gullies, than their conventional monoculture neighbours. The survey, spearheaded by the CAC movement, mobilized a hundred farmer-technician teams to carry out paired observations of specific agroecological indicators on 1,804 neighbouring agroecological and conventional farms. The study spanned 360 communities and twenty-four departments in Nicaragua, Honduras and Guatemala. Agroecological plots had 20–40 percent more topsoil, greater soil moisture and less erosion and experienced lower economic losses than their conventional neighbours (Holt-Giménez 2002). Similarly in the Soconusco, Chiapas, coffee systems exhibiting high levels of vegetational complexity and plant diversity suffered less damage from Hurricane Stan than more simplified coffee systems (Philpott et al. 2008). Forty days after Hurricane Ike hit Cuba in 2008, researchers conducted a farm survey in the provinces of Holguin and Las Tunas and found that diversified farms exhibited losses of 50 percent compared to 90–100 percent in neighbouring monocultures. Likewise, agroecologically managed farms showed a faster recovery of productive capacity (80–90 percent forty days after the hurricane) than monoculture farms (Rosset et al. 2011).

In Colombia, intensive silvopastoral systems (ISS) are a sustainable form of agroecological integration based on agroforestry with livestock production that combines grasses and fodder shrubs planted at high densities under trees and palms. In 2009, the driest year in the Cauca Valley, with precipitation having dropped by 44 percent compared to the historical average, these systems were able to perform well. Despite a reduction of 25 percent in pasture biomass, the fodder production of trees and shrubs remained constant throughout the year, neutralizing the negative effects of drought on the whole system. Milk production was the highest on record with a surprising 10 percent increase compared to the previous four years. Meanwhile, neighbouring farmers growing monoculture pastures reported severe animal weight loss and high mortality rates due to starvation and thirst (Murgueitio et al. 2011).

All the above studies emphasize the importance of enhancing plant diversity and complexity in farming systems to reduce vul-

Figure 3-3 Agroecosystem Resiliency



nerability to extreme climatic events. The literature suggests that agroecosystems will be more resilient when inserted in a complex landscape matrix, featuring genetically heterogeneous and diversified cropping systems managed with organic matter rich soils and water conservation techniques (Figure 3-3). Most research focuses on the ecological resiliency of agroecosystems, but little has been written about the social resilience of the rural communities that manage such agroecosystems. The ability of groups or communities to adapt in the face of external social, political and environmental stresses must go hand-in-hand with ecological resiliency. To be resilient, rural societies must generally demonstrate the ability to buffer disturbance with agroecological methods adopted and disseminated through self-organization, reciprocity and collective action (Tompkins and Adger 2004). Reducing social vulnerability through the extension and consolidation of social networks, both locally and at regional scales, can contribute to increases in agroecosystem resilience. The vulnerability of farming communities depends on how well developed is their natural and social capital, which in turn makes farmers and their systems more or less vulnerable to climatic shocks (Altieri et al. 2015). Most traditional communities still maintain a set of social and agroecological preconditions that enables their farms to respond to climate change in a resilient manner.

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Chapter 4

Bringing Agroecology to Scale

Peasant and family farm-based agroecological farming has significant advantages over industrial agriculture, both for people and for the planet, as argued in the previous chapters. Why then is it not the dominant paradigm? On the one hand, diverse versions of traditional agriculture and self-provisioning of food, spanning a continuum from less to more agroecological, do indeed feed most of the human race today (ETC Group 2009, 2014; GRAIN 2014). Yet in areas that are now, or have been in the past, under some form of conventional "modern" agriculture, the dominant paradigm is still based on commercial seeds, monoculture and farm chemicals. When we say "dominant," we mean it both in epistemological terms and in the sense that most farmers in such areas, whether they are small or large, practise some variant of this conventional model.

Agroecological farmers, indeed even organic farmers, seem to be the minority in these areas, and while *organic* gets little airtime in the discourse of institutions (ministries of agriculture, agricultural extension services, faculties of agronomy, rural development banks, the mass media, etc.), agroecology seems to get none at all (until recently, but that is a story for the next chapter). In other words, there are a number of arguments in favour of the agroecological transformation of farming systems. Yet the challenge remains of how to bring agroecology to scale, such that it is practised by ever more families, over ever larger territories.

Scaling-Up and Scaling-Out Agroecology

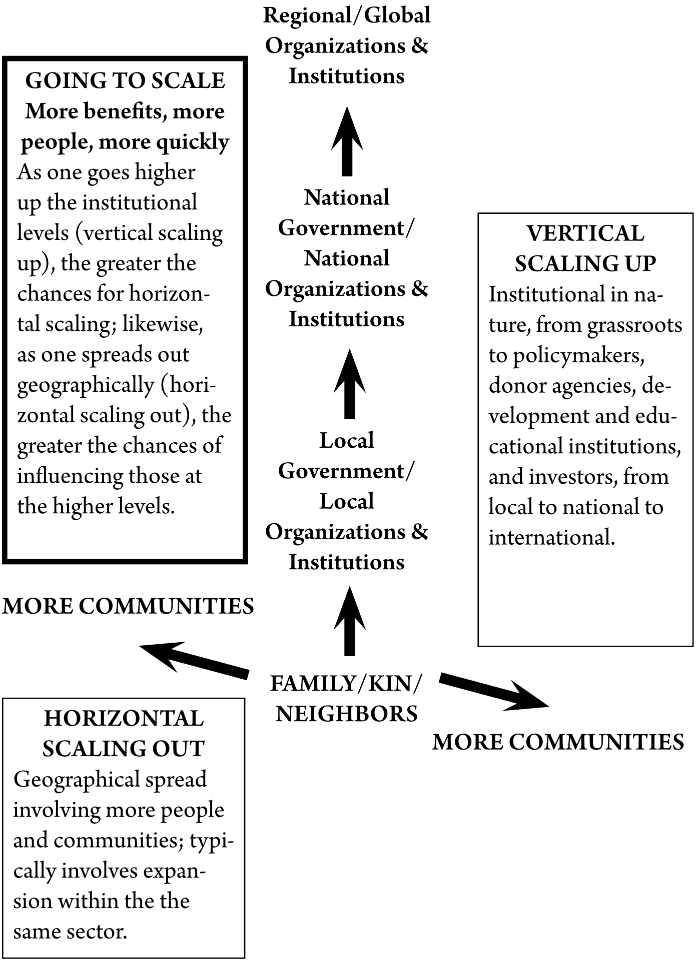
Our understanding of how to bring agroecology to scale is nascent. There has been a tendency to privilege investigation on the technical aspects of agroecology, while research on its social science aspects remains weaker (Rosset et al. 2011; Méndez, Bacon and Cohen 2013; Rosset 2015b; Dumont et al. 2016). Agroecology is not just a set of farming practices or a scientific discipline based on ecological theory, but it is also a growing social movement (Wezel et al. 2009). Analyzing the social aspects of agroecology can provide critical insights into how to achieve scale. This is not meant in any way to minimize the technical-agronomic aspects; rather, for the sake of this chapter, we beg the reader to take those as a given.

The question of scaling-up successful local innovations and processes in rural development has been analyzed numerous times over the years, though generally not with a specific focus on agroecology. Uvin and Miller (1996: 346) proposed a taxonomy of scaling-up. In quantitative scaling-up, a program or an organization expands its size through increasing its numbers of people or families and/or its geographic coverage. This kind of scaling-up is the most obvious and is equivalent to growth or expansion. Functional scaling-up is when a program or an organization adds new activities to its portfolio, for example, adding a focus on nutrition to a focus on farming practices. Political scaling-up occurs when structural of public policy change is achieved through active political engagement with the state. Finally, organizational scaling-up occurs when a local or grassroots organization increases their organizational strength and improves their effectiveness, efficiency and sustainability of the process. The authors break down each type of scaling-up into various components. For example, quantitative scaling-up can occur through spread, as more individuals, families or groups are drawn into a process; through replication, when a process is repeated elsewhere; through nurture, when an outside actor (like a funder or external NGO) adopts and supports an endogenous process; through horizontal aggregation, when several peer groups or organizations merge their processes; and through integration, when a public sector agency — like a government extension office — essentially takes on and massifies a methodology and a process.

In 2000, the International Institute of Rural Reconstruction (IIRR 2000) hosted a conference in the Philippines called "Going to Scale: Can We Bring More Benefits to More People More Quickly?" The title gives the operational definition of scaling-up proposed by the organizers, and the participants distinguished two broad categories, which they called horizontal scaling-up (analogous to the quantitative scaling-up of Uvin and Miller) and vertical scaling up (analogous to political scaling-up), as shown in Figure 4-1.

In this conceptualization, horizontal scaling-up refers to geographical spread and numerical increase, including more people, families and communities in a process in which "it is not tech-

Figure 4-1 Horizontal and Vertical Dimensions of Scaling-Up



Source: IIRR *2000: 10*

nologies that are scaled up, but processes and principles behind the technologies/innovations" (IIRR 2000). This emphasis on principles is important when the scaling process refers to agroecology. A compilation volume edited by Pachico and Fujisaka of CIAT (International Centre for Tropical Agriculture 2004), summarizes the overall debate and leaves us with the now commonly accepted terminology where scaling-out refers to numerical and geographical expansion, and scaling-up refers to institutionalization of support in public policies and institutions.

In terms of agroecology, then, scaling-up would mean institutionalizing supportive policies for agroecology, whether in terms of education, training, research, extension, credit, market or whatever. In the strictest sense, scaling-out would mean that ever more families, over ever larger territories, practise some form of agroecological farming. However, given that this scaling-out would also be the goal, the *raison d'être*, of scaling-up, the latter has come to be used as the general term for bring agroecology to more people (Parmentier 2014; von der Weid 2000; Holt-Giménez 2001, 2006; Altieri and Nicholls 2008; Rosset et al. 2011; Rosset 2015b; McCune 2014; McCune at al. 2016; Khadse at al. 2017). Nevertheless, others speak of "territorializing," "constructing agroecological territories," "massifying," and "amplifying" agroecology (Muterlle and Cunha 2011; Rosset and Martínez-Torres 2012; Machín Sosa et al. 2013; Rosset 2006, 2015a, 2015b; Bruil and Milgroom 2016; Wezel et al. 2016).

Obstacles and Barriers to Scaling-Up Agroecology

In order to bring agroecology to scale, the following are some of the major constraints and obstacles that must be overcome (Alonge and Martin 1995; Sevilla Guzmán 2002; Carolan 2006; Altieri et al. 2012; Parmentier 2014):

- *Land tenure issues:* Lack of access to land or insecure land tenure is an important barrier to adopting agroecological practices in most countries. Insecure property rights make it difficult for farmers to adopt agroforestry and invest in soil conservation. Without land, one cannot practise agroecology.

- *Farmers' knowledge and information needs:* A lot of peasant and farmer knowledge was lost during the decades of the Green Revolution and agricultural modernization. As agroecological practices are highly complex and management intensive, adopting them imposes a need for increased learning, particularly through farmer-to-farmer, horizontal mechanisms.
- *Persistent bias, ideological and epistemic barriers and lack of practical knowledge:* Misconceptions and lack of information abound. Ideas like agroecology being a "return to the past," "only applicable to marginal, subsistence agriculture," "could never feed the world," etc. impede serious support for implementation. Public officials, researchers and extension agents are influenced by private interests to promote conventional approaches. Agronomy curricula remain stacked in favour of conventional industrial agriculture. Western, Cartesian-style reductionist science is not friendly to the more holistic agroecology, where synergistic, higher-order interactions are often more important that the direct effects of inputs.
- *Site specificity*: Agroecological principles have universal applicability but the technological practices through which those principles become operational depend on the prevailing environmental and socio-economic conditions at each site. Such site specificity requires local research and innovation, especially unlocking the creativity of farmers.
- *Lack of farmers' organizations:* An absence of social networks for farmers in many localities, for collective experimentation and exchange of agroecological information, is an important constraint for the adoption and dissemination of agroecological innovations. The biggest success stories have typically been led by peasant and farmer organizations.
- *Economic barriers:* Many farmers are locked into a technological treadmill by the high cost of conventional farming, with the ensuing debt it implies. Lender requirements for indebted farmers typically do not permit experimentation, much less a complete change in farming systems. There are few sources of financial support for transition and transformation of farming systems, especially when there is a temporary loss of productivity during

transition, and few market opportunities that recognize such investment and reward it with price incentives.

- *National agricultural policies*: National policies not supportive of agroecological approaches are largely responsible for alternatives remaining in the margins. In most countries there is a continuous policy failure in providing the adequate economic environment needed for the transition to agroecological production systems. Bad policies lead to persistent market failures that are often a great obstacle for advancement of agroecology. Low commodity prices, caused in part by continued subsidization of agricultural exports in much of the developed world, reduce the incentives to invest in agricultural innovations, including agroecology. The real prices of agricultural products are usually so low that it is very difficult for farmers to obtain the capital needed to make the change to sustainable agriculture. The deregulated market, privatization and free market treaties negatively affect both small farmers and consumers. The situation is aggravated by the systematic elimination of the national food production capacity by the promotion of agro-exports and biofuels partly stimulated by government subsidies.
- *Infrastructure problems:* For a more widespread adoption of sustainable practices, countries must invest in alternative market options, including more farmers markets and public sector acquisition of ecological small farm products, as well as in transportation to help farmers bring products to market. In many countries lack of sufficient quantities of seeds for cover crops and green manures can be a difficult barrier to overcome for widespread implementation of agroecology.

Organization Is the Key

Overcoming the obstacles to scaling-up agroecology requires organization. Systematic pressure to change policies cannot be brought to bear without strong organizations and organizational capacity. The same goes for changing educational curricula and for constructing effective processes for the horizontal transmission of knowledge. Social organization is the culture medium upon which agroecology grows, and social process methodologies accelerate that growth. Imagine a peasant family or family farm that is not part of any organizational fabric. If they successfully transform their farm agroecologically, it is not clear how other farmers would want or be able to learn from their experience. But if they are part of an organization that is intentionally carrying out farmer-to-farmer exchanges, then it is much easier to imagine that they could have a multiplier effect.

The experience of rural social movements and farmer and peasant organizations indicates that the degree of organization (called "organicity" by social movements) and the extent to which horizontal social methodologies based on peasant and farmer protagonism are employed to collectively construct social processes are key factors in "massifying" and bringing agroecology to scale. Farmer-to-farmer processes and agroecology schools run by peasant organizations themselves are useful examples of these principles (Holt-Giménez 2006; Rosset et al. 2011; Rosset and Martínez-Torres 2012; Machín Sosa et al. 2013; McCune, Reardon and Rosset 2014; Rosset 2015b; Khadse et al. 2017).

If we look at agroecology success stories from around the world, we can identify the key role played by social organization and process in each. This is most immediately apparent in the *campesino a campesino* (CAC) scaling-out of agroecology first in Mesoamerica and then in Cuba and elsewhere (Kolmans 2006; Holt-Giménez 2006; Rosset et al. 2011; Machín Sosa et al. 2013). In each of these, the introduction of the social process methodology led to rapid take off.

Campesino a Campesino in Cuba

The debate on how to scale-up agroecology is paralleled in the literature by authors who question the ability and appropriateness of conventional agricultural research and extension systems to reach peasant families in general (Freire 1973), and more specifically for promoting agroecology rather than the Green Revolution (see, for example, Chambers 1990, 1993; Holt-Giménez 2006; Rosset et al. 2011).

While conventional, top-down agricultural research and extension methods have shown a negligible ability to develop and achieve broad adoption when used to promote the practices of agroecological diversified farming, social movements and socially dynamizing methodologies appear to have significant advantages (Rosset et al. 2011; Rosset 2015b; McCune 2014). Social movements incorporate large numbers of people — in this case large numbers of peasant families — in self-organized processes that can dramatically increase the rate of innovation and the spread and adoption of innovations. The fact that agroecology is based on applying principles in ways that depend on local realities means that the local knowledge and ingenuity of farmers must necessarily take a front seat. This is in contrast to conventional practices, where farmers follow pesticide and fertilizer recommendations prescribed on a recipe basis by extension agents or sales representatives. Methods in which the extensionist or agronomist is the key actor and farmers are passive are, in the best of cases, limited to the number of peasant families that can be effectively attended to by each technician; there is little or no self-catalyzed dynamic among farmers themselves to carry innovations well beyond the last technician. Thus, these cases are finally limited by the budget — that is, by how many technicians can be hired. Many project-based rural development NGOs face a similar problem. When the project funding cycle comes to an end, virtually everything reverts to the pre-project state, with little lasting effect (Rosset et al. 2011).

As alluded to above and in Chapter 3, the most successful way to promote farmer innovation and horizontal sharing and learning is the *campesino a campesino* methodology. While farmers innovating and sharing goes back to time immemorial, the more contemporary and formalized version was developed locally in Guatemala and spread through Mesoamerica beginning in the 1970s (Holt-Giménez 2006). *Campesino a campesino* is a Freirian horizontal communication, or social process, methodology that is based on farmer-promoters who have innovated solutions to common agricultural problems or have recovered/rediscovered older traditional solutions, and who use "popular education" to share them with their peers, using their own farms as their classrooms. A fundamental tenet of CAC is that farmers are more likely to believe and emulate another farmer who is successfully using an alternative on their own farm than they are to take the word of an agronomist of possibly urban extraction. This is even more the case when they can visit the farm of their peer and see the alternative functioning with their own eyes. In Cuba, for example, farmers say "seeing is believing" (Rosset et al. 2011).

Whereas conventional extension can be demobilizing for farmers, CAC is mobilizing, as they become the protagonists in the process of generating and sharing technologies (Figure 4-2). CAC is a participatory method based on local peasant needs, culture and environmental conditions. It unleashes knowledge, enthusiasm and leadership as a way of discovering, recognizing, taking advantage of and socializing the rich pool of family and community agricultural knowledge that is linked to their specific historical conditions and

Figure 4-2 Conventional Agricultural Extension versus Campesino-to-Campesino

Conventional Extension	Campesino to Campesino
Researchers develop a technology	A peasant already has a solution, or innovates a solution, to a problem that is common for many peasants
↓	↓
They conduct field trials at an experiment station	S/he becomes a promoter of this new or rediscovered solution
↓	↓
They do more trials on a farmer's field	Exchanges are set up, where other peasants visit his or her farm to learn, or where s/he visits the farms of other peasants to share the solution with them.
↓	↓
Extensionists set up demonstration plots, and host field days for farmers, and/or visit farmers to promote the technology	Other peasants teach other peasants this as well as other solutions
↓	
The peasant family adopts or rejects the technology	

Source: Machín Sosa et al. 2013: 76

identities. In conventional extension, the objective of technical experts all too often has been to replace peasant knowledge with purchased chemical inputs, seeds and machinery in a top-down process where education is more like domestication (Freire 1973; Rosset et al. 2011). Eric Holt-Giménez (2006) has extensively documented the Mesoamerican CAC social movement experiences of using the methodology for promoting agroecological farming practices, which he calls "peasant pedagogy."

Cuba is where the CAC social methodology achieved its greatest impact, when the National Association of Small Farmers (ANAP), a member of La Vía Campesina, adopted it along with a conscious and explicit goal of building a grassroots movement for agroecology inside the national organization (extensively detailed in Machín Sosa et al. 2010, 2013 and Rosset et al. 2011). In fewer than ten years, the process of transforming production into agroecologically integrated and diversified farming systems had spread to more than a third of all peasant families in Cuba, a remarkable rate of growth. During the same time period, the total contribution of peasant production to national production jumped dramatically, with other advantages, in the form of reduced use of farm chemicals and purchased off-farm inputs (more autonomy) and greater resiliency to climate shocks (Machín Sosa at al. 2013).

As we have argued elsewhere (Rosset et al. 2011), the much greater growth in Cuba than in Central America is due to the greater degree of organicity exhibited by the ANAP in Cuba, and to the greater intentionality by which the organization took on and promoted the CAC methodology.

Zero Budget Natural Farming Movement in India

Zero Budget Natural Farming (ZBNF) is another peasant movement that has successfully taken agroecology to scale, in this case in Southern India, though it has now spread at varying levels to most Indian states. It has especially achieved scale in the southern Indian states of Tamil Nadu, Andhra Pradesh and Kerala, though it first gained popularity in the state of Karnataka. Many members of the Karnataka Rajya Raitha Sangha (KRRS), a powerful middle peasant organization in India and a member of La Vía Campesina, are also members of ZBNF. The KRRS promotes ZBNF in both discourse and practice. The KRRS recently opened a peasant agroecology school where its members receive training on ZBNF methods. The basic toolkit of ZBNF methods was put together by Subhash Palekar, an agricultural scientist who, disillusioned by the ill effects of the Green Revolution on his own family farm, drew from extensive research and observation of ecological processes and indigenous farming methods during his work as an extension officer in the 1990s (Khadse et al. 2017; FAO 2016).

Zero Budget Natural Farming aims to drastically cut production costs by ending dependence on all outside inputs and loans for farming. The phrase "Zero Budget" means without using any credit and without spending any money on purchased inputs. "Natural Farming" means farming with Nature and without chemicals. Its advocates position ZBNF as a solution to the agrarian crisis and rising trend of farmer suicides in India.

In terms of its reach, ZBNF is possibly one of the most successful agroecology movements globally. The movement's leaders claim that millions of farmers nationally practise ZBNF, while a rough estimation for just Karnataka puts the figure at some 100,000. The ZBNF movement has organized about sixty massive state-level training camps in the last decade, with an average of one or two thousand farmer participants at each camp, including women, men and youth. Most districts have a local self-organized dynamic to promote ZBNF at the grassroots level. All this has been achieved without any formal movement organization, paid staff or even a bank account. ZBNF generates a spirit of volunteerism and enthusiasm among its peasant farmer members, who are the main protagonists of the movement.

A necessary factor in the success of ZBNF in India, though not sufficient in itself, is that the farming practices function well in both agronomical and economic terms (see Chapter 3). But ZBNF has also attained scale in Karnataka because of its social movement dynamic, created via the classic tasks carried out by social movements, such as mobilization of a range of resources both internally and from allies, charismatic leadership, effective framing and self-organized processes with a strong pedagogical content. A central reason why ZBNF took off only after reaching Karnataka state was the fact that it landed there in communities that already had a rich organizational fabric provided by the KRRS farmer organization. This transformed ZBNF from a largely unknown farming method into a massive grassroots social movement.

Social Movements and Peasant Agroecology Schools

The experience of rural social movements and farmer and peasant organizations indicates that the degree of organization, or organicity, and the extent to which horizontal social methodologies based on peasant and farmer protagonism are employed to collectively construct social processes are key factors in bringing agroecology to scale. The campesino a campesino processes and peasant agroecology schools run by peasant organizations themselves are useful examples of these principles (Rosset and Martínez-Torres 2012; McCune et al. 2014).

La Vía Campesina and its members have in recent years set up CAC agroecology programs in many countries in the Americas, Asia and Africa and have produced agroecology training materials and sponsored seed fairs and seed saving and exchange networks in a number of regions and countries. One enormously successful national program has been developed in Cuba, under which farmers breed and select their own varieties, with smaller scale programs in other countries. La Vía Campesina has not only organized national and international exchanges so that farmers can see for themselves ("seeing is believing") and learn from the best cases, but it has also begun to identify, self-study, document, analyze and horizontally share the lessons of the best cases of farmer-led climate-robust agroecology and food sovereignty experience. LVC and member organizations have opened regional agroecology training schools and/or peasant universities, where peasants teach peasants, and which are also political leadership training academies, in Venezuela, Paraguay, Brazil, Chile, Colombia, Nicaragua, Indonesia, India, Mozambique, Zimbabwe, Niger and Mali, in addition to dozens of national and sub-national-level schools where peasants learn from peasant experiences through peer-to-peer teaching. Peasant social movements are developing their own agroecological pedagogy, inspired by Brazilian educator and philosopher Paulo Freire (1970, 1973) and infused with elements of territoriality (Stronzake 2013; Meek 2014, 2015; McCune et al. 2014, 2016; Martínez-Torres and Rosset 2014; Rosset 2015a; Gallar Hernández and Acosta Naranjo 2014; Barbosa and Rosset in press). Elements in this emerging pedagogy include the following:

- horizontal dialog between different knowledges (*diálogo de saberes*) and horizontal exchange of experiences (like CAC and community-to-community) are basic. This includes horizontal dialogs between farmer knowledge, which is often local and detailed, and scientist knowledge, which can be more abstract, theoretical and universal (see Levins and Lewontin 1985: 222);
- holistic integration of technical-agroecological training with political, humanistic and internationalist values, including respect for Mother Earth and *buen vivir*;
- alternation of time in the classroom with time in the community and on the farm;
- design of all physical and temporal spaces in the school experience — not just classroom time, but also farm work, the collective maintenance and cleaning of the school itself, the collective preparation of meals and cultural activities — as be part of the process of "forming" people to be militant peasant agroecologists, to be "subjects in the making of their own history";
- self- or collective-organization and administration of the school and the design and implementation of the curriculum as also part of the formative experience;
- training not by "know it all" agroecological agronomists or technicians, but rather of facilitators of horizontal processes of knowledge exchange and transformation; and
- notions that agroecology is fundamental for peasant resistance, for the construction of food sovereignty and autonomy, and for the building of a different relationship between humans and nature, and that agroecology is "territorial," that it requires organicity and that it is primarily a tool for struggle and for the collective transformation of rural reality.

Factors in Achieving Scale

Examining successful cases of scaling-out agroecology from around the world (including, but not limited to, cases from LVC) throws light on reproducible factors that contribute to success. Based on the cases discussed earlier and others, we can tentatively list some of these factors (Rosset 2015b; Khadse et al. 2017).

Social organization–social movements: As explained above, rural social movements and their ability to strengthen social organization and construct social processes appear to be very important. Social organization is the culture medium on which agroecology grows and upon which it can be scaled-out (Rosset and Martínez-Torres 2012; McCune 2014).

Horizontal social process methodology and pedagogy: As the case of Cuba illustrates, the use of a social process methodology like CAC, based on a "peasant pedagogy," is often a critical element in the acceleration of an agroecology process (Rosset et al. 2011; Machín Sosa et al. 2013; Holt-Giménez 2006).

Peasant protagonism: Preliminary evidence suggests that when peasants and farmers themselves lead the process, it moves much faster than when technical staff or extensionists are in the lead (Rosset et al. 2011, Machín Sosa et al. 2013; Holt-Giménez 2006; Kolmans 2006).

Farming practices that work: Agroecology cannot spread based solely on social processes. Of course, any process must be based on agroecological farming practices that provide farmers with good results; that are "solutions" to problems or obstacles that farmers face (Rosset et al. 2011; Machín Sosa et al. 2013; Holt-Giménez 2006; Kolmans 2006). This does not mean that these solutions or practices are the product of formal research institutions. In fact, they are just as likely, or more likely, to come from peasant or farmer innovation, once the social process has unleashed farmer/peasant creativity and interest in recovering ancestral practices.

Motivating discourse and framing: Rosset and Martínez-Torres (2012; Martínez-Torres and Rosset 2014) distinguish between "agroecology as *farming*," and "agroecology as *framing*." This is because, while agroecology must of course work as farming, the social process of dissemination and adoption is often driven just as much by the ability of an organization or movement to develop and use a motivating and mobilizing discourse that makes people actually want to transform their farms.

Political opportunity, external allies, charismatic leaders, local champions: Like any other form of social movement, agroecology movements can be energized by or take advantage of political opportunities and external allies. This can take the form of things like a food scare, a government official willing to have training materials printed, a public figure, artist or religious figure who champions the movement, or charismatic leadership from within (Khadse et al. 2017).

Linking peasant production to local and regional markets: The demand for agroecological products and opportunities for farmers to sell their produce grown ecologically at a profit can be key driving forces in successful cases of bringing agroecology to scale (Brown and Miller 2008; Rover 2011; Niederle, de Almeida and Vezzani 2013). Conversely, failure to pay attention to the market can lead to the failure of a process. A major challenge for a transformational agroecology is to explore how to link redesigned diversified farms with appropriate market outlets for peasants. There are many different types of markets at the local, national and regional levels in which smallholders engage and have some degree of influence and/or control over, and it is imperative to promote public policies that can support, defend and strengthen them. Policies that can secure appropriate credit and infrastructure and fair pricing both for consumers and producers, and promote public procurement schemes (institutional markets) and local, regional and solidarity farmer markets and CSAs (community supported agriculture schemes) are key to improving peasant livelihoods (CSM 2016). In contrast, when policies and economic forces and power relations push small farmers into supplying global value chains, the result often is to enhance farmers' degree of debt and precariousness. This is because of the position that small farmers generally occupy in the chain — their low levels of control and autonomy

— and the way value flows throughout the chain (McMichael 2013). An important reason to support smallholder markets is that in many respects these markets are better equipped to deal with global challenges — such as increasing climate and price shocks — than global commodity markets. According to the International Civil Society Mechanism for Food Security and Nutrition this is largely due to the "multi-functionality of territorial markets involving smallholder agriculture and diversified farming systems. Multiple marketing channels for selling and accessing food, with the possibility of relying on self-consumption or short circuits when this is the best option, mean that producers in territorial markets are less vulnerable to price swings in international markets and the breakdown of long, centralised agro-food chains" (CSM 2016).

Favourable public policies: Public policies can play a key role in whether agroecology processes can achieve scale (Gonzalez de Molina 2013). LVC (2010), for example, advocates for a broad range of such policies. Note that they call for policies that both boost peasant and family farm agriculture in general, as well as agroecology more specifically. Their demands include the following: renationalize food reserves into improved parastatals and marketing boards based on co-ownership and co-management between the public sector, and farmer and consumer organizations; implement real agrarian reform and stop land grabbing; ban and break up agribusiness monopolies; ban large-scale confined animal production and promote decentralized livestock systems; orient public sector food procurement toward ecological peasant and family farm products; provide price support mechanisms, subsidized credit (especially by farmer- and community-controlled alternative credit mechanisms), and marketing support for ecological, peasant and family farm production; re-orient research, education and extension systems toward the support of farmer-led processes for seeds and agroecological technologies; support self-organization by peasants and family farmers; promote ecological urban agriculture; (re)introduce barriers to food imports; ban GMOs and dangerous farm chemicals; stop subsidies for chemical inputs and commercial seeds; carry out educational campaigns with consumers about the benefits to all of society of peasants and ecological family farms; and ban junk food in schools.

A number of the policies have been tried out in different countries. Machín Sosa et al. (2010, 2013) provide a chapter on how policies in Cuba have favoured agroecology, while Nehring and McKay (2014), Niederle, de Almeida and Vezzani (2013) and Petersen, Mussoi and Soglio (2013) do the same for Brazil. Governments can, and should, use government procurement, credit, education, research, extension and other policy instruments to favour agroecological transformation. However, a word of caution is in order. These policies in Brazil were achieved under the Workers' Party government, which was overthrown in a 2016 parliamentary *coup d'etat*, and many of the policies were reversed, destabilizing farmer co-ops that had scaled-up production in ways that were dependent on continued public sector support. This raises an interesting debate: is it better to bring processes to scale more rapidly, but *dependent* on external support, or more slowly, in a more autonomous way, based on peasants' and farmers' own resources?

Social Organization, Social Process Methodology and Social Movements

While all of these factors may play important roles in bringing agroecology to scale, the roles of social organization, social process methodology and social movements are emphasized throughout this chapter. The experience of rural social movements and farmer and peasant organizations indicates that the degree of organization and the extent to which horizontal social methodologies based on peasant and farmer protagonism are employed to collectively construct social processes are key factors in "massifying" and bringing agroecology to scale. *Campesino a campesino* processes and peasant agroecology schools run by peasant organizations themselves are useful examples of these principles. While most agroecology research to date has emphasized natural science, these results point to the need to prioritize social science approaches and self-study by rural movements, to draw systematic lessons from their successful experiences. This can produce the information and principles needed to design new collective processes.

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Chapter 5

The Politics of Agroecology

> Popular pressure has caused many multilateral institutions, governments, universities and research centers, some NGOs, corporations and others, to finally recognize "agroecology." However, they have tried to redefine it as a narrow set of technologies, to offer some tools that appear to ease the sustainability crisis of industrial food production, while the existing structures of power remain unchallenged. This co-optation of agroecology to fine-tune the industrial food system, while paying lip service to the environmental discourse, has various names, including "climate smart agriculture," "sustainable-" or "ecological-intensification," industrial monoculture production of "organic" food, etc. For us, these are not agroecology: we reject them, and we will fight to expose and block this insidious appropriation of agroecology. The real solutions to the crises of the climate, malnutrition, etc., will not come from conforming to the industrial model. We must transform it and build our own local food systems that create new rural-urban links, based on truly agroecological food production by peasants, artisanal fishers, pastoralists, indigenous peoples, urban farmers, etc. We cannot allow agroecology to be a tool of the industrial food production model: we see it as the essential alternative to that model, and as the means of transforming how we produce and consume food into something better for humanity and our Mother Earth.
>
> — Declaration of the International Forum for Agroecology at Nyéléni (LVC 2015a)

Agroecology and Contested Territories

Theorists of contested or disputed territories argue that social classes and relationships generate territories and spaces that are reproduced under conditions of conflict, which gives rise to spaces of domination and spaces of resistance. Territorial contestation is carried out in all possible dimensions: economic, social, political, cultural, theoretical and ideological. In the case of rural areas, this gives rise to disputes between grassroots social movements and agribusiness, mining companies and other forms of extractive capitalism and their allies in government over both *material* and *immaterial* territories (Fernandes 2009, 2008a,b; Rosset and Martinez-Torres 2012).

The dispute over material territories refers to the struggle to access, control, use and shape, or configure, land and physical territory. Immaterial territory refers to the terrain of ideas, of theoretical constructs, and there are no contested material territories that are not associated with contestation over immaterial territories. The dispute over real and tangible territories and the resources they contain necessarily goes hand in hand with the dispute over immaterial territories, or the space of ideology and ideas. Disputes over immaterial territories are characterized by the formulation and defence of concepts, theories, paradigms and explanations. Thus, the power to interpret and to determine the definition and content of concepts is itself a territory in dispute. Rosset and Martínez-Torres (2012), Martínez-Torres and Rosset (2014) and Giraldo and Rosset (2016, 2017) argue that agroecology is itself a terrain or territory that is disputed both materially ("agroecology as farming") and immaterially ("agroecology as framing"). This chapter focuses on the intensification and evidencing of this dispute.

The Dispute for Agroecology

Agroecology has gone from being ignored, ridiculed and/or excluded by the large institutions that preside over world agriculture, to being recognized as *one* of the possible alternatives available to address the crises caused by the Green Revolution. This is surprising. Until recently, the institutions that have steered agricultural policy throughout the world had not recognized agroecology either as a realm of scientific enquiry or as a social practice and movement (Wezel et al. 2009). In fact, beyond being neglected, during the past forty years those who have promoted agroecology have had to defy power structures in all spheres, including, obviously, the institutions that for decades promoted industrial agriculture throughout the world as the panacea to alleviate hunger and poverty. Yet, in 2014, it was apparent that that context had changed radically when some of these same institutions began to address agroecology with interest following the International Symposium on Agroecology for Food Security and Nutrition, organized that year in Rome by the Food and Agriculture Organization of the United Nations (FAO 2014). However, rather than picking up on the transformational potential of agroecology, they mostly see it as offering technical options to make industrial agriculture less unsustainable (LVC 2015a), creating a real threat of co-optation.

This new situation has created a dilemma for agroecologists: give in to being co-opted and captured, or take advantage of the opening of political opportunities to push forward the transformation of the prevailing industrial agriculture model (Levidow, Pimbert and Vanloqueren 2014; Holt-Giménez and Altieri 2016). Although institutions are not monoliths and do allow for internal debates, this scenario can be framed, for simplicity, as a two-sided struggle. Government institutions, international agencies and private companies are on one side, while the social movements, scientists and NGOs that are on the other side see agroecology as being precisely about transforming the system (Table 5-1). The question is whether agroecology, in the hands of the mainstream, will be stripped of all but its most simplistic technical content and left as an empty concept that can mean almost anything to anyone, much as happened decades ago with "sustainable development" (Lélé 1991).

To illustrate the larger dichotomy, we contrast the FAO's process that began publically in Rome in 2014 with the global symposium and continued in 2015 and 2016 with continental and regional forums, with the process leading up to, during and after the International Forum for Agroecology, held at Nyéléni, Mali, in 2015. The Nyéléni forum was organized by the International Planning Committee for Food Sovereignty (IPC), a representative body composed of social movements and other civil society actors that grew out of parallel spaces at world food summits and lobbies and engages with the FAO to push for food sovereignty. At Nyéléni, "delegates representing diverse organizations and international movements of small-scale food producers and consumers, including peasants, indigenous

Table 5-1 Conform versus Transform

Camp and Vision	The *institutional camp* sees agroecology as offering more tools to fine tune industrial agriculture and *conforms* to monoculture, input dependence and structures of power	The *civil society camp* sees agroecology as the *alternative* to industrial agriculture and as part of the struggle to challenge and *transform* monoculture, input dependence and existing structures of power
Actors	World Bank, governments, many large NGOs, private sector, agricultural universities	Social movements and allies like IPC, LVC, MAELA, SOCLA, etc.
Examples	Climate-smart agriculture, sustainable or ecological intensification, Save and Grow (FAO), industrial organic, minimum tillage (with herbicides), conservation agriculture, "agro-ecology" (with the hyphen), etc.	Peasant agroecology, natural farming, ecological or biological agriculture, peasant organic farming, low input, permaculture, biointensive, traditional peasant or indigenous agriculture, etc.

Source: Giraldo and Rosset 2017

peoples and communities (together with hunters and gatherers), family farmers, rural workers, herders and pastoralists, fisherfolk and urban people … gathered … to come to a common understanding of agroecology as a key element in the construction of food sovereignty, and to develop joint strategies to promote agroecology and defend it from co-optation" (LVC 2015a).

Thus, one space in which the larger dispute plays out was created when the FAO began discussing agroecology. The governments of France and Brazil supported a nascent agroecology process (though with wildly different notions of agroecology), while the United States and its allies were against holding the international symposium. The ensuing compromise eliminated any content at the symposium linked to public policies and particularly forbade discussion of international trade policies, genetically modified organisms or even the use of the term "food sovereignty," thus limiting the program to the technical aspects of agroecology. Thanks to its allies within the FAO, civil society was able to obtain slots for participation in the proceedings (Nicholls 2014; Giraldo and Rosset 2016). In the end, peasant organizations, NGOs, and academics succeeded in voicing their critiques regarding the agribusiness model, even though their opinions were essentially minimized in the final report (FAO 2015). Following the symposium, the official pronouncement, released by the agriculture ministers of Japan, Algiers, France, Costa Rica and Brazil, the agriculture and rural commissioner of the European Union and the general director of the FAO, stated that agroecology was a valid option and should receive support. However, it ought to be combined, they felt, with other approaches, such as sustainable intensification (Scoones 2014), climate-smart agriculture (Delvaux et al. 2014; Pimbert 2015) and genetically modified organisms (Nicholls 2014; Giraldo and Rosset 2016).[1]

The social movements and civil society actors that are part of the IPC, including La Vía Campesina, the National Coordination of Peasants' Organizations of Mali, the Latin American and Caribbean Agroecology Movement, the Latin American Scientific Society for Agroecology and others, went on record at Nyéléni to oppose what they perceive as a move by mainstream institutions to co-opt and reduce agroecology to a set of eco-techniques in the toolkit of the industrialized food production model (LVC 2015a). It was the first time that representatives of not just peasants and family farmers but also of indigenous peoples, pastoralists, artisan fisherfolk, city dwellers, consumers and others met to jointly analyze agroecology — similar to previous global forums to discuss food sovereignty and agrarian reform — (Martínez-Torres and Rosset 2014; Rosset 2013). Thanks to this dialogue among different grassroots knowledges, wisdoms and ways of knowing, the forum's main declaration was the first to gather and unify the different visions of what agroecology is for social movements. In the document, participating movements warn that agroecology is in danger of being co-opted, given attempts by agribusiness and other actors in the industrial food system to "greenwash" their discourse, and they reject equating agroecology with industrial monoculture production of "organic" foods and similar approaches promoted by the private sector and mainstream institutions. Forum delegates voiced their approval of an eminently political and grassroots agroecology that seeks to challenge and change power structures, i.e., "put the control of seeds, biodiversity, land and territories, waters, knowledge, culture and the commons in the hands of the peoples who feed the world."

We face a dispute between two radically different ways of conceiving agroecology: one that is technical and technocentric, scientificist and institutional, and the other, a "peoples' way," that is deeply political and champions distributive justice and a profound rethinking of the food system. This more discursive part of this struggle continued at the FAO regional agroecology conferences that followed the Rome symposium in 2015: in Brasilia for Latin America and the Caribbean, in Dakar for Sub-Saharan Africa and in Bangkok for Asia and the Pacific. Of the three events, Brasilia's was the most favourable for social movements, who were able to prevail in discussions and include most of their positions in the final document — with the notable exceptions of explicit criticisms of agribusiness and GMOs. This declaration was ratified by representatives of the FAO, governments, academics, the Community of Latin American and Caribbean States, and Mercosur's Office of Family Farm Agriculture (REAF). The Dakar and Bangkok conferences were more conflictive, insofar as there was a move to make agroecology synonymous with ecological intensification and climate-smart agriculture, while social movements rejected attempts to co-opt the term (Rogé, Nicholls and Altieri 2015; Nicholls 2015; Giraldo and Rosset 2016, 2017).

Over a period of one to two years, several things became clear. Agroecology was recognized for the first time by the institutions that govern world agricultural policy and, subsequently, two opposing sides drew battle lines over the meaning of the word. Today, the FAO has an agroecology office at its headquarters in Rome, agriculture ministers from around the world are drafting public policy on "agroecology," and universities are scrambling to offer agroecology curricula and initiate new research programs.[2] This is significant. Agroecology will soon begin to have earmarked budgets, multinational corporations and international cooperation agencies will invest in agroecology, and NGOs new to agroecology and other opportunistic players who had not previously defended or even spoken of agroecology will become spokespersons and beneficiaries of the economic and political opportunities that arise in this new international context (Giraldo and Rosset 2016, 2017).

In this chapter, we interpret the rise of agroecology within the institutional agenda using the FAO as a proxy for the larger institutional space. We are interested in analyzing how and why agroecology came to be of interest in global geopolitics just as agro-capitalism attempts to address some of its contradictions and how social movements can be strengthened by defending agroecology as an alternative to development as usual and as an essential component in post-capitalist transformation.

The Appropriation of Agroecology

Giraldo and Rosset (2016, 2017) argue that agribusiness and financial capital are interested in agroecology because it can help them escape from the latest of the periodic crises of capitalism and from the persistent contradictions inherent to the extractivism that characterizes industrial agriculture (Giraldo 2015). The economic crisis is reflected by idle surplus capital, without enough investment options to generate attractive profits. Financialization and its speculative bubbles have been the stopgap solutions that have staved off the crisis caused by an oversupply of goods and under-consumption due the limited purchasing power of the impoverished masses around the world. Nevertheless, capital's long-term solution is to implement a strategy of dispossession and pillage, backed and promoted by the governments of most countries through neoliberal privatization strategies, which have transferred public assets and common goods to private companies and incorporated these assets and goods into private capital accumulation flows. This process, which is reminiscent of Marx's primitive accumulation and has more recently been labelled "accumulation by dispossession" by geographer David Harvey (2003), is nothing more than brazen plundering, aimed at appropriating resources without compensating their rightful owners, including peasants and indigenous peoples.

Undoubtedly, in the context of the most recent crisis — which grew deeper when the financial bubble burst between 2007 and 2009 — speculative capital needed new ways to accumulate and speculate. This leads to the first explanation of why institutions renewed their interest in promoting and supporting agroecology. For many years, capital found refuge in ethereal financial markets but then began to search extensively for ways to appropriate the natural resources on which real economic activity depends. Land grabs, investment fever in monoculture crops and forestry products, oil, non-traditional hydrocarbons and minerals in the Global South are well-known examples (Borras et al. 2011). It is increasingly clear that capital also seeks to commodify seeds and agrobiodiversity; dispossess peasants and indigenous communities of their agroecological knowledge; encourage greater agricultural diversity in food markets, the cosmetic industry and pharmacology; increase the profits derived from carbon credits and from neoliberal-style conservation through forestry agreements; and profit by broadening industrialized organic product markets, which may soon be renamed "agroecological" in hyper-markets. The objective is to convert people's communal goods into private property rights, thus separating communities from their material and symbolic conditions of life and making it impossible for people to live outside market-based networks (Giraldo and Rosset 2016, 2017; Levidow, Pimbert and Vanloqueren 2014; LVC 2016).

While agroecology marshals the various practices created by peoples through thousands of years of ecosystemic transformation, the worldwide capitalist crisis is driving capital to channel those practices into circuits of global capital accumulation. There is no better way to appease the demands of social movements and deflect their defence of agroecology — as an alternative to hegemonic capitalism — than to capture, co-opt and suppress its anti-systemic content. This is why capital now refrains from marginalizing agroecology and seeks to keep it under control, making peasants, pastoralists, family farmers and fisherfolk functional to accumulation by linking them to entrepreneurial economies. In essence, these groups plant, herd and fish in areas that are not of direct interest to agribusiness, at least not in the classical manner of direct production. Therefore, capital finds it more practical to de-territorialize people without displacing them from their lands, for example through contract farming for distant markets, a useful way of obtaining extraordinary rents (Giraldo 2015). As a strategy, accumulation by dispossession leaves no stone unturned in its search for any economic area that could be used for capital's valorization. If currently 70 percent of world food production is in the hands of small producers (ETC Group 2009), many of whom are agroecological producers, it would be a waste to exclude their work from capitalist accumulation. Yet, given that it is virtually impossible to convert marginal land into capital-intensive monoculture, the commercialization of agroecology may be an excellent way to control these lands that could be a source of sizable rents (Giraldo and Rosset 2016, 2017).

Another explanation for why institutions have recently shown interest in including agroecology in their agenda lies in what in Marxism is known as the second contradiction of capital. This contradiction, derived from Marx's observation regarding the metabolic rift caused by the development of technology in agriculture,[3] highlights the fact that the technology used by capitalism degrades the naturally occurring conditions of production, putting capital's profits at risk (Martinez-Alier 2011; O´Connor 1998). Agribusiness constantly seeks greater output, increased yields and improved efficiency, leading, paradoxically, to plateauing yields (Ray et al. 2012) and even an overall decline in areas where the Green Revolution was first implemented (Pingali, Hossain and Gerpacio 1997); in addition to erosion, compacting, salinization and sterilization of the soil (Kotschi 2013); loss of functional biodiversity for agroecosystems; resistance to insecticides; and lowered effectiveness of chemical fertilizers. The inclination of agribusiness to hyper-productivity threatens the basis of its own production, contributing to the crisis in agriculture and the food system (Leff 1986, 2004).

It is increasingly evident that agro-capitalism is self-destructive in terms of the ecological conditions of production, by simplifying and over-exploiting ecosystems, eroding soil fertility, contaminating water and spewing greenhouse gases into the atmosphere.

Economically, this means that there is a falling rate of profit crisis for capital, i.e., a decrease in profits caused by an increase in production costs. For example, increasingly greater amounts of fertilizers and insecticides must be applied to maintain past yields. Yet, although it has been yet impossible to halt environmental devastation by technological fixes within the system itself, the ongoing crisis has opened an opportunity for agricultural capital to restructure itself and implement changes in pursuit of lower production costs and increased productivity.

As James O´Connor (1998) says, not only is capitalism prone to crisis, but it depends on crises to restructure. Currently, agricultural capitalism, with some help from nation-states and multilateral organizations, is undergoing transformations in order to resolve this crisis in its favour. The changes underway include appropriating elements of agroecology, seen as offering technical options that can help in re-establishing the conditions of production. Admittedly, the efforts in industrial agriculture to find technical fixes for the system address a legitimate concern, driven by the deterioration of the sustainability of the system. But beyond the need to fine-tune the system, there is a generalized move to "greenwash" agribusiness, including climate-smart agriculture, sustainable intensification, organic agriculture based on commercial inputs, drought-resistant GMOs, the "new Green Revolution" and precision agriculture (Pimbert 2015; Patel 2013).

Furthermore, the crisis, caused by the tendency of capitalist agribusiness to wreak havoc on the natural resource base on which it depends, is also a good time to expand and create new business opportunities. These may become future "agroecological input industries" or organic monoculture crops for export niches or mechanisms to internalize the cost of environmental deterioration by generating income through the sale of carbon credits (LVC 2013; Leff 2004), or ecotourism and bio-commerce enterprises. The crisis can also be leveraged to increase the flexibility and lower the costs of labour, thanks to contract farming with small producers or with families who practise agroecology with an entrepreneurial mindset, geared to supplying capitalist value chains (Giraldo and Rosset 2016, 2017).

In summary, environmental destruction can be an opportunity to create new planning instruments for capital on a large scale, with a focus on restructuring to improve profits, reducing costs, creating new consumer goods and re-establishing conditions of production (O´Connor 1998). Thus, we can interpret the changes that have allowed agroecology to become part of the FAO's discourse as partially the result of the recent intensification of the strategy of accumulation by dispossession and of attempts by agribusiness to reorganize itself in a context of a crisis brought on by its own internal contradictions (Giraldo and Rosset 2016, 2017).

Agricultural capitalism typically blocks users from having knowledge about how their technologies are designed and made, which is a powerful way of preventing certain forms of social self-organization (Harvey 2003). This is precisely what agroecology challenges with methodologies used by, for example, the *campesino a campesino,* or peasant-to-peasant, movement (Vásquez and Rivas 2006; Holt-Gimenez 2006; Rosset at al. 2011; Machín Sosa et. al. 2013), where producers are experimenters who disseminate their wisdom through horizontal dialogue and teaching by example. However, with the very likely invasion of institutionalized agroecological projects driven by public policies, these kinds movements may be colonized, exposing people to the dictatorship of experts. While it is true that peasant movements have always benefitted from external allies, rather than appearing in complete isolation, we should remember that development is designed to increase control by external institutions, disguised as an attempt to redeem and teach "the ignorant," taking communities by the hand, like children in need of adult guidance, while assuming complete control of their time and daily activities. Through countless projects, development has made people the target of expert knowledge, stripping communities of their creativity, hobbling their social imagination, imposing knowledge and dictating expected ways of producing and consuming (Illich 2006). The industrial colonization of agroecology will be achieved by input substitution (Rosset and Altieri 1997) — bio-pesticides, bio-solids and other alternative, yet still commercial, inputs — through the same capitalist rationality that structures all forms of existence in response to market demands and the profit motive (Polanyi 1957). Development programs and projects have carried out precisely this work for decades; nothing indicates that any of this will change if ministers of agriculture appropriate agroecology and include it in the national plans of neoliberal or progressive governments (Giraldo and Rosset 2016, 2017).

Greenwashed capitalism has discovered agroecology as a way of legitimizing a dual agricultural geopolitics that, on the one hand, seeks to restructure agribusiness with a renovated discourse steeped in sustainability and responsible investment, while, on the other hand, it promotes peasant agriculture based on agroecology and tied to market economics through partnership agreements with agro-industrial entrepreneurs, suppliers of "alternative" inputs, contract farming or other forms of insertion into commercial chains (Patel 2013). A greenwashed discourse is undoubtedly a powerful legitimizing tactic that tries to counter abundant evidence that capitalist agricultural technology is destroying capital's sources of economic and ecological sustainability. Perhaps we are witnessing the beginning of a new stage whereby the Green Revolution is moulting, to take on a new, more "green" disguise, to legitimize itself though an agroecological discourse based on social inclusion, healthy foods and safeguarding Mother Earth (Giraldo and Rosset 2016, 2017).

Political Agroecology and Social Movements

Clearly, a dispute to define agroecology has begun between at least two forces. The outcome will depend on the balance of power in venues where the struggle occurs and on the ability of social movements to eschew the precepts of so-called development. In our opinion, it is an ideal moment to voice our critiques of a concept of agroecology that hews narrowly to economic rationality and to the imaginaries of progress, just as we defend a broader concept of agroecology as a fundamental component of alternatives that seek to address the crisis of civilization. Challenging new models of agroecological simulation and co-optation require defending political visions and strategies that are more akin to what in Latin America has been called *buen vivir*, which includes people resisting control by outside institutions, practising autonomous agroecology and assuming responsibility for the problems that directly affect them (Giraldo 2014; Giraldo and Rosset 2016, 2017).

Social movements and grassroots organizations need to construct intentional organizing processes to scale-out agroecology at the territorial level (Rosset et al. 2011; Khadse et al. 2017; McCune, Reardon and Rosset 2014, 2016; Rosset 2015b). They must struggle for land and defend their territories from land grabbers (Rosset 2013). And they must build powerful imaginaries — mobilizing frames — to motivate their peasant membership for the process of agroecological transformation and for the immaterial dispute to defend and transform their real territories (Rosset and Martínez-Torres 2012; Martínez-Torres and Rosset 2014).

The defence of territories should also involve rejecting attempts to impose technical fixes and one-size-fits-all models, increasing the power of agroecology as an alternative to development processes that mobilizes collective creativity and social ingenuity while diversifying all manner of producing, consuming, being and existing. Paraphrasing the Zapatistas in Mexico, while we ought to reject a world based exclusively on a mindset of development that robs individuals of their creative abilities, we should revitalize the many worlds that learn from one another, a task that agroecological methodologies do so well when they contribute to relative autonomy (Rosset and Martínez-Torres 2012; Martínez-Torres and Rosset 2014) and that runs counter to the rationale of clientelism within governmental programs and projects. Ways of living exist, founded on cultural creativity and the ecosystemic ordering of each specific locale, that encourage real agroecology by improving community relations, deepening mutual aid, increasing people's control over their lives and placing all tools under the control of producers, i.e., the polar opposite of the conventional development paradigm (Giraldo and Rosset 2016, 2017).

Defending agroecology from institutional plunder and co-optation means rejecting the narrow economicism that would reduce the concept to a matter of productivity, yields and competitiveness based on neoliberal economic and scientific precepts. It also involves constructive criticisms that reshape agroecology and link people's worldviews, their forms of symbolic understanding, their relations of reciprocity and their ways of existing and re-existing, to ways of inhabiting the Earth. Much more than a way of producing, agroecology, like being a peasant, is a way of being, understanding, living and feeling this world (Fals Borda 2009; da Silva 2014). It is a social relationship distinct from capitalism that encourages the recovery and interchange of local wisdom, communal creation of new knowledge where problems occur and eco-systemic transformation in line with the conditions appropriate to regenerating life (da Silva 2014). As La Vía Campesina (2015b) states:

> Ours is the "model of life," of the countryside with peasants, of rural communities with families, of territories with trees and forests, mountains, lakes, rivers and coastlines, and is in firm opposition to the "model of death" of agribusiness, of farming without peasants or families, of industrial monocultures, of rural areas without trees, of green deserts and land poisoned by chemical pesticides and genetically modified organisms. We are actively challenging capital and agribusiness, disputing land and territory with them.

We need to decolonize agroecology (Rivera Cusicanqui 2010) and resist current global, rent-seeking, dispossessing, capitalist mechanisms; and the defence of agroecology needs to recover a sense of the commons (Giraldo 2016). This implies continued rejection of agribusiness models, large landholdings and economic globalization, while defending territories from attempts by capital to expand into new geographic spaces and continuing mobilizations aimed at gaining control of production, distribution and consumption. Yet, communizing, or widening the commons, is not solely about community appropriation of all material and cultural ways of existing. Proponents of grassroots agroecology need to think hard about the technical tools they promote. Will the tools be at the service of the collectivity? Or will they constitute the kind of input substitution that deepens dependence on external suppliers of inputs and risks further indebtedness, threatening to further enslave people to technology and preserve exploitation (Rosset and Altieri 1997; Khadse et al. 2017)? This is precisely what is at stake in the dispute over and the attempts by mainstream institutions to depoliticize agroecology and incorporate it into their development jargon and practices.

We do not wish to suggest that, just because the FAO and development institutions have an interest in agroecology, this is not a good opportunity for social movements to voice their demands. Just the opposite: it will not be possible to scale-out agroecology if the institutional machinery continues to favour industrial agribusiness and Green Revolution technology with subsidies, credits, extension programs and the whole gamut of incentives that have helped the rural development paradigm to expand over the past fifty years. Now that the FAO has given its "seal of approval" to agroecology, we already see universities scrambling to add agroecology to their curricula and ministries of agriculture creating agroecology programs, with research, extension and credits and subsidies to agroecological production and "agroecological" inputs (beware of "input substitution"!). But which agroecology will be taught? And which farmers and which consumers will benefit from new public policies?

People should take care to avoid naïve beliefs that the path is finally clear for moving the world's agricultural structure toward agroecology. Social movements must remain watchful and avoid excessive dependency on public programs and projects and private sector partnerships and contracts that institutionalized agroecology would bring (Giraldo and Rosset 2016, 2017).

We are at a moment when movements cannot turn away. Furthermore, refusing to take part in relevant debates helps capital find solutions to its chronic crisis of over-accumulation through dispossession, while temporarily restructuring its production conditions. Along the lines of what occurred at the International Forum for Agroecology at Nyéléni, this is by far the best moment, as movements reject appropriation, for political forces to reposition themselves, for new assumptions regarding the struggle to be conceived, for methods of resistance to be updated, for scattered organizations to be unified and for the meaning of alternatives to be redefined. Ultimately, the endeavour by capital to devour everything and bring every spatial bastion and human being into its circuits of accumulation is one of its greatest contradictions, since it actually strengthens people's will to resist. In fact, capital has an effect opposite to its intentions: mobilizations are revitalized and people re-appropriate their natural resources, revalue their cultures and step up efforts to build effective social processes aimed at territorializing agroecology (Giraldo and Rosset 2016, 2017). Institutionality is putting forth a sterile, techno-centric, supposedly *apolitical* agroecology; thus now is the time for social movements to defend their truly *political* agroecology (Calle Collado, Gallar and Candón 2013).

Notes

1. See Altieri and Rosset (1999a,b), Altieri (2005) and Rosset (2005) for discussion of the issues raised by genetically modfied organisms and agroecology.
2. While the FAO agroecology office is largely staffed with well-intentioned people who are sympathetic to social movement visions of agroecology, they are an embattled minority inside the institution, which overall continues to push for industrial agriculture and "lite" alternatives like climate-smart agriculture (Pimbert 2015).
3. "All progress in capitalistic agriculture is a progress in the art, not only of robbing the laborer, but of robbing the soil; all progress in increasing the fertility of the soil for a given time, is a progress towards ruining the lasting sources of that fertility.... Capitalist production, therefore, develops technology, and the combining together of various processes into a social whole, only by sapping the original sources of all wealth — the soil and the laborer" (Marx 1946: 423–24; see also Foster 2000; Martinez-Alier 2011).

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