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Eric Lichtfouse
Editor

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Editor
Eric Lichtfouse
INRA, UMR1347 Agroécologie
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Agroecology Scaling Up for Food Sovereignty and Resiliency

Miguel A. Altieri and C.I. Nicholls

Abstract The Green Revolution not only failed to ensure safe and abundant food production for all people, but it was launched under the assumptions that abundant water and cheap energy to fuel modern agriculture would always be available and that climate would be stable and not change. In some of the major grain production areas the rate of increase in cereal yields is declining as actual crop yields approach a ceiling for maximal yield potential. Due to lack of ecological regulation mechanisms, monocultures are heavily dependent on pesticides. In the past 50 years the use of pesticides has increased dramatically worldwide and now amounts to some 2.6 million tons of pesticides per year with an annual value in the global market of more than US$ 25 billion. Today there are about one billion hungry people in the planet, but hunger is caused by poverty and inequality, not scarcity due to lack of production. The world already produces enough food to feed nine to ten billion people, the population peak expected by 2050. There is no doubt that humanity needs an alternative agricultural development paradigm, one that encourages more ecologically, biodiverse, resilient, sustainable and socially just forms of agriculture. The basis for such new systems are the myriad of ecologically based agricultural styles developed by at least 75% of the 1.5 billion smallholders, family farmers and indigenous people on 350 million small farms which account for no less than 50% of the global agricultural output for domestic consumption.

This position paper draws from material used in the paper "It is possible to feed the world by scaling up agroecology" written by Miguel A Altieri for the Ecumenical Advocacy Alliance, May 2012.

M.A. Altieri (✉)
Department of Environmental Science, Policy, & Management,
University of California Berkeley, 215 Mulford Hall #3114, Berkeley, CA 94720, USA
e-mail: agroeco3@berkeley.edu

C.I. Nicholls
International and Area Studies, University of California, Berkeley
e-mail: nicholls@berkeley.edu

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As an applied science, agroecology uses ecological concepts and principles for the design and management of sustainable agroecosystems where external inputs are replaced by natural processes such as natural soil fertility and biological control. The global south has the agroecological potential to produce enough food on a global per capita basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base.

Keywords Agroecology • Organic farming • Food security • Industrial agriculture • World hunger • Peasant agriculture

1 Why Industrial Agriculture Is No Longer Viable?

The Green Revolution, the symbol of agricultural intensification not only failed to ensure safe and abundant food production for all people, but it was launched under the assumptions that abundant water and cheap energy to fuel modern agriculture would always be available and that climate would be stable and not change. Agrochemicals, fuel-based mechanization and irrigation operations, the heart of industrial agriculture, are derived entirely from dwindling and ever more expensive fossil fuels. Climate extremes are becoming more frequent and violent and threaten genetically homogeneous modern monocultures now covering 80% of the 1,500 million hectares of global arable land. Moreover industrial agriculture contributes with about 25–30% of greenhouse gas (GHG) emissions, further altering weather patterns thus compromising the world's capacity to produce food in the future.

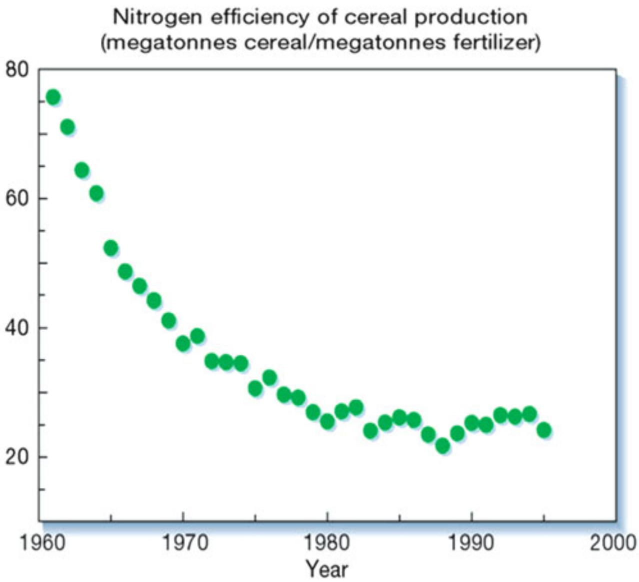

Fig. 1 The law of diminishing returns: more inputs, less yields

1.1 The Ecological Footprint of Industrial Agriculture

In some of the major grain production areas of the world, the rate of increase in cereal yields is declining as actual crop yields approach a ceiling for maximal yield potential (Fig. 1). When the petroleum dependence and the ecological footprint of industrial agriculture are accounted for, serious questions emerge about the social, economic and environmental sustainability of modern agricultural strategies. Intensification of agriculture via the use of high-yielding crop varieties, fertilization, irrigation and pesticides impact heavily on natural resources with serious health and environmental implications. It has been estimated that the external costs of UK agriculture, to be at least 1.5–2 billion pounds each year. Using a similar framework of analysis the external costs in the US amount to nearly 13 billion pounds per year, arising from damage to water resources, soils, air, wildlife and biodiversity, and harm to human health. Additional annual costs of USD 3.7 billion arise from agency costs associated with programs to address these problems or encourage a transition towards more sustainable systems. The US pride about cheap food, is an illusion: consumers pay for food well beyond the grocery store.

http://www.agron.iastate.edu/courses/agron515/eatearth.pdf

Due to lack of ecological regulation mechanisms, monocultures are heavily dependent on pesticides. In the past 50 years the use of pesticides has increased dramatically worldwide and now amounts to some 2.6 million tons of pesticides per year with an annual value in the global market of more than US$25 billion. In the

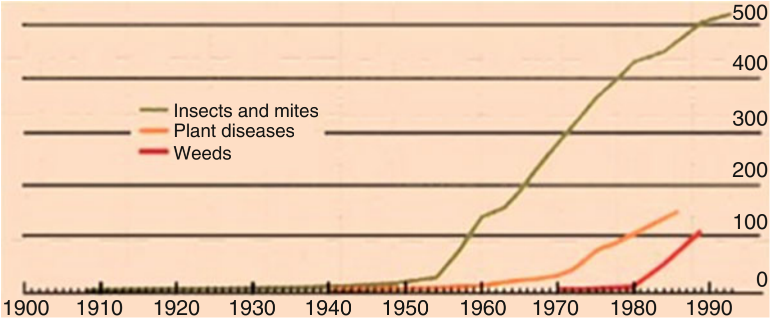

Fig. 2 The rapid development of resistance to pesticides by insects, pathogens and weeds

US alone, 324 million kg of 600 different types of pesticides are used annually with indirect environmental (impacts on wildlife, pollinators, natural enemies, fisheries, water quality, etc.) and social costs (human poisoning and illnesses) reaching about $8 billion each year. On top of this, 540 species of arthropods have developed resistance against more than 1,000 different types of pesticides, which have been rendered useless to control such pests chemically (Fig. 2).

http://ipm.ncsu.edu/safety/factsheets/resistan.pdf

Although there are many unanswered questions regarding the impact of the release of transgenic plants into the environment which already occupy >180 million hectares worldwide, it is expected that biotech crops will exacerbate the problems of conventional agriculture and, by promoting monoculture, will also undermine ecological methods of farming. Transgenic crops developed for pest control emphasize the use of a single control mechanism, which has proven to fail over and over again with insects, pathogens and weeds. Thus transgenic crops are likely to increase the use of pesticides as a result of accelerated evolution of 'super weeds' and resistant insect pest strains. Transgenic crops also affect soil fauna potentially upsetting key soil processes such as nutrient cycling. Unwanted gene flow from transgenic crops may compromise via genetic pollution crop biodiversity (i.e. maize) in centers of origin and domestication and therefore affect the associated systems of agricultural knowledge and practice along with the millenary ecological and evolutionary processes involved.

http://www.colby.edu/biology/BI402B/Altieri%202000.pdf

1.2 *Agribusiness and World Hunger*

Today there are about one billion hungry people in the planet, but hunger is caused by poverty (1/3 of the planet's population makes less than $2 a day) and inequality (lack of access to land, seeds, etc.), not scarcity due to lack of production. The world already produces enough food to feed nine to ten billion people, the population peak expected by 2050. The bulk of industrially produced grain crops goes to biofuels and confined animals. Therefore the call to double food production by 2050 only applies if we continue to prioritize the growing population of livestock and automobiles over hungry people. Overly simplistic analyses in support of industrialized agriculture cite high yields and calculations of total food supply to illustrate its potential to alleviate hunger. However, it has been long understood that yields are a necessary but not sufficient condition to meeting people's food needs (Lappe et al. 1998). Seventy eight percent of all malnourished children under five who live in the Third World are in countries with food surpluses. There is already an abundant supply of food even while hunger grows worldwide. It is not supply that is the crucial factor, but distribution – whether people have sufficient "entitlements" through land, income, or support networks to secure a healthy diet. Rather than helping, too much food can actually add to hunger by undercutting prices and destroying the economic viability of local agricultural systems. Farmers are not able to sell their produce in a way that allows them to cover costs, and so food may rot in the fields while people go hungry (Holt Gimenez and Patel 2009).

In addition roughly one-third of food produced for human consumption is wasted globally, which amounts to about 1.3 billion tons per year, enough to feed the entire African continent. Most of this food is wasted by consumers in Europe and North-America is 95–115 kg/year/per capita while this figure in Sub-Saharan Africa and South/Southeast Asia is only 6–11 kg/year.

http://www.fao.org/fileadmin/user_upload/ags/publications/GFL_web.pdf

1.3 The Concentration of Global Food Production

Solutions to hunger and food supply need to take into account distribution of food and access to income, land, seeds and other resources. Industrial agriculture has accelerated land and resource concentration in the hands of a few undermining the possibility of addressing the root causes of hunger (Lappe et al. 1998). The concentration of global food production under the control of a few transnational corporations, bolstered by free trade agreements, structural adjustment policies, and subsidies for the overproduction of crop commodities, has created North-South food trade imbalances and import dependencies that underlie a growing food insecurity in many countries. Production of cash crop exports in exchange for food imports and the expansion of biofuels can undermine food self-sufficiency and threaten local ecosystems. This situation is aggravated by food insecure governments including China, Saudi Arabia and South Korea that rely on imports to feed their people which are snatching up vast areas of farmland (>80 millions hectares already transacted) abroad for their own offshore food production. Food corporations and private investors, hungry for profits in the midst of the deepening financial crisis, see investment in foreign farmland as an important new source of revenue from the production of biomass.

http://www.grain.org/bulletin_board/tags/221-land grabbing

2 Peasant Agriculture: The Basis for the New Twenty-first Century Agriculture

There is no doubt that humanity needs an alternative agricultural development paradigm, one that encourages more ecologically, biodiverse, resilient, sustainable and socially just forms of agriculture. The basis for such new systems are the myriad of ecologically based agricultural styles developed by at least 75% of the 1.5 billion smallholders, family farmers and indigenous people on 350 million small farms which account for no less than 50% of the global agricultural output for domestic consumption (ETC 2009). Most of the food consumed today in the world is derived from 5,000 domesticated crop species and 1.9 million peasant-bred plant varieties mostly grown without agrochemicals (ETC 2009). Industrial agriculture threatens this crop diversity through the replacement of native varieties with hybrid strains and the contamination of crop and wild species from the introduction of genetically modified organisms. As the global food supply relies on a diminishing variety of crops, it becomes vulnerable to pest outbreaks, the breeding of superbugs, and climate disruptions.

In Brazil there are about 4.8 million traditional family farmers (about 85% of the total number of farmers) that occupy 30% of the total agricultural land of the country. Such family farms control about 33% of the area sown to maize, 61% of that under beans, and 64% of that planted to cassava, thus producing 84% of the total cassava and 67% of all beans. Smallholder farmers in India possessing on average 2 ha of land each, make up about 78% of the country's farmers while owning only 33% of the land, but responsible for 41% of national grain production. Their contribution to both household food security and to farm outputs is thus disproportionately high (Via Campesina 2010).

The majority of the world's peasant farmers tend small diversified farming systems which offer promising models for promoting biodiversity, conserving natural resources, sustaining yield without agrochemicals, providing ecological services and remarkable lessons about resiliency in the face of continuous environmental and economic change. For these reasons most agroecologists acknowledge that traditional agroecosytems have the potential to bring solutions to many uncertainties facing humanity in a peak oil era of global climate change and financial crisis (Altieri 2004; Toledo and Barrera- Bassols 2009). Undoubtedly, the ensemble of traditional crop management practices used by many resource-poor farmers which fit well to local conditions and can lead to the conservation and regeneration of the natural resource base represents a rich resource for modern workers seeking to create novel agroecosystems well adapted to the local agroecological and socioeconomic circumstances of smallholders.

Peasant practices and techniques tend to be knowledge-intensive rather than input-intensive, but clearly not all are effective or applicable, therefore modifications and adaptations may be necessary and this is where **agroecology** has played a key role in revitalizing the productivity of small farming systems (Altieri et al. 1998). Since the 1980s thousands of projects launched by non-governmental organisations (NGO), farmers organizations and some University and research centers reaching hundreds of thousands of farmers, have applied general agroecological principles to customize agricultural technologies to local needs and circumstances, improving yields while conserving natural resources and biodiversity. The conventional technology transfer model breaks down in peasant regions as it is top down and based on a magic-bullet technology transfer approach incapable of understanding that new agroecological systems require peoples' participation and need to be tailored and adapted in a site-specific way to highly variable and diverse farm conditions (Uphoff 2002).

3 How Is the International Community Reacting?

The solutions for smallholder agriculture advocated by big bilateral donors, governments and the initiatives of private foundations have tended to center around the promotion of synthetic fertilizers and pesticides, which are costly for farmers and often resource depleting. This drive for a new 'Green Revolution' as exemplified by the Alliance for a Green Revolution in Africa (AGRA) has tended to sideline more sustainable, farmer led approaches. Others [(CGIAR 2012, recent sustainable intensification report of FAO- (http://www.fao.org/agriculture/crops/core-themes/theme/spi/scpi-home/framework/sustainable-intensification-in-fao/en/), latest report of the expert Montpellier Panel - (https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/Montpellier%20Panel%20Report%202012.pdf)] have tried to co-opt agroecology by stating that it is an option that can be practiced along with other approaches such as transgenic crops, conservation farming, microdosing of fertilisers and herbicides, and integrated pest management. Of course in this way the term agroecology would be rendered meaningless, like sustainable agriculture, a concept devoid of meaning, and divorced from the reality of farmers, the politics of food and of the environment. As a science however, agroecology provides the productive basis for rural movements that promote food sovereignty and confront head on the root causes that perpetuate hunger, therefore it cannot be appropriated by conventional institutions. Agroecology does not need to be combined with other approaches. Without the need of hybrids and external agrochemical inputs, it has consistently proven capable of sustainably increasing productivity and has far greater potential for fighting hunger, particularly during economic and climatically uncertain times, which in many areas are becoming the norm (Altieri et al. 2011b).

Despite these co-opting attempts, the realization of the contribution of peasant agriculture to food security in the midst of scenarios of climate change, economic and energy crisis led to the concepts of food sovereignty and agroecology to gain much worldwide attention in the last two decades. Two recent major international reports (IAASTD 2009; de Schutter 2010) state that in order to feed nine billion people in 2050, we urgently need to adopt the most efficient farming systems and recommend for a fundamental shift towards agroecology as a way to boost food production and improve the situation of the poorest. Both reports based on broad consultations with scientists and extensive literature reviews contend that small-scale farmers can double food production within 10 years in critical regions by using agroecological methods already available. The future food challenge should be met using environmentally friendly and socially equitable technologies and methods, in a world with a shrinking arable land base (which is also being diverted to produce biofuels), with less and more expensive petroleum, increasingly limited supplies of water and nitrogen, and within a scenario of a rapidly changing climate, social unrest and economic uncertainty (Godfray et al. 2010). The only agricultural systems that will be able to confront future challenges are agroecological systems that exhibit high levels of diversity, integration, efficiency, resiliency and productivity (Holt Gimenez and Patel 2009).

4 What Are Agroecological Production Systems?

As an applied science, agroecology uses ecological concepts and principles for the design and management of sustainable agroecosystems where external inputs are replaced by natural processes such as natural soil fertility and biological control (Altieri 1995). Agroecology takes greater advantage of natural processes and beneficial on-farm interactions in order to reduce off-farm input use and to improve the efficiency of farming systems. Agroecological principles used in the design and management of agroecosystems (Table 1) enhances the

Table 1 Agroecological principles for the design of biodiverse, energy efficient, resource-conserving and resilient farming systems

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

functional biodiversity of agroecosystems which is integral to the maintenance of immune, metabolic and regulatory processes key for agroecosystem function (Gliessman 1998).

Agroecological principles take different technological forms depending on the biophysical and socioeconomic circumstances of each farmer or region. A key principle of agroecology is the diversification of farming systems promoting mixtures of crop varieties, intercropping systems, agroforestry systems, livestock integration, etc. which potentiate the positive effects of biodiversity on productivity derived from the increasing effects of complementarity between plant-animal species translated in better use of sunlight, water, soil resources and natural regulation of pest populations. Promoted diversification schemes (Box 1) are multi-functional as their adoption usually means favorable changes in various components of the farming systems at the same time (Gliessman 1998). In other words they function as an "ecological turntable" by activating key processes such as recycling, biological control, antagonisms, allelopathy, etc., essential for the sustainability and productivity of agroecosystems. Agroecological systems are not intensive in the use of capital, labor, or chemical inputs, but rather rely on the efficiency of biological processes such as photosynthesis, nitrogen fixation, solubilization of soil phosphorus, and the enhancement of biological activity above and below ground. The "inputs" of the system are the natural processes themselves, this is why agroecology is referred to as an "agriculture of processes".

When designed and managed with agroecological principles, farming systems exhibit attributes of diversity, productivity, resilience and efficiency. Agroecological initiatives aim at transforming industrial agriculture partly by transitioning the existing food systems away from fossil fuel-based production largely for agroexport

Box 1 Temporal and Spatial Designs of Diversified Farming Systems and Their Main Agroecological Effects (Altieri 1995; Gliessman 1998)

Crop Rotations: Temporal diversity in the form of cereal-legume sequences. 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 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 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-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 is a strategy to reduce soil erosion and lower fluctuations in soil moisture and temperature, improve soil quality, and enhance weed suppression resulting in better crop performance.

Crop- livestock mixtures: High biomass output and optimal nutrient recycling can be achieved through crop- animal 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 of external inputs.

crops and biofuels towards an alternative agricultural paradigm that encourages local/national food production by small and family farmers based on local innovation, resources and solar energy. This implies access of peasants to land, seeds, water, credit and local markets, partly through the creation of supportive economic policies, financial incentives, market opportunities and agroecological technologies (Vía Campesina 2010). Agroecological systems are deeply rooted in the ecological rationale of traditional small-scale agriculture, representing long established examples of successful agricultural systems characterized by a tremendous diversity of domesticated crop and animal species maintained and enhanced by ingenuous soil, water and biodiversity management regimes, nourished by complex traditional knowledge systems (Koohafkan and Altieri 2010).

5 How Does Agroecology Differ from Other Alternative Agricultural Approaches?

Organic agriculture is practiced 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. FIBL scientists in Central Europe conducted a 21-year study of the agronomic and ecological performance of organic, and conventional farming systems. They found crop yields to be 20% lower in the organic systems, although input of fertilizer and energy was reduced by 31–53% and pesticide input by 98%. Researchers concluded that the enhanced soil fertility and higher biodiversity found in organic plots rendered these systems less dependent on external inputs. When practiced based on agroecological principles organic practices buildup of soil organic matter and soil biota, – minimize pest, disease and weed damage, conserve soil, water, and biodiversity resources, promote long-term agricultural productivity with produce of optimal nutritional value and quality. http://www.fibl.org/en.html

Organic farming systems managed as monocultures that are in turn dependent on external biological and/or botanical (i.e. organic) inputs are not based on agroecological principles. This 'input substitution' approach essentially follows the same paradigm of conventional farming: that is, overcoming the limiting factor but this time with biological or organic inputs. Many of these "alternative inputs" have become commodified, therefore farmers continue to be dependent on input suppliers, cooperative or corporate (Rosset and Altieri 1997). Agroecologists argue that organic farming systems that do not challenge the monoculture nature of plantations and rely on external inputs as well as on foreign and expensive certification seals, or fair-trade systems destined only for agro-export, offer little to small farmers who in turn become dependent on external inputs and foreign and volatile markets. By keeping farmers dependent on an input substitution approach, organic agriculture's fine-tuning of input use does little to move farmers toward the productive redesign of agricultural ecosystems that would move them away from dependence on external inputs. Niche (organic and/or fair trade) markets for the rich in the North exhibit the same problems of any agro-export scheme that does not prioritize food sovereignty (defined here as 'the right of people to produce, distribute and consume healthy food in and near their territory in ecologically sustainable manner'), often perpetuating dependence and at times hunger (Altieri 2010).

6 Assessing the Performance of Agroecological Projects

There are many competing visions on how to achieve new models of a biodiverse, resilient, productive and resource efficient agriculture that humanity desperately needs in the immediate future. Conservation (no or minimum tillage) agriculture,

Box 2 Requirements of Agroecologically Based Agricultural Systems (Koohafkan et al. 2011). GHG: greenhouse gases

1. Use of local and improved crop varieties and livestock breeds so as to enhance genetic diversity and enhance adaptation to changing biotic and environmental conditions.
2. Avoid the unnecessary use of agrochemical and other technologies that adversely impact on the environment and on human health (e.g. heavy machineries, transgenic crops, etc.)
3. Efficient use of resources (nutrients, water, energy, etc.), reduced use of non-renewable energy and reduced farmer dependence on external inputs
4. Harness agroecological principals and processes such as nutrient cycling, biological nitrogen fixation, allelopathy, biological control via promotion of diversified farming systems and harnessing functional biodiversity
5. Making productive use of human capital in the form of traditional and modern scientific knowledge and skills to innovate and the use of social capital through recognition of cultural identity, participatory methods and farmer networks to enhance solidarity and exchange of innovations and technologies to resolve problems
6. Reduce the ecological footprint of production, distribution and consumption practices, thereby minimizing GHG emissions and soil and water pollution
7. Promoting practices that enhance clean water availability, carbon sequestration, and conservation of biodiversity, soil and water conservation, etc.
8. Enhanced adaptive capacity based on the premise that the key to coping with rapid and unforeseeable change is to strengthen the ability to adequately respond to change to sustain a balance between long-term adaptability and short-term efficiency
9. Strengthen adaptive capacity and resilience of the farming system by maintaining agroecosystem diversity, which not only allows various responses to change, but also ensures key functions on the farm
10. Recognition and dynamic conservation of agricultural heritage systems that allows social cohesion and a sense of pride and promote a sense of belonging and reduce migration

sustainable intensification production, transgenic crops, organic agriculture and agroecological systems are some of the proposed approaches, each claiming to serve as the durable foundation for a sustainable food production strategy. Although goals of all approaches may be similar, technologies proposed (high versus low input) methodologies (farmer-led versus market driven, top down versus bottom-up) and scales (large scale monocultures versus biodiverse small farms) are quite different and often antagonistic. However when one examines the basic attributes that a sustainable production system should exhibit (Box 2), agroecological approaches certainly meet most of these attributes and requirements (Altieri 2002;

Table 2 A set of guiding questions to assess if proposed agricultural systems are contributing to sustainable livelihoods (Koohafkan et al. 2011)

1. Are they reducing poverty?
2. Are they based on rights and social equity?
3. Do they reduce social exclusion, particularly for women, minorities and indigenous people?
4. Do they protect access and rights to land, water and other natural resources?
5. Do they favor the redistribution (rather than the concentration) of productive resources?
6. Do they substantially increase food production and contribute to household food security and improved nutrition?
7. Do they enhance families' water access and availability?
8. Do they regenerate and conserve soil, and increase (maintain) soil fertility?
9. Do they reduce soil loss/degradation and enhance soil regeneration and conservation?
10. Do practices maintain or enhance organic matter and the biological life and biodiversity of the soil?
11. Do they prevent pest and disease outbreaks?
12. Do they conserve and encourage agrobiodiversity?
13. Do they reduce greenhouse gas emissions?
14. Do they increase income opportunities and employment?
15. Do they reduce variation in agricultural production under climatic stress conditions?
16. Do they enhance farm diversification and resilience?
17. Do they reduce investment costs and farmers dependence on external inputs?
18. Do they increase the degree and effectiveness of farmer organizations?
19. Do they increase human capital formation?
20. Do they contribute to local/regional food sovereignty?

Gliessman 1998; UK Food Group 2010; Parrot and Mardsen 2002; Uphoff 2002). Similarly by applying the set of questions listed in Table 2 to assess the potential of agricultural interventions in addressing pressing social, economic and ecological concerns, it is clear that most existing agroecological projects confirm that proposed management practices are contributing to sustainable livelihoods by improving the natural, human, social, physical and financial capital of target rural communities (Koohafkan et al. 2011).

In order for an agricultural strategy to fit within the sustainability criteria, it must contain the basic requirements of a viable and durable agricultural system capable of confronting the challenges of the twenty-first century while carrying out its productive goals within certain limits in terms of environmental impact, land degradation levels, input and energy use, GHG emissions, etc. As depicted in Fig. 3 threshold indicators may be defined that are site or region specific, thus their values will change according to prevailing environmental and socio- economic conditions. In the same region, threshold value ranges may be the same for an intensive large scale system and a low-input small scale system as yields would be measured per unit of GHG emitted, per unit of energy or water used, per unit of N leached, etc. Without a doubt most monoculture based systems will surpass the threshold levels and therefore will not be considered sustainable and unfit for food provisioning in an ecologically and socially sound manner (Koohafkan et al. 2011).

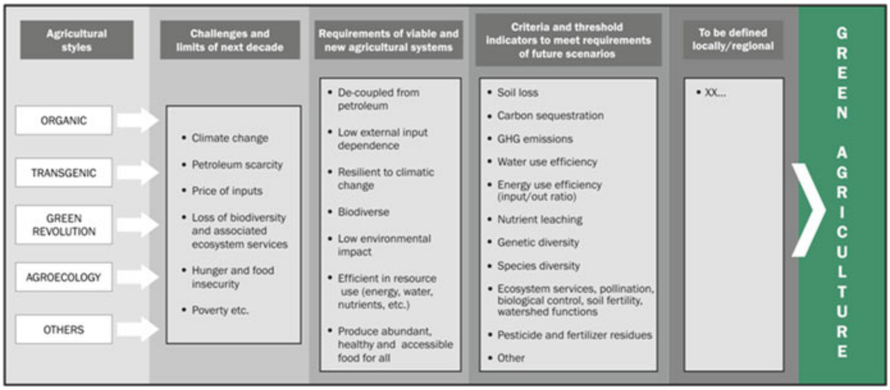

Fig. 3 The basic requirements of a viable and durable agricultural system capable of confronting the challenges of the twenty-first century while carrying out its productive goals within certain thresholds established locally or regionally (Koohafkan et al. 2011)

7 The Spread and Productive/Food Security Potential of Agroecological Systems

The first global assessment of agroecologically based projects and/or initiatives throughout the developing world was conducted by Pretty et al. (2003) who documented clear increases in food production over some 29 million hectares, with nearly nine million households benefiting from increased food diversity and security. Promoted sustainable agriculture practices led to 50–100% increases in per hectare cereal production (about 1.71 Mg per year per household – an increase of 73%) 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 14 projects where root crops were main staples (potato, sweet potato and cassava), the 146,000 farms on 542,000 ha increased household food production by 17 t per year (increase of 150%). Such yield enhancements are a true breakthrough for achieving food security among farmers isolated from mainstream agricultural institutions. A re-examination of the data in 2010, the analysis demonstrates the extent to which 286 interventions in 57 "poor countries" covering 37 million hectares (3% of the cultivated area in developing countries) have increased productivity on 12.6 million farms while improving ecosystem services. The average crop yield increase was 79%. http://www.bis.gov.uk/assets/foresight/docs/food-and-farming/11-546-future-of-food-and-farming-report.pdf

8 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 empowering communities (Christian Aid

2011). For example the UK Government's Foresight Global Food and Farming project conducted an analysis of 40 projects and programs in 20 African countries where sustainable crop intensification was promoted during the 1990s–2000s. The cases included crop improvements, agroforestry and soil conservation, conservation agriculture, integrated pest management, horticulture, livestock and fodder crops, aquaculture and novel policies and partnerships. By early 2010, these projects had documented benefits for 10.39 million farmers and their families and improvements on approximately 12.75 million hectares. Food outputs by sustainable intensification via the use of new and improved varieties was significant as crop yields rose on average by 2.13-fold (Pretty et al. 2011). Most households substantially improved food production and household food security. In 95% of the projects where yield increases were the aim, cereal yields improved by 50–100%. Total farm food production increased in all. The additional positive impacts on natural, social and human capital are also helping to build the assets base so as to sustain these improvements in the future (Action Aid 2010).

Although some of the reported yield gains reported in the study depended on farmers having access to improved seeds, fertilizers and other inputs (which more than often is not the case) food outputs improved mainly by diversification with 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 or trees brought into rotations with maize or sorghum, adoption of short- maturing varieties (e.g. sweet potato and cassava) that permit the cultivation of two crops per year instead of one (Pretty et al. 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%. In Kenya, maize yields increased by 71% and bean yields by 158%. 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 compared with 5 t obtained under monoculture (Garrity 2010).

Another agroforestry system in Africa is one dominated by Faidherbia trees which improve crop yields, 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 (CA) is an important 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 while conventional yields average between 0.5 and 0.7 MT/ha. Improved maize yields increase the amount of food available at the household level, but also increase income levels (Owenya et al. 2011).

9 Asia

Pretty and Hine (2009) evaluated 16 agroecological projects/initiatives spread across eight Asian countries and found that some 2.86 million households have substantially improved total food production on 4.93 million hectares, resulting in greatly improved household food security. Proportional yield increases are greatest in rainfed 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) (Action Aid 2010).

The System of Rice Intensification (SRI) is an agro- ecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients (Stoop et al. 2002). It has spread throughout China, Indonesia, Cambodia and Vienam reaching more than a million hectares with average yield increases of 20–30%. The benefits of SRI, which have been demonstrated in over 40 countries include: increased yield at times >50%, up to 90% reduction in required seed, up to 50% savings in water. SRI principles and practices have also been adapted for rainfed rice as well as for other crops such as wheat, sugarcane and teff, among others, with yield increases and associated economic benefits.

(http://sri.ciifad.cornell.edu/countries/cambodia/camcedacimpact03.pdf)

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

Table 3 Main findings of the MASIPAG study on farmers practicing farmer-led sustainable agriculture (Bachmann et al. 2009)

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

10 Latin America

Since the early 1980s rural producers in partnership with NGOs and other organizations, have promoted and implemented alternative, agroecological featuring resource-conserving yet highly productive systems, such as polycultures, agroforestry, and the integration of crops and livestock (Altieri 2009).

An analysis of several agroecological field projects in operation during the 1990s (these initiatives now involve almost 100,000 farming families/units and cover more than 120,000 ha of land) showed that traditional crop and animal combinations can often be adapted to increase productivity when the biological structuring of the farm is improved and labor and local resources are efficiently used (Altieri 1999). In fact, most agroecological technologies promoted by NGOs improve traditional agricultural yields increasing output per area of marginal land from 400–600 to 2,000–2,500 kg ha^{-1} enhancing also the general agrobiodiversity and its associated positive effects on food security and environmental integrity. Some projects emphasizing green manures and other organic management techniques can increase maize yields from 1 to 1.5 t ha^{-1} (a typical highland peasant yield) to 3–4 t ha^{-1}.

An IFAD (2004) study which covered a total of 12 farmer organizations that comprise about 5,150 farmers and close to 9,800 ha showed that small farmers who shifted to organic agricultural 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 the states of Parana and Santa Catarina, Brazil thousands of hillside family using cover crops minimize soil erosion and weed growth and exhibit positive effects on soil physical, chemical and biological properties (Petersen et al. 1999). This is how an innovative organic minimum tillage system emerged. 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% or more inhibition of weed emergence. Maize yields have risen from 3 to 5 t ha^{-1} and soybeans from 2.8 to 4.7 t ha^{-1} without using herbicides or chemical fertilizers (Altieri et al. 2011a).

In Cuba, it is estimated that agroecological practices are used in 46–72% of the peasant farms producing over 70% of the domestic food production, e.g. 67% of roots and tubers, 94% of small livestock, 73% of rice, 80% of fruits and most of the honey, beans, cocoa, maize, tobacco, milk and meat production (Funes et al. 2002; Machin et al. 2010; Rosset et al. 2011). Small farmers using agroecological methods obtain yields per hectare sufficient to feed about 15–20 people per year with energy efficiencies of no less than 10:1 (Funes-Monzote 2009). Another study conducted by Funes-Monzote et al. (2009) shows that small farmers using 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.

Perhaps the most widespread agroecological effort in Latin America promoted by NGOs and peasant organizations is the rescuing of traditional or local crop varieties (variedades criollas), their in-situ conservation via community seed banks and their exchange through hundreds of seed fairs (ferias de semillas) notoriously in Mexico, Guatemala, Nicaragua, Peru, Bolivia, Ecuador and Brasil. For example in Nicaragua the project Semillas de Identidad which involves more than 35,000 families on 14,000 ha have already recuperated and conserved 129 local varieties of maize and 144 of beans. http://www.swissaid.org.co/kolumbien/global/pdf/campa_a_28.05.08.pdf

In Brasil, the Bionatur Network for Agro-ecological Seeds (Rede Bionatur de Sementes Agroecológicas) is one of the strategic tools that the Landless peasant movement (MST) has launched for the participatory breeding of seeds adapted to agroecological management and their dissemination among hundreds of thousands of peasants.

An increasing number of indigenous groups or cabildos in the Andean and MesoAmerican countries have adopted agroecology as a fundamental strategy for the conservation of their germplasm and the management of agriculture in their autonomous territory. These efforts are tied to their struggle to preserve their land and cultural identity. The Mesoamerican indigenous population includes about 12 million people. In Mexico, the peasant sector that still uses indigenous languages controls an area estimated at 28 million hectares.

11 Agroecology and Resiliency to Climatic Extremes

Of key importance for the future of agriculture are results from observations of agricultural performance after extreme climatic events which reveal that resiliency to climate disasters is closely linked to the level of on-farm biodiversity, a major feature of agroecological systems (Altieri and Koohafkan 2008). 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 than their conventional monoculture neighbors. The study revealed that diversified plots had 20–40% more topsoil, greater soil moisture and less erosion and experienced lower economic losses than their conventional neighbors (Holt-Gimenez 2000). Similarly in Sotonusco, 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). In the case of coffee, the more shaded systems have also been shown to protect crops from decreasing precipitation and reduced soil water availability because the overstory tree cover is able to reduce soil evaporation and increase soil water infiltration (Lin 2007). 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% compared to 90 or 100% in neighboring monocultures. Likewise agroecologically managed farms showed a faster productive recovery (80–90%) 40 days after the hurricane than monoculture farms (Rosset et al. 2011).

Diversified farming systems such as agroforestry, silvopastoral and polycultural systems provide a variety of examples on how complex agroecosystems are able to adapt and resist the effects of drought. Intercrops of sorghum and peanut, millet and peanut, and sorghum and millet exhibited greater yield stability and less productivity declines during a drought than in the case of monocultures (Natarajan and Willey 1996). In 2009 the valle del Cauca in Colombia experienced the driest year in a 40 year record. Intensive silvopastoral systems for livestock production combining fodder shrubs planted at high densities under trees and palms with improved pastures, not only provided environmental goods and services for livestock producers but also greater resilience to drought (Murgueitio et al. 2011).

12 Scaling Up Agroecological Innovations

The cases reported above show that in Africa, Asia and Latin America there are many NGO and farmer led initiatives promoting agroecological projects that have demonstrated a positive impact on the livelihoods of small farming communities in various countries (Altieri et al. 2011b). Agroecological production is particularly well suited for smallholder farmers, who comprise the majority of the rural poor. Resource-poor farmers using agroecological systems are less dependent on external resources and experience higher and more stable yields enhancing food security. Some of these farmers, who may devote part of their production for certified organic export production without sacrificing food security, exhibit significantly higher incomes than their conventional counterparts. Agroecological management makes conversion to organic production fairly easy, involving little risk and requires few, if any, fixed investments.

With so many proven on-farm social, productive and ecological benefits, the relatively limited adoption and dissemination of agroecological innovations begs two questions: (1) If agroecological systems are so profitable and efficient, why have they not been more widely disseminated and adopted? and (2) and how can agroecology be multiplied and scaled up? There are a number of constraints that discourage adoption and dissemination of agroecological practices thus impeding its widespread adoption. Barriers range from technical issues such as lack of information by farmers and extension agents to policy distortions, market failure, lack of land tenure and infrastructural problems. In order to further spread agroecology among farmers it is essential to overcome part or all of these constraints. Major reforms must be made in policies, institutions, and research and development agendas to make sure that agroecological alternatives are massively adopted, made equitably and broadly accessible, and multiplied so that their full benefit for sustainable food security can be realized. Farmers must have higher access to local-regional markets, government support such as credit, seeds and agroecological technologies. It should also be recognized that a major constraint to the spread of agroecology has been that powerful economic and institutional interests have backed research and development for the conventional agroindustrial approach, while research and development for agroecology and sustainable approaches has in most countries been largely ignored or even ostracized (Altieri 2002).